

Руководство пользователя

QSR-2830

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1 CONFIGURING MPLS



Note The term “router” and router icons in this chapter refer to routers in a generic sense and layer-3 switches running routing protocols.

1.1 Understanding MPLS

Multiprotocol Label Switching (MPLS) supports multiple network-layer protocols such as IP, IPv6, and IPX and is compatible with multiple link-layer technologies including ATM, frame relay, Ethernet, and PPP. MPLS forwards packets based on labels attached to them. It works at both the connectionless control plane and the connection-oriented data plane, thereby introducing connection-oriented attributes to connectionless IP networks. The MPLS technology was first introduced to enhance the forwarding rate of routing devices. However, with the development of hardware technologies and network processors, this competitive edge gradually loses its appeal. Because MPLS combines Layer 2 switching with Layer 3 routing technologies, it has unprecedented edges over other technologies in terms of addressing issues of virtual private networks (VPNs) and traffic engineering (TE). MPLS VPN is increasingly favored by carriers to address interconnection problems between companies and to provide various new services. It has already become an important means for carriers to provide value-added services over IP networks. At the same time, the MPLS TE technology also turns into a major method to reduce congestion and guarantee quality of service (QoS) on IP networks by managing network traffic. Therefore, the MPLS technology receives more and more attention and the MPLS applications gradually shift to MPLS VPN and TE applications.

- Basic Concept
- Different from incoming label map (ILM), FEC-to-NHLFE (FTN) maps each forwarding equivalence class (FEC) to a series of next hop label forwarding entries (NHLFEs) which indicates there are multiple paths. An FTN table is used when a label edge router (LER) encapsulates a label in an unlabeled packet before forwarding the packet.
- Label
- Label Distribution Protocol
- MPLS Network
- An MPLS network comprises two basic components: Label Switching Routers (LSRs) and LERs. An LSR is located at the core of the MPLS network and runs the LDP signaling protocol to forward labeled packets. An LER classifies and labels incoming packets into FECs and encapsulates the labeled packets as MPLS packets for forwarding. The LER also removes the labels from outgoing MPLS packets and restores these packets to the original packets. On the MPLS network, packets with labels are forwarded along the label switched path (LSP) set up through LDP.

The MPLS architecture is divided into two parts: the forwarding unit (data plane) and control unit (control plane). The former forwards a packet by searching the label forwarding information base (LFIB) based on the label carried by the packet whereas the latter is responsible for creating and maintaining the LFIB between the connected MPLS nodes. Each MPLS node must run one or more routing protocols (including static routes) to exchange routing information with other MPLS nodes on the MPLS network. Therefore, in effect, each MPLS node is an IP router on the control plane. Similar to a conventional IP router, an MPLS node also uses unicast routing protocols (including static routes) to create and maintain a routing table. The difference is that the traditional router uses the routing table to create a forwarding table and the MPLS node uses the routing table to exchange label binding information between each destination subnet and neighboring MPLS nodes. The protocol responsible for exchanging label binding information is LDP.

- MPLS Forwarding Behaviors
- The MPLS forwarding process is as follows (IP routing for example):
 - 1) All LSRs (including LERs) run routing protocols such as Open Shortest Path First (OSPF) and Intermediate System to Intermediate System (IS-IS) to establish IP routing tables on LSRs and LERs.
 - 2) LDP creates an LSP based on the IP routing tables.
 - 3) The ingress LER receives an IP packet, analyzes the IP header, associates it with an FEC, labels the IP header with L1, and sends the labeled packet to the next-hop LSR along the LSP.
 - 4) After receiving the packet, the next-hop LSR searches the next LSP based on the label on the stack top, replaces the label with a new label, and sends the packet to the next LSR of the LSP.
 - 5) The subsequent LSRs repeat as step 4.
 - 6) When the last but one LSR receives the labeled packet and looks up the LFIB, if the egress label is found to be an implicit label, it pops the label and forwards the pure IP packet to the last hop LSR; and if the egress label is

an explicit null one, the LSR pops the label and forwards the packet by looking up the IP forwarding table based on the IP header..

- 7) If the last but one LSR pops the label, the egress LER receives the original IP packet and forwards the packet according to the IP routing table.
 - LSP Establishment and Loop Detection
 - MPLS Applications

1.1.1 Basic Concepts

■ MPLS Node

MPLS-enabled nodes can identify MPLS signaling protocols (control protocols), support one or more Layer 3 routing protocols (including static routes), and forward packets based on MPLS labels. Generally, an MPLS node can forward original Layer 3 packets (such as IP packets).

■ FEC

An FEC refers to a set of data packets that are forwarded in the same way, such as data packets that have the same prefix in their destination addresses. The FEC supports different classification methods for different applications. For example, the FEC classifies IP unicast routes based on the address prefixes. That is, one route corresponds to one FEC. All the packets in the same FEC are equally handled on the MPLS network.

■ LSR

As a core device on an MPLS network, the LSR provides label switching and distribution functions. As specified in RFC 3031 for MPLS system, an LSR is also an MPLS node which is capable of forwarding original Layer 3 packets (such as IPv4 and IPv6 packets). Since MPLS can forward normal IP packets, LSRs also have this capability.

■ LER

Located on the edge of an MPLS network, an LER classifies incoming traffic into different FECs, requests labels for these FECs, and restores outgoing traffic to the original packets by popping labels. The LER thus provides traffic classification, label mapping, and label removal functions.

■ LSP

An FEC data stream is assigned with specific labels on different nodes and transmitted along the nodes according to the switching of assigned labels. The path where the data stream travels is an LSP. It is a collection of multiple LSRs. Therefore, an LSP can be considered as a tunnel that traverses the MPLS core network.

■ NHLFE

An NHLFE table is used to store the next-hop information about MPLS packets. Typically, a next hop label forwarding entry contains the following information:

- 1) Next hop of data packets
- 2) Link layer encapsulation to use when forwarding data packets
- 3) Coding scheme for the label stack when forwarding data packets
- 4) Operations on the label stack of data packets, including:
 - a) Replacing the label at the top of the label stack with a new label
 - b) Popping the label off the stack top
 - c) Pushing one or more labels
 - d) Replacing the label at the top of the label stack with a new label and pushing one or more new labels on the label stack

■ ILM

An ILM table is a label forwarding table where each incoming label is mapped to a series of NHLFEs (multiple NHLFEs indicate multiple paths). The ILM is used when an LSR receives and forwards MPLS packets with labels.

■ FTN

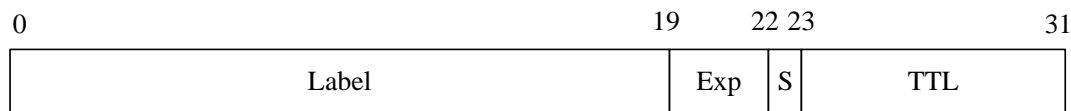
Different from ILM, FTN maps each FEC to a series of NHLFEs (multiple NHLFEs indicate multiple paths). An FTN table is used when an LER encapsulates labels to an unlabeled packet before forwarding the packet.

1.1.2 Label

A label is a short identifier with fixed length and of local significance. The label is distributed and transmitted only between two adjacent LSRs. As a result, it is valid only between the two LSRs. One label identifies one FEC. When arriving at the MPLS ingress, packets are classified into different FECs according to certain rules. Based on the FECs, the packets are encapsulated with different labels and then forwarded on the MPLS network based on the labels.

1.1.2.1 Label Format

Figure 1 MPLS label format



As shown in Figure-1, a label consists of four fields, which is described as follows:

- Label field

The label field is a 20-bit label value. The label value is an index for the label forwarding table. The Internet Engineering Task Force (IETF) classifies 0 to 15 as reserved labels and predefines their meanings:

Reserved Label	Description
0	IPv4 explicit null label. As specified in RFC 3032, label 0 must be placed at the bottom of the label stack, which means that the label must be popped before packets are forwarded according to destination IP addresses. RFC 4182 modifies the description of label 0 in RFC 3032. In RFC 4182, label 0 is popped directly upon receipt of a label 0 packet. The subsequent forwarding behavior is determined by the content behind the label 0. If another label follows, the packet is forwarded according to the label; if the packet is an IPv4 packet, it is forwarded based on the destination IP address.
1	Router alert label. This label is not allowed to be placed at the bottom of the label stack. When a receiving packet carries a router alert label, it must be sent to the local software module for processing. The actual forwarding of the packet must be based on the label behind the router alert label. Before the packet is forwarded, however, the router alert label must be pushed to the label stack again. This option is similar to the Router Alert Option of IP packets. You can use this option to configure each LSR to check MPLS packets.
2	IPv6 explicit null label. As specified in RFC 3032, label 2 must be placed at the bottom of the label stack. This means that the label must be popped before the packet is forwarded according to the destination IP address. RFC 4182 modifies the description of label 2 in RFC 3032. In RFC 4182, label 2 is popped directly upon receipt of a label 2 packet. The subsequent forwarding behavior is based on the content behind the label2. If another label follows, the packet is forwarded according to the label; if it is an IPv6 packet, it is forwarded according to the destination IP address.
3	Implicit null label. This label can be distributed by LDP but can never be transmitted in the label stacks of MPLS packets. When an LSR exchanges MPLS packets, if the label on the top of the label stack has a value of 3, it can be popped but should not be replaced with another label. The implicit null label is used in the Penultimate Hop Popping (PHP) function.
4 to 15	Reserved by the IETF for future use.

- Exp field

The Exp field is currently used to store the QoS information about MPLS. This field contains 3 bits.

- S mark

The S mark field indicates the stack bottom. It contains one bit. If multiple labels exist, the S bit of the label at the stack bottom is set to **1** and the S bits of other labels are **0**. If only one label exists, the S bit is set to **1**.

- TTL

Time to Live. This field contains 8 bits. It is similar to the TTL value in an IP packet header. When a label is first added to an IP packet, the TTL value can be copied from the TTL field (or Hop Limit of IPv6) of the IP packet header. The TTL value of the outer (stack top) label then decreases by one at every label switching. When MPLS runs on ATM links, the label encoding methods are different and no TTL field exists. For methods and solutions, refer to RFC 3032.

Label Stack

An MPLS packet can contain several labels to form a label stack. The label after the link layer header is the top label and the label before the IP header is the bottom label. An LSR exchanges labels based on the top label. When multiple labels exist, each label must be complete and contain 32 bits. A label stack supports multiple layers of labels to be carried in an MPLS packet. The purpose is to enable the MPLS technology to support hierarchical network systems and LSP tunnels.

Operation Methods of Labels

The following lists basic label operations on MPLS nodes:

- Push

Insert a label between the link layer header and the network layer header on an ingress LER or add a new label to the stack top of an MPLS packet on an intermediate LSR.

- Pop

Remove labels off packets on the egress LER to restore the IP packets or remove the top label on an intermediate LSR to reduce layers of a label stack.

- Swap

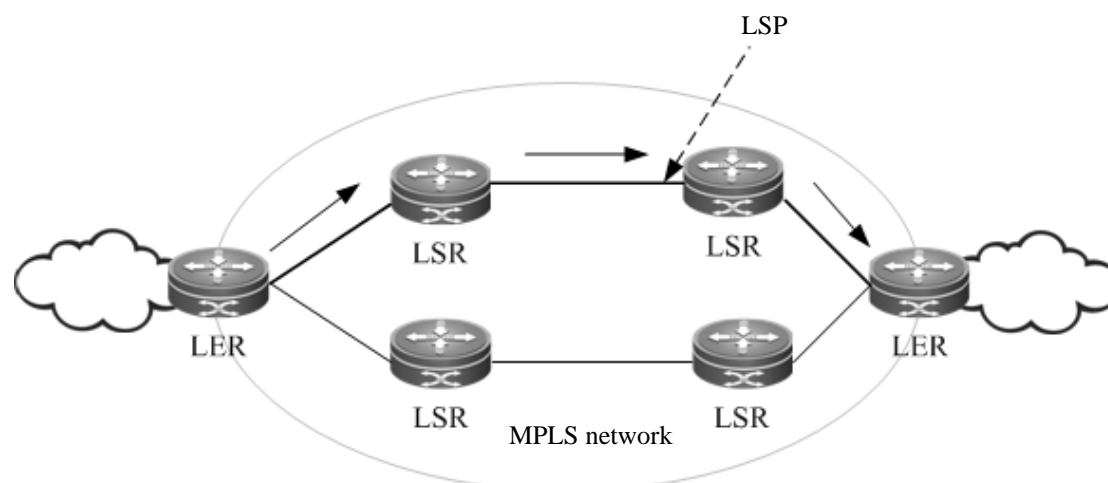
Replace the top label in the label stack of a packet based on the ILM during forwarding of the packet.

LDP

As an emerging network system, MPLS also has its own signaling protocols or "routing protocols". One of the basic concepts in the MPLS system is that two LSRs must reach consensus on the meaning of labels used for traffic transmission. This consensus is realized through a series of processes, that is, LDP. Through LDP, one LSR can notify the other LSR of the label binding. The MPLS system architecture does not assume that there is only a single LDP. Some MPLS systems use independent distribution protocols, such as LDP defined in RFC 3036 by the IETF; other MPLS systems support the distribution of labels by extending existing protocols in piggybacking mode, such as MP-BGP and RSVP. You can choose different LDPs for MPLS networks based on different application scenarios.

1.1.3 MPLS Network

Figure 2

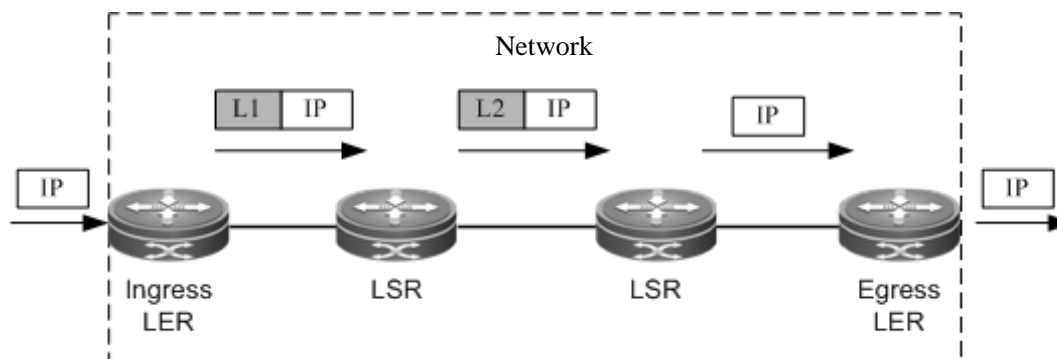


An MPLS network comprises two basic components: Label Switching Routers (LSRs) and LERs. An LSR is located at the core of the MPLS network and runs the LDP signaling protocol to forward labeled packets. An LER classifies and labels incoming packets into FECs and encapsulates the labeled packets as MPLS packets for forwarding. The LER also removes the labels from outgoing MPLS packets and restores these packets to the original packets. On the MPLS network, packets with labels are forwarded along the label switched path (LSP) set up through LDP.

The MPLS architecture is divided into two parts: the forwarding unit (data plane) and control unit (control plane). The former forwards a packet by searching the label forwarding information base (LFIB) based on the label carried by the packet whereas the latter is responsible for creating and maintaining the LFIB between the connected MPLS nodes. Each MPLS node must run one or more routing protocols (including static routes) to exchange routing information with other MPLS nodes on the MPLS network. Therefore, in effect, each MPLS node is an IP router on the control plane. Similar to a conventional IP router, an MPLS node also uses unicast routing protocols (including static routes) to create and maintain a routing table. The difference is that the traditional router uses the routing table to create a forwarding table and the MPLS node uses the routing table to exchange label binding information between each destination subnet and neighboring MPLS nodes. The protocol responsible for exchanging label binding information is LDP.

1.1.4 MPLS Forwarding Behaviors

Figure 3 Forwarding process of MPLS packets that support PHP



The following takes traditional IP routing services as an example to show the MPLS forwarding process:

- Enable traditional routing protocols (OSPF or IS-IS) on all LSRs (including LERs) and create IP routing tables on the LSRs and LERs.
- Set up an LDP LSP based on the IP routing table.
- Upon receipt of an IP packet, the ingress LER analyzes the IP packet header and maps it to an FEC. The ingress LER then adds the label L1 to the packet and sends the labeled packet to the next hop LSR along the LSP.
- The next-hop LSR receives the labeled packet, searches the LSP based on the label on the stack top, and then forwards the packet to the next-hop LSR along the LSP after replacing the label with a new one.
- The intermediate LSRs perform the same actions as step 4.
- Upon receipt of the labeled packet, the PHP LSR searches the label forwarding table and pops the label after learning that the outgoing label is the implicit null label 3. The PHP LSR then forwards the original IP packet to the last-hop LSR. If the outgoing label is the explicit null label, the PHP LSR pops the label and directly sends the original packet based on the routes of the IP header in the IP forwarding table.
- If the label is popped on the PHP LSR, the last-hop egress LER receives the original IP packet and forwards it according to the IP routing table.

1.1.5 LSP Establishment and Loop Detection

A virtual MPLS connection is an LSP. One FEC data stream is assigned with different labels on different MPLS nodes and forwarded according to the labels. The path that the data stream travels is an LSP that consists of a series of LSRs. Data streams of the same FEC pass through the same LSP.

- LSP Establishment
- LSP Loop Control

1.1.5.1 LSP Establishment

The LSP establishment is the process of binding an FEC to a label and notifying adjacent LSRs of the binding. This process is completed by LDP. RFC 3036 stipulates the protocol specifications of LDP, the interactive process of LSRs, and the message formats.

LDP detects adjacent LSRs by sending Hello messages periodically. The LDP Hello messages are encapsulated using the User Datagram Protocol (UDP) and use the well-known port 646 as the destination port. The destination address of these packets is 224.0.0.2, the multicast address of all routers in the subnet. The discovery of an adjacent LSR triggers the creation of LDP sessions. An LDP session is created in the following two steps:

- Establish a transmission connection. The connection is established after the completion of TCP three-way handshakes that do not require any interaction of LDP messages.
- Initialize the session. Both parties exchange their initialization information to negotiate and determine the LDP session parameters such as the label distribution mode, Keepalive duration, and the maximum length of Protocol Data Unit (PDU).

After the LDP session is created and both parties enter the operational state, the two parties can exchange label messages to distribute and manage labels, and create an LSP for each FEC.

During the process of LSP establishment, two label distribution modes are used: Downstream on Demand (DOD) and Downstream Unsolicited (DU). In DOD mode, an LSR responds to a label binding message only after it receives

a label request from an adjacent LSR. In DU mode, the LSR voluntarily sends label binding messages to its adjacent LSRs without receiving any request.

During the LSP establishment, two label control methods are used: independent and ordered control. In independent control mode, each LSR announces to its adjacent devices the binding of labels and FECs at any required time. In independent DOD mode, one LSR can immediately answer an upstream label mapping request without waiting for the label mapping from the next hop device. In independent DU mode, one LSR can announce the label mapping of an FEC at any time deemed as proper for swapping the label of the FEC.

In ordered control mode, one LSR binds an FEC to a label and sends the binding upstream only when the FEC has the next-hop label mapping or the LSR is the egress of the FEC. Otherwise, the LSR does not bind the FEC to a label, or send the binding to an upstream LSR until receiving the label mapping of the FEC from a downstream LSR. In ordered control and DU mode, one LSR announces the label to an upstream LSR only when the LSR is the egress of the FEC or the LSR receives the label distributed by a downstream LSR. If the label distribution mode of the downstream LSR is DOD, the LSR, either in DOD or DU mode, passes on the label request from an upstream LSR to downstream devices.

1.1.5.2 LSP Loop Control

During the LSP setup process, the loop detection mechanism must be provided to ensure timely detection of any loops formed by the LSP. The maximum number of hops and path vector can be used to avoid LSP loops.

When the maximum number of hops is used, the message that transmits label binding information records the number of bypassing LSRs. The number increases by one after passing an LSR. If the number exceeds the specified maximum value, the system considers that a loop occurs and terminates the LSP.

When the path vector is used, the message that transmits label binding information records IDs of bypassing LSRs. The ID of an LSR is recorded to the vector table of the message after each LSR. Upon receipt of a label binding message, an LSR checks whether its ID is included in the vector table. If not, the LSR adds its ID to the record when distributing the message; if yes, the LSR considers that a loop occurs and terminates the LSP.

1.1.6 MPLS Applications

Thanks to the combination of Layer 2 switching and Layer 3 routing technologies, the MPLS technology improves the forwarding rate of packets. With the development of the Application-Specific Integrated Circuit (ASIC) technologies, the forwarding rate is no longer a bottleneck in network development. As a result, the edges of MPLS in enhancing forwarding rates are not remarkable. Due to the innate advantage of combining Layer 2 switching and Layer 3 routing technologies, however, MPLS still has unprecedented edges over other technologies in terms of VPNs and TE. In this context, MPLS receives more and more attention. The MPLS applications also gradually shift to the application areas of MPLS VPN and MPLS TE.

1.2 Configuring MPLS



Caution

1. LDP is a topology-driven protocol. To ensure normal operation of LDP, enable IPv4 routing protocols and ensure their normal operations.
2. To enable the router MPLS express forwarding function and improve the forwarding performance of routers, use the **ip ref** command in interface configuration mode.

1.2.1.1 Enabling MPLS Forwarding Globally

Use the **mpls ip** command to enable a device to support MPLS forwarding in configuration mode. By default, MPLS forwarding is disabled on a device. After MPLS forwarding is enabled, the device first forwards packets according to their labels. When the label forwarding fails, the device attempts to forward packets based on their IP addresses.

Use the **no mpls ip** command to disable MPLS forwarding.

Command	Function
Qtech(config)# mpls ip	Enables MPLS forwarding globally.
Qtech(config)# no mpls ip	Disables MPLS forwarding globally.

**Caution**

This command is not applicable to controlling switch chip forwarding.

1.2.1.2 Enabling LDP Globally

Use the **mpls router ldp** [*vrf-name*] command to enable LDP for a VRF instance in global configuration mode and enter LDP configuration mode.

Use the **no mpls router ldp** [*vrf-name*] command to disable LDP for a VRF instance.

Command	Function
Qtech(config)# mpls router ldp [<i>vrf-name</i>]	Enables LDP for a VRF instance and enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback <i>id</i> [force]	Configures the LDP router ID. The loopback address is generally used as the router ID.
Qtech(config)# no mpls router ldp [<i>vrf-name</i>]	Disables LDP for a VRF instance.

**Caution**

1. After LDP is enabled globally, use the **mpls ip** command to enable LDP for an interface in interface configuration mode.
2. If *vrf-name* is not specified, LDP is globally enabled for all VRF instances.
3. You are required to specify the router ID for an LDP when enabling LDP.

1.2.1.3 Enabling Label Switching on an Interface

By default, interfaces do not forward MPLS packets. To enable MPLS forwarding on a device, use the **mpls ip** command in global configuration mode. To explicitly enable MPLS forwarding on a specified interface, use the **label-switching** command. When enabling the label forwarding function of an interface, adjust the maximum transmission unit (MTU) of the interface based on service types to facilitate the transmission of large packets.

Command	Function
Qtech(config-if-type <i>ID</i>)# label-switching	Enables MPLS forwarding on an interface.
Qtech(config-if-type <i>ID</i>)# no label-switching	Disables MPLS forwarding on an interface.

- To enable the MPLS express forwarding function of a router and to improve the forwarding performance, use the **ip ref** command in interface configuration mode
- If label forwarding is enabled on a switch on a VLAN, there must be only one member port. Otherwise, packets cannot be flooded on the VLAN.
- When unknown unicast packets or broadcast packets enter the switch through a port, these packets (including packets of VLANs with label forwarding disabled) cannot be forwarded if label forwarding is enabled on a VLAN where the port belongs to. You are advised to enable label forwarding on routing ports.

**Note**

After the MPLS packet forwarding is disabled on a public network interface, packet forwarding from the AC to the PW is not affected.

1.2.1.4 Enabling LDP on an Interface

After LDP is enabled globally, use the **mpls ip** command to enable LDP on an interface in interface configuration mode.

Command	Function
Qtech(config-if-type <i>ID</i>)# mpls ip	Enables LDP on an interface.
Qtech(config-if-type <i>ID</i>)# no mpls ip	Disables LDP on an interface.

**Caution**

After LDP is enabled in interface configuration mode, LDP does not take effect on an interface if the **mpls router ldp** command is not used in global configuration mode. To enable LDP on the interface, you must also use the **label-switching** command to enable MPLS forwarding on the interface.

1.2.1.5 Configuring MPLS MTU on an Interface (Optional)

By default, values of the MPLS MTU and the MTU are the same for an interface. The MPLS MTU determines whether MPLS packets must be fragmented during forwarding. The MPLS MTU indicates the overall length of MPLS encapsulation and encapsulated (such as IP) layers.

Use the **no mpls mtu** command to restore the default value of the MPLS MTU on an interface.

Command	Function
Qtech(config-if-type ID)# mpls mtu bytes	Configures the MPLS MTU on an interface.
Qtech(config-if-type ID)# no mpls mtu	Restores the default value of the MPLS MTU on an interface.

**Caution**

The MPLS MTU on an interface cannot exceed the actual size of packets transmitted on the interface. For switches that forward packets based on ASIC, this configuration is invalid. These switches forward packets based on the MTU configured on interfaces and directly discard packets that exceed the MTU rather than performing fragmentation. To adjust the MTU of an interface, use the **mtu** command in interface configuration mode. Fragmentation is supported by only process forwarding and router forwarding. In actual applications, you must adjust the MTU value to avoid performance degradation caused by fragmentation.

1.2.1.6 Fragmenting MPLS Packets (Optional)

By default, MPLS packets that exceed the MPLS MTU on an interface are fragmented as IP fragmentations. The fragmented IP packets are still encapsulated with the original labels and transmitted along the original LSP.

Use the **no mpls ip fragment** command to directly discard packets that must be fragmented.

Command	Function
Qtech(config)# no mpls ip fragment	Directly discards MPLS packets that exceed the MPLS MTU on an interface.
Qtech(config)# mpls ip fragment	Restores the default value to fragment packets that exceed the MPLS MTU on an interface.

**Caution**

This command is valid only for the encapsulated IP packets.

1.2.1.7 Handling ICMP Error Messages (Optional)

ICMP error messages (such as typical MPLS TTL timeout messages) generated during the forwarding of MPLS packets are forwarded along the LSP of the label stack by default. To provide different processing methods for MPLS packets with different numbers of labels, use the **mpls ip icmp-error pop labels** command. For ICMP error messages with the forwarding label stack not greater than the specified number of labels, they are forwarded through routes on the IP routing table where the FEC of the stack top label is stored. For ICMP error messages with the forwarding label stack greater than the specified number of labels, they are forwarded along the LSP of the original label stack.

Command	Function
Qtech(config)# mpls ip icmp-error pop labels	Controls the handling of ICMP error messages generated by labeled MPLS packets.
Qtech(config)# no mpls ip icmp-error pop	Restores the default value.

1.2.1.8 Configuring the MPLS TTL Replication Function (Optional)

There are two modes for handling the TTL of encapsulated and de-encapsulated IP (or MPLS) packets on an MPLS network:

- **TTL replication mode:** This is the default working mode. The procedure is as follows: When a label is pushed, the label TTL copies the TTL of the existing IP or MPLS header to the TTL field of the label. When a label is popped out, the TTL is copied back from the outer label to the inner IP packet or MPLS packet.
- **TTL non-replication mode:** In this mode, the TTL is not copied. The procedure is as follows: When a label is pushed, the TTL value of the label is directly set to 255. When a label is popped out, the original TTL value of the inner IP packet or MPLS packet is exposed and retained.

Use the **mpls ip ttl propagate { public | VPN }** command to configure the TTL replication function for packets sent and forwarded by a device.

Command	Function
Qtech(config)# [no] mpls ip ttl propagate public	Enables or disables the TTL replication function for MPLS packets sent by the device.
Qtech(config)# [no] mpls ip ttl propagate VPN	Enables or disables the TTL replication function for MPLS service packets forwarded by the device.

After the TTL replication function is enabled on an MPLS network, you can use the Tracert tool on a CE to track all the LSRs that the packets pass through in the MPLS domain. If the TTL non-replication mode is configured on PEs, the entire LSP of the packets is considered as only one hop.



Caution

After TTL replication is enabled, the TTL of the inner header is not copied but retained if it is smaller than the TTL of the outer header.

1.2.1.9 Verifying the MPLS Information

To view MPLS information and verify the configuration results, use the **show** commands in privileged mode.

- Displaying MPLS information

Display the utilization information about the label space and the interfaces enabled with MPLS. You can verify whether the configurations are accurate based on the information.

Command	Function
Qtech# show mpls summary	Displays basic MPLS information.

- Displaying the MPLS forwarding table

Display contents of MPLS forwarding entries and MPLS forwarding entries added to an MPLS application protocol (such as LDP and MP-BGP).

Command	Function
Qtech# show mpls forwarding-table [summary] [[ip-address/mask label label interface interface-name next-hop ip-address] [[ftn [ip vc] ilm [ip vc]]] [{ vrf vrf-name global } [ftn ilm]] [fr] [detail]]	Displays the information about the MPLS forwarding table.

- Displaying the utilization of the label pool

Command	Function
Qtech# show mpls label-pool	Displays information about the utilization of the MPLS label pool.

- Check the LSP connectivity.

Command	Function
Qtech# ping mpls ipv4 ip-address/mask [repeat repeat] [ttl time-to-live] [timeout timeout] [size size] [interval mseconds] [source ip-address] [destination ip-address] [force-explicit-null] [pad pattern] [reply mode { ipv4 router-alert }] [dsmap] [flags fec] [verbose]	Checks the LSP connectivity.
Qtech# traceroute mpls ipv4 ip-address/mask [timeout timeout] [ttl ttl] [source ip-address] [destination ip-address] [force-explicit-null] [reply mode { ipv4 router-alert }] [flags fec] [verbose]	Checks the LSR nodes that the LSP passes through.

1.2.2 Configuring Optional LDP Parameters (Optional)

You can modify the default LDP parameter settings as required. To modify LDP parameters, use the commands in LDP configuration or interface configuration mode.

1.2.2.1 Configuring Parameters for an LDP Session

Configuring the LDP Router ID

The LDP router ID, expressed in the format of IP addresses, uniquely identifies one LSR in a domain. By default, the system router ID is used as the LDP router ID, that is, the LSR ID. The value of an LDP router ID must be globally unique. In addition, the LDP router ID must be reachable to other LSRs because LDP uses the LDP router ID as the transport address by default. To modify the LSR ID, use the **ldp router-id** command.

Command	Function
Qtech(config-mpls-router)# ldp router-id interface interface-name [force]	Specifies the address of an interface as the LDP router ID of the LSR. force indicates that the current configurations immediately take effect.
Qtech(config-mpls-router)# no ldp router-id	Restores the default value. The system router ID is used as the LDP router ID.

Configuring transport-address

By default, the LSR ID is used as the global transport address. As an option, you can choose the main address of an interface or specify an IP address as the transport address to set up an LDP session on the interface. The following shows two configuration methods.

Use the following commands to configure the transport address of an interface.

Command	Function
Qtech(config-if-type ID)# mpls ldp transport-address { interface ip-address }	Configures the transport address for LDP sessions on an interface.
Qtech(config-if-type ID)# no mpls ldp transport-address	Deletes the configuration on the interface. By default, the global transport address is used. If no global transport address is configured, the LSR ID is used as the transport address.

Use the following commands to globally configure a transport address for all LDP sessions in LDP configuration mode.

Command	Function
Qtech(config-mpls-router)# transport-address { interface ip-address interface-name }	Configures a global transport address for LDP sessions.
Qtech(config-mpls-router)# no transport-address	Removes the global setting and restores the LSR ID as the transport address.



Caution

1. When you specify an IP address as the transport address, ensure that the address is reachable to other directly connected LSRs; otherwise, the LDP session cannot be set up.
2. If transport addresses are configured on an interface and globally, the basic LDP session set up on the interface prefers the transport address configured for the interface.
3. The configured transport address is valid only for the basic LDP session. The LDP session set up through extended mechanisms use the LSR ID as the transport address.

Configuring the Time Interval for Hello Packets

LDP periodically sends Hello packets to detect LDP peers. By default, the interval for sending Hello packets in the basic LDP discovery mechanism is 5 seconds. You can freely set the interval that ranges from 1 to 65535 seconds in interface mode.

Command	Function
Qtech(config-if-type ID)# mpls ldp hello-interval seconds	Sets the interval for sending Hello packets in the basic LDP discovery mechanism.
Qtech(config-if-type ID)# no mpls ldp hello-interval	Restores the default interval for sending Hello packets in the basic LDP discovery mechanism.

The default interval for sending Hello packets in the extended LDP discovery mechanism is 10 seconds. To modify the interval, use the **discovery target-hello interval** command.

Command	Function
Qtech(config-mpls-router)# discovery target-hello interval seconds	Sets the interval for sending Hello packets in the extended LDP discovery mechanism.
Qtech(config-mpls-router)# no discovery target-hello interval	Restores the default interval for sending Hello packets in the extended LDP discovery mechanism.

Configuring the Hold Time of Hello Packets

After an LDP peer is detected by periodically sent Hello packets, the local LDP device retains the peer for a period of time although no Hello packet is received from the peer, and considers that the peer expires after this period. This period of time is called the hold time of Hello packets. The default hold time of Hello packets is 15 seconds. You can freely set the interval that ranges from 1 to 65535 seconds in interface mode. The value 65535 indicates an indefinite hold time.

Command	Function
Qtech(config-if-type ID)# mpls ldp hello-holdtime seconds	Sets the hold time of Hello packets.
Qtech(config-if-type ID)# no mpls ldp hello-holdtime	Restores the default hold time of Hello packets.

The default hold time of Hello packets in the extended LDP discovery mechanism is 45 seconds. To modify this value, use the **discovery target-hello holdtime** command.

Command	Function
Qtech(config-mpls-router)# discovery target-hello holdtime seconds	Sets the hold time of Hello packets in the extended LDP discovery mechanism.
Qtech(config-mpls-router)# no discovery target-hello holdtime	Restores the default hold time of Hello packets in the extended LDP discovery mechanism.

Configuring the Hold Time of Keepalive Packets

After an LDP peer is detected by periodically sent Hello packets and an LDP session is set up in TCP mode, the local LDP device retains the peer for a period of time although no Keepalive packet is received from the peer. The local LDP device considers that the peer expires and voluntarily terminates the LDP session after this period. This period of time is called the hold time of Keepalive packets. The default hold time of Keepalive packets for the session set up in the basic discovery mechanism is 45 seconds and that for the session set up in the extended discovery mechanism is 180 seconds. You can freely set the value at the range of 15 to 65535. The interval for sending Keepalive packets is one third of the hold time of Keepalive packets.

Command	Function
Qtech(config-if-type ID)# mpls ldp keepalive-holdtime seconds	In interface mode, sets the hold time of Keepalive packets for the session set up in the basic discovery mechanism.
Qtech(config-if-type ID)# no mpls ldp keepalive-holdtime	Restores the default hold time of Keepalive packets for the session set up in the basic discovery mechanism.
Qtech(config-mpls-router)# targeted-session holdtime seconds	In LDP mode, sets the hold time of Keepalive packets for the session set up in the extended discovery mechanism.
Qtech(config-mpls-router)# no targeted-session holdtime	Restores the default hold time of Keepalive packets for the session set up in the extended discovery mechanism.

Configuring the Maximum Number of Repeated Label Requests

When an LDP device requests labels, it waits for a period of time to start another attempt if no label is detected due to various reasons. The default number of repeated requests is indefinite. You can freely set the value that ranges from 0 to 255 in interface mode.

Command	Function
Qtech(config-mpls-router)# mpls ldp max-label-requests times	Sets the maximum number of repeated LDP label requests.
Qtech(config-mpls-router)# no mpls ldp max-label-requests	Restores the default number of repeated LDP label requests.

Configuring the Maximum PDU

The messages exchanged between LDP devices are all contained in PDUs. You can freely set the value of the PDU that ranges from 256 to 4096 in interface mode. The default PDU value is 4096.

Command	Function
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Command	Function
Qtech(config-mpls-router)# mpls ldp max-pdu <i>max-pdu</i>	Sets the maximum PDU.
Qtech(config-mpls-router)# no mpls ldp max-pdu	Restores the default PDU (4096).

Configuring the Extended LDP Discovery Mechanism

The basic discovery mechanism is used to detect the local LDP peers. That is, set up a local LDP session with the directly connected LSR. The extended discovery mechanism is used to detect the remote LDP peers. That is, set up a remote LDP session with the non-directly connected LSR.

Command	Function
Qtech(config-mpls-router)# neighbor <i>ip-address</i>	Creates an extended LDP peer.
Qtech(config-mpls-router)# no neighbor <i>ip-address</i>	Deletes an extended LDP peer.

1.2.2.2 Configuring LDP Loop Detection

Configuring the Loop Detection Mode

LDP provides two methods to detect loops: maximum number of hops and path vector. By default, loop detection is disabled for LDP.

In the loop detection based on the maximum number of hops, a packet carries both label information and the number of hops. The number increases by one every time the packet passes an LSR. When the number exceeds a preconfigured maximum value, the device considers that a loop occurs on the LSP.

In the loop detection based on the path vector, the packet carries the LSR ID apart from the label information. At each hop, an LSR first checks whether the number of LSRs in the path vector list exceeds the preset maximum number in the path vector list. If yes, a loop occurs. If no, the LSR continues to check whether its LSR ID exists in the path vector list of the LDP message. If yes, a loop occurs; if no, the LSR adds its own LSR ID to the path vector list.

Command	Function
Qtech(config-mpls-router)# loop-detection	Enables loop detection.
Qtech(config-mpls-router)# no loop-detection	Disables loop detection.

Configuring the Maximum Number of Hops

In interface mode, you can set the maximum number of hops allowed in loop detection mode. By default, the number is 254. You can set the value at the range of 1 to 255. If loop detection is enabled and the number of hops in an LDP message is detected to exceed the preset value, the LSR considers that a loop occurs.

Command	Function
Qtech(config-if-type ID)# mpls ldp max-hop-count <i>number</i>	Sets the maximum number of hops in loop detection.
Qtech(config-if-type ID)# no mpls ldp max-hop-count	Restores the default value of the maximum number of hops in loop detection.

Configuring the Maximum Number in the Path Vector List

In interface mode, you can set the maximum number of LSRs included in the path list of the loop detection based on path vector. By default, the number is 254. You can set the number at the range of 0 to 254. The number means the maximum number of LSRs that can be carried in the path vector list. After loop detection is enabled, an LSR considers that a loop occurs if the LSR detects its own LSR ID in the path vector list or the number of LSR IDs in the path vector list exceeds the preset value.

Command	Function
Qtech(config-mpls-router)# mpls ldp max-path-vector <i>number</i>	Sets the maximum number in the path vector list of loop detection.
Qtech(config-mpls-router)# no mpls ldp max-path-vector	Restores the default value of the maximum number in the path vector list of loop detection.

1.2.2.3 Configuring the LDP Working Mode

Configuring the LDP Label Distribution Control Mode

The LDP label distribution control mode specifies when an LSR notifies its neighbors of the binding between labels and FECs. There are two control modes: independent control and ordered control.

In independent control mode, the LSR can announce the binding of labels and FECs to its neighbors at any required time. In ordered control mode, an LSR binds an FEC to a label and sends the binding upstream only when the FEC has the next-hop label mapping or the LSR is the egress LSR of the FEC.

By default, LDP uses the independent control mode. To configure the LDP control mode, use the **lsp-control-mode** command.

Command	Function
Qtech(config-mpls-router)# lsp-control-mode { independent ordered }	Configures the label distribution control mode.
Qtech(config-mpls-router)# no lsp-control-mode	Restores the default label distribution control mode.

Configuring the LDP Label Distribution Mode

The LDP label distribution mode specifies how an LSR notifies its neighbors of the binding between labels and FECs. There are two modes: DOD and DU.

In DOD mode, a downstream LSR responds to a label binding message only after receiving a label request from an upstream LSR. In DU mode, one LSR voluntarily sends label binding messages to its upstream LSRs according to certain triggering policies. If the upstream and downstream LSRs use different label distribution modes, the DU mode is used if the LSRs are connected to each other through Ethernet.

By default, LDP works in DU mode. You can use the **mpls ldp distribution-mode** command in interface mode to set the label distribution mode on an interface.

Command	Function
Qtech(config-if-type ID)# mpls ldp distribution-mode { du dod }	Configures the label distribution mode.
Qtech(config-if-type ID)# no mpls ldp distribution-mode	Restores the default label distribution mode (DU).

Configuring the LDP Label Retention Mode

The label retention mode specifies whether an LSR should retain the label binding learnt from a label mapping message if the message is not sent from the next hop of the corresponding FEC or the message does not match any existing IP route. There are two label retention modes: conservative and liberal modes.

When the preceding situations occur, the liberal mode retains the binding of the FEC and label from the neighbor whereas the conservative mode does not retain the binding information.

The conservative label retention mode uses and maintains a small number of labels. The LSR should re-obtain the label values in case of route changes, prolonging responses. The liberal label retention mode, however, responds rapidly to route changes but unnecessary label mappings are also distributed and maintained.

By default, LDP uses the liberal label retention mode.

Use the **label-retention-mode** command to configure the label retention mode.

Command	Function
Qtech(config-mpls-router)# label-retention-mode { liberal conservation }	Configures the label retention mode.
Qtech(config-mpls-router)# no label-retention-mode	Restores the default label retention mode.

Configuring Label Merging

If an LSR binds several incoming labels for a FEC but uses the same outgoing label for all packets in the FEC, it indicates that the LSR is capable of label merging. You can enable or disable label merging through LDP configurations.

By default, label merging is enabled for LDP.

Use the **label-merge** command to enable or disable label merging.

Command	Function
Qtech(config-mpls-router)# label-merge	Enables label merging.
Qtech(config-mpls-router)# no label-merge	Disables label merging.

Configuring the Transmission Mode of Label Release Messages

When an FEC becomes invalid, LDP sends label release messages to downstream devices to cancel the label bound to the FEC. Each LDP device on the LSR determines whether to transmit the messages to downstream devices based on the transmission mode of label release messages.

By default, an LDP device does not send label release messages received from an upstream device to downstream devices.

Use the **propagate-release** command to configure the transmission mode of label release messages.

Command	Function
Qtech(config-mpls-router)# propagate-release	Configures a device to send label release messages to downstream devices.
Qtech(config-mpls-router)# no propagate-release	Configures a device not to send label release messages to downstream devices.

1.2.2.4 Configuring Label Control Policies

Configuring Label Distribution Policies

By default, LDP assigns labels to all valid IGP routes (excluding BGP routes). In some special situations, you may only want to assign labels to some routes or to certain LDP peers to reduce the number of labels and the number of LSPs to lessen device and network burdens.

Command	Function
Qtech(config-mpls-router)# advertise-labels for host-routes	Configures the device to assign labels to only host routes that satisfy the mask length of 32 bits in the route forwarding table. By default, the mask length of routes is not restricted.
Qtech(config-mpls-router)# advertise-labels for bgp-routes [acl acl-name]	Configures the device to assign labels to BGP routes. By default, LDP does not assign labels to BGP routes.
Qtech(config-mpls-router)# advertise-labels for default-route	Configures the device to assign labels to default routes. By default, LDP assigns implicit null label 3 to default routes.
Qtech(config-mpls-router)# advertise-labels for acl prefix-access-list [to peer-access-list]	Configures the device to assign labels to FECs that match ACL rules and specify the device to assign labels only to LDP peers that match the rules.



Caution

1. By default, LDP assigns labels to only IGP routes. To assign labels to BGP routes, use the **advertise-labels for bgp-routes** command.
2. By default, LDP does not set up an LSP for default routes.

Configuring Label Reception Policies

By default, LDP can receive all label binding information sent from all neighbors. In certain situations, you may need to control the device to receive only some binding information about FECs and labels from certain neighbors. In this case, use the **neighbor ip-address labels accept** command.

Command	Function
Qtech(config-mpls-router)# neighbor ip-address labels accept acl-name	Configures a label reception policy.

Configuring Policies for Distributing Explicit Null Labels

By default, LDP assigns implicit null labels to the FEC (such as direct routes) with the local device as the egress. You can use the **explicit-null** command to assign explicit null labels to all direct routes or routes that match certain ACL rules. To restore the default setting, use the **no explicit-null** command.

Command	Function
Qtech(config-mpls-router)# explicit-null [for prefix_acl to peer_acl]	Configures a device to assign explicit null labels to all direct routes or routes that match certain ACL rules.
Qtech(config-mpls-router)# no explicit-null	Restores the default setting.

**Caution**

1. For an FEC with the local device as the egress, the device cannot assign explicit null labels to the FEC if the corresponding LSP is a tunnel that carries L2VPN or L3VPN services.
2. Configure this function only for the global LDP instance. This function is not supported by the VRF instance.

1.2.2.5 Configuring the LDP MD5 Authentication

To enhance the reliability of LDP sessions, you can configure the MD5 authentication for the TCP connections used by the LDP sessions. To configure the MD5 authentication for TCP connections between a device and its peer, use the **neighbor ip-address password [0 | 7] pwd-string** command. To restore the default setting, use the **no neighbor ip-address password [0 | 7] pwd-string** command.

Command	Function
Qtech(config-mpls-router)# neighbor ip-address password [0 7] pwd-string	Configures a device to adopt the MD5 authentication for the TCP connections with its peer.
Qtech(config-mpls-router)# no neighbor ip-address password	Restores the default setting.

1.2.2.6 Verifying the LDP Information

- Displaying LDP attributes

Use the **show mpls ldp parameters [all | vrf vrf-name]** command to view information about LDP attributes, including the LSR ID, transport address, loop detection mechanism, label distribution control mode, label retention mode, the interval and hold time of Hello packets with extended peers, and the interval and hold time of Keepalive packets with extended peers. You can verify the information to check whether the configurations are correct. By default, the LDP attributes of the default VRF are displayed. If **all** is chosen, the LDP attributes of all VRFs are displayed; if **vrf-name** is specified, the LDP attributes of a specified VRF are displayed.

Command	Function
Qtech# show mpls ldp parameters [all vrf vrf-name]	Displays information about LDP attributes.

- Displaying information about an interface enabled with LDP

Use the **show mpls ldp interface [all | vrf vrf-name | interface-name]** command to display the LDP status of interfaces in all or a specified VRF. You can also query the LDP status of specific interfaces. By default, the interface LDP status of interfaces in the default VRF is displayed. If **all** is chosen, the LDP status of interfaces in all VRFs is displayed; if **vrf-name** is specified, the LDP status of interfaces in a specified VRF is displayed; if **interface-name** is specified, the LDP status of the specified interface is displayed.

Command	Function
Qtech# show mpls ldp interface [all vrf vrf-name interface-name]	Displays information about the interface enabled with LDP.

- Displaying the binding between FECs and labels

Use the **show mpls ldp bindings [all | vrf vrf-name] [ip-address/mask | label label] [remote | local]** command to display the binding information between FECs and labels. You can also use this command to view the LDP working status, to check whether an FEC is properly bound to a label, or query the specific label value bound to an FEC. When using this command, you can filter the display information based on the VRF, address prefix, label value, remote binding, or local binding.

Command	Function
Qtech# show mpls ldp bindings [all vrf vrf-name] [ip-address/mask label label] [remote local]	Displays the binding between FECs and labels.

- Displaying LDP neighbors

Use the **show mpls ldp neighbor [all | vrf vrf-name] [ip-address] [detail]** command to view the LDP neighbors of all or a specified VRF, including the TCP connection port, LDP status, statistics about packets received and transmitted, and the voluntary LDP discovery party of the local and remote LDP devices. If parameter **detail** is added, detailed information about LDP neighbors is displayed.

Command	Function
Qtech# show mpls ldp neighbor [all vrf vrf-name] [detail]	Displays information about LDP neighbors.

- Displaying information about discovered LDP neighbors

Use the **show mpls ldp discovery** [**all** | **vrf vrf-name**] | [**detail**] command to display ports where LDP neighbors are discovered and information about the neighbors. If parameter **detail** is added, detailed information about LDP neighbors is displayed.

Command	Function
Qtech# show mpls ldp discovery [all vrf vrf-name] [detail]	Displays information about discovered LDP neighbors.
■ Resetting the LDP session	

Use the **clear mpls ldp neighbor** command to reset an LDP session and set up a new session.

Command	Function
Qtech# clear mpls ldp neighbor [all vrf vrf-name] [*] ip-address]	Resets an LDP session and sets up a new session.

1.2.3 Configuring Static MPLS Forwarding

To support basic MPLS forwarding functions, you can also use static configurations other than LDP. To configure basic MPLS forwarding functions in static mode, perform the following configuration procedures:

- (Mandatory) Enable MPLS forwarding globally.
- (Mandatory) Enable MPLS forwarding on an interface.
- (Mandatory) Configure a static LSP.



Caution

LDP is not required when configuring a static LSP. As a result, IPv4 routes are also not required. If no IPv4 route exists on the network, the static LSP can still take effect as long as the physical network is reachable.

For configuration procedures to enable MPLS forwarding globally or on an interface, refer to the basic procedures for configuring MPLS forwarding.

1.2.3.1 Configuring a Static LSP

The configuration of an MPLS network in static mode centers around the static LSP. The other configurations are the same as those of LDP. To configure a static LSP, perform the following steps:

- Configure a static FTN on the ingress LSR.
- Configure a static ILM on the intermediate LSR.
- Configure a static ILM on the PHP LSR.



Note

Label values 16 to 1024 are reserved for static LSPs. You can select only from these label values when configuring static LSPs.

- On a router, use the **ip ref** command on the label forwarding interface to enable MPLS fast forwarding to improve forwarding performance of the router.

Configuring a Static FTN on the Ingress LSR

On the ingress LSP, set up an FTN entry for the FEC, that is, bind the FEC to a label.

Use the **mpls static ftn** command to configure a static FTN in global configuration mode. The syntax of the command is as follows:

Command	Function
Qtech(config)# mpls static ftn ip-address / mask out-label label nexthop interface nexthop-ip	Adds a global FTN.
Qtech(config)# no mpls static ftn ip-address/mask	Deletes a global FTN.

For example, to configure a global FTN that binds label 16 to FEC 192.168.1.0/24 and supports the next hop of the LSP as 192.168.10.10 and the outgoing interface as GigabitEthernet 2/1, run the following command:

```
Qtech(config)# mpls static ftn 192.168.1.0/24 out-label 16 GigabitEthernet 2/1 192.168.10.10
```

To delete the TFN, run the following command. In this case, you are required to only enter the FEC. Other parameters are not required.

```
Qtech(config)# no mpls static ftn 192.168.1.0/24
```

Configuring a Static ILM on the Intermediate LSR

An intermediate LSR forwards labels for incoming labeled packets. In this case, you are required to configure ILM forwarding entries to map incoming labels to outgoing ones. Use the **mpls static ilm in-label** command to configure a static ILM in global configuration mode. The syntax of the command is as follows:

Command	Function
Qtech(config)# mpls static ilm in-label <i>in_label</i> forward-action swap-label <i>swap_label</i> nexthop interface <i>nexthop-ip</i> fec <i>ip-address/mask</i>	Adds a global ILM.
Qtech(config)# no mpls static ilm in-label <i>in_label</i>	Deletes a global ILM.

For example, to configure a global ILM that maps the incoming label 16 to the outgoing label 17 and supports the next hop of the LSP as 192.168.11.11, the outgoing interface as GigabitEthernet 2/2, and the FEC of the LSP as 192.168.1.0/24, run the following command:

```
Qtech(config)# mpls static ilm in-label 16 forward-action swap-label 17 nexthop GigabitEthernet 2/2 192.168.11.11 fec 192.168.1.0/24
```

To delete the ILM, run the following command:

```
Qtech(config)# no mpls static ilm in-label 16
```

Configuring a Static ILM on the PHP LSR

Because the second but last hop is required to perform PHP, its ILM entries must be different from those on other intermediate LSRs. That is, the outgoing label in the ILM of the PHP LSR on the LSP should be an implicit null label (3).



Note For information about the PHP, refer to related materials.

For example, you are required to configure a global ILM on the PHP LSR of the LSP. The LSR is required to pop out the incoming label 17 and send the packets from GigabitEthernet 2/2. The next hop address is 192.168.12.12 and the corresponding FEC is 192.168.1.0/24. Run the following command:

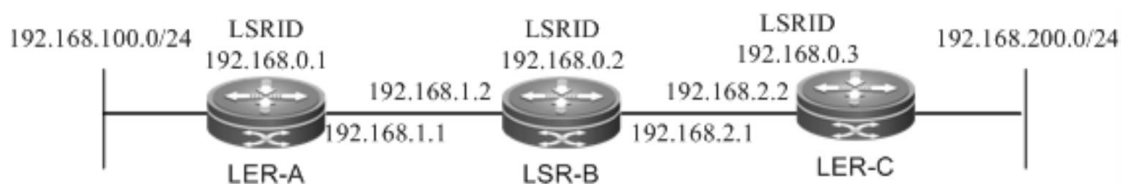
```
Qtech(config)# mpls static ilm in-label 17 forward-action swap-label 3 nexthop GigabitEthernet 2/2 192.168.11.11 fec 192.168.1.0/24
```

To delete the ILM, run the following command:

```
Qtech(config)# no mpls static ilm in-label 17
```

1.2.4 Example for Configuring Basic MPLS Functions

Figure 4



As shown in the preceding figure, three MPLS devices are deployed to construct an MPLS network. The following section introduces the setup of an LSP through LDP and the setup of a static LSP to show the MPLS configuration procedures.

1.2.4.1 Setting Up an LSP Through LDP

LDP works only with IPv4 routes. Here, OSPF is enabled to set up IPv4 routes. Before the following configuration, ensure that you have created a loopback interface (Loopback 0) and assigned an IP address, which also serves as the router ID, to the loopback interface on each device.

Configurations on LER_A:

Command	Function
Qtech(config)# mpls ip	Enables MPLS forwarding globally. (Note: This command is not applicable to switch chip forwarding.)
Qtech(config)# mpls router ldp	Enables LDP and enters LDP mode.
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force	Configures the LDP router ID. The loopback address is generally used as the router ID.
Qtech (config-mpls-router)# exit	Exits LDP mode and enters global configuration mode.
Qtech(config)# interface gigabitEthernet 2/2	Enters interface mode of GigabitEthernet 2/2.
Qtech(config-if-GigabitEthernet 2/2)# mpls ip	Enables LDP on the interface.
Qtech(config-if-GigabitEthernet 2/2)# label-switching	Enables MPLS on the interface.
Qtech(config-if-GigabitEthernet 2/2)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/2)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# router ospf 10	Enables OSPF and enters OSPF mode.
Qtech (config-router)# network 192.168.100.0 0.0.0.255 area 0 Qtech (config-router)# network 192.168.0.1 0.0.0.0 area 0 Qtech (config-router)# network 192.168.1.0 0.0.0.255 area 0	Adds routing information to OSPF.
Qtech(config-router)# end	Ends the configuration.

Configurations on LER_B:

Command	Function
Qtech (config)# mpls ip	Enables MPLS forwarding globally. (Note: This command is not applicable to switch chip forwarding.)
Qtech (config)# mpls router ldp	Enables LDP and enters LDP mode.
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force	Configures the LDP router ID. The loopback address is generally used as the router ID.
Qtech (config-mpls-router)# exit	Exits LDP mode and enters global configuration mode.
Qtech (config)# interface gigabitEthernet 2/1	Enters interface mode of GigabitEthernet 2/1.
Qtech(config-if-GigabitEthernet 2/1)# mpls ip	Enables LDP on the interface.
Qtech(config-if-GigabitEthernet 2/1)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/2)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/1)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# router ospf 10	Enables OSPF and enters OSPF mode.
Qtech (config-router)# network 192.168.1.0 0.0.0.255 area 0 Qtech (config-router)# network 192.168.2 .0 0.0.0.255 area 0 Qtech (config-router)# network 192.168.0.2 0.0.0.0 area 0	Adds routing information to OSPF.
Qtech (config-router)# end	Ends the configuration.

Configurations on LER_C:

Command	Function
Qtech (config)# mpls ip	Enables MPLS forwarding globally. (Note: This command is not applicable to switch chip forwarding.)
Qtech (config)# mpls router ldp	Enables LDP and enters LDP mode.
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force	Configures the LDP router ID. The loopback address is generally used as the router ID.
Qtech (config-mpls-router)# exit	Exits LDP mode and enters global configuration mode.
Qtech (config)# interface gigabitEthernet 2/1	Enters interface mode of GigabitEthernet 2/1.
Qtech(config-if-GigabitEthernet 2/1)# mpls ip	Enables LDP on the interface.
Qtech(config-if-GigabitEthernet 2/1)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/2)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/1)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# router ospf 10	Enables OSPF and enters OSPF mode.

Command	Function
Qtech (config-router)# network 192.168.200.0 0.0.0.255 area 0 Qtech (config-router)# network 192.168.0.3 0.0.0.0 area 0 Qtech (config-router)# network 192.168.2.0 0.0.0.255 area 0	Adds routing information to OSPF.
Qtech (config-router)# end	Ends the configuration.

1.2.4.2 Configuring a Static LSP

You can configure a static LSP without IPv4 routes.

For example, set up two LSPs between interface 1 at the 192.168.100.0/24 network segment on LER_A and interface 2 at the 192.168.200.0/24 network segment on LER_C to connect the two network segments. You need to configure one LSP from LER_A to LER_C and the other LSP from LER_C to LER_A. This is because the LSP is unidirectional.

- On a router, you must use the **ip ref** command on the label forwarding interface to enable MPLS fast forwarding to improve forwarding performance of the router.

Configurations on LER_A:

Command	Function
Qtech (config)# mpls ip	Enables MPLS forwarding globally. (Note: This command is not applicable to switch chip forwarding.)
Qtech (config)# interface gigabitEthernet 2/2	Enters interface mode of GigabitEthernet 2/2.
Qtech(config-if-GigabitEthernet 2/2)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/2)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/2)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# mpls static ftn 192.168.200.0/24 out-label 16 nexthop gigabitEthernet 2/2 192.168.1.2	Creates an FTN that binds 192.168.200.0/24 to label 16. Specifies the next hop of the FTN as 192.168.1.2 and the outgoing interface as GigabitEthernet 2/2.
Qtech(config-router)# end	Ends the configuration.

Configurations on LER_B:

Command	Function
Qtech (config)# mpls ip	Enables MPLS forwarding globally. (Note: This command is not applicable to switch chip forwarding.)
Qtech (config)# interface gigabitEthernet 2/1	Enters interface mode of GigabitEthernet 2/1.
Qtech(config-if-GigabitEthernet 2/1)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/1)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/1)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# interface gigabitEthernet 2/2	Enters interface mode of GigabitEthernet 2/2.
Qtech(config-if-GigabitEthernet 2/2)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/1)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/2)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# mpls static ilm in-label 16 forward-action swap-label 3 nexthop gigabitEthernet 2/2 192.168.2.2 fec 192.168.200.0/24	Creates an ILM that maps the incoming label 16 to the outgoing label 3 (implicit null label) on GigabitEthernet 2/2. Specifies the next hop address as 192.168.2.2 and the FEC as 192.168.200.0/24.
Qtech (config)# mpls static ilm in-label 17 forward-action swap-label 3 nexthop gigabitEthernet 2/1 192.168.1.1 fec 192.168.100.0/24	Creates an ILM that maps the incoming label 17 to the outgoing label 3 (implicit null label) on GigabitEthernet 2/1. Specifies the next hop address as 192.168.1.1 and the FEC as 192.168.100.0/24.
Qtech (config-router)# end	Ends the configuration.

Because LER_B is the PHP LSR for the FEC 192.168.100.0/24, the incoming label 17 is mapped to the outgoing label 3 (implicit null label). The outgoing interface is GigabitEthernet 2/1.

Similarly, because LER_B is the PHP LSR for the FEC 192.168.200.0/24, the incoming label 16 is also mapped to the outgoing label 3 (implicit null label). The outgoing interface is GigabitEthernet 2/2.

Configurations on LER_C:

Command	Function
Qtech (config)# interface gigabitEthernet 2/1	Enters interface mode of GigabitEthernet 2/1.
Qtech(config-if-GigabitEthernet 2/1)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-GigabitEthernet 2/1)# ip ref	Enables MPLS fast forwarding on the interface of a router.
Qtech(config-if-GigabitEthernet 2/1)# exit	Exits interface mode and enters global configuration mode.
Qtech (config)# mpls static ftn 192.168.100.0/24 out-label 17 nexthop gigabitEthernet 2/1 192.168.2.1	Creates an FTN that binds 192.168.200.0/24 to label 17. Specifies the next hop of the FTN as 192.168.2.1 and the outgoing interface as GigabitEthernet 2/1.
Qtech (config-router)# end	Ends the configuration.

After the preceding configurations, packets destined for the 192.168.200.0/24 network segment on LER_A are sent out through GigabitEthernet 2/2 on LER_A and pushed with label 16. After arriving at the GigabitEthernet 2/1 interface on LER_B, these packets with label 16 are then transformed to IP packets and sent out through GigabitEthernet 2/2 on LER_B. After these IP packets destined for the 192.168.200.0/24 network segment arrives at LER_C, LER_C selects routes based on the destination IP address and sends out the packets from GigabitEthernet 2/1.

2 CONFIGURING BGP/MPLS IP VPN

2.1 Understanding the BGP/MPLS IP VPN

2.1.1 Overview

In traditional VPNs, private network data streams are generally transmitted over public networks through Generic Routing Encapsulation (GRE), Layer 2 Tunneling Protocol (L2TP), and Point-to-Point Tunneling Protocol (PPTP). As another implementation of a VPN, a BGP/MPLS IP VPN can be considered as a VPN between Layer 2 and Layer 3. A label switched path (LSP) is a tunnel that is set up through MPLS LDP on the public network. In an MPLS VPN, the different branches of private networks at different locations are connected to form one network through LSPs. The MPLS VPN also supports interworking between different VPNs. The implementation of the VPN through MPLS has natural advantages. For VPN users, the workload is largely reduced because no special VPN devices are required to construct the VPN. Instead, the VPN users can directly use traditional routers. For carriers, the MPLS VPN can be easily expanded.

As a highly effective technical platform for IP backbone networks, MPLS provides VPNs with flexible and scalable technical foundations.

The L3VPN based on BGP/MPLS IP VPN has the following features:

- The VPN tunnels are set up on the provider edge (PE) devices of network service providers rather than the customer edge (CE) devices. The VPN routes are also transmitted between PEs. In this manner, users are not required to maintain VPN information.
- Existing routing protocols are directly utilized. The setup of VPN tunnels and route advertising are dynamically implemented, facilitating the expansion of VPNs.
- Address overlapping is supported. Different VPN users can use the same address space.
- On the network of service providers, VPN services are exchanged by label switching rather than traditional route distribution.
- The L3VPN is as secure as user dedicated lines.

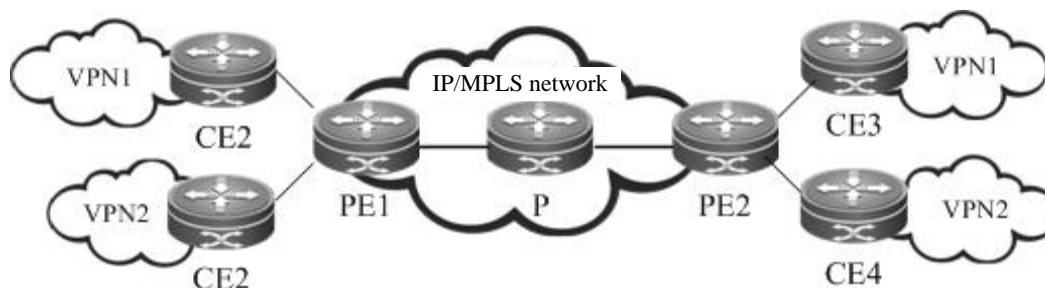
The BGP/MPLS IP VPN provides the following functions:

- Adopts the LDP to set up LSPs on the backbone network. This process is generally performed on the provider's network and completed when the topology becomes stable.
- Forwards data packets based on the pushed labels and the local mapping table.
- Supports MP-BGP and extended BGP attributes to transmit VPN routes and carry VPN attributes and labels.
- Manages VPN routes to set up multiple routing tables and maintain VPN routes.

2.1.2 Components of the BGP/MPLS IP VPN

A BGP/MPLS IP VPN model consists of three components, as shown in the following figure.

Figure 5 Basic components of the VPN



- CE

Located at a customer edge, a CE logically belongs to a user VPN. One interface on the CE is directly connected to a PE device. The CE can be a host, router or switch that may not support MPLS. As shown in the figure, CE1, CE2, CE3, and CE4 are CE devices.

- PE

A PE is an edge device on the SP backbone network. It can be a router, an ATM switch, or an FR switch, as shown by PE1 and PE2 in the figure. A PE logically belongs to the service provider and is directly connected to a CE. You

can connect one PE to multiple CEs. The PE is mainly responsible for receiving the VPN information from CEs and transmitting the information to other PEs, or receiving the VPN information from other PEs and distributing it to the CEs. The PEs should support MPLS.

■ P

The provider router (P) is a core device on the SP backbone network, as shown by P1, P2, and P3 in the figure. The P is not connected to CEs. It is responsible for routing and rapid forwarding. As a device on the core MPLS backbone network, the P should support MPLS. The P knows the routes to any destination on the backbone network but does not know the routes to a VPN.

2.1.3 VRF

■ VRF

The VPN routing and forwarding table (VRF) is used to solve the conflicts of local routes. Each connection between a PE and a CE is associated with a VRF. One PE can have several VRFs to exchange route information with CEs. You can consider a VRF as a virtual router. Each virtual router should be connected to a CE to receive route information from the CE or advertise the VPN route information to the CE. The VRF solves the conflicts of local routes due to the adoption of the same address space by different VPNs. One VRF includes:

- 5) An independent routing table
- 6) A group of interfaces that belong to the VRF
- 7) A group of routing protocols that are used in the VRF

The VRF has two important attributes: route distinguisher (RD) and route-target (RT) attributes.

■ RD

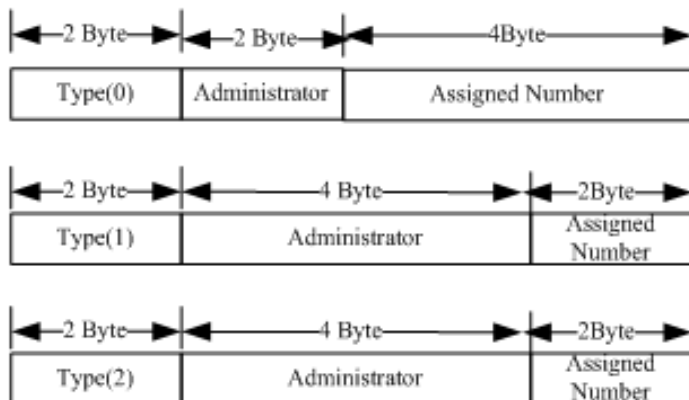
The RD is introduced to solve the conflict of routes during the transmission.

You can consider the RD as a distinguisher. If different VPNs use the same network address and advertise their route information on the backbone network through BGP, BGP chooses and advertises only the best route from the overlapped addresses. As a result, some VPNs cannot obtain their route information. If the RD values are added to the overlapped addresses, BGP identifies the same network addresses based on the different RDs carried in the VPN information. In this manner, each VPN can obtain its own route information. The RD only serves as a distinguisher to distinguish the same network addresses. If address overlapping does not exist for different VPNs, you can configure no RD values.

Generally, a unique RD value is specified for one VPN. In this manner, different VPNs have different RDs, facilitating the transmission of route information on the backbone network. The RD value is generally defined as xx: xx, such as RD 1: 100, where 1 stands for the AS number of the backbone network and 100 is a number specified by the user. One VPN route can carry only one RD value.

The RD consists of three fields: type, administrator, and assigned number. Based on the value of the type field, the encoding formats are classified into the following three types:

Figure 6 RD structure.



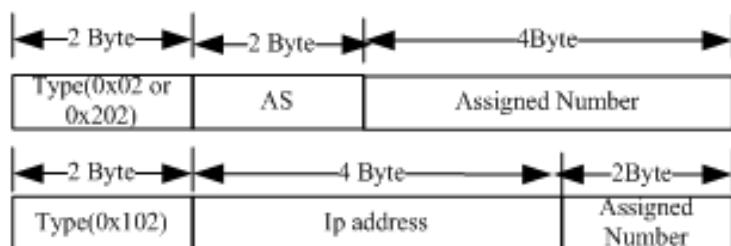
- 8) When Type = 0, the administrator field has two bytes and is marked by the AS number that must be a public AS number. The assigned number has four bytes and is managed by the service provider.
- 9) When Type = 1, the administrator field has four bytes and uses an IPv4 address that must be a global IP address. The assigned number has two bytes and is managed by the service provider.
- 10) When Type = 2, the administrator field has four bytes and is marked by the four-byte AS number. The assigned number has two bytes and is managed by the service provider.

■ Route-Target

The introduction of the RT attribute is to let the VRF choose its route selection mode. The RT attributes are classified into route-target export and route-target import. A PE receives routes from a CE and adds route-target export to the VPN routes and then advertises the VPN routes to other PEs. The PE determines whether to import the routes received from other PEs to the VRF based on the route-target import. One principle is that when a PE receives a VPN route, the PE imports the route to the VRF only when at least one RT attribute carried in the route is the same as the import RT in the VRF of the PE. In this manner, you can flexibly control the distribution of VPN routes. One VPN route can carry multiple RT values.

The BGP extended community attribute defines the RT encoding structure, as shown in the following figure.

Figure 7 RT structure



The definition of RT is similar to that of RD. For 0x02 and 0x202, the AS number must be a public one. For 0x102, the IPv4 address must be a global one rather than a private address.

2.1.4 MP-BGP

The VPN route information is transmitted on the backbone network through BGP. The export RT attribute is carried in the BGP extended community attribute. The traditional BGP4, however, transmits only IPv4 routes and cannot carry the VPN route that includes RDs. Therefore, the BGP is extended to introduce new attributes. One of the biggest advantages of BGP is its scalability. The Multi-Protocol (MP-BGP) is a new attribute introduced to the original BGP to support multiple protocols. The MP-BGP can carry VPN information. In this manner, the VPN route takes up the form of RD + IP address prefix. By adding RDs to VPN routes exchanged between PEs, the MP-BGP allows VPN users to change the IPv4 routes to VPN-IPv4 routes and transmit the routes on the backbone network.

2.1.5 Protocol Specification

- IETF RFC 4364: BGP/MPLS IP Virtual Private Networks (VPNs)

2.2 Configuring the BGP/MPLS IP VPN

On a router, you must use the **ip ref** command on the interface to enable MPLS fast forwarding to improve forwarding performance of the router.

2.2.1 Default Configuration

BGP/MPLS L3 VPN is disabled by default.

Function	Default Setting
Basic BGP/MPLS L3 VPN functions	Disabled

Function	Default Setting
VPN label distribution mode	Distributing labels to each VRF
Inter-AS VPN	Disabled
CSC VPN	Disabled
MPLS VPN over GRE	Disabled

2.2.2 Configuring the Basic BGP/MPLS IP VPN


To configure basic BGP/MPLS IP VPN functions, perform the following configurations:

- Configuring an MPLS Network (Mandatory)
- Configuring a VPN Routing Instance (Mandatory)
- Configuring PEs to Transmit VPN Routes (Mandatory)
- Configuring Route Exchange Between PEs and CEs (Mandatory)
- Configuring VPN Label Distribution Mode (Optional)
- Configuring Import and Export Policies for VPN Routes (Optional)
- No import VPN route-target community //Import extended community attribute list (not configured)
-

2.2.2.1 Configuring an MPLS Network

To use MPLS on the backbone network, you must configure the MPLS LDP on the P and PE to set up public tunnels. This means that you must configure LDP on MPLS devices and enable MPLS on each interface.

Use the following commands to configure an MPLS network.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# mpls ip	Enables MPLS globally.  Caution This command is not available on a switch chip.
Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback id [force]	Configures the LDP router ID. The IP address of the loopback interface is generally used as the router ID.
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Ruijie(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# ip address ip-address mask	Assigns an IP address to the interface.
Qtech(config-if-type ID)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables MPLS fast forwarding on the interface.
Qtech(config-if-type ID)# mpls ip	Enables LDP on the interface.
Qtech(config-if-type ID)# show running-config	Displays existing configuration information.

Configure an MPLS network.

```
Qtech# configure terminal
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)#interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 192.168.10.1 255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
```

2.2.2.2 Configuring a VPN Routing Instance

A VPN routing instance is the VRF that is configured on PEs. The CE and P devices do not have VRFs.

The configuration of a VRF includes defining the VRF, assigning RD and RT values to the VRF, and associating the VRF with an interface.

Use the following commands to configure a VPN routing instance.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# ip vrf vrf-name	Creates a VRF and enters VRF configuration mode.
Qtech(config-vrf)# rd rd-value	Sets the RD value.
Ruijie(config-vrf)# route-target {both export import} rt-value	Sets the RT value.
Qtech(config-vrf)# exit	Exits VRF configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# ip vrf forwarding vrf-name	Associates the interface with the VRF.
Qtech(config-if-type ID)# ip address address mask	Assigns an IP address to the interface.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables MPLS fast forwarding on the interface.
Qtech(config-if-type ID)# show running-config	Displays existing configuration information.

Configure a VRF and bind it to interface Gigabitethernet 1/1.

```
Qtech(config)# ip vrf vpn1
Qtech(config-vrf)# rd 100: 1
Qtech(config-vrf)# route-target both 100: 1
Qtech(config-vrf)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip vrf forwarding vpn1
Qtech(config-if-gigabitethernet 1/1)# ip address 192.168.10.1
255.255.255.0
```

**Caution**

If an RD value is specified for the VRF on a PE or the BGP VRF function is enabled on the PE, the RD value cannot be modified or deleted. In this case, you can only delete the VRF and create the VRF again to set the RD value.

Two different VRFs on the same PE cannot be assigned the same RD.

If you enter the **ip vrf forwarding vrf-name** command, the IP address assigned to the interface earlier is deleted. In this case, you need to redefine the IP address in interface configuration mode.

2.2.2.3 Configuring PEs to Transmit VPN Routes

PEs transmit route information to each other through BGP. Because a PE needs to transmit VPN route information rather than common IPv4 route information to another PE, you need to enter VPN address family configuration mode to configure the PE to transmit VPN routes to the peer PE.

Use the following commands to configure the PE to transmit VPN routes to another PE.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-num	Creates a BGP domain and enters BGP configuration mode.
Qtech(config-router)# neighbor ip-address remote-as asn-number	Configures a BGP session.
Ruijie(config-router)# neighbor ip-address update-source interface-name	Sets the interface address used to set up the MP-IBGP session as the source address. The address of the loopback interface is generally used as the source address.
Ruijie(config-router)# address-family vpnv4	Enters the VPN address family.
Qtech(config-router-af)# neighbor ip-address activate	Activates the BGP session to exchange VPN routes.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

Set up an MP-BGP session with the neighboring PE at 1.1.1.1.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
```

2.2.2.4 Configuring Route Exchange Between PEs and CEs

Running BGP Between PEs and CEs to Transmit Route Information

To configure a BGP session with a CE, you need to enter VRF address family configuration mode on the PE and then configure the routing protocol with the CE.

Use the following commands on the PE to configure BGP.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp pe-asn-num	Creates a BGP domain and enters BGP configuration mode.
Qtech(config-router)# address-family ipv4 vrf vrf-name	Configures and enters BGP VRF address family configuration mode.
Ruijie(config-router-af)# neighbor ip-address remote-as ce-asn-num	Sets up an EBGP session with a CE.

Qtech(config-router-af)# show running-config	Displays existing configuration information.
---	--

Set up an EBGP session with the neighboring CE at 192.168.10.2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf1
Qtech(config-router)# neighbor 192.168.10.2 remote-as 2
```



Caution

If no RD is specified for the VRF, you will be reminded that no RD value is configured when you use the **address-family ipv4 vrf vrf-name** command to enter the specified VRF address family. As a result, you cannot enter the address family.

Use the following commands on the CE to configure a PE peer.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>ce-asn-num</i>	Creates a BGP domain and enters BGP configuration mode.
Ruijie(config-router)# neighbor <i>ip-address</i> <i>pe-asn</i>	Sets up an EBGP session with a PE.
Qtech(config-router)# show running-config	Displays existing configuration information.

Set up an EBGP session with the PE at 192.168.10.1.

```
Qtech# configure terminal
Qtech(config)# router bgp 2
Qtech(config-router)# neighbor 192.168.10.1 remote-as 1
```

Configuring OSPF Between PEs and CEs to Transmit Route Information

To run OSPF between a PE and a CE, you must configure an OSPF instance for the VRF on the PE. The VRF then uses the OSPF instance to exchange route information between the PE and the CE. By redistributing BGP routes, OSPF sends the VPN routes received from other PEs to the CE. At the same time, by redistributing OSPF routes, BGP sends the VPN route information that is distributed to the PE by the CE to other PE peers.

Use the following commands on the PE to configure OSPF.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router ospf <i>ospf-id</i> vrf <i>vrf-name</i>	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# network <i>prefix mask</i> area <i>area-id</i>	Configures an OSPF link.
Ruijie(config-router)# redistribute bgp subnets	Configures OSPF to redistribute BGP routes.
Ruijie(config-router)# exit	Exits OSPF configuration mode.
Qtech(config)# router bgp <i>asn</i>	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# address-family ipv4 vrf <i>vrf-name</i>	Enters BGP VRF configuration mode.
Qtech(config-router-af)# redistribute ospf <i>ospf-id</i>	Redistributes OSPF routes.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

Run OSPF between a PE and a CE to distribute VPN routes.

```
Qtech# configure terminal
```

```

Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf1
Qtech(config-router-af)# redistribute ospf 10

```

Configuring RIP Between PEs and CEs to Transmit Route Information

The PE and CE run RIP. The VRF on the PE can exchange route information between the PE and the CE. RIP redistributes BGP routes and transmits VPN routes from other PEs to the CE. Meanwhile, BGP redistributes RIP routes and transmits VPN routes distributed by the CE to the PE to other PE peers.

Use the following commands on the PE to configure RIP.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router rip	Creates a RIP instance and enters RIP configuration mode.
Ruijie(config-router)# address-family ipv4 vrf vrf-name	Enters RIP VRF address family configuration mode.
Qtech(config-router)# version 2	Configures the version of RIP.
Ruijie(config-router-af)# network network-number [wildcard]	Configures RIP on the PE and CE.
Ruijie(config-router-af)# redistribute bgp	Configures RIP to redistribute BGP routes.
Ruijie(config-router-af)# exit	Exits address family configuration mode.
Qtech(config)# router bgp asn	Configures BGP and enters BGP configuration mode.
Qtech(config-router)# address-family ipv4 vrf vrf-name	Enters BGP VRF configuration mode.
Qtech(config-router-af)# redistribute rip	Redistributes OSPF routes.
Qtech(config-router)# show running-config	Displays existing configuration information.

Run RIP between a PE and a CE to distribute VPN routes.

```

Qtech# configure terminal
Qtech(config)# router rip
Qtech(config-router)# address-family ipv4 vrf vrf1
Qtech(config-router-af)# version 2
Qtech(config-router-af)# network 192.168.10.0
Qtech(config-router-af)# redistribute bgp
Qtech(config-router-af)# exit-address-family
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf1
Qtech(config-router-af)# redistribute rip

```

Transmitting Route Information Between a PE and a CE Through Static Configurations

In simple network environments, you can generally configure static routes. Use the following commands to configure a static route.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# ip route vrf vrf-name prefix mask interface-name nexthop	Configures a static route.

Qtech(config)# router bgp asn	Enters BGP configuration mode.
Qtech(config-router)# address-family ipv4 vrf vrf-name	Enters BGP VRF address family configuration mode.
Qtech(config-router-af)# redistribute static	Redistributes static routes.
Qtech(config-router)# show running-config	Displays existing configuration information.

Configure a static route on the PE to distribute VPN routes.

```
Qtech# configure terminal
Qtech(config)# ip router vrf vrf1 192.168.20.0 255.255.255.0 gigabitEthernet 2/3
192.168.10.2
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf1
Qtech(config-router-af)# redistribute static
```

2.2.2.5 Configuring VPN Label Distribution Mode (Optional)

RFC 4364 describes two label distribution modes for L3VPN applications: route-based label distribution and VRF-based label distribution. The advantage of the former is rapid forwarding that allows a device to forward packets to the next hop by searching the ILM table. The disadvantage, however, is the large capacity of the ILM table. The advantage of the latter is the reduced capacity of the ILM table. This is because one label is assigned to each VRF and all routes in the VRF thus share the label. The disadvantage is the lower forwarding efficiency because it requires two times of table searching. The device should first locate the VRF of the packets based on the ILM table and then forward the packets by searching routes in the VRF based on the destination IP address.

An L3VPN adopts VRF-based label distribution mode by default. You can run the **alloc-label** command in VRF configuration mode to change default label distribution mode. You can also choose different distribution modes for different VRFs.

To configure label distribution mode, enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# ip vrf vrf-name	Creates a VRF and enters VRF configuration mode.
Qtech(config-vrf)# alloc-label per-vrf	Assigns one label to all routes in the VRF. When distributing VPN routes, MP-BGP uses the same label for all routes.
Qtech(config-vrf)# alloc-label per-route	Assigns one label to each route in the VRF. When distributing VPNv4 routes, MP-BGP uses a different label for each route.
Qtech(config-vrf)# show running-config	Displays existing configuration information.



Caution

When you change label distribution mode, MP-BGP cancels all routes advertised in the VPN and advertises the routes again. VRF-based label distribution mode is adopted by default. In this case, a PE first pops out the received packets with labels and then chooses routes to forward the packets based on the IP routing table. [Configuring Import and Export Policies for VPN Routes \(Optional\)](#)

In most situations, you can define the route-target import attribute in VRF configuration mode to determine the routes to be imported into the VRF and define the route-target export attribute to determine the RTs to be carried in the routes. These configurations are effective for all routes. In certain application scenarios that require accurate policy-based control on the import and export of VPN routes, however, you need to adopt policies.

Enter privileged EXEC mode and use the following commands to configure import and export policies.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# ip vrf vrf-name	Creates a VRF and enters VRF configuration mode.
Qtech(config-vrf)# import map routemap-name	Sets the policy to import VPNv4 routes from the remote end to the local VPN routes based on the rules defined in the route map.
Qtech(config-vrf)# export map routemap-name	Sets the extended community attribute to export VPNv4 routes from the local end to the remote end based on the rules defined in the route map.
Qtech(config-vrf)# show running-config	Displays existing configuration information.

**Caution**

The rules defined by using the **import map** command take effect after the import extended community attribute defined in the VRF. That is, VPN routes received from the remote end can be further filtered by using the rules defined with the **import map** command only after the routes match the extended community attribute defined by the **route-target import** command in the VRF.

Configure a route map for importing VPN routes with the RT of 100:1 to vrf1.

```
Qtech# configure terminal
Qtech(config)# ip extcommunity-list 1 permit rt 100: 1
Qtech(config)# route-map IN-RT-FILTER
Qtech(config-route-map)# match extcommunity 1
Qtech(config-route-map)# exit
Qtech(config)# ip vrf vrf1
Qtech(config-vrf)# rd 100: 2
Qtech(config-vrf)# route-target export 100: 30
Qtech(config-vrf)# import map IN-RT-FILTER
Qtech(config-route-map)# end
Qtech# show ip vrf detail vrf1
VRF vrf1: default RD : 100: 2
Interfaces:
Vlan 1 //Interface bound to the VRF
Export VPN route-target communities: //Export extended community attribute list
RT : 100: 30
No import VPN route-target community //Import extended community attribute list (not
configured)
import-map: IN-RT-FILTER//Import policy
```

2.2.2.6 Configuring a Static L3VPN FTN and ILM (Optional)

In most situations, MP-BGP assigns labels to private routes and a public LSP is generated by running LDP on a public network. You can also configure a static LSP to assign labels to private routes and set up private LSPs.

To configure an FTN for the L3VPN on the PE, enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls static l3vpn-ftn vrf-name ip-address/mask out-label out-label remote-pe ip-address	Configures a static private FTN that specifies the egress of the FEC as another PE. In this case, you must specify the private label and the egress PE. The address of the egress PE is then used to configure the public LSP.

<pre>Qtech(config)# mpls static l3vpn-ftn vrf- name fec-prefix/fec-mask local-forward nexthop interface-name nexthop-ip</pre>	<p>Configures a static private FTN that specifies the egress of the FEC as the local PE. In this case, you must specify the outgoing interface on the local PE and the next-hop address (the outgoing interface and the next hop are generally in another VRF). You can use this command when the local PE has several VRFs that belong to the same VPN.</p>
<pre>Qtech# show running-config</pre>	<p>Displays existing configuration information.</p>

To configure an ILM for the L3VPN on the PE, enter privileged EXEC mode and use the following commands.

Command	Function
<pre>Qtech# config terminal</pre>	<p>Enters global configuration mode.</p>
<pre>Qtech(config)# mpls static ilm in-label in- label forward-action pop-l3vpn-nexthop vrf-name nexthop interface-name nexthop- ip-address fec ip-address/mask</pre>	<p>Configures an ILM entry for the L3VPN on the PE. You need to specify the incoming label, the outgoing interface, and the next-hop address.</p>
<pre>Qtech# show running-config</pre>	<p>Displays existing configuration information.</p>



Caution

The configured static private FTN and ILM take effect only after the corresponding public LSP is set up. To set up the public LSP, see the "Configuring an MPLS Network" section. You can set up a public LSP through LDP or static configurations.

2.2.3 Configuring an Inter-AS VPN

On an actual network, different sites of VPN users may be located on different ASs and mutual communication is required between these sites. In this case, the VPN routes should be exchanged between different ASs. This technology is called the inter-AS VPN.

RFC 4364 introduces three inter-AS VPN schemes:

- OptionA: VRF-to-VRF mode
- OptionB: single-hop MP-EBGP mode
- OptionC: multi-hop MP-EBGP mode

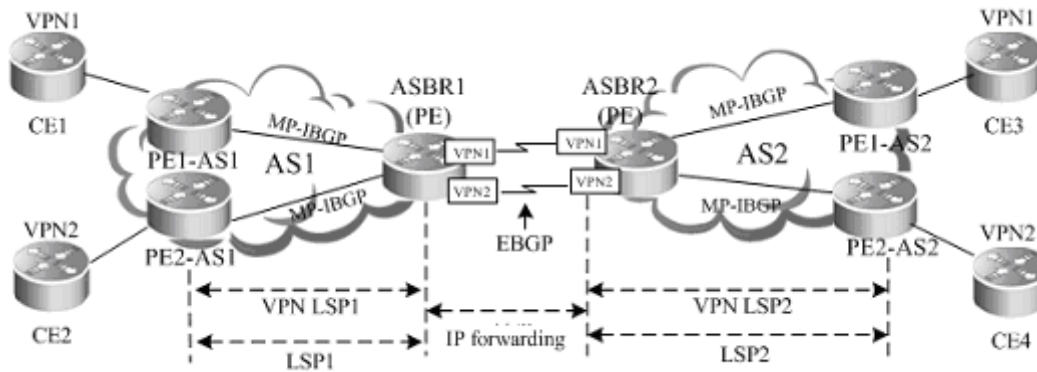
2.2.3.1 OptionA: VRF-to-VRF Mode

Also referred to as VRF back-to-back, VRF-to-VRF mode is easy to implement. The autonomous system boundary router (ASBR) of an AS sets up a VRF for each inter-AS VPN to bind an interface to the VRF. The VRFs on ASBRs then exchange VPN routes through the interface.

The purpose of creating a VRF and binding an interface to it is as follows:

- To receive VPN routes from the local AS
- To set up an EBGP connection between the VRF and the VRF of another AS to exchange IPv4 routes

Figure 8 VRF-to-VRF inter-AS VPN



As shown in the preceding figure, the VRFs between the ASBRs set up common EBGP sessions to exchange IPv4 routes and the ASBRs and PEs set up MP-IBGP sessions to exchange VPN routes. For the VRF on an ASBR, the other VRF, with which the EBGP session is set up, is equivalent to a CE. This configuration scheme is similar to the common intra-domain configuration scheme. The ASBRs and PEs set up MP-IBGP sessions to exchange VPN routes. The VRFs of ASBRs set up EBGP sessions in BGP VRF address family configuration mode to exchange IPv4 routes.

■ Characteristics and limitations

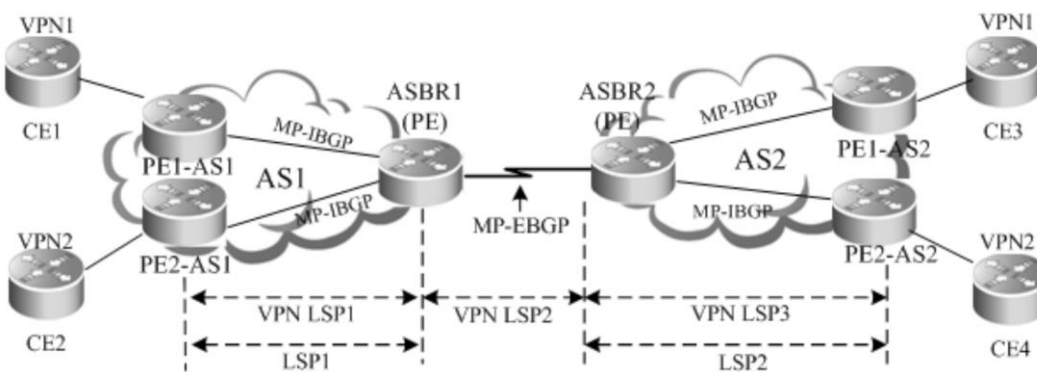
VRF-to-VRF mode is easy to implement by directly using MP-IBGP. The service deployment is also simple. This scheme, however, requires an interface (generally a logical sub-interface) for each inter-AS VPN on an ASBR. The number of bound interfaces at least should be equal to the number of inter-AS VPNs. You should configure an interface for each VPN on the ASBR, complicating network expansion. In addition, the separate creation of sub-interfaces for each VPN imposes high requirements on ASBRs. As a result, this scheme is generally applicable to networks with a small number of inter-AS VPNs.

The configuration of OptionA is similar to that of a BGP/MPLS IP VPN and is not described here.

2.2.3.2 OptionB: Single-Hop MP-EBGP Mode

In the OptionA scheme, you need to configure a VRF for each VPN on an ASBR and bind an interface to the VRF. This is because VPN routes cannot be directly transmitted between EBGP peers and can only be carried through MP-IBGP. If the VPN routes can be directly transmitted between EBGP peers, you are not required to configure VRFs on the ASBR. This is clearly a better implementation mode. In this case, the OptionB scheme extends MP-IBGP and allows the direct distribution of VPN routes between ASBRs. This is called single-hop EBGP, as shown in the following topology.

Figure 9 OptionB inter-AS VPN



■ Characteristics and limitations

The advantage of this MP-EBGP scheme is that you are not required to configure a sub-interface for each site of VPN users on an ASBR. You are also not required to set up an inter-AS LSP. The VPN routes are directly transmitted between single-hop MP-EBGP neighbors. The VPN route information, however, is maintained and spread by the ASBRs between ASs. If a large number of VPN routes exist, the ASBRs are faced with heavy pressure. Because the ASBRs also generally assume tasks of forwarding IP packets on the public network, high requirements are imposed on these devices. In addition, the ASBRs cancel the RT filtering function for received VPN

routes. The VPN routes on PEs may be spread to the ASBRs in another AS. This may lead to the leakage of VPN routes. As a result, the SPs, who exchange VPN routes, must reach trust agreements on route exchange. The ASBRs should trust each other and implement corresponding route filtering policies. The OptionB scheme is applicable to networks with lots of inter-AS VPN services.

OptionB has two schemes:

- The ASBR does not change the next hop of a VPN route.
- The ASBR changes the next hop of a VPN route.

The following describes the configuration procedures of the two schemes.

Scheme 1: Next Hop Unchanged

When an ASBR receives VPN routes sent from the ASBR in another AS and sends the routes to the MP-IBGP neighbors in the local AS, the next hop of the routes is not changed. This mode is called the "OptionB Next Hop Unchanged Scheme". In this mode, the PEs and ASBRs in an AS still set up MP-IBGP sessions to exchange VPN routes and the two ASBRs set up MP-EBGP sessions to directly exchange VPN routes. When sending routes to an MP-IBGP neighbor, the ASBR does not change the next hop of the VPN routes received from the MP-EBGP neighbor. This requires that the PE in the AS should have a route to the next hop address (that is, the ASBR in another AS). For this purpose, you can configure the local ASBR to redistribute routes destined for the other ASBR to the IGP protocol in the local AS. In this manner, the address of the ASBR in another AS becomes reachable and you can set up an LSP through LDP.

The configuration procedure is as follows:

- 11) Configuring route exchange between PEs and CEs
 - 12) Configuring an IGP and MPLS signaling protocol in an AS
 - 13) Configuring an ASBR to cancel the default RT filtering function
 - 14) Configuring PEs and ASBRs in the same AS to exchange VPN route information
 - 15) Setting up an MP-EBGP session between ASBRs
 - 16) Configuring route map rules to filter VPN routers (optional)
 - 17) Configuring an IGP to redistribute ASBR routes of another AS
- Configuring route exchange between PEs and CEs

This procedure is similar to configuring route exchange between PEs and CEs and is not described here.

- Configuring an IGP and MPLS signaling protocol in an AS

This procedure is similar to configuring an MPLS network and is not described here.

- Configuring an ASBR to cancel the default RT filtering function

By default, a PE rejects a VPN route sent by another PE (or ASBR), if the route is not imported by any VRF on the PE. Therefore, you should disable the default filtering on an ASBR so that the ASBR can receive all VPN routes from others PEs (or ASBRs), no matter whether these routes are imported into the local VRF or not.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-number	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# no bgp default route-target filter	Disables RT filtering.
Qtech(config-router)# show running-config	Displays existing configuration information.

Disable RT filtering.

```
Qtech# configure terminal
Qtech(config)# router bgp 2
Qtech(config-router)# no bgp default route-target filter
```

- Configuring PEs and ASBRs in the same AS to exchange VPN route information

This procedure is similar to configuring PEs to transmit VPN routes and is not described here.

- Setting up an MP-EBGP session between ASBRs

Set up directly-connected single-hop MP-EBGP sessions between inter-AS ASBRs to distribute VPN routes.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-number</i>	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>asbr-address</i> remote-as <i>asbr-asn-number</i>	Configures an ASBR EBGP session.
Qtech(config-router)# address-family vpnv4	Enters the BGP VPN address family.
Qtech(config-router-af)# neighbor <i>asbr-address</i> activate	Enables the VPN route exchange with the peer.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

Configure an EBGP neighbor at 20.20.20.2 and activate the VPN address family.

```
Qtech# configure terminal
Qtech(config)# router bgp 2
Qtech(config-router)# neighbor 20.20.20.2 remote-as 1
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 20.20.20.2 activate
```



Caution

You must run the **label-switching** command on the interface that connects two ASBRs to enable MPLS on the interface so that the links between the ASBRs can forward MPLS packets.

- On a router, use the **ip ref** command on the interface to enable fast forwarding to improve forwarding performance.



Caution

If the ASBRs do not use directly connected addresses to set up an MP-EBGP session but use the loopback address with a 32-bit mask as the source address to set up an MP-EBGP session, you must use the **neighbor ebgp-multihop** command to enable multi-hop EBGP. At the same time, you must configure static routes on the ASBR to the loopback address on the peer, enable LDP or configure a static FTN (with an outgoing label as 3, indicating that the ASBR is the second to last hop).

- Configuring route map rules to filter VPN routes (optional)

In view of the AS security in actual applications, you can generally configure policies on ASBRs to send or receive only certain VPN routes. You can realize this purpose by filtering the RT extended community attributes of VPN routes. In addition, all VPN routes are saved because the default RT filtering function is disabled on the ASBR. In this case, you can configure VPN routing policies to receive only inter-AS VPN routes sent from the local AS, lessening the capacity pressure of the ASBR.

To configure a filtering policy, enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# ip extcommunity-list standard <i>extcommunity-name</i> <i>extcommunity-number</i> { permit deny } rt <i>rt-value</i>	Creates a rule for the extended community attribute list.

Command	Function
Qtech(config)# show ip extcommunity-list [list-number/list-name]	Verifies the configured rule for the extended community attribute list.
Qtech(config)# route-map route-map-name permit [number]	Creates a route map rule and enters route map configuration mode.
Qtech(config-route-map)# match extcommunity extcommunity-name/extcommunity-number	Sets the RT matching rule for a route map.
Qtech(config-route-map)# show route-map route-map-name	Displays the route map rule.
Qtech(config-route-map)# exit	Exits route map configuration mode.
Qtech(config)# router bgp as-num	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# address-family vpnv4	Enters the VPN address family.
Qtech(config-router-af)# neighbor peer-address route-map route-map-name in	Filters the VPN routes received from the ASBR in another AS.
Qtech(config-router-af)# neighbor peer-address route-map route-map-name out	Filters the VPN routes sent to the ASBR in another AS.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

Configure an ASBR to receive VPN routes with an RT value of 100:1 from the MP-IBGP peer at 1.1.1.1.

```
Qtech# configure terminal
Qtech(config)# ip extcommunity-list standard RT permit rt 100:1
Qtech(config)# show ip extcommunity-list RT
Named extended community standard list RT
permit rt 100:1
Qtech(config)# route-map RT-IN permit
Qtech(config-route-map)# match extcommunity RT
Qtech(config-route-map)# show route-map RT-IN
route-map map, permit, sequence 10
  Match clauses:
  extcommunity (extcommunity-list filter):RT
  Set clauses:
  Policy routing matches: 0 packets, 0 bytes
Qtech(config-route-map)# exit
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 route-map RT-IN in
Qtech(config-router-af)# end
```

■ Configuring an IGP to redistribute ASBR routes of another AS

Because the ASBR does not change the next hop of VPN routes sent to the IBGP peer, the next hop address of VPN routes learned by the PEs in the local AS is the ASBR address in another AS. Therefore, you must configure the PEs to learn the route to the next hop address. For the single-hop directly-connected MP-EBGP session where BGP is enabled to carry labels (through IPv4 routes or VPN routes), MP-BGP supports the automatic generation of a host route with a 32-bit mask and FTN entry (with the outgoing label 3) on the ASBR. In this manner, the tunnel egress is not terminated on the local ASBR. Therefore, as long as the ASBR redistributes the host route to the IGP in the local AS, the PEs can learn routes to the ASBR in the other AS.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router igp	Enables an IGP that can be OSPF, RIP, or IS-IS.

Qtech(config-router)# redistribute connected subnets	Redistributes directly connected subnet routes.
Qtech(config-router)# show running-config	Displays existing configuration information.

Configure OSPF on an ASBR to redistribute the directly connected subnet routes.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# redistribute connected subnets
```

Scheme 2: Next Hop Changed

When an ASBR receives VPN routes sent from the ASBR in another AS and sends the routes to the PEs in the local AS, the next hop of the routes is changed. This mode is called the "OptionB Next Hop Changed Scheme". In this mode, the PEs and ASBRs in the same AS can set up MP-IBGP sessions to exchange VPN routes. Two ASBRs can set up MP-EBGP sessions to exchange VPN routes. Upon receipt of a VPN route from another ASBR neighbor, an ASBR changes the next hop to its own address when advertising the route to the MP-IBGP peer in the AS.

The configuration procedure is as follows:

- 18) Configuring route exchange between PEs and CEs
- 19) Configuring an IGP and MPLS signaling protocol in an AS
- 20) Configuring an ASBR to cancel the default RT filtering function
- 21) Setting up an MP-IBGP session between an ASBR and PE and changing the next hop address to its own address
- 22) Setting up an MP-EBGP session between ASBRs
- 23) Configuring route map rules to filter VPN routes (optional)
 - Configuring route exchange between PEs and CEs

This procedure is similar to configuring route exchange between PEs and CEs and is not described here.

- Configuring an IGP and MPLS signaling protocol in an AS

This procedure is similar to configuring an MPLS network and is not described here.

- Configuring an ASBR to cancel the default RT filtering function

This procedure is similar to configuring an ASBR to cancel the default RT filtering function in Scheme 1 and is not described here.

- Setting up an MP-IBGP session between an ASBR and PE and changing the next hop address to its own address

By default, an ASBR does not change the next hop of the VPN route received from an MP-EBGP peer when the ASBR sends the route to the MP-IBGP peer. You can configure the ASBR to forcibly change the next hop of the VPN route to the ASBR address in the local AS. In this manner, the PEs in the local AS are not required to learn the address of the peer ASBR. This is the major difference with Scheme 1 (Next Hop Unchanged Scheme).

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-num	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor pe-address remote-as asn-num	Sets up an IBGP session with a PE.
Qtech(config-router)# neighbor pe-address update-source interface-name	Specifies the local loopback interface as the source address to set up an IBGP session.
Qtech(config-router)# address-family vpnv4	Enters BGP VPN address family configuration mode.
Qtech(config-router-af)# neighbor pe-address activate	Enables the VPN route exchange with the peer.
Qtech(config-router-af)# neighbor pe-address next-hop-self	Sets the ASBR to change the next hop to its own address when sending VPN routes to the IBGP neighbor.

Qtech(config-router-af)# show running-config	Displays existing configuration information.
---	--

Set up an MP-IBGP session, activate the VPN address family, and change the next hop address to the ASBR address.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 next-hop-self
Qtech(config-router-af)# end
```

■ **Setting up an MP-EBGP session between ASBRs**

This procedure is similar to setting up an MP-EBGP session between ASBRs in Scheme 1 and is not described here.

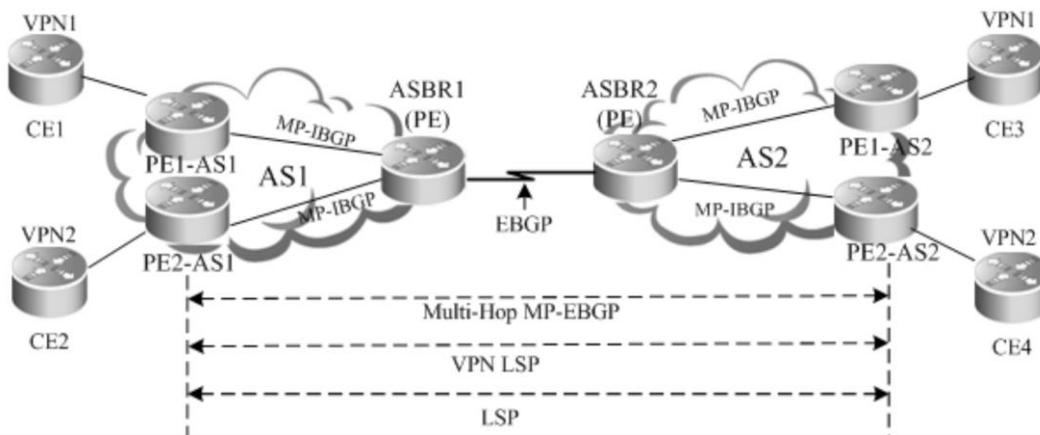
■ **Configuring route map rules to filter VPN routes (optional)**

This procedure is similar to configuring route map rules to filter VPN routers (optional) in Scheme 1 and is not described here.

2.2.3.3 OptionC: Multi-Hop MP-EBGP Mode

Both OptionA and OptionB can meet the networking requirements of inter-AS VPNs. In these two schemes, ASBRs are required to maintain and advertise VPN routes. If a large number of inter-AS VPN routes should be advertised in each AS, the ASBRs may become the bottleneck of further network expansion. To solve this problem, a third scheme is developed, that is, the multi-hop MP-EBGP. In multi-hop MP-EBGP mode, the PEs in different ASs set up multi-hop MP-EBGP sessions to directly exchange VPN routes. As a result, the ASBRs are not required to maintain or advertise VPN routes.

Figure 10 Multi-hop MP-EBGP



■ **Characteristics and limitations**

In multi-hop MP-EBGP mode, only PEs rather than ASBRs are required to store VPN information. This incurs complex configurations. This scheme is applicable to networks to be deployed with inter-AS VPN services on a large scale.

In terms of implementation principle, OptionC is further classified into two modes:

- 24) Enabling label distribution for IPv4 routes only between EBGP neighbors.
- 25) Enabling label distribution for IPv4 routes between EBGP and IBGP neighbors.

To facilitate expansion in OptionC, each AS is generally deployed with a route reflector (RR). The RRs of two ASs set up multi-hop MP-EBGP sessions to exchange VPN routes. Judged from deployment, OptionC can be referred to as the scheme of "Setting Up a Multi-Hop MP-EBGP Session Between RRs".

The following describes the configuration procedures of these schemes.

Scheme 1: Enabling Label Distribution for IPv4 Routes Only Between EBGPeighbors

In this scheme, the IGP (such as OSPF or RIP) that runs on an ASBR is required to redistribute BGP routes so that each device in the AS can have routes to the PE in another AS. In the AS, you can use LDP to assign labels to the routes to the PE in another AS and set up an LSP. On the directly connected ASBRs of the two ASs, enable label distribution for IPv4 routes. In this manner, BGP serves as the MPLS signaling protocol to assign labels to the routes to the PE in another AS and set up an inter-AS LSP.

The configuration procedure is as follows:

- 26) Configuring route exchange between PEs and CEs in each AS
- 27) Configuring an IGP and MPLS signaling protocol in an AS
- 28) Setting up an EBGPe session between ASBRs to distribute labels for IPv4 routes
- 29) Configuring an ASBR to redistribute inter-AS PE routes learned from EBGPe to the IGP
- 30) Configuring a multi-hop MP-EBGPe session
 - Configuring route exchange between PEs and CEs

This procedure is similar to configuring route exchange between PEs and CEs and is not described here.

- Configuring an IGP and MPLS signaling protocol in an AS

This procedure is similar to configuring an MPLS network and is not described here.

- Setting up an EBGPe session between ASBRs to enable label distribution for IPv4 routes

Set up an EBGPe session between inter-AS ASBRs and enable label distribution of IPv4 routes. To import PE routes to BGP, you can use the **network** command in BGP IPv4 address family configuration mode or run commands to redistribute IGP routes. In view of the AS security in actual applications, you are generally required to configure IPv4 route distribution policies on ASBRs. By configuring route map rules, you can control the routes sent to neighbors and specify whether the routes carry labels. Similar control is available for receiving routes.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-num	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor asbr-address remote-as asbr-asn-num	Sets up an EBGPe session with an ASBR.
Qtech(config-router)# address-family ipv4	Enters BGP IPv4 address family configuration mode.
Qtech(config-router-af)# neighbor asbr-address send-label	Configures the device to exchange labeled IPv4 routes with the ASBR peer in another AS.
Qtech(config-router-af)# network pe-address mask mask	(Optional) Configures PE addresses to be imported into the BGP routing table in the local AS, that is, host routes of each PE in the AS.
Qtech(config-router-af)# neighbor asbr-address route-map routemap-name out	(Optional) Configures a route distribution policy to control the routes sent to neighbors and specify whether the routes can carry labels, by defining a route map rule.
Qtech(config-router-af)# neighbor asbr-address route-map routemap-name in	(Optional) Configures a route distribution policy to receive only labeled routes by defining a route map rule.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

**Caution**

You must run the **label-switching** command on the interface that connects two ASBRs to enable MPLS on the interface so that the links between the ASBRs can forward MPLS packets.



- On a router, use the **ip ref** command on the interface to enable fast forwarding to improve forwarding performance.

**Caution**

If the ASBRs do not use directly connected addresses to set up an MP-EBGP session but use the loopback address with a 32-bit mask as the source address to set up an MP-EBGP session, you must use the **neighbor ebgp-multihop** command to enable multi-hop EBGP. At the same time, you must configure static routes on the ASBR to the loopback address on the peer, enable LDP or configure a static FTN (with an outgoing label as 3, indicating that the ASBR is the second to last hop).

Set up an EBGP session between ASBRs, enable label distribution for IPv4 routes, and run the **network** command to import PE routes to BGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 20.20.20.2 remote-as 2
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 20.20.20.2 send-label
Qtech(config-router-af)# network 10.10.10.10 mask 255.255.255.255
Qtech(config-router-af)# end
```

In actual applications, an ASBR is generally required to distribute labels for PE routes for only inter-AS VPN services. For this purpose, you can use the route map rules defined by the **set mpls-label** command.

The **set mpls-label** command sets labels for routes. You can create a route map rule to distribute only inter-AS PE routes to the peer ASBR and set labels for the routes. Set route map rules and then run the **neighbor peer-address route-map rmap_name out** command in BGP IPv4 address family configuration mode to associate the rules with the route map.

The following example creates a route map to assign an MPLS label to the route with a prefix as 1.1.1.1/32, to assign a common IPv4 route without a label to the route with a prefix as 1.1.1.2/32, and not to send neighbors routes that fail to match acl1 and acl2.

```
Router(config)# ip access-list standard acl1
Router(config-std-nacl)# permit host 1.1.1.1
Router(config-std-nacl)# exit
Router(config)# ip access-list standard acl2
Router(config-std-nacl)# permit host 1.1.1.2
Router(config-std-nacl)# exit
Router(config)# route-map out-as permit 10
Router(config-route-map)# match ip address acl1
Router(config-route-map)# set mpls-label
Router(config-std-nacl)# exit
Router(config)# route-map out-as permit 20
Router(config-route-map)# match ip address acl2
Router(config)# router bgp 100
Router(config-router)# neighbor 30.30.30.2 remote-as 100
Router(config-router)# neighbor 30.30.30.2 route-map out-as out
```

Similarly, to receive only labeled IPv4 routes, you can run the **match mpls-label** command in route map mode. Set route map rules and then run the **neighbor peer-address route-map rmap_name in** command to associate the rules with the route map.

The following example creates a route map to receive labeled IPv4 routes from only the BGP peer at 30.30.30.2 and reject other routes.

```
Router(config)# route-map match-mpls
Router(config-route-map)# match mpls-label
Router(config)# router bgp 100
```



```
Router(config-router)# neighbor 30.30.30.2 remote-as 100
Router(config-router)# neighbor 30.30.30.2 route-map match-mpls in
```

- Configuring an ASBR to redistribute inter-AS PE routes learned from EBGP to the IGP

When an ASBR learns a route to the PE in another AS from the peer ASBR, the ASBR should advertise the route to other PEs in the local AS. The ASBR should also set up an LSP to the PE in another AS. In this manner, the ASBR can redistribute routes learned from EBGP to the IGP and at the same time, enable LDP to distribute labels for BGP routes and then set up an LSP to the PE in another AS.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router igp	Enters IGP configuration mode.
Qtech(config-router)# redistribute bgp subnets [route-map routemap-name]	Redistributes BGP routes. Route filtering by using route map rules is optional.
Qtech(config-router)# exit	Exits IGP configuration mode.
Qtech(config)# mpls router ldp	Enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force	Configures the LDP router ID. The loopback address is generally used as the router ID.
Qtech(config-mpls-router)# advertise-labels for bgp-routes [acl acl-name]	Distributes labels for BGP routes. Filtering based on ACL rules is optional.
Qtech(config-mpls-router)# show running-config	Displays existing configuration information.



Caution

By default, LDP distributes labels for only IGP routes and does not distribute labels for BGP routes. To distribute labels for BGP routes, you can run the **advertise-labels for bgp-routes** command.

Configure an IGP and MPLS signaling protocol in an AS.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# end
```

When an IGP redistributes the learned BGP routes in the OptionC scheme, you can run the **redistribute bgp subnets route-map routemap-name** command in IGP configuration mode to control the BGP routes to be redistributed to the IGP. In LDP configuration mode, you can run the **advertise-labels for bgp-routes acl acl-name** command to control the labels distributed for BGP routes.

Configure ACL rules and route map routes so that:

- The IGP redistributes only routes 1.1.1.1 and 2.2.2.2.
- The LDP assigns labels to only routes 1.1.1.1 and 2.2.2.2.

The configuration procedure is as follows:

```
Router(config)# ip access-list extended 101
Router(config-ext-nacl)# permit ip host 1.1.1.1 any
Router(config-ext-nacl)# permit ip host 2.2.2.2 any
Router(config-ext-nacl)# exit
Router(config)# route-map pe-routes
Router(config-route-map)# match ip address 101
Router(config-route-map)# exit
Router(config)# router ospf 1
Router(config-router)# redistribute bgp subnets route-map pe-routes
Router(config-route-map)# exit
```

```
Router(config)# mpls router ldp
Router(config-mpls-router)# advertise-labels for bgp-routes acl 101
```

■ Configuring a multi-hop MP-EBGP session

In the earlier steps, the inter-AS LSP is already set up. At this time, you can directly set up a multi-hop MP-EBGP session on the PE to be deployed with inter-AS VPN services with the PE in another AS. The session can then exchange VPN routes.

To configure a multi-hop MP-EBGP session, enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-num	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor ebgp-peer-address remote-as ebgp-asn-num	Sets up a multi-hop EBGP session with the PE in another AS.
Qtech(config-router)# neighbor ebgp-peer-address update-source interface-name	Configures the device to use the loopback address to set up a neighbor relation with the EBGP peer.
Qtech(config-router)# neighbor ebgp-peer-address ebgp-multihop	Configures multi-hop attributes.
Qtech(config-router)# address-family vpnv4	Enters BGP VPN address family configuration mode.
Qtech(config-router-af)# neighbor ebgp-peer-address activate	Enables the VPN route exchange with the peer.
Qtech(config-router-af)# exit	Exits the BGP VPN address family.
Qtech(config-router)# address-family ipv4	Enters BGP IPv4 address family configuration mode.
Qtech(config-router-af)# no neighbor ebgp-peer-address activate	Disables the IPv4 route exchange.
Qtech(config-router)# show running-config	Displays existing configuration information.



Caution

The exchange of IPv4 routes is not required in a multi-hop MP-EBGP session. At least the routes of the two addresses used to set up the BGP session should be avoided. Otherwise, a PE has two routes to the PE in another AS. One route is advertised by the ASBR in the local AS and the other is advertised by the multi-hop EBGP session. According to the BGP specification, the EBGP route has a higher priority over the IBGP route by default. As a result, BGP chooses the route advertised by the multi-hop BGP, resulting in continuous flapping of routes on the PE to the PE in another AS. The VPN routes are thus not reachable.

Set up a multi-hop EBGP session.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 2
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 1.1.1.1 ebgp-multihop
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 1.1.1.1 activate
Qtech(config-router-af)# end
```

Scheme 2: Enabling Label Distribution for IPv4 Routes Between EBGP and IBGP Neighbors

In Scheme 1 (Enabling Label Distribution for IPv4 Routes Only Between EBGP Neighbors), the IGP and LDP in one AS are required to maintain the PE routes from another AS. That is, inter-AS PE routes should be advertised to each device in the AS. In view of the AS security in actual applications, the PE routes of another AS are generally not advertised to each device in the local AS. Instead, these routes should be owned by the BGP protocol so that the routes can be transparent to the IGP and LDP in the local AS. You can enable label distribution for IPv4 routes between EBGP and IBGP neighbors.

This scheme differs from Scheme 1 in that the IGP on an ASBR is not required to redistribute BGP routes and that the LDP is not required to assign labels to BGP routes, though the LDP is still responsible for the setup of an LSP in the local AS. The setup of an inter-AS LSP, however, requires label distribution for IPv4 routes between both IBGP and EBGP neighbors. The PEs are also required to push three consecutive layers of labels.

The configuration procedure is as follows:

- 31) Configuring route exchange between PEs and CEs in each AS
- 32) Configuring an IGP and MPLS signaling protocol in an AS
- 33) Setting up an IBGP session between a PE and an ASBR to distribute labels for IPv4 routes
- 34) Setting up an EBGP session between ASBRs to distribute labels for IPv4 routes
- 35) Configuring a multi-hop MP-EBGP session
 - Configuring route exchange between PEs and CEs

This procedure is similar to configuring route exchange between PEs and CEs and is not described here.

- Configuring an IGP and MPLS signaling protocol in an AS

This procedure is similar to configuring an MPLS network and is not described here.

- Setting up an IBGP session between a PE and an ASBR to distribute labels for IPv4 routes

This scheme differs from Scheme 1 mainly in this configuration procedure. In this scheme, the PE routes that are learned by EBGP from another AS are not redistributed to the IGP in the local AS. Instead, the IBGP session between an ASBR and a PE is used to transmit the PE routes of another AS and BGP is used to assign labels to the PE routes.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-number</i>	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>peer-address</i> remote-as <i>asn-number</i>	Sets up an IBGP session with an ASBR (PE).
Qtech(config-router)# neighbor <i>peer-address</i> update-source <i>interface-name</i>	Configures the device to use the loopback address as the source address to set up the BGP session with an ASBR (PE) peer.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# neighbor <i>peer-address</i> send-label	Configures the device to exchange labeled IPv4 routes with an ASBR (PE) peer.
Qtech(config-router-af)# show running-config	Displays existing configuration information.



Caution

Before you enable label distribution for IPv4 routes for an IBGP session with an IBGP peer, run the **neighbor update-source** command to specify the source address of the IBGP session. This source address must be the address of the loopback interface; otherwise, the inter-AS LSP cannot be set up.

Configure a PE to set up an MP-IBGP session with the ASBR at 10.10.10.2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.2 remote-as 1
```

```

Qtech(config-router)# neighbor 10.10.10.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.2 activate
Qtech(config-router-af)# neighbor 10.10.10.2 send-label
Qtech(config-router-af)# exit

```

Configure an ASBR to set up an MP-IBGP session with the PE at 10.10.10.1 in the local AS.

```

Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.1 remote-as 1
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.1 send-label
Qtech(config-router-af)# end

```

- Setting up an EBGP session between ASBRs to enable label distribution for IPv4 routes

This procedure is similar to the corresponding procedure in Scheme 1 and is not described here.

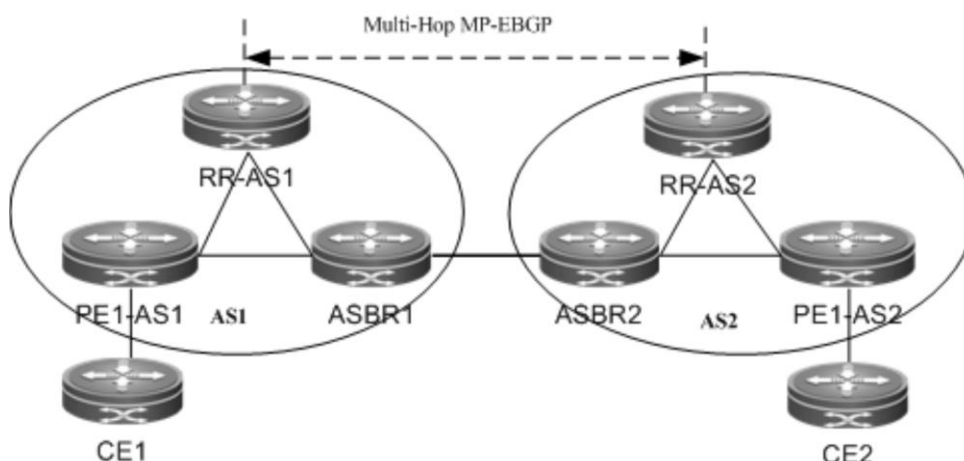
- Configuring a multi-hop MP-EBGP session

This procedure is similar to the corresponding procedure in Scheme 1 and is not described here.

Scheme 3: Setting Up a Multi-Hop MP-EBGP Session Between RRs

In the traditional OptionC scheme, the inter-AS VPN sites should be connected in full mesh mode. The addition of a single VPN site requires the setup of MP-MBGP connections with the PEs in other ASs, hindering the expansion of VPN sites. In this case, you can deploy an RR in each AS to solve this problem. Set up multi-hop MP-EBGP sessions between the RRs to exchange VPN routes.

Figure 11 Setting up a multi-hop MP-EBGP session between RRs in OptionC mode



As shown in the preceding figure, the RRs in the two ASs set up a multi-hop MP-EBGP session to exchange VPN routes. The configuration procedure is as follows:

- 36) Configuring route exchange between PEs and CEs in each AS
- 37) Configuring an IGP and MPLS signaling protocol in an AS
- 38) Setting up an MP-IBGP session between the RR and the PE and enabling label distribution for IPv4 routes
- 39) Setting up an IBGP session between the RR and the ASBR and enabling label distribution for IPv4 routes
- 40) Setting up an EBGP session between ASBRs to distribute labels for IPv4 routes
- 41) Configuring a multi-hop MP-EBGP session

- Configuring route exchange between PEs and CEs

This procedure is similar to configuring route exchange between PEs and CEs and is not described here.

- Configuring an IGP and MPLS signaling protocol in an AS

This procedure is similar to configuring an MPLS network and is not described here.

- Setting up an MP-IBGP session between the RR and the PE and enabling label distribution for IPv4 routes

Configure a PE to set up an MP-IBGP session with the RR to transmit VPN routes. At the same time, enable label distribution for IPv4 routes for the session.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-number</i>	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>peer-address</i> remote-as <i>asn-number</i>	Sets up the IBGP session.
Qtech(config-router)# neighbor <i>peer-address</i> update-source <i>interface-name</i>	Uses the address of the loopback address as the source address to set up an IBGP session.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# neighbor <i>peer-address</i> Activate	Enables IPv4 route exchange.
Qtech(config-router-af)# neighbor <i>peer-address</i> send-label	Enables label distribution for IPv4 routes.
Qtech(config-router-af)# neighbor <i>peer-address</i> route-reflector-client	Configures all PE peers as the clients of the IPv4 RR.
Qtech(config-router-af)# exit	Exits the IPv4 address family.
Qtech(config-router)# address-family vpnv4	Enters the VPN address family.
Qtech(config-router-af)# neighbor <i>peer-address</i> Activate	Enables the VPN route exchange with the peer.
Qtech(config-router-af)# neighbor <i>peer-address</i> route-reflector-client	Configures all PE peers as the clients of the VPN RR.
Qtech(config-router-af)# show running-config	Displays existing configuration information.

Set up an MP-IBGP session between the RR and the PE. The configuration on the RR is as follows:

```
Qtech# configure terminal
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.1 remote-as 1
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.1 activate
Qtech(config-router-af)# neighbor 10.10.10.1 send-label
Qtech(config-router-af)# neighbor 10.10.10.1 route-reflector-client
Qtech(config-router-af)# exit
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 10.10.10.1 activate
Qtech(config-router-af)# neighbor 10.10.10.1 route-reflector-client
Qtech(config-router-af)# end
```

- Setting up an IBGP session between the RR and the ASBR and distributing labels for IPv4 routes

Set up an MP-IBGP session between the ASBR and the RR to receive routes from the RR to the PEs in the local AS and send routes from the RR to the PEs in another AS. At the same time, enable label distribution for IPv4 routes for the session.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-number</i>	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>peer-address</i> remote-as <i>asn-number</i>	Sets up the IBGP session.

Qtech(config-router)# neighbor peer-address update-source interface-name	Uses the address of the loopback address as the source address to set up an IBGP session.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# neighbor peer-address activate	Enables IPv4 route exchange.
Qtech(config-router-af)# neighbor peer-address send-label	Enables label distribution for IPv4 routes.
Qtech(config-router)# show running-config	Displays existing configuration information.

**Note**

For the IBGP session between an RR and an ASBR, you are generally not required to set the ASBR as the client of the RR unless the ASBR also serves as a PE.

Set up an IBGP session between the RR and the ASBR. The configuration on the RR (the configuration on the ASBR is similar) is as follows:

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.2 remote-as 1
Qtech(config-router)# neighbor 10.10.10.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.2 activate
Qtech(config-router-af)# neighbor 10.10.10.2 send-label
Qtech(config-router-af)# end
```

- Setting up an EBGP session between ASBRs to enable label distribution for IPv4 routes

This procedure is similar to the corresponding procedure in Scheme 1 and is not described here.

- Configuring a multi-hop MP-EBGP session

Set up a multi-hop MP-EBGP session between the RRs of two ASs to exchange inter-AS VPN routes. At the same time, disable the transmission of IPv4 routes for the session. The PE routes are advertised to another AS through the ASBR.

Enter privileged EXEC mode and use the following commands.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-number	Enables BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor rr-address remote-as ebgp-asn-numbe	Sets up the EBGP session.
Qtech(config-router)# neighbor rr-address update-source interface-name	Uses the address of the loopback address as the source address to set up an EBGP session.
Qtech(config-router)# neighbor rr-address ebgp-multihop	Configures multi-hop EBGP attributes.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# no neighbor rr-address activate	Disables IPv4 route exchange for the session.
Qtech(config-router-af)# exit	Exits the IPv4 address family.
Qtech(config-router)# address-family vpnv4	Enters the VPN address family.
Qtech(config-router-af)# neighbor rr-address Activate	Enables the device to exchange VPN routes with the RR in another AS.

Qtech(config-router-af)# neighbor rr-address next-hop-unchanged	(Optional) Configures the device not to change the next hop when advertising VPN routes to the peer.
Qtech(config-router)# show running-config	Displays existing configuration information.



Caution

By default, the device changes the next hop of a route to its own address when advertising the route to an EBGp peer. Upon receipt of the VPN route, the PE site in another AS considers the next hop of the route as the RR. As a result, all inter-AS VPN traffic is transmitted through the RR. This is generally not the optimal forwarding path and has high requirements on the forwarding performance of the RR. To avoid the preceding situation, you can run the **neighbor next-hop-unchanged** command in VPNv4 address family configuration mode to configure the device not to change the next hop of a VPNv4 route sent to the BGP peer when you set up a multi-hop MP-EBGP session on the RR.

The exchange of IPv4 routes is not required in a multi-hop MP-EBGP session. At least the routes of the two addresses used to set up the BGP session should be avoided. Otherwise, a PE has two routes to the PE in another AS. One route is advertised by the ASBR in the local AS and the other is advertised by the multi-hop EBGp session. According to the BGP specification, the EBGp route has a higher priority over the IBGP route by default. As a result, BGP chooses the route advertised by the multi-hop BGP, resulting in continuous flapping of routes on the PE to the PE in another AS. The VPN routes are thus not reachable.

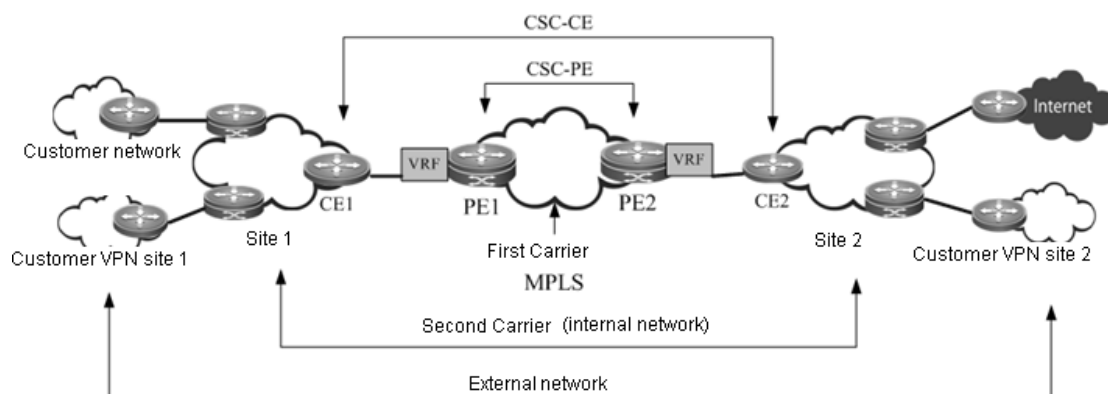
Configure an RR to set up a multi-hop MP-EBGP session with the RR in another AS.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# neighbor 30.30.30.2 update-source loopback 0
Qtech(config-router)# neighbor 30.30.30.2 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 30.30.30.2 activate
Qtech(config-router-af)# exit
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 30.30.30.2 activate
Qtech(config-router-af)# neighbor 30.30.30.2 next-hop-unchanged
Qtech(config-router-af)# end
```

2.2.4 Configuring Carrier's Carrier (CSC)

In a basic MPLS VPN, each site is a traditional IP network with a simple network structure. However, in there are some special VPN users. For example, a VPN user is also a service provider who leases the VPN service of an MPLS VPN service provider and then provides specific services for users. In this case, the MPLS VPN service provider is called a provider carrier or first carrier, while the VPN user who is also a service provider is called a customer carrier or second carrier. This networking model is called carrier's carrier (CSC).

Figure 12 Model of Carrier's Carrier



2.2.4.1 Basic Concepts

- First carrier

The first carrier is also called a provider carrier, who provides MPLS VPN services for second carriers. In order to support second carriers to provide services for their users, the PE device of the first carrier must support CSC. The first carrier PE that provides services for second carriers is also called a CSC-PE.

- Second carrier

The second carrier is also called a customer carrier, who leases the MPLS L3VPN service from the first carrier in order to build its own intranet and then provide services for users. The second carrier CE connected to the first carrier is also called a CSC-CE.

- Internal route

The internal routes refer to the routes inside the network of the second carrier, namely, the intranet routes. The internal routes are used to guarantee the intercommunication of the second carrier's own network. Such routes must be jointly maintained by the first carrier PE and the second carrier.

- External route

Because the second carrier is a service provider, its network may be connected to multiple third-party networks. The route between the second carrier and the third-party network is called an external route. If the second carrier provides traditional IP services for users, the external routes include routes of user networks; if the second carrier is connected to the Internet, the external routes include Internet routes; if the second carrier provides MPLS VPN services for users, the external routes include user VPN routes.

Generally, there are tremendous external routes. To maintain good scalability, the first carrier will not maintain external routes, and external routes will be maintained independently by the second carrier.

- VPN tunnel

A VPN tunnel is an LSP tunnel established between VPN devices. In the CSC model, the LSP tunnel between second carrier devices is the VPN tunnel.

2.2.4.2 Working Principle

PE-CE Route and Label Distribution

To achieve good scalability, the number of routes to be maintained by the first carrier must be reduced. Therefore, the CSC model hands over external route maintenance to the second carrier, while the external traffic must use the VPN tunnel to traverse the first carrier. To support the CSC model, the first carrier PE must support VPN tunnels.

To support VPN tunnels, the first carrier PE (CSC-PE) and the second carrier CE (CSC-CE) must distribute the label binding information to each other. Depending on whether the CSC-PE and CSC-CE are in the same AS, the following routing protocols may be used to exchange internal routes and distribute labels for the internal routes:

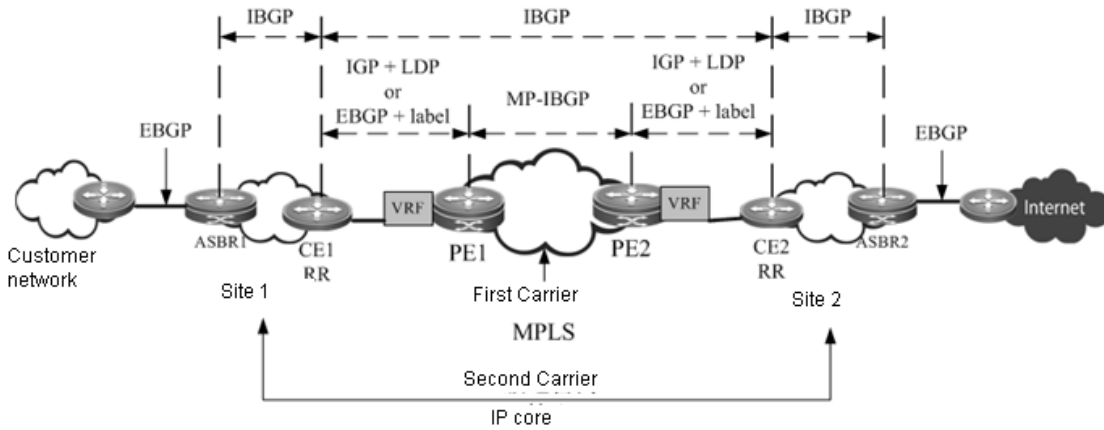
- If the CSC-PE and CSC-CE are in the same AS, IGP is generally used to exchange internal routes, and LDP is used to exchange label binding information.
- If the CSC-PE and CSC-CE are in different ASs, EBGP is generally used to exchange internal routes, and EBGP is enabled to perform label distribution for IPv4 routes and label distribution for internal routes.

Typical Application Scenarios

The second carrier can be an ordinary ISP or an MPLS service provider. Depending on the type of the second carrier network and the services provided by the second carrier for users, there are following typical application scenarios:

■ Scenario I: IP core second ISP

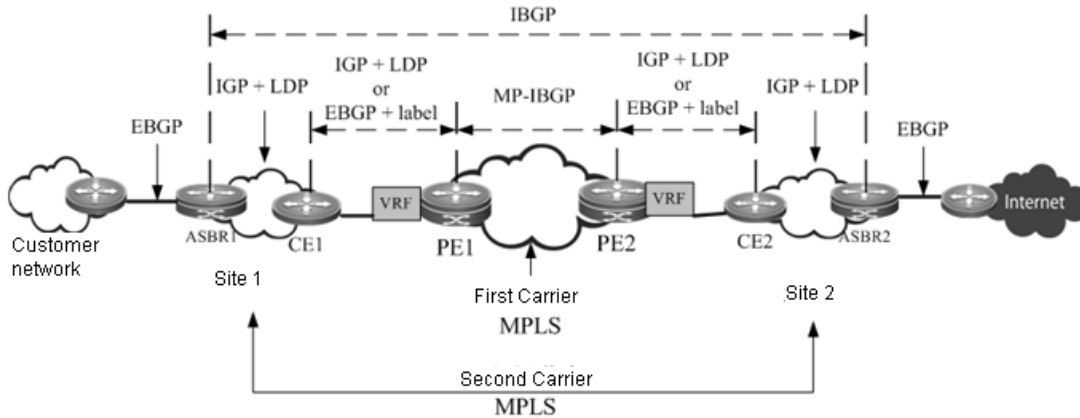
Figure 13 Scenario I: IP core second ISP



As shown in the figure, the second carrier is the IP core and provides network access services for users. IBGP neighbor relations are established between ASBR1, ASBR2, CE1 and CE2 to exchange external routes. CE1 and CE2 are RRs to reflect external routes between different sites. The Internet-access traffic of users flows from ASBR1 into the second carrier network and then flows out of the second carrier network from ASBR2. When the traffic flows from CE1 to CE2, the traffic is forwarded in the VPN LSP tunnel.

■ Scenario II: MPLS core second ISP

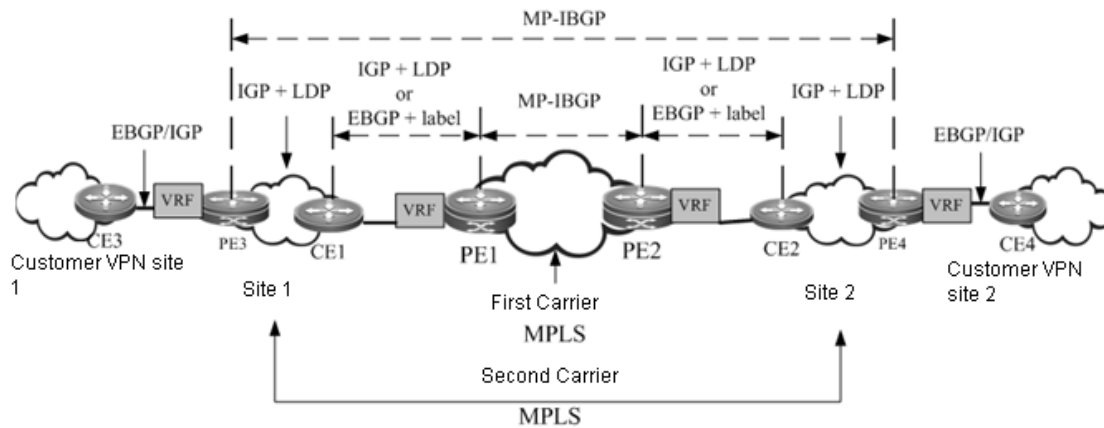
Figure 14 Scenario II: MPLS core second ISP



As shown in the figure, the second carrier is the MPLS core and provides network access services for users. An IBGP neighbor relation is established between ASBR1 and ASBR2 to exchange external routes. The Internet-access traffic of users flows from ASBR1 into the network of the second carrier and then flows out of the second carrier network from ASBR2. When the traffic flows from ASBR1 to ASBR2, the traffic is forwarded in the VPN LSP tunnel.

■ Scenario III: MPLS core second VPN provider

Figure 15 Scenario III: MPLS core second VPN provider



As shown in the figure, the second carrier is the MPLS core and provides MPLS L3VPN services for users. An MP-IBGP neighbor relation is established between PE3 and PE4 to exchange user VPN routes. The VPN LSP between PE3 and PE4 acts as the external tunnel of a user VPN.

2.2.4.3 Configuration Steps

The CSC configuration includes:

- Configuring basic BGP/MPLS IP VPN functions for the first carrier
- Configuring the first carrier to enable CSC
- Configuring the second carrier
- Configuring user access for the second carrier

Configuring Basic BGP/MPLS IP VPN Functions for the First Carrier

The configuration of basic BGP/MPLS IP VPN functions includes:

- 42) Configuring an MPLS network
 - 43) Configuring a VRF
 - 44) Configuring an MP-IBGP neighbor
 - 45) Configuring route exchange between PEs and CEs
- Configuring an MPLS network

The configuration in this section is similar to "Configuring an MPLS Network" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.

- Configuring a VRF

The configuration in this section is similar to "Configuring a VPN Routing Instance" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.



Caution

The CSC configuration requires "per-route" label allocation for each VRF. Therefore, you need to run the **alloc-label per-route** command in VRF configuration mode to select the label allocation mode.

- Configuring an MP-IBGP neighbor

The configuration in this section is similar to "Configuring PEs to Transmit VPN Routes" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.

- Configuring route exchange between PEs and CEs

The configuration in this section is similar to "Configuring Route Exchange Between PEs and CEs" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.

**Caution**

In Scenario I: In the network of the IP core second ISP, if the PE and CE use EBGP to exchange internal routes, because the external routes are exchanged using BGP and the CE is the route reflector, a route map needs to be configured for the PE and CE to filter external routes and avoid leaking external routes into the PE of the first carrier.

Configuring the First Carrier to enable CSC

Enable CSC on the first carrier PE. Depending on the protocol used for exchanging routes between a PE and a CE, the following two cases may apply:

- 46) The PE and CE use LDP to distribute labels.
- 47) The PE and CE use EBGP to distribute labels.
- The PE and CE use LDP to distribute labels.

If the PE and CE use IGP to exchange routes, run the following commands on the PE and CE respectively to configure the PE and CE to use LDP to distribute labels.

Use the following commands on the PE.

Command	Function
Qtech(config)# mpls router ldp <i>vrf-name</i>	Enables LDP (PE) for the VRF.
Qtech(config-mpls-router)# ldp router-id interface <i>interface-name</i> force	Configures the router ID of LDP.
Qtech(config-mpls-router)# advertise-labels for bgp-routes [acl <i>acl-name</i>]	Configures LDP to distribute labels for BGP routes. LDP does not assign labels to BGP routes by default.
Qtech(config-mpls-router)# exit	Exits LDP instance configuration mode.
Qtech(config)# interface <i>interface-name</i>	Configures the interface connecting the CE.
Qtech(config-if)# label-switching	Enables MPLS forwarding on the interface.
Qtech(config-if)# mpls ip	Enables LDP on the interface.
Qtech(config-if)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables fast forwarding on the interface (not applicable to a switch).
Qtech(config-if)# end	Exits interface configuration mode.
Qtech# show running-config	Displays existing configuration information.
Qtech# show mpls ldp bindings vrf <i>vrf-name</i>	Displays LDP label binding information under this VRF instance.

Use the following commands on the CE.

Command	Function
Qtech(config)# mpls router ldp	Enables LDP (CE).
Qtech(config-mpls-router)# ldp router-id interface <i>interface-name</i> force	Configures the router ID of LDP.
Qtech(config-mpls-router)# exit	Exits LDP instance configuration mode.
Qtech(config)# interface <i>interface-name</i>	Configures the interface connecting the PE.
Qtech(config-if)# label-switching	Enables MPLS forwarding on the interface.

Qtech(config-if)# mpls ip	Enables LDP on the interface.
Qtech(config-if)# end	Exits interface configuration mode.
Qtech# show running-config	Displays existing configuration information.
Qtech(config-if)# ip ref	In case of a router, enables fast forwarding on the interface (not applicable to a switch).
Qtech# show mpls ldp bindings	Displays LDP label binding information.

- The PE and CE use EBGp to distribute labels.

If the PE and CE use EBGp to exchange routes, run the following commands on the PE and CE respectively to configure the PE and CE to use EBGp to distribute labels.

Use the following commands on the PE.

Command	Function
Qtech(config)# interface <i>interface-name</i>	Configures the interface connecting the CE.
Qtech(config-if)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables fast forwarding on the interface (not applicable to a switch).
Qtech(config-if)# label-switching	Enables MPLS on the interface.
Qtech(config-if)# router bgp <i>asn</i>	Enters BGP configuration mode.
Qtech(config-router)# address-family ipv4 vrf <i>vrf-name</i>	Enters IPv4 address family configuration mode.
Qtech(config-router-af)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } send-label	Enables BGP to carry labels for IP routes.
Qtech(config-router-af)# end	Returns to privileged EXEC mode.
Qtech# show running-config	Displays existing configuration information.
Qtech# show bgp vpnv4 unicast vrf <i>vrf-name</i> labels	Displays BGP label information.

Use the following commands on the CE.

Command	Function
Qtech(config)# interface <i>interface-name</i>	Configures the interface connecting the PE.
Qtech(config-if)# label-switching	Enables MPLS on the interface.
Qtech(config-if)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables fast forwarding on the interface (not applicable to a switch).
Qtech(config-if)# router bgp <i>asn</i>	Enters BGP configuration mode.
Qtech(config-router)# address-family ipv4	Enters IPv4 address family configuration mode.
Qtech(config-router-af)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } send-label	Enables BGP to carry labels for IP routes.
Qtech(config-router-af)# end	Returns to privileged EXEC mode.
Qtech# show running-config	Displays existing configuration information.
Qtech# show ip bgp labels	Displays BGP label information.

Configuring the Second Carrier

Before the configuration, configure IGP for the second carrier network in order to guarantee the connectivity of the second carrier network. Depending on the application scenarios of the second carrier, different configuration schemes will be adopted:

- Scenario I: IP core second ISP
- Scenario II: MPLS core second ISP
- Scenario III: MPLS core second VPN provider

The Second Carrier Provides Internet Services Based on IP Core

In Scenario I, IBGP neighbor relations are established between ASBRs and CEs to exchange external routes. CEs are RRs to reflect external routes between different sites. The configuration task includes:

- 48) Configuring an intra-site BGP session
 - 49) Configuring a BGP session between CSC-CEs of different sites
 - 50) Configuring route map filtering
- Configuring an intra-site IBGP session

Use the following commands to configure an IBGP session between an intra-site ASBR and a CSC-CE, and configure the CSC-CE as an RR.

Command	Function
Qtech(config)# router bgp <i>asn</i>	Configures a BGP router.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } remote-as <i>asn</i>	Configures a BGP neighbor.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } route-reflector-client	Configures the CSC-CE as the RR client.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } update-source <i>interface-name</i>	Configures a BGP source address.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } next-hop-self	For the ASBR, changes the next hop to the router itself when configuring the router to advertise BGP routes.

- Configuring an IBGP session between CSC-CEs of different sites

Use the following commands to set up a fully meshed IBGP session between CSC-CEs of different sites to exchange external routes of different sites.

Command	Function
Qtech(config)# router bgp <i>asn</i>	Configures BGP.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } remote-as <i>asn</i>	Configures a BGP neighbor.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } update-source <i>interface-name</i>	Configures a BGP source address.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } route-reflector-client	(Optional) Configures the CSC-CE of a peer site as the RR client.
Qtech(config-router)# exit	Exits BGP configuration mode.
Qtech(config)# recursive-route lookup lsp	Enables resolution of the next hop of a BGP route to an LSP tunnel.

- Configuring route map filtering

When BGP is used to exchange internal routes, because the CSC-CE is responsible for propagating both external routes and internal routes, you must guarantee that only the EBGP session between the CSC-CE and the CSC-PE can propagate internal routes, and that the IBGP session between CSC-CEs and between the CSC-CE and the ASBR can only propagate external routes; otherwise, routing loops or chaos may occur. To achieve this goal, you

must run **neighbor route-map {in | out}** on the IBGP neighbor and EBGP neighbor to filter the corresponding routes, and the AS-path filtering rule is generally used. You can also use other rules.

Use the following commands to configure route map filtering.

Command	Function
Qtech(config)# ip as-path access-list <i>access-list-number</i> { permit deny } <i>regex</i>	Configures an AS-path ACL.
Qtech(config)# route-map <i>route-map-name</i> { permit deny } <i>sequence-number</i>	Configures a route map.
Qtech(config-route-map)# match as-path <i>access-list-number</i>	Matches the AS-path ACL.
Qtech(config-route-map)# exit	Returns to global configuration mode.
Qtech(config)# router bgp <i>asn</i>	Configures a BGP router.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } route-map <i>route-map-name</i> { in out }	Applies the route map to a BGP neighbor.

The Second Carrier Provides Internet Services Based on MPLS

In Scenario II, the second carrier network is an MPLS core in which IBGP neighbor relations are established between ASBRs to exchange external routes. There is no need to propagate external routes via the CSC-CE. The configuration task includes:

51) Configuring an intra-site MPLS network

52) Configuring an inter-site IBGP session

- Configuring an intra-site MPLS network

The configuration of the intra-site MPLS network of the second carrier is similar to "Configuring an MPLS Network" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.



Note

You need to enable LDP on the CSC-CE in order to set up sessions with other intra-site devices to build an MPLS network. If the CSC-CE and CSC-PE use BGP to exchange routes, you must run **advertise-labels for bgp-routes** on the CSC-CE to enable LDP to distribute labels for BGP routes.

- Configuring an IBGP session between ASBRs of different sites

Use the following commands to configure the BGP session between the local ASBR and the ASBR of a peer site in order to exchange external routes.

Command	Function
Qtech(config)# router bgp <i>asn</i>	Configures BGP.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } remote-as <i>asn</i>	Configures a BGP neighbor.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } update-source <i>interface-name</i>	Configures a BGP source address.
Qtech(config-router)# neighbor { <i>peer-address</i> <i>peer-group-name</i> } next-hop-self	Changes the next hop to the router itself when configuring the ASBR router to advertise external routes.
Qtech(config-router)# exit	Exits BGP configuration mode.
Qtech(config)# recursive-route lookup <i>lsp</i>	Enables resolution of the next hop of a BGP route to an LSP tunnel.

**Note**

To reduce the configuration cost of a fully meshed IBGP session, you can configure the RR role inside the site. The intra-site ASBR can set up a BGP session with the RR, while an inter-site BGP session can only be set up between RRs.

The Second Carrier Provides VPN Services Based on MPLS Core

In Scenario III, the second carrier network is an MPLS core in which MP-IBGP neighbor relations are established between second carrier PEs to exchange user VPN routes. The configuration task includes:

53) Configuring an intra-site MPLS network

54) Configuring an MP-IBGP neighbor

- Configuring an intra-site MPLS network

The configuration of the intra-site MPLS network of the second carrier is similar to "Configuring an MPLS Network" in the "Configuring Basic BGP/MPLS IP VPN Functions" section.

**Note**

You need to enable LDP on the CSC-CE in order to set up sessions with other intra-site devices to build MPLS network. If the CSC-CE and CSC-PE use BGP to exchange routes, you must run **advertise-labels for bgp-routes** on the CSC-CE to allow LDP to distribute labels for BGP routes.

- Configuring PEs of each site to establish MP-IBGP neighbors

Configure PEs of each site to set up MP-IBGP sessions between intra-site PEs of the second carrier and between PEs of different sites in order to transmit VPN routes served by the second carrier. The configuration of the second carrier PE is similar to the PE configuration in the "Configuring Basic BGP/MPLS IP VPN Functions" section.

**Note**

To reduce the configuration cost of a fully meshed MP-IBGP session, you can configure the RR role inside the site. Intra-site PEs can set up an MP-IBGP session with the RR, while an inter-site MP-IBGP session can only be set up between RRs.

Configuring User Access for the Second Carrier

The configuration in this section relates to the services provided by the second carrier, and is irrelevant to the CSC model. If the second carrier provides IP services for users, see the "Configuring IP Routes" section. If the second carrier provides MPLS VPN services for users, see the "Configuring the MPLS VPN" section.

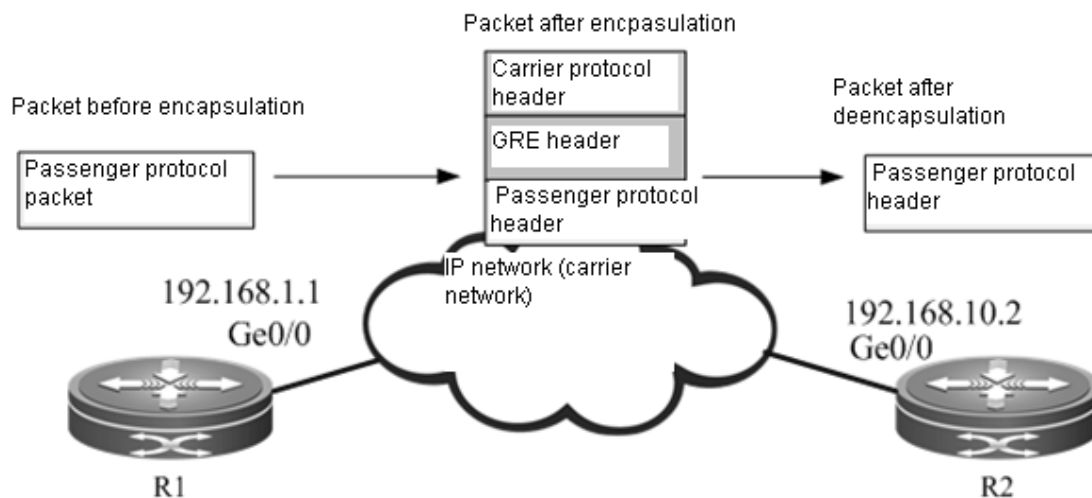
2.2.5 Configuring the MPLS VPN over GRE

- Currently, only router products of Qtech support the MPLS VPN over GRE feature. This feature is not supported by Qtech switch products.

2.2.5.1 Basic Concepts

The traditional MPLS VPN uses an LSP as the public tunnel, that is, VPN traffic flows from an upstream PE to a downstream PE by means of label switching. This requires the carrier's core network to fully support MPLS. For certain considerations or due to certain limitations, if the carrier's core network cannot fully support MPLS, the MPLS VPN over GRE can provide a mechanism to allow the carrier to use a GRE tunnel as a hop on the LSP tunnel to guarantee the integrity of the public LSP.

Figure 16 GRE tunnel



- GRE tunnel

GRE provides a mechanism to encapsulate the packets of one protocol (passenger protocol) into another protocol (carrier protocol). The encapsulated packets consist of: carrier protocol header, GRE header and original passenger protocol header. After being encapsulated by the carrier protocol, the passenger protocol packets can be forwarded in the carrier network. After the encapsulated packets reach the destination address of the carrier protocol, the destination device will decapsulate the packets and then forward the packets according to the inner-layer passenger protocol used by packets. Such an encapsulation technology allows passenger protocol packets to traverse a heterogeneous carrier network and reach the destination device. It is a tunnel encapsulation technology.

- Passenger protocol

The passenger protocol is the protocol being encapsulated during the process of GRE encapsulation. In the application scenario of MPLS VPN over GRE, the passenger protocol refers to packets carrying MPLS labels.

- Carrier protocol

The carrier protocol is the protocol used to encapsulate the passenger protocol during the process of GRE encapsulation. In the application scenario of MPLS VPN over GRE, the carrier protocol is generally IPv4.

- Source address and destination address

While encapsulating the passenger protocol, you need to know the source address and destination address of the carrier protocol, so that the encapsulated packets can be forwarded on the carrier network. The abovementioned source address and destination address are the source address and destination address of a GRE tunnel.

- Tunnel endpoint

When packets are transported on the tunnel, one device carries out carrier protocol encapsulation and another device carries out decapsulation. The passenger protocol information can only be known and processed by these two devices, while other carrier network devices between the two devices are unaware of the existence of the passenger protocol. These two devices are the endpoints of the GRE tunnel.

2.2.5.2 Working Principle

In the traditional MPLS VPN, private-network traffic carrying an inner-layer VPN label and an outer-layer public-network label reaches the peer PE by means of label switching. When a non-MPLS network exists in the backbone network, the LSP will become discontinuous. The GRE tunnel can help MPLS packets traverse a non-MPLS domain and realize a continuous LSP.

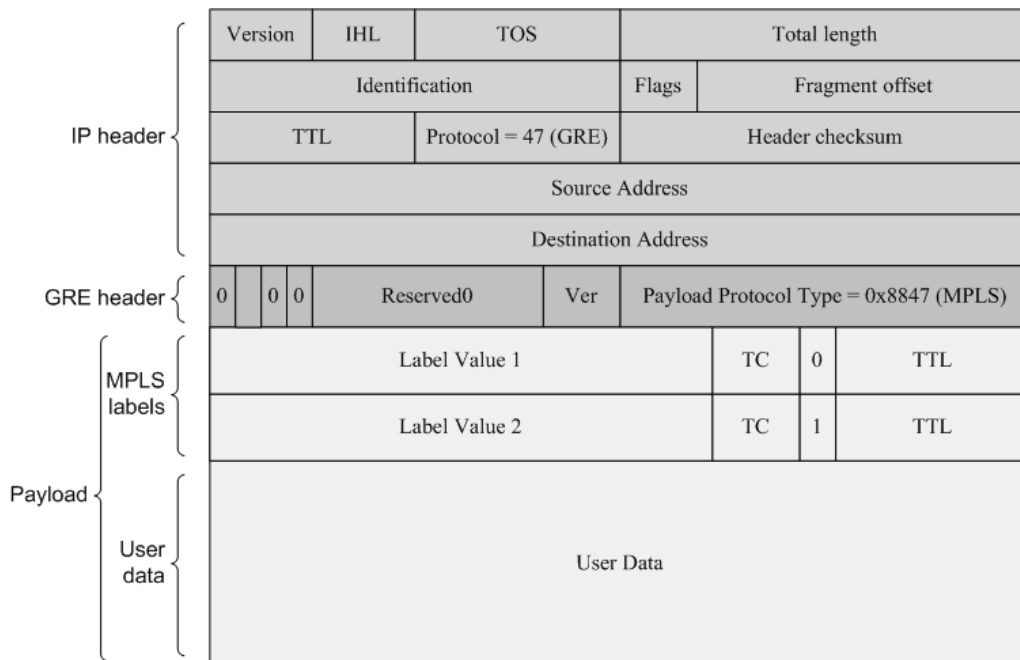
The GRE tunnel is a tunneling mechanism in an IP network and support GRE with MPLS as the passenger protocol, so that two devices on both sides of the IP network can exchange MPLS packets. Considering the GRE tunnel as a point-to-point logical link, devices at both ends of the tunnel directly establish IGP neighbor relations and LDP neighbor relations on this link to distribute routes and labels for the LSP, while the GRE tunnel becomes one hop of the LSP.

MPLS as a Passenger Protocol

MPLS is used as the GRE tunnel of the passenger protocol so that two devices interconnected through a non-MPLS network can forward MPLS packets to each other. After a label operation at one end of the tunnel, MPLS packets are GRE-encapsulated and then transported over the carrier network to the other end of the tunnel; label switching is

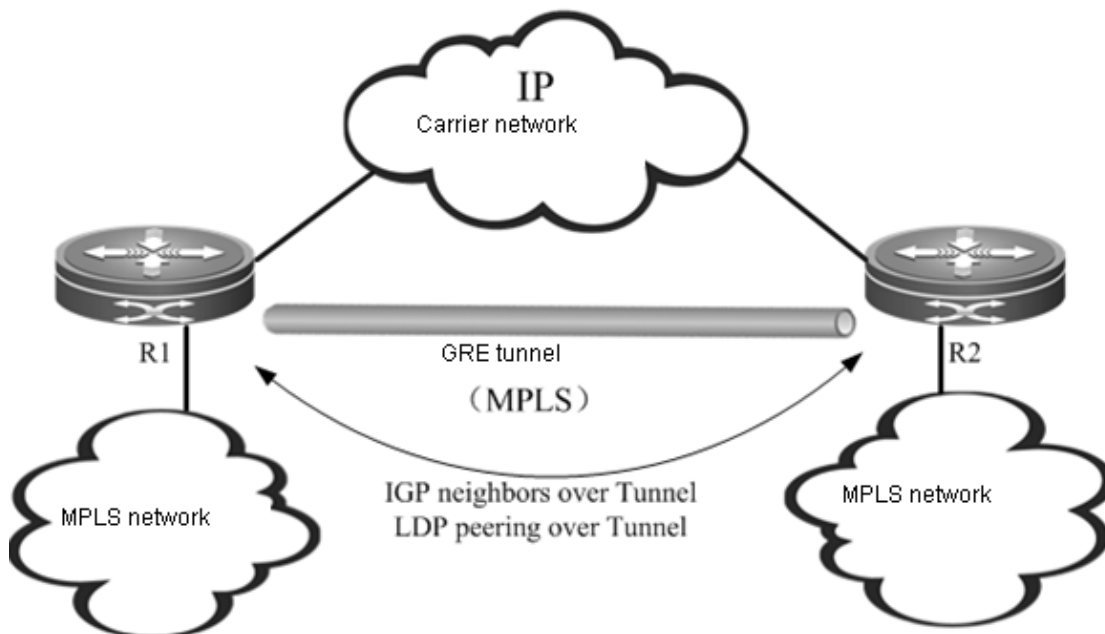
then carried out after packet decapsulation at the other end of the tunnel. The following figure shows the format of encapsulated packets with IPv4 being the carrier protocol and MPLS being the passenger protocol.

Figure 17 MPLS as the passenger protocol



GRE Tunnel as a Point-To-Point Link

Figure 18 GRE tunnel link



As shown in the figure, R1 and R2 are connected to an MPLS network respectively, while both routers are interconnected via a carrier network (IP). The GRE tunnel allows both endpoints (R1 and R2) to use the carrier network (IP) to transmit MPLS packets, so that two separated MPLS networks can be connected. The GRE tunnel is the point-to-point logical link between R1 and R2. It bypasses the carrier network (IP) and becomes one part of the MPLS network, so that the MPLS networks at both ends of the tunnel can maintain continuity. Considering the GRE

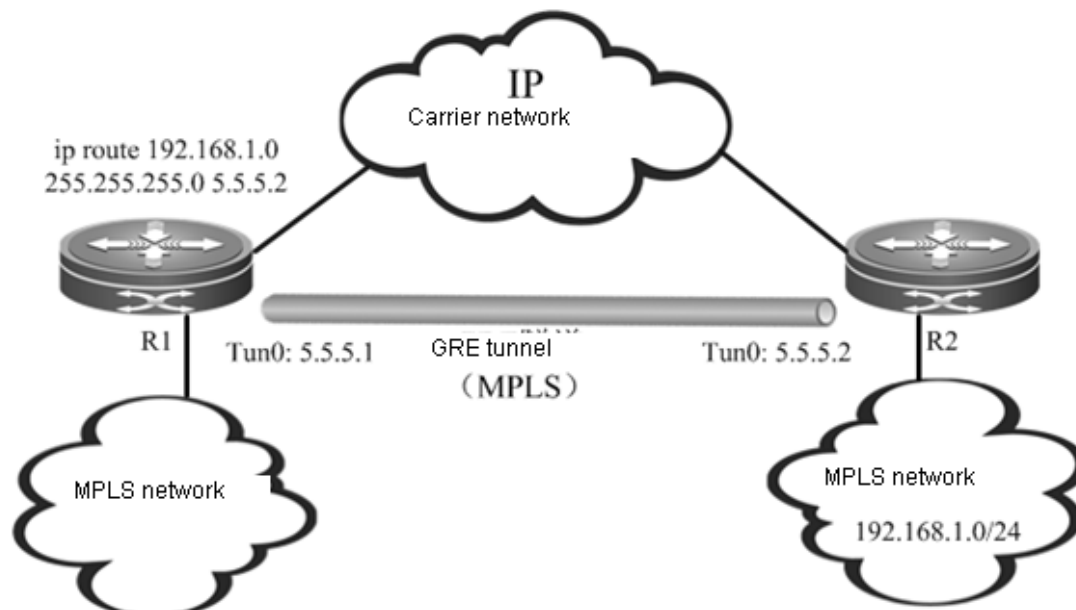
tunnel as a point-to-point link, the IGP protocol can run on the link, while LDP can also distribute labels between R1 and R2.

Introduction of Tunnel Traffic

In either the carrier network (IP) or the MPLS network, traffic forwarding is driven by routers. Therefore, a dynamic routing protocol needs to be run in the carrier network (IP) and MPLS network. There are two possible schemes: single routing instance and dual routing instances.

- Single routing instance

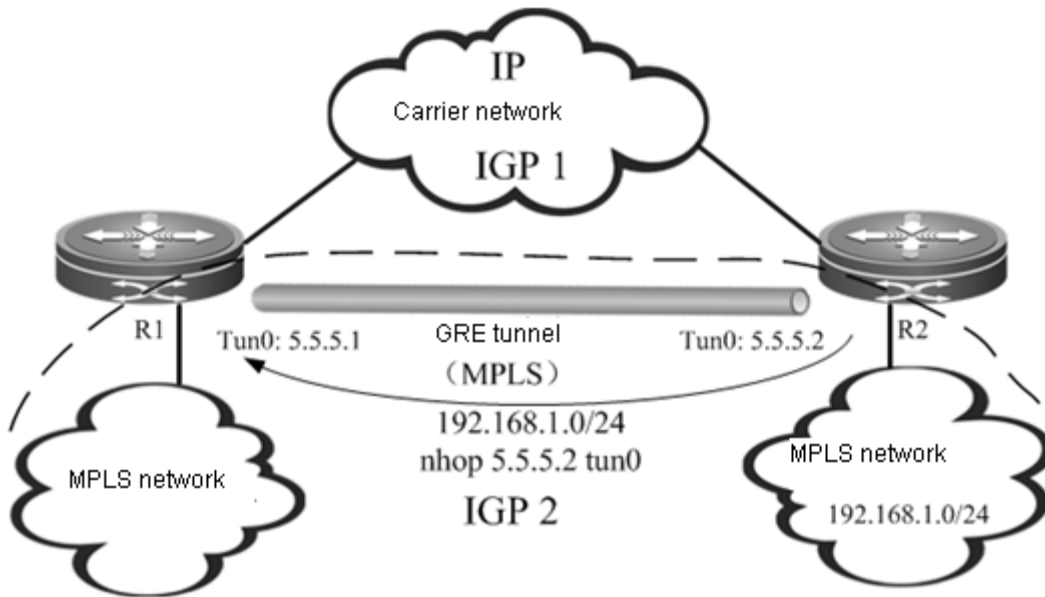
Figure 19 Single routing instance



In this scheme, the MPLS network and carrier network (IP) are in the same routing instance, and the entire network is in the plane form, as shown in Figure 15. By default, because the metric value of the GRE tunnel is far greater than that of an ordinary link, no traffic will be introduced into the GRE tunnel (which means that the GRE tunnel is not the next-hop egress interface of any route). Therefore, you must configure static routes in order to introduce MPLS traffic into the GRE tunnel. The static routes must be configured in this scheme, and the number of static routes depends on the number of route prefixes to be introduced into the GRE tunnel. The scalability is not satisfactory.

■ Dual routing instances

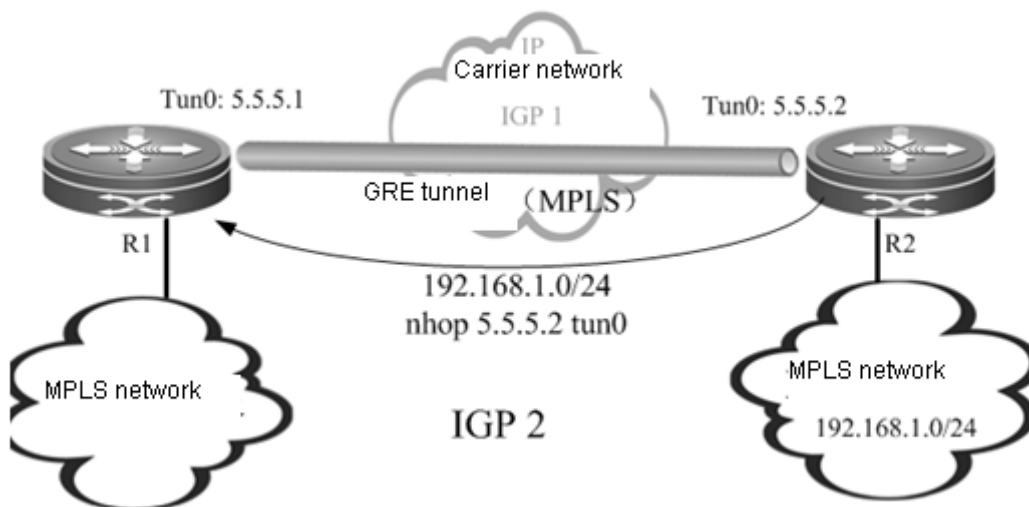
Figure 20 Dual routing instances



In this scheme, there are two different routing instances on each endpoint device of the GRE tunnel, as shown in Figure 16. One routing instance participates in route exchange in the carrier network (IP), while the other routing instance will participate in the route exchange in the MPLS network (including the GRE tunnel link). At this time, R1 learns the route to the remote MPLS network through the GRE tunnel, with the egress interface being the GRE tunnel. The traffic can be introduced into the GRE tunnel without configuring any static route.

Dual routing instances are actually dividing the network into different layers. As the upper-layer network, the MPLS network (including the GRE tunnel) acts as the backbone network running consistent IGP instances, supporting MPLS and providing MPLS VPN services. As the bottom-layer network, the carrier network (IP) is the local network between R1 and R2 and runs independent IGP instances. If the GRE tunnel is the "layer-3 interface" between R1 and R2, the IP network and the IGP instance between R1 and R2 will be the "layer-2 network" and "layer-2 link protocol" between R1 and R2, as they guarantee the link state of the GRE tunnel. The relation can be indicated in Figure 17.

Figure 21 Dual IGP instances

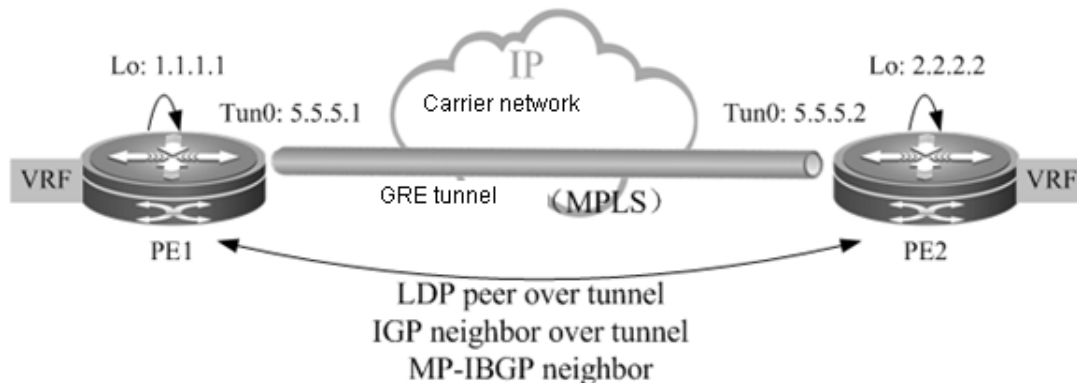


The scheme of dual routing instances divides the network into different layers and boasts better scalability. The following example is mainly based on this scheme.

Typical Applications

- Establishing a GRE tunnel between PEs

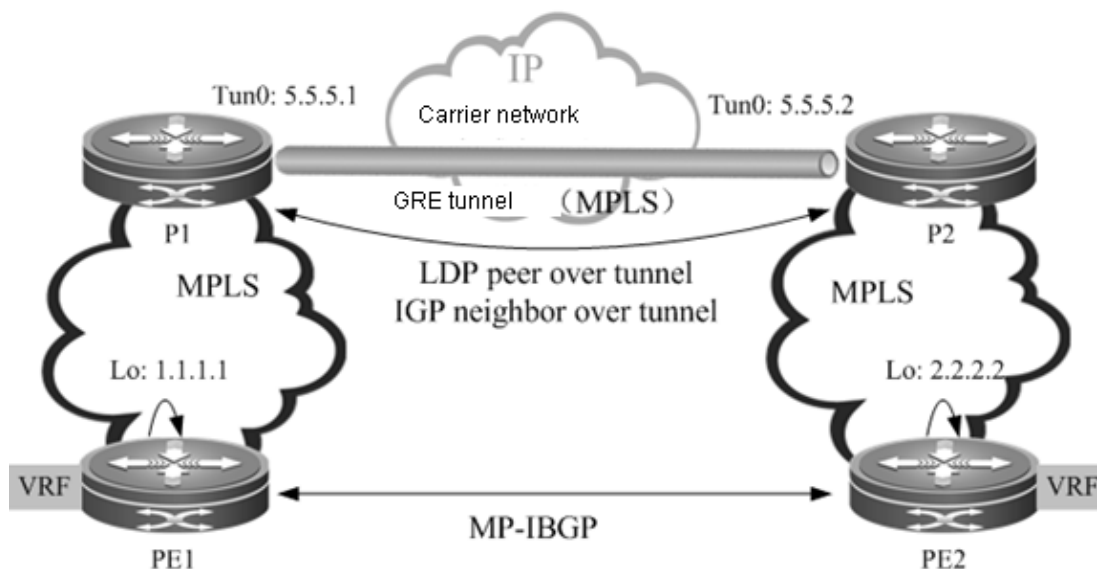
Figure 22 Scenario I: PE-PE



As shown in Figure 18, the core network between PEs is completely an IP network. The GRE tunnel is established between two PEs, and the LSP between PE1 and PE2 has only one hop.

- Establishing a GRE tunnel between Ps

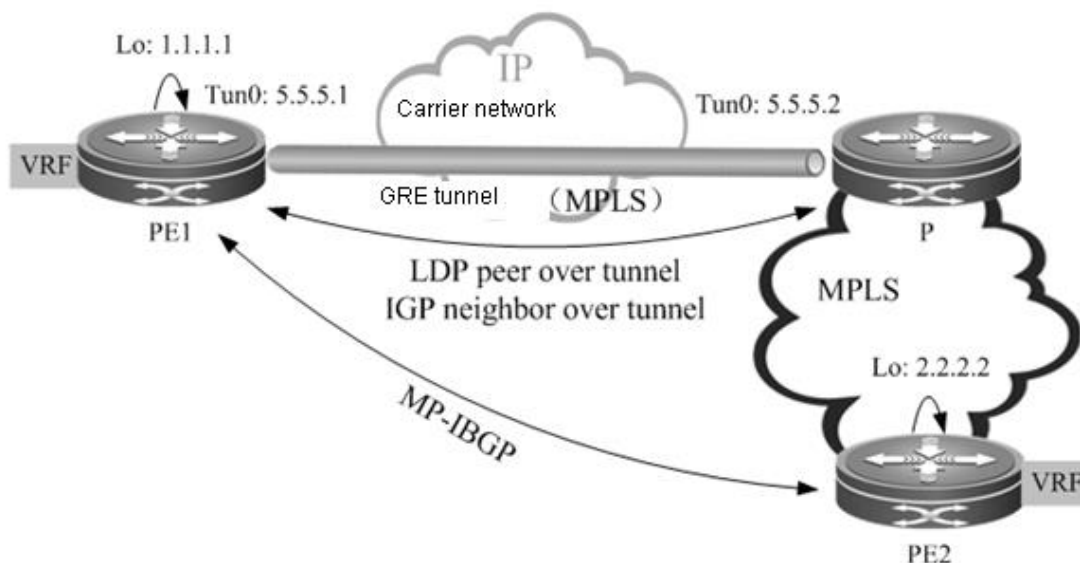
Figure 23 Scenario II: P-P



As shown in Figure 19, PE1 and PE2 are in two MPLS domains. P1 and P2 are interconnected through an IP network. The GRE tunnel is established between P1 and P2. The public LSP between PE1 and PE2 goes through P1 and P2, and the GRE tunnel between P1 and P2 is one hop of the LSP.

- Establishing a GRE tunnel between P and PE

Figure 24 Scenario III: P-PE



As shown in Figure 20, the network between PE1 and P does not support MPLS. The LSP is connected by establishing a GRE tunnel between PE1 and P.

2.2.5.3 Protocol Specification

- RFC 4023: Encapsulating MPLS in IP or GRE.
- RFC 4797: Use of Provider Edge to Provider Edge (PE-PE) Generic Routing Encapsulation (GRE) or IP in BGP/MPLS IP Virtual Private Networks.

2.2.5.4 Configuration Steps

The configuration of the MPLS VPN over GRE includes:

- Creating a tunnel interface
- Configuring an IGP route
- Configuring an MPLS network
- Configuring an MPLS VPN

Creating a Tunnel

Use the following commands to create a GRE tunnel (interface).

Command	Function
Qtech(config)# interface tunnel <i>tunnel-id</i>	Creates a tunnel interface.
Qtech(config)# tunnel mode gre ip	Configures the tunnel as a GRE in IP tunnel.
Qtech(config-if)# ip address <i>ip-address</i> <i>address-mask</i>	Configures an address for the tunnel interface.
Qtech(config-if)# tunnel source { <i>ip-address</i> <i>interface-name</i> }	Configures the source address of the GRE tunnel.
Qtech(config-if)# tunnel destination <i>ip-address</i>	Configures the destination address of the GRE tunnel.
Qtech(config-if)# no shutdown	Enables the interface.

Configuring a Route to Introduce Traffic into the Tunnel

There are two ways to introduce traffic into the tunnel:

- 55) Configuring IGP
- 56) Configuring a static route

■ Configuring IGP

Generally, multiple OSPF processes are used to create different routing instances. One OSPF process learns the route to the destination address of the tunnel, so that the tunnel interface is up if the route is reachable. Another OSPF process runs OSPF on the GRE tunnel to set up a session in order to learn the route to the destination address of the PE. For the configuration steps of multiple OSPF processes, see the "Configuring the Unicast Routing Protocol" section.

■ Configuring a static route

Use the following command to configure a static route directly: Configure the tunnel interface as the egress of the host route to the specified PE address.

Command	Function
Qtech(config)# ip route ip-address address-mask tunnel tunnel-id	Configures a static route.



Caution

If a static route is used to introduce traffic into the tunnel, the destination address of the tunnel cannot be the route prefix of the static route, that is, the address of the specified PE and the destination address of the tunnel must be different. This is because the state of the tunnel interface depends on the route to the destination address of the tunnel, while the static route will cause the route to the destination address to rely on the state of the tunnel interface, thus leading to the state flapping of the tunnel interface.

Configuring the Tunnel Interface to Enable MPLS

Use the following commands to enable LDP on the tunnel interface and enable MPLS forwarding.

Command	Function
Qtech(config)# mpls ip	Enables MPLS globally. <input checked="" type="checkbox"/> This command is not available on a switch chip.
Qtech(config)# mpls router ldp	Enables LDP globally.
Qtech(config-mpls-router)# ldp router-id interface <i>interface-name</i>	Configures the router ID of LDP.
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Qtech(config)# interface tunnel <i>tunnel-id</i>	Enters tunnel interface configuration mode.
Qtech(config-if)# ip ref	<input checked="" type="checkbox"/> In case of a router, enables fast forwarding (not applicable to a switch).
Qtech(config-if)# mpls ip	Enables LDP on the interface.
Qtech(config-if)# label-switching	Enables MPLS forwarding on the interface.
Qtech(config-if)# exit	Exits interface configuration mode.

Currently, only router products support the MPLS VPN over GRE-in-IPv4 tunnel. This feature is not supported by switch products.

Configuring the MPLS VPN

The configuration of the MPLS VPN includes:

- Configuring a VRF
- Configuring an MP-IBGP
- Configuring route exchange between PEs and CEs

For details, see the "Configuring Basic BGP/MPLS IP VPN Functions" section.

2.2.6 Configuring the OSPF VPN Extension

2.2.6.1 Understanding the L3VPN OSPF VPN Extension

PE-CE OSPF Feature

OSPF is a widely used IGP protocol. In most of the existing application schemes, VPN users generally select OSPF as the interior routing protocol. If OSPF is used between a PE and a CE, you do not need to run other routing protocols, thus simplifying CE configuration and management.

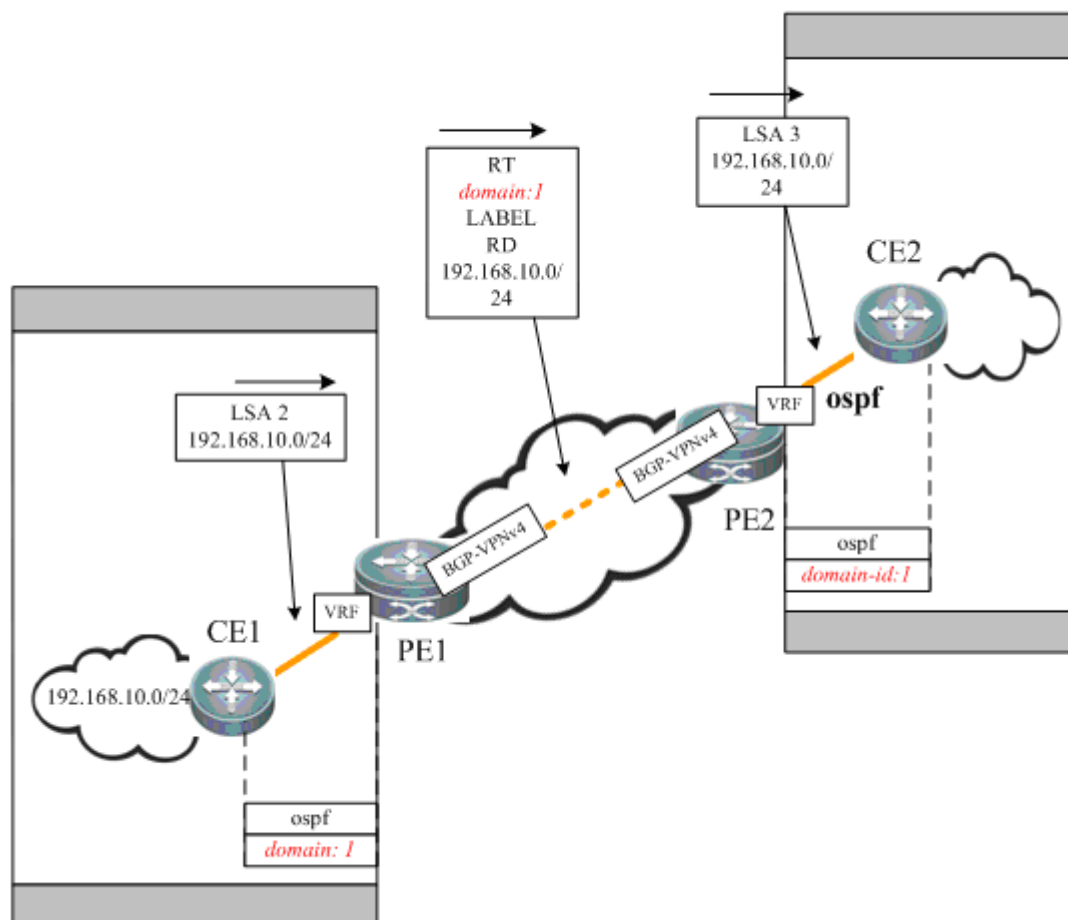
The PE-CE OSPF feature is described from the following four aspects.

■ Domain ID

A domain ID refers to the OSPF domain to which the route belongs. When the CE has learned an OSPF route from an intra-VPN site, this route will be advertised to a PE in type-1, type-2 or type-3 link state advertisements (LSAs) and redistributed to BGP to form a VPN route. Meanwhile, the domain ID will also be redistributed to BGP together with the route and advertised as the extended community attribute in the VPN route. When other PEs receive this VPN route and redistribute it to the VRF OSPF instance, the domain ID will also be redistributed to the corresponding VRF OSPF instance together with this route. If the VRF OSPF instance confirms that the domain ID contained in the route is the same as the domain ID of this VRF OSPF instance, the route will be advertised to the CE as an internal route. Contrarily, if the VRF OSPF instance confirms the domain ID contained in the route is different from the domain ID of this VRF OSPF instance, the route will be advertised to the CE as an external route.

As shown in the following figure, for a route that belongs to the same OSPF domain, CE1 advertises the route to PE1 in a type-2 LSA and then a VPN route is formed and advertised to PE2. PE2 receives this route and redistributes it to the VRF OSPF instance. Because the VRF OSPF instance shares the same domain ID with this VPN route, this site will eventually be advertised to VPN sites in the form of an internal route.

Figure 25

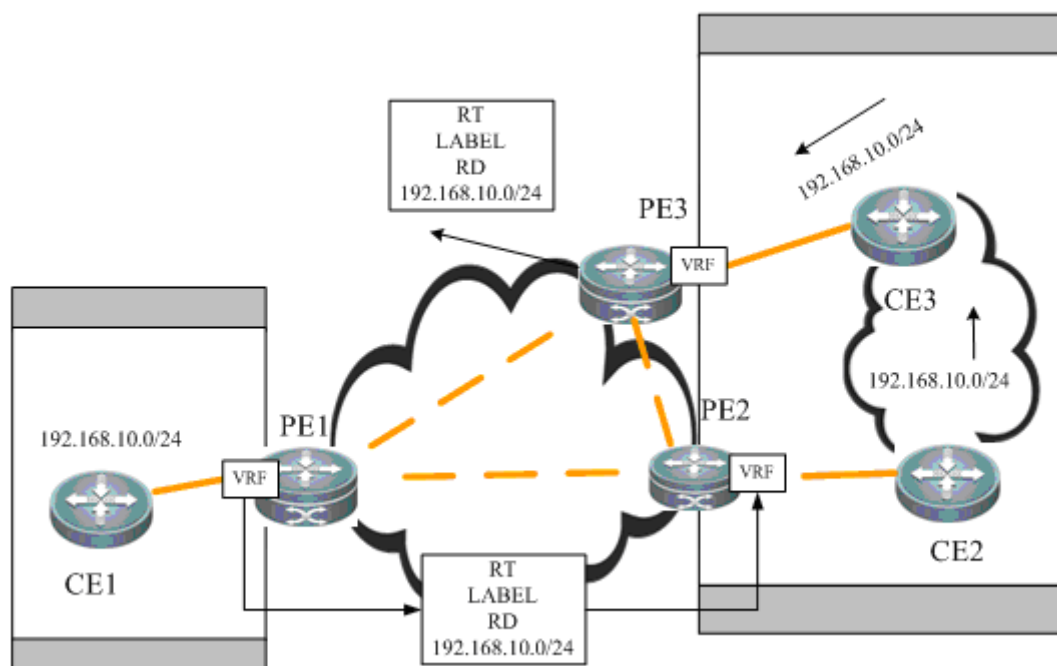


■ DN bit

A DN bit is a loop detection technique when OSPF is run between the PE and the CE. In a certain scenario, running OSPF between the PE and the CE may cause loops. For example, when multiple PEs are connected to one VPN site, if one PE advertises the VPN route learned to the VPN site, and the route is further advertised to another PE by running OSPF inside the VPN site and then propagated, a routing loop may take place.

As shown in the following figure: The route from 192.168.10.0/24 is advertised by PE1 to PE2 and PE3. CE2 advertises the route to CE3 through OSPF. The route is then advertised to PE3 and redistributed to the BGP protocol of PE3. PE3 selects the route redistributed by OSPF and converts this route into a VPN-IPV4 route before advertising the route, thus causing a routing loop.

Figure 26



To avoid such potential loop, when the PE advertises a type-3, type-5 or type-7 LSA to the CE, it will set a DN bit in an optional field of the LSA. When other PEs receive any LSA containing a DN bit in the optional field, the OSPF protocol on the PE does not allow this LSA to participate in OSPF route computation.

■ VPN route tag

A VPN route tag is another loop detection technique. When OSPF is run between the PE and the CE, the corresponding VRF OSPF instance on the PE will by default have a route tag called "VPN route tag". The VRF OSPF instance on the PE imports the VPN route and converts the route into a type-5 or type-7 LSA. When LSA is advertised to CE, this LSA will carry a VPN route tag. In the circumstance in which one VPN site is connected with multiple PEs, if a PE receives a type-5 or type-7 LSA that carries a VPN route tag and this VPN route tag is the same as the that of the OSPF instance, this LSA will not participate in OSPF route calculation.

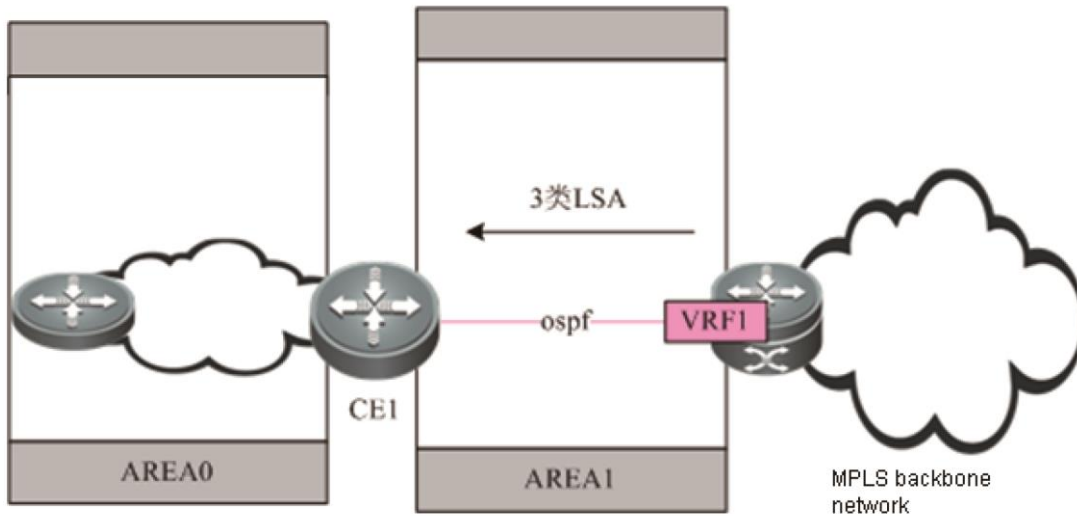
■ PE-CE inter-area deployment

Under normal circumstances, the link between the PE and the CE can be in any OSPF area. However, if the link between the PE and the CE falls into a non-zero area, the PE is an area border router (ABR) to the OSPF area where the CE is located. This may cause some problems because the OSPF protocol acting as an ABR device has the following features:

- 57) The ABR only calculates the type-3 LSA in the backbone area.
- 58) The ABR only forwards the type-3 LSA in the backbone area to a non-backbone area.

As shown in the following figure, if the link between the PE and the CE is in a non-zero area, the PE will redistribute the VPNv4 route advertised by MP-BGP to OSPF and restore it to a type-3 LSA to be advertised to CE1. CE1 will not calculate the non-backbone area LSAs. Therefore, these LSAs will not be advertised to routers in Area 0, and intra-VPN sites may fail to learn the route to other sites. Therefore, pay special attention when deploying a non-zero area between the PE and the CE.

Figure 27

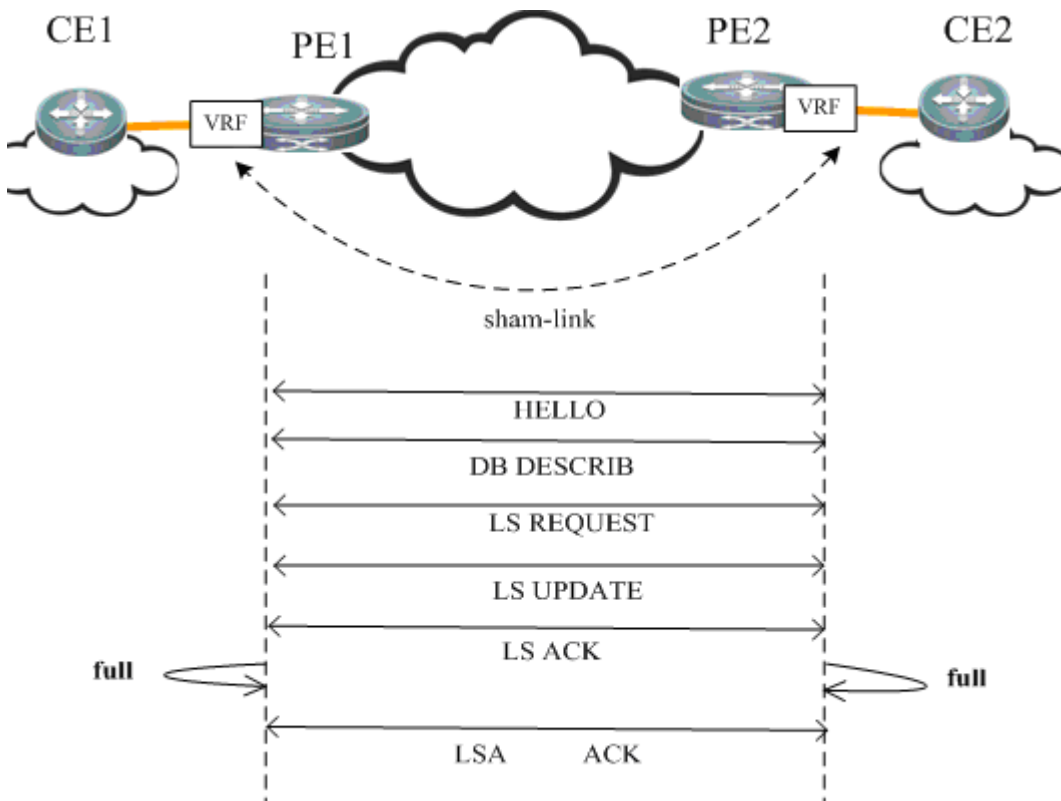


Generally, in L3VPN applications, if OSPF is run between the PE and the CE to exchange VPN routes, it is suggested not to deploy the backbone area at an intra-VPN site. In practice, if intra-VPN routers other than the PE sites also fall into the backbone area, there must be at least one router at this intra-VPN site to connect to the PE, and the link between the CE and the PE must belong to Area 0, so that intra-area routes and external routes can be propagated between the PE and the VPN site.

Sham Link

A sham link is not a real link. It refers to a "virtual link" established between the VRFs of two PEs. The sham link is the same as the normal OSPF link. With its own OSPF interface, it can send OSPF protocol packets, establish neighbors, and send LSAs. When LSAs are flooded over the sham link, all OSPF route types will not be changed, as shown in the following figure.

Figure 28



The purpose of establishing a sham link between VRF OSPF instances on different PEs is as follows:

- The approach of using MP-IBGP to carry a private route will only propagate the route, and the restoration after reaching the peer PE is only to import the original OSPF route information as far as possible, during which the OSPF topology information cannot be truly communicated. By establishing an OSPF link through a sham link, all OSPF instances inside each site can be truly connected and work out complete topology information.
- Different sites in the same VPN exchange information via the MPLS backbone network, but a link is established between VPN sites so that VPN sites can still communicate via this link when the MPLS backbone network fails. This link is called the "backdoor link". If two sites of VPN users fall into the same OSPF area and there is a "backdoor link" connecting these two sites, routes will be exchanged via both the MPLS backbone network and the "backdoor link". Because the routes exchanged via the MPLS backbone network are inter-area routes and the routes exchanged via the "backdoor link" are intra-area routes, and the intra-area routes are apparently superior to inter-area routes, the route forwarding between two sites will hence use the backdoor link. This goes against the purpose of establishing the "backdoor link". Therefore, the sham link must be used in such applications.

Protocol Specification

- RFC 4576 and RFC 4577 specify the mechanism to realize L3VPN OSPF.

2.2.6.2 Default Configuration

Function	Default Setting
domain-tag	AS number of local BGP
domain-id	Default value: NULL; default type: 0x0005
capability vrf-lite	The PE-CE OSPF feature is supported by the VRF OSPF instance by default.
extcommunity-type	In the OSPF instance extended community attribute carried by BGP, the default type of route-id is 0x0107, and the default type of route-type is 0x0306.

2.2.6.3 Configuring a Domain ID (Optional)

The domain ID is used to indicate the domain to which the OSPF instance belongs. Generally, all VRF OSPF instances belonging to the same VPN must use the same domain ID.

Use the following commands to configure the domain ID.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router ospf ospf-id vrf vrf-name	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# domain-id {ip-address [secondary] null type {0005 0105 0205 8005} value hex-value [secondary]}	(Optional) Configures the domain ID of the OSPF instance. The OSPF domain ID is 0 by default.
Qtech(config-router)# show running-config	Displays existing configuration information.

- Supported by RSR20 series running 10.4(3) or later versions
- Supported by RSR30 series running 10.4(3) or later versions
- Supported by RSR50 series running 10.4(3) or later versions
- Supported by RSR50E series running 10.4(3) or later versions

**Note**

This command is only applicable to an OSPF instance associated with a VRF.

A VRF OSPF instance can be configured with multiple domain IDs, but there is only one primary domain ID. Others are secondary domain IDs. The only primary domain ID is configured with the **domain-id value** command, while multiple secondary domain IDs are configured with the **domain-id value secondary** command. OSPF routes are advertised when converted into VPN routes, and VPN routes only contain the primary domain ID.

You can use the **domain-id ip-address** command or the **domain-id type {0005|0105|0205|8005} value** command to configure the primary and secondary domain IDs.

Different VRF OSPF instances can have the same domain ID. However, VRF OSPF instances in the same VPN must be configured with the same domain ID in order to guarantee the correctness of route advertisements.

Configure the primary domain ID and secondary domain ID of the VRF OSPF protocol to 4.4.4.4 and 5.5.5.5 respectively.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# domain-id 4.4.4.4
Qtech(config-router)# domain-id 5.5.5.5 secondary
Qtech(config-router)# domain-id type 0005 value 010101010101 secondary
```

2.2.6.4 Configuring a VPN Route Tag (Optional)

Use the following commands to configure a VPN route tag.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router ospf ospf-id vrf vrf-name	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# domain-tag value	(Optional) Configures a VPN route tag (1 to 4294967295) for the OSPF instance.
Qtech(config-router)# show running-config	Displays existing configuration information.

- Supported by RSR20 series running 10.4(3) or later versions
- Supported by RSR30 series running 10.4(3) or later versions
- Supported by RSR50 series running 10.4(3) or later versions
- Supported by RSR50E series running 10.4(3) or later versions

**Note**

This command is only applicable to an OSPF instance associated with a VRF.

If the domain tag of a VRF is not configured manually, the default value is the AS number of the local BGP protocol.

In an L3VPN, if one VPN site is connected with multiple PEs, the VPN route learned by a PE through MP-BGP will be advertised to a VPN site in a type-5 or type-7 LSA. The route may also be learned by other PEs connecting to this VPN site and then advertised, hence causing a loop. To avoid such loop, the same VPN route tag must be configured on the PE for VRF OSPF instances connected to the same VPN site. When a VRF OSPF instance sends a type-5 or type-7 LSA to the VPN site, this LSA will also carry the VPN route tag. When other PEs receive such type-5 or type-7 LSA containing the VPN route tag, if such route tag is the same as the route tag of the corresponding OSPF instance, this LSA will not participate in OSPF route computation.

Generally, OSPF instances associated with the same VPN must be configured with the same VPN route tag.

Configure the domain tag of the VRF OSPF protocol to 10.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# domain-tag 10
```

2.2.6.5 Configuring a Sham Link (Optional)

The sham link is mainly used in the scenario where there is a backdoor link between VPN sites. If you still expect to transmit VPN data via the MPLS backbone network, you can establish a sham link between the VRF OSPF instances of two PEs. Both instances can establish OSPF neighbors through this sham link and distribute LSA packets over the sham link.

Use the following commands to configure a sham link.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router ospf <i>ospf-id</i> vrf <i>vrf-name</i>	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# area <i>area-id</i> sham-link <i>source-address</i> <i>destination-address</i> [cost <i>number</i>] [dead-interval <i>seconds</i>] [hello-interval <i>seconds</i>] [retransmit-interval <i>seconds</i>] [transmit-delay <i>seconds</i>] [authentication [message-digest null]] [[authentication-key [0 7] <i>key</i>] [message-digest-key <i>key-id</i> md5 [0 7] <i>key</i>]]	Configures the area ID, source address and destination address of the sham link.
Qtech(config-router)# show running-config	Displays existing configuration information.

- Supported by RSR20 series running 10.4(3) or later versions
- Supported by RSR30 series running 10.4(3) or later versions
- Supported by RSR50 series running 10.4(3) or later versions
- Supported by RSR50E series running 10.4(3) or later versions



Note

The sham link must be configured on two PEs that intend to establish the sham link. The sham link cannot be established if only one PE is configured.

The following conditions must be met in order to establish the sham link between two PEs:

1. The area-id of the sham link configured on two PEs must be identical.
2. The source address and destination address of the sham link configured on one PE must correspond to the destination address and source address of the sham link configured on another PE.
3. The source address and destination address used to establish the sham link on the PE must be a 32-bit loopback address bound to a VRF.

Because OSPF routes advertised by a sham link do not carry VPN labels, the routes cannot be used to forward packets. Packets are forwarded through BGP VPNv4 routes. Therefore, there must be VPNv4 routes corresponding to the OSPF routes learned from the sham link.

The source address for a sham link is advertised in BGP VPNv4 routes, but not calculated in OSPF instances.

Configure a sham link for a VRF OSPF instance, with the area ID being 0, the source address being 1.1.1.1, and the destination address being 2.2.2.2.

```
Qtech# configure terminal
```

```
Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# area 0 sham-link 1.1.1.1 2.2.2.2
```

2.2.6.6 Configuring Capability vrf-lite (Optional)

The PE-CE OSPF feature of the VRF OSPF instance includes LSA conversion according to the domain ID, DN bit, and VPN route tag. In certain circumstances, if you do not expect the VRF OSPF instance to support the PE-CE OSPF feature, you can use the **capability vrf-lite** command to disable the feature.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router ospf <i>ospf-id</i> vrf <i>vrf-name</i>	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# capability vrf-lite	(Optional) Disables the PE-CE OSPF feature of the VRF OSPF instance.
Qtech(config-router)# show running-config	Displays existing configuration information.

- Supported by RSR20 series running 10.4(3) or later versions
- Supported by RSR30 series running 10.4(3) or later versions
- Supported by RSR50 series running 10.4(3) or later versions
- Supported by RSR50E series running 10.4(3) or later versions
- Supported by 3760E series running 10.4(3) or later versions
- Supported by 5750 series running 10.4(3) or later versions
- Supported by 5760E series running 10.4(3) or later versions



Note

This command is only applicable to an OSPF instance associated with a VRF. In certain scenarios, you may expect to disable the loop detection function of the VRF OSPF instance. For example: A VPN user uses an MCE device to exchange VPN routes with a PE. If the MCE and PE exchange VPN routes via OSPF, to allow the VPN site to learn the routes of other VPN sites, you must use the **capability vrf-lite** command on the MCE device to disable the loop detection function of the VRF OSPF instance.

Disable the loop detection function of the VRF OSPF instance.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# capability vrf-lite
```

2.2.6.7 Configuring extcommunity-type (Optional)

When an OSPF route is redistributed to BGP to form a VPN route, the extended community attributes of the OSPF route are also attached, including router-id and route-type. By default, the type of the extended community attribute of router-id is 0x0107, and that of route-type is 0x0306.

You can use the following commands to manually configure the extended community attributes of router-id and route-type.

Command	Function
Qtech# configure terminal	Enters global configuration mode.

Qtech(config)# router ospf <i>ospf-id</i> vrf <i>vrf-name</i>	Creates an OSPF instance and enters OSPF configuration mode.
Qtech(config-router)# extcommunity-type { router-id {0107 8001}} route-type {0306 8000}}	(Optional) Configures the extended community attributes of OSPF router-id and route-type.
Qtech(config-router)# show running-config	Displays existing configuration information.

- Supported by RSR20 series running 10.4(3) or later versions
- Supported by RSR30 series running 10.4(3) or later versions
- Supported by RSR50 series running 10.4(3) or later versions
- Supported by RSR50E series running 10.4(3) or later versions



Note

This command is only applicable to an OSPF instance associated with a VRF. The type configuration of router-id provides good compatibility with multiple manufacturers. For example, some manufacturers support only the router-id type of 0x0107. When interconnecting with devices from such manufacturers, you must use the **extcommunity-type** command to set the type of router-id to 0x0107.

The type configuration of route-type provides good compatibility with multiple manufacturers. For example, some manufacturers support only the route-type type of 0x8000. When interconnecting with devices from such manufacturers, you must use the **extcommunity-type** command to set the type of route-type to 0x8000.

Configure the type of router-id of the VRF OSPF protocol to 0x0107.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf vrf1
Qtech(config-router)# extcommunity-type router-id 0107
```

2.3 Verifying the BGP/MPLS IP VPN Configurations

This section describes how to verify the L3VPN configurations and VPN routes.

Enter privileged EXEC mode and run the following commands.

Command	Function
Qtech# show ip vrf [<i>vrf_name</i>]	Displays the VRF configuration information.
Qtech# show bgp vpnv4 unicast all [<i>network</i> <i>neighbor</i> [<i>peer-address</i>] summary label]	Displays the VPN route information.
Qtech# show ip route vrf <i>vrf_name</i> [<i>ip-address</i> bgp connected isis ospf rip static]	Displays the information about the VRF forwarding table.

Display the VPN route information.

```
Qtech# show bgp vpnv4 unicast all
Network          Nexthop          Metric          Localprf          Path
Route Distinguisher : 100:2
*>i 192.168.0.1/32 192.168.0.2      0              100             10 ?
*>i 192.168.1.0/32 192.168.0.2      0              100             ?
Route Distinguisher : 100:30
*>i 192.168.0.1/32 192.168.0.2      0              100             10 ?
*> 192.168.4.0    192.168.4.1      0              20             ?
* 192.168.4.0    0.0.0.0          0              32768          ?
```

Field	Description
*	Indicates a valid route.
s (lower-case)	Indicates that the route is suppressed by an aggregate route.
S (upper-case)	Indicates that the route is a stale entry.
>	Indicates that the route is an optimal one.
I	Indicates that the route is learned from the IBGP.
Nexthop	Indicates the next hop information of the route.
Metric	Indicates the route metric.
Localprf	Indicates the local preference of the route.
Path	Indicates the AS path included in the route.
I	Indicates that the origin of the route is IGP.
E	Indicates that the origin of the route is EGP.
?	Indicates that the origin of the route is another attribute except IGP or EGP (for example, a redistributed BGP route).

Display the information about the VRF routing table.

```
Qtech# show ip route vrf vrf1
Codes: C - connected, S - static, R - RIP, B - BGP
O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2 , ia - IS-IS inter area
* - candidate default
B   192.168.0.1/32 , [200/0] via 192.168.0.2, 01:02:33
B   192.168.0.3/32 , [200/0] via 192.168.4.1 , 01:02:33
C   192.168.4.0/24 is directly connected , eth1
```

Display the VRF configuration information.

```
Qtech# show ip vrf vrf1
VRF vrf1; default RD : 100: 2
Interfaces:
Eth0
Export VPN route-target communities:
RT : 100: 30
No import VPN route-target community
No import route-map
```

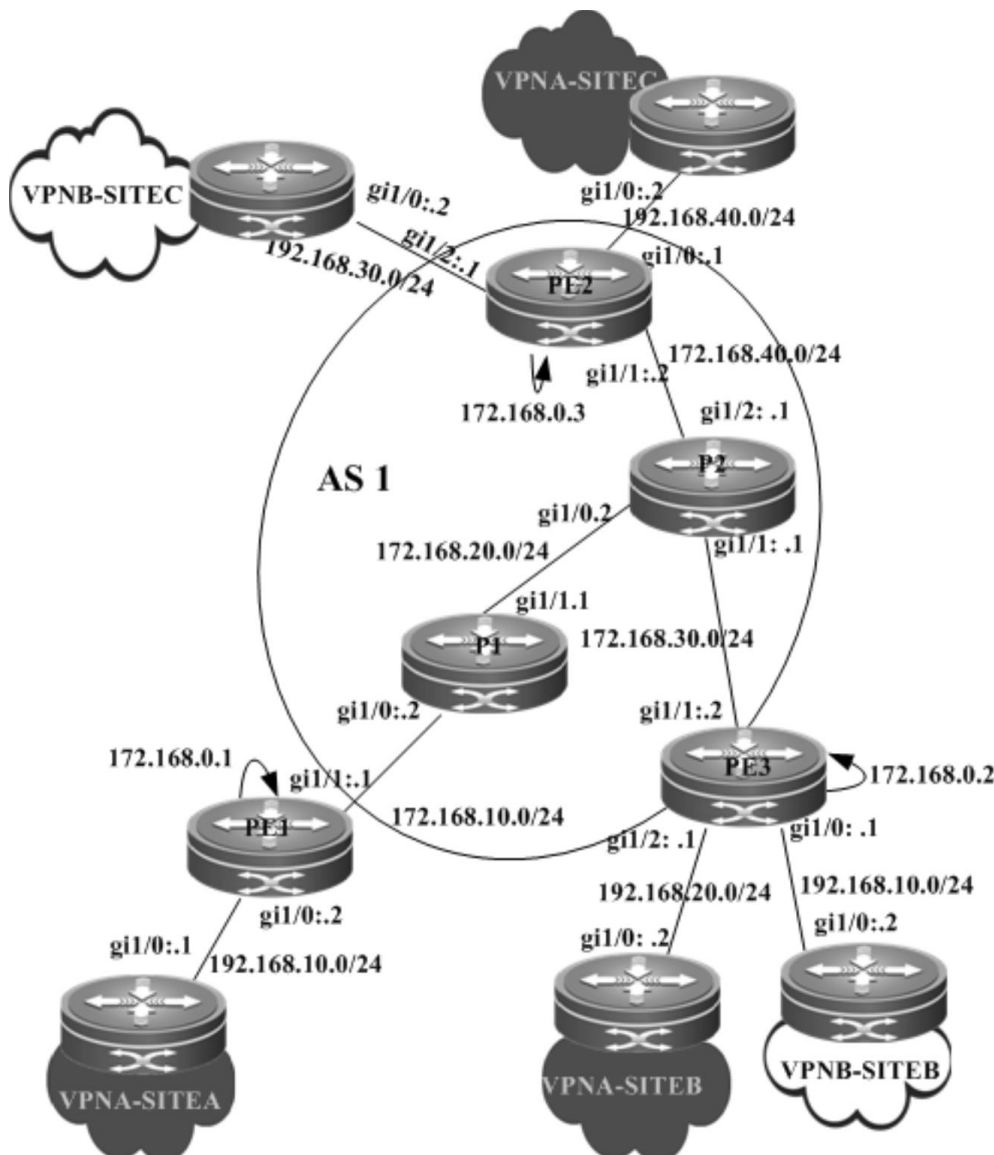
2.4 BGP/MPLS IP VPN Configuration Examples

2.4.1 Intranet Configuration Example

Networking Requirements

There are two VPN users: VPNA and VPNB. VPNA has sites at SITEA, SITEB, and SITEC and VPNB has sites at SITEB and SITEC. It is now required that: the users at different sites of VPNA access each other, the users at different sites of VPNB access each other, and the users at the two VPNs not access each other, as shown in the following figure.

Figure 29



Configuration Steps

PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure the VRF.

Create one VRF instance: VPNA. Set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
```

Associate the VRF with an interface.

```
Qtech# configure terminal
```

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# end
```

Enable BGP and set up MP-IBGP sessions with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGp.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# neighbor 172.168.10.1 remote-as 65002
Qtech(config-router-af)# end
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qtech(config-router)# end
```

PE2:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.3 255.255.255.255
```

Configure the VRF.

Create two VRFs: VPNA and VPNB. Set the RD and RT values, and associate the VRFs with corresponding interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# exit
Qtech(config)# ip vrf VPNB
Qtech(config-vrf)# rd 1:200
Qtech(config-vrf)# route-target both 1:200
Qtech(config-vrf)# exit
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding VPNB
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.20.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Enable BGP and set up MP-IBGP sessions with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.1 activate
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# neighbor 172.168.20.2 remote-as 65003
Qtech(config-router-af)# exit
Qtech(config)# address-family ipv4 vrf VPNB
Qtech(config-router-af)# neighbor 172.168.10.2 remote-as 65004
Qtech(config-router-af)# end
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

```
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.30.0 255.255.255.0 area 0
Qtech(config-router)# network 172.168.0.2 255.255.255.255 area 0
Qtech(config-router)# end
```

PE3:

The configuration procedure is similar to that of PE2.

VPNA-SITEA:

Set up an EBGP session with PE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 65002
Qtech(config-router)# neighbor 172.168.10.2 remote-as 1
Qtech(config-router-af)# end
```

VPNA-SITEB:

The configuration procedure is similar to that of VPNA-SITEA.

VPNA-SITEC:

The configuration procedure is similar to that of VPNA-SITEA.

VPNB-SITEB:

The configuration procedure is similar to that of VPNA-SITEA.

VPNB-SITEC:

The configuration procedure is similar to that of VPNA-SITEA.

P1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.5 255.255.255.255
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip address 172.168.10.2 255.255.255.0
```

```
Qtech(config-if-GigabitEthernet 1/0)# label-switching
Qtech(config-if-GigabitEthernet 1/0)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.20.0 0.0.0.255 area 0
Qtech(config-router)# end
```

P2:

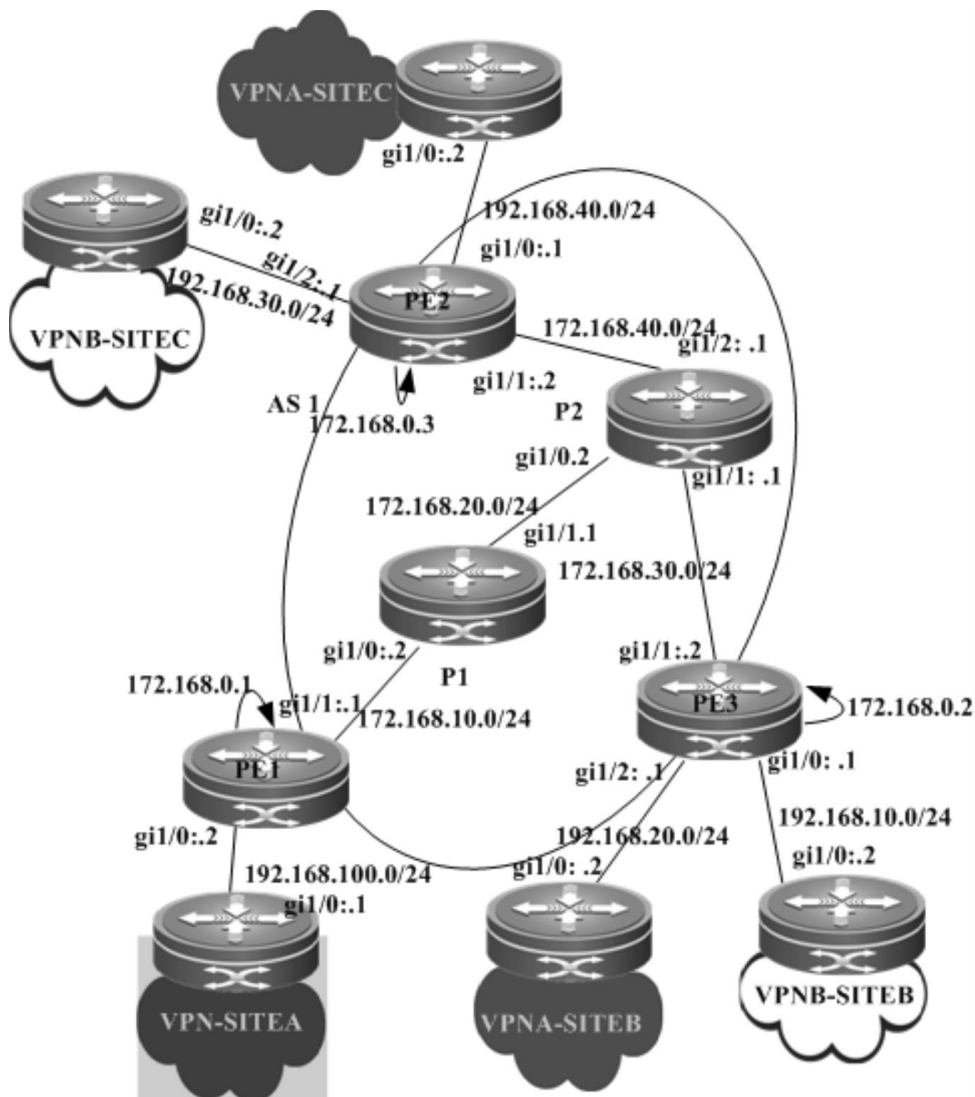
The configuration procedure is similar to that of P1.

2.4.2 Extranet Configuration Example

Networking Requirements

There are two VPN users: VPNA and VPNB. Mutual access is required in a VPN. The two VPNs cannot access each other but can access some shared resources. As shown in the following figure, VPNA and VPNB sites should access the resources of VPN-SITEA.

Figure 30



Configuration Steps

PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure the VRF.

Create one VRF instance: VPN_EXTRA. Set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN_EXTRA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# route-target both 1:200
Qtech(config-vrf)# end
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding VPN_EXTRA
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.100.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# end
```

Enable BGP and set up MP-IBGP sessions with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# end
```

Enable OSPF to exchange routes with a CE.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf VPN_EXTRA
Qtech(config-router)# network 192.168.100.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPN_EXTRA
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# end
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qtech(config-router)# end
```

PE2:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.3 255.255.255.255
```

Configure the VRF.

Create two VRF instances: VPNA and VPNB. Set the RD and RT values, and associate the VRFs with corresponding interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# exit
Qtech(config)# ip vrf VPNB
Qtech(config-vrf)# rd 1:200
Qtech(config-vrf)# route-target both 1:200
Qtech(config-vrf)# exit
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding VPNB
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.20.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Enable BGP and set up MP-IBGP sessions with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.1 activate
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# end
```

Enable OSPF to exchange VPN routes with a CE.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf VPNA
Qtech(config-router)# network 192.168.20.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router ospf 20 vrf VPNB
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# exit
```



```
Qtech(config-router)# address-family ipv4 vrf VPNB
Qtech(config-router-af)# redistribute ospf 20
Qtech(config-router-af)# exit
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.30.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
Qtech(config-router)# end
```

PE3:

The configuration procedure is similar to that of PE2.

VPNA-SITEA:

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 192.168.100.0 255.255.255.0 area 0
Qtech(config-router)# end
```

VPNA-SITEB:

The configuration procedure is similar to that of VPNA-SITEA.

VPNA-SITEC:

The configuration procedure is similar to that of VPNA-SITEA.

VPNB-SITEB:

The configuration procedure is similar to that of VPNA-SITEA.

VPNB-SITEC:

The configuration procedure is similar to that of VPNA-SITEA.

P1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.5 255.255.255.255
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip address 172.168.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# label-switching
Qtech(config-if-GigabitEthernet 1/0)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.20.0 0.0.0.255 area 0
Qtech(config-router)# end
```

P2:

The configuration procedure is similar to that of P1.

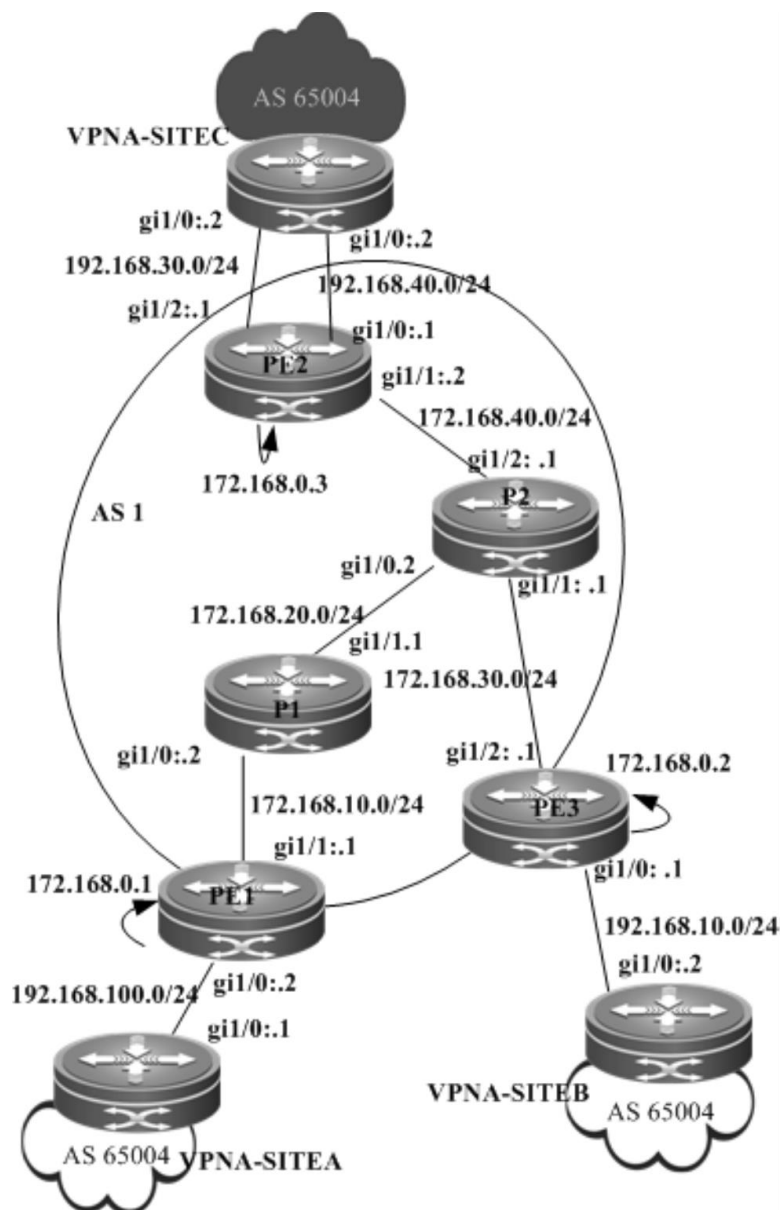
For the protocol between PEs and CEs, you can choose EBGp, OSPF, RIP, or other routing protocol as required.

2.4.3 Hub-and-Spoke Configuration Example

Networking Requirements

The VPN internal data should not be directly exchanged. Instead, the data must be exchanged through the unified control center. Only the control center is entitled to access all resources of a VPN. Any VPN users who want to obtain the VPN resources, must be notified through the control center. As shown in the following figure, to access VPNA-SITEB resources, VPNA-SITEA must pass the control center VPNA-SITEC. Direct access is not available.

Figure 31



Configuration Steps

PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure the VRF.

Create one VRF instance: spoke1. Set the RD and RT values, and associate the VPNA with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf spoke1
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target export 1:200
Qtech(config-vrf)# route-target import 1:100
Qtech(config-vrf)# end
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding spoke1
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.100.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# end
```

Enable BGP and set up MP-IBGP sessions with PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# neighbor 172.168.0.3 allowas-in
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGp.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config)# address-family ipv4 vrf spoke1
Qtech(config-router-af)# neighbor 192.168.100.1 remote-as 65004
Qtech(config-router-af)# neighbor 192.168.100.1 as-override
Qtech(config-router-af)# end
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qtech(config-router)# end
```

PE2:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.3 255.255.255.255
```

Configure the VRF.

Create one VRF instance: spoke2. Set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf spoke2
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target export 1:300
Qtech(config-vrf)# route-target import 1:100
Qtech(config-vrf)# exit
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding spoke2
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# exit
```

Enable BGP and set up MP-IBGP sessions with PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.3 remote-as 1
Qtech(config-router)# neighbor 172.168.0.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# neighbor 172.168.0.3 allowas-in
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf spoke2
Qtech(config-router-af)# neighbor 192.168.10.2 remote-as 65004
Qtech(config-router-af)# neighbor 192.168.10.2 as-override
Qtech(config-router-af)# end
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.30.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
```

```
Qtech(config-router)# end
```

PE3:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.2 255.255.255.255
```

Configure the VRF.

Create two VRF instances: from-spoke and from-hub. Set the RD and RT values, and associate the VRFs with corresponding interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf from-spoke
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target import 1:300
Qtech(config-vrf)# route-target import 1:200
Qtech(config-vrf)# exit
Qtech(config)# ip vrf from-hub
Qtech(config-vrf)# rd 1:200
Qtech(config-vrf)# route-target export 1:100
Qtech(config-vrf)# exit
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding from-hub
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.40.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip vrf forwarding from-spoke
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.30.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Enable BGP and set up MP-IBGP sessions with PE1 and PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.3 activate
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGp.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf from-spoke
```

```
Qtech(config-router-af)# neighbor 192.168.30.2 remote-as 65004
Qtech(config-router-af)# neighbor 192.168.30.2 as-override
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4 vrf from-hub
Qtech(config-router-af)# neighbor 192.168.40.2 remote-as 65004
Qtech(config-router-af)# neighbor 192.168.40.2 allows-in
Qtech(config-router-af)# exit
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

Enable MPLS fast forwarding on a router. This command is unnecessary on a switch.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 172.168.30.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
Qtech(config-router)# end
```

VPNA-SITEA:

Configure a PE session through EBGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 65004
Qtech(config-router)# neighbor 192.168.100.2 remote-as 1
Qtech(config-router)# exit
```

The configuration of VPNA-SITEB is similar to that of VPNA-SITEA.

VPNA-SITEC:

Configure a PE session through EBGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 65004
Qtech(config-router)# neighbor 192.168.30.1 remote-as 1
Qtech(config-router)# neighbor 192.168.40.1 remote-as 1
Qtech(config-router)# exit
```

2.4.4 Internet Unified Egress Interface Configuration Example

Networking Requirements

Several VPNs cannot access each other, but the VPNs need to access the Internet through a device. As shown in Figure 32 and Figure 33, VPN1 and VPN2 cannot access each other but can access the Internet through PE1.

To isolate VPN1 and VPN2, you can use centralized isolation or distributed isolation. The differences between the above schemes are as follows:

For the centralized isolation, add filtering rules on only a CE egress interface for subsequently added VPN sites to access the Internet through the unified egress interface. Other VPN sites do not need any change of configuration. This scheme features good scalability. The disadvantage of this scheme is that isolated packets can be discarded only when they reach the CE egress interface, which consumes network bandwidth.

For the distributed isolation, add filtering rules on the CE of each VPN site that needs to access the Internet through the unified egress interface. This scheme features poor scalability. The advantage of this scheme is that isolated packets are discarded on the CE of a VPN site, which saves network bandwidth.

Networking Requirements

Several VPNs cannot access each other, but the VPNs need to access the Internet through a device. As shown in Figure 32 and Figure 33, VPN1 and VPN2 cannot access each other but can access the Internet through PE1.

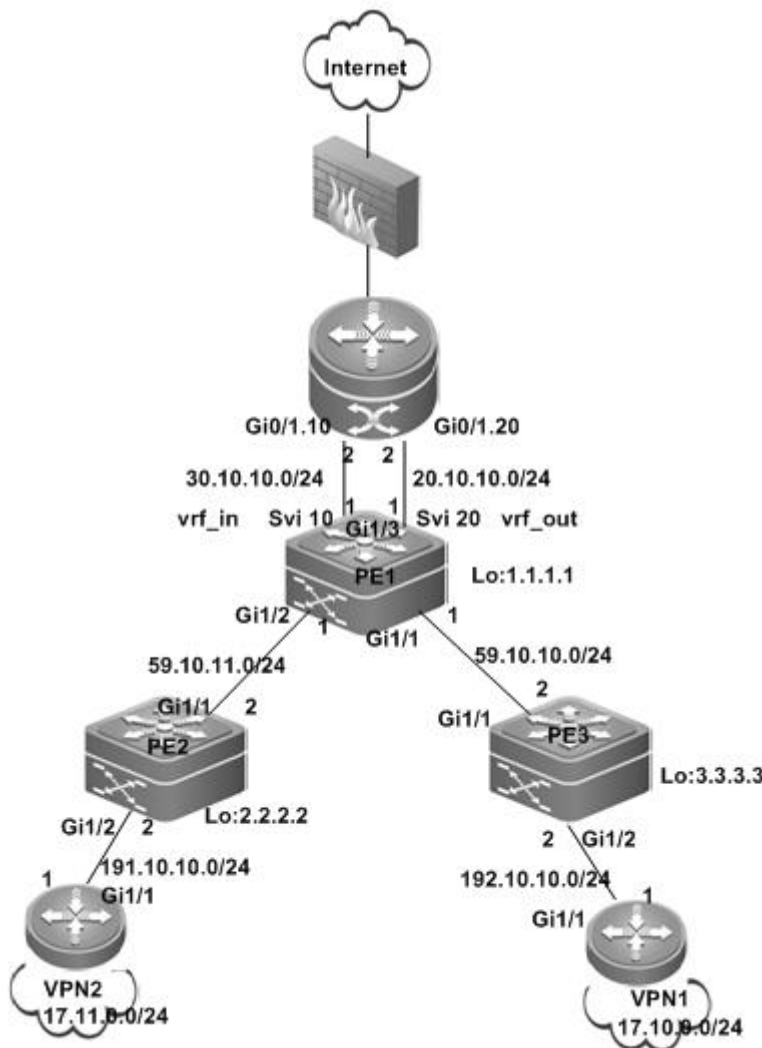
To isolate VPN1 and VPN2, you can use centralized isolation or distributed isolation. The differences between the above schemes are as follows:

For the centralized isolation, add filtering rules on only a CE egress interface for subsequently added VPN sites to access the Internet through the unified egress interface. Other VPN sites do not need any change of configuration. This scheme features good scalability. The disadvantage of this scheme is that isolated packets can be discarded only when they reach the CE egress interface, which consumes network bandwidth.

For the distributed isolation, add filtering rules on the CE of each VPN site that needs to access the Internet through the unified egress interface. This scheme features poor scalability. The advantage of this scheme is that isolated packets are discarded on the CE of a VPN site, which saves network bandwidth.

2.4.4.1 Centralized Isolation

Figure 32



Configuration Steps

■ Configuring PE2

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
```

Configure the VRF.

Create a VRF, create VPN1, and set the RD and RT values.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN1
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/2
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/2)# no switchport
Qtech(config-if-GigabitEthernet 1/2)# ip vrf forwarding VPN1
Qtech(config-if-GigabitEthernet 1/2)# ip address 191.10.10.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# end
```

Configure OSPF route exchange with CE2.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 vrf VPN2
Qtech(config-router)# network 191.10.10.0 0.0.0.255 area 0
Qtech(config-router)# default-information originate
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
```

Establish an IBGP neighbor relation with PE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# end
```

Configure IP route distribution.

```
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPN1
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# end
```

Configure MPLS signaling for the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 59.10.11.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
```

```
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 59.10.11.0 0.0.0.255 area 0
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# end
```

■ Configuring CE2

Configure the IP address of an interface connected to PE2.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 191.10.10.1 255.255.255.0
```

Configure OSPF route exchange with PE2.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 191.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.11.0.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

■ Configuring PE3

The configuration is similar to the PE2 configuration. Assume that the export and import RT of VPN2 is 1: 200.

■ Configuring PE1

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
```

Create the trunk interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/3
Qtech(config)# switch mode trunk
Qtech(config)# switch trunk vlan allow remove vlan 1-9,11-19,21-4094
```

Configure the out_vrf as the outgoing interface for accessing the Internet.

Create a VRF, configure the vrf_out, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf vrf_out
Qtech(config-vrf)# rd 1:300
Qtech(config-vrf)# route-target export 1:100
Qtech(config-vrf)# route-target export 1:200
Qtech(config-vrf)# end
```

Bind the interface to the VRF.

```
Qtech# configure terminal
Qtech(config)# interface vlan 20
Qtech(config-if-Vlan 20)# ip vrf forwarding vrf_out
Qtech(config-if-Vlan 20)# ip address 20.10.10.1 255.255.255.0
```

Configure the default route to the Internet.

```
Qtech# configure terminal
Qtech(config)# ip route vrf vrf_out 0.0.0.0 0.0.0.0 vlan 20 20.10.10.2
```

Configure in_vrf as the incoming interface of traffic returned from the Internet.

Create a VRF, configure the vrf_in, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf vrf_in
Qtech(config-vrf)# rd 1:400
```

```
Qtech(config-vrf)# route-target import 1:100
Qtech(config-vrf)# route-target import 1:200
Qtech(config-vrf)# end
```

Bind the interface to the VRF.

```
Qtech# configure terminal
Qtech(config)#interface vlan 10
Qtech(config-if-Vlan 20)# ip vrf forwarding vrf_in
Qtech(config-if-Vlan 20)# ip address 30.10.10.1 255.255.255.0
```

Configure EBGP route exchange with CE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf_in
Qtech(config-router-af)# neighbor 30.10.10.2 remote-as 100
```

Establish IBGP neighbor relations with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 2.2.2.2 remote-as 1
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Qtech(config-router)# neighbor 3.3.3.3 remote-as 1
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# end
```

Configure VRF vrf_out route exchange.

```
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf_out
Qtech(config-router-af)# default-information originate
Qtech(config-router-af)# redistribute static
Qtech(config-router-af)# end
```

Configure MPLS signaling for the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/2
```

Use the `no switchport` command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/2)# no switchport
Qtech(config-if-GigabitEthernet 1/2)# ip address 59.10.11.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# end
Qtech(config)# interface gigabitethernet 1/1
```

Use the `no switchport` command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 59.10.10.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 59.10.11.0 0.0.0.255 area 0
Qtech(config-router)# network 59.10.10.0 0.0.0.255 area 0
```

```
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# end
```

■ Configuring CE1

Create the sub-interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 0/1.10
Qtech(config-if-Gigabitethernet 0/1.10)# encapsulation dot1q 10
Qtech(config-if-Gigabitethernet 0/1.10)# ip address 30.10.10.2 255.255.255.0
Qtech(config)# exit
Qtech(config)# interface gigabitethernet 0/1.20
Qtech(config-if-Gigabitethernet 0/1.20)# encapsulation dot1q 20
Qtech(config-if-Gigabitethernet 0/1.20)# ip address 20.10.10.2 255.255.255.0
```

Establish an EBGp neighbor relation with PE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 100
Qtech(config)# neighbor 30.10.10.1 remote-as 1
```

Create an ACL rule.

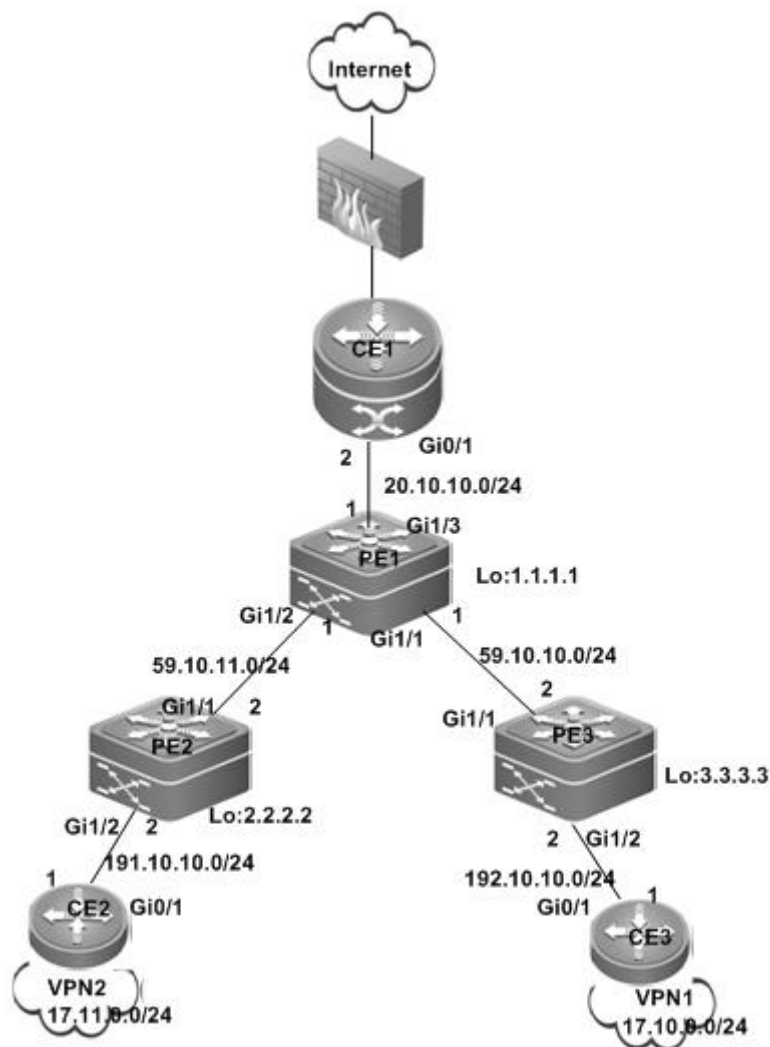
```
Qtech(config)#access-list 1 deny 17.0.0.0 0.255.255.255
Qtech(config)# access-list 1 permit any
```

Configure the ACL rule on the sub-interface Gi 0/1.10.

```
Qtech(config)# interface gigabitethernet 0/1.10
Qtech(config-if-Gigabitethernet 0/1.10)# ip access-group 1 out
```

2.4.4.2 Distributed Isolation

Figure 33



■ Configuring PE1

Configure the loopback interface.

This configuration is the same as Centralized Isolation.

Configure the VRF.

Create a VRF, create vrf_net, and set the RD and RT values.

```
Qtech# configure terminal
Qtech(config)# ip vrf vrf_net
Qtech(config-vrf)# rd 1:300
Qtech(config-vrf)# route-target import 1:100
Qtech(config-vrf)# route-target import 1:200
Qtech(config-vrf)# route-target export 1:100
Qtech(config-vrf)# route-target export 1:200
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/3
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/3)# no switchport
Qtech(config-if-GigabitEthernet 1/3)# ip vrf forwarding vrf_net
Qtech(config-if-GigabitEthernet 1/3)# ip address 20.10.10.1 255.255.255.0
```

Configure the default route to the Internet.

```
Qtech(config)#ip route vrf vrf_net 0.0.0.0 0.0.0.0 gigabitethernet 1/3 20.10.10.2
```

Configure EBGp route exchange with CE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf_net
Qtech(config-router-af)# neighbor 20.10.10.2 remote-as 100
```

Establish IBGP neighbor relations with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 2.2.2.2 remote-as 1
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Qtech(config-router)# neighbor 3.3.3.3 remote-as 1
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# end
```

Configure VRF vrf_net route exchange.

```
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf vrf_net
Qtech(config-router-af)# default-information originate
Qtech(config-router-af)# redistribute static
Qtech(config-router-af)# end
```

Configure MPLS and routes for the backbone network.

This configuration is the same as Centralized Isolation **Ошибка! Не указано имя закладки..**

■ Configuring CE1

```
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip address 20.10.10.2 255.255.255.0
```

Establish an EBGp neighbor relation with PE1.

```
Qtech# configure terminal
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 20.10.10.1 remote-as 1
```

■ Configuring PE2

This configuration is the same as Centralized Isolation **Ошибка! Не указано имя закладки..**

■ Configuring CE2

Configure an ACL rule.

```
Qtech# configure terminal
Qtech(config)# access-list 2000 deny ip any 17.10.0.0 0.0.255.255
Qtech(config)# access-list 2000 permit ip any any
```

Apply the ACL rule to the interface.

```
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip access-group 2000 out
```

Configure route exchange with PE2.

This configuration is the same as Centralized Isolation.

Configure the default static route.

This configuration is the same as Centralized Isolation.

Configuring PE3

This configuration is the same as Centralized Isolation.

Configuring CE3

Configure an ACL rule.

```
Qtech# configure terminal
Qtech(config)# access-list 2000 deny ip any 17.11.0.0 0.0.255.255
Qtech(config)# access-list 2000 permit ip any any
```

Apply the ACL rule to the interface.

```
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip access-group 2000 out
```

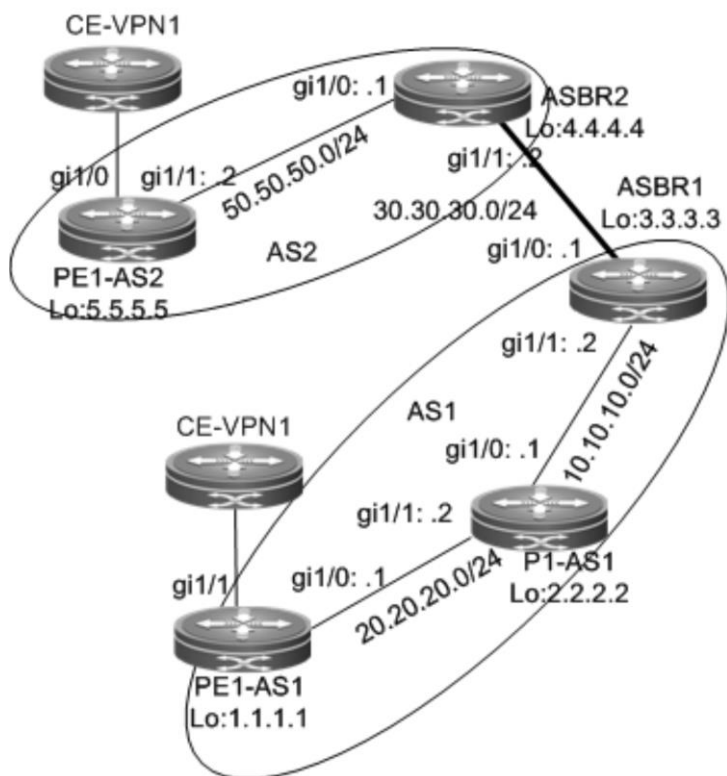
Other configurations are the same as Centralized Isolation.

2.4.5 Inter-AS VPN OptionB: Next Hop Unchanged

Networking Requirements

One VPN user has sites at both ASs. It is required that the VPN sites in different ASs access each other.

Figure 34 OptionB: Next Hop Unchanged



The configuration scheme is as follows:

PE1-AS1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
```

Configure the VRF.

Create one VRF instance: VPN1. Set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN1
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
```

```
Qtech(config-vrf)# end
```

Associate the VRF with an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip vrf forwarding VPN1
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.16.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# end
```

Enable BGP and set up MP-IBGP sessions with ASBR1.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 3.3.3.3 remote-as 1
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGP.

See the configuration procedure in the "Running BGP Between PEs and CEs to Transmit Route Information" section and the related configurations in the "Intranet Configuration Examples" section.

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-GigabitEthernet 1/0)# ip address 20.20.20.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# label-switching
Qtech(config-if-GigabitEthernet 1/0)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# end
```

The configuration procedure of **PE1-AS2** is similar to the preceding one.

P1-AS1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
```

Configure the MPLS signaling protocol on the backbone network and enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
```



```
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-GigabitEthernet 1/0)# ip address 10.10.10.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# label-switching
Qtech(config-if-GigabitEthernet 1/0)# mpls ip
Qtech(config-if-GigabitEthernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# end
```

ASBR1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
```

Enable BGP, disable the BGP RT filtering function, and establish neighbor relations with PE1-AS1 and ASBR2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# no bgp default route-target filter
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 30.30.30.2 activate
Qtech(config-router-af)# end
```

Configure MPLS signaling and enable MPLS on a public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 10.10.10.2
255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
Qtech(config-if-gigabitethernet 1/1)# end
```

Run OSPF on the backbone network to transmit routes and redistribute directly connected subnet routes.

```
Qtech# configure terminal
```

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# redistribute connected subnets
Qtech(config-router)# end
```

Assign an IP address to the interface connected to ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitEthernet 1/0)# no switchport
Qtech(config-if-gigabitEthernet 1/0)# ip address 30.30.30.1
255.255.255.0
```

Enable label switching on an interface.

```
Qtech(config-if-gigabitEthernet 1/0)# label-switching
```

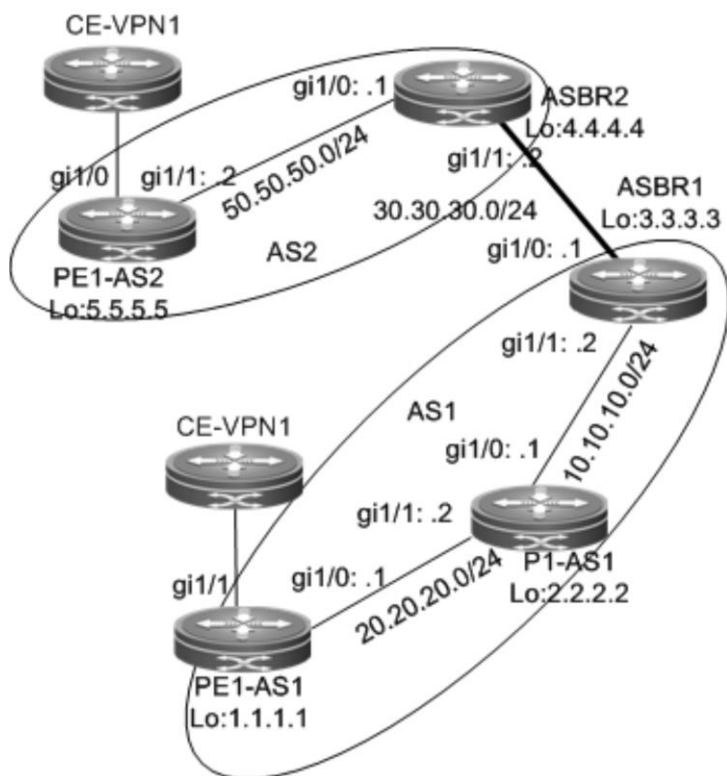
The configuration scheme of ASBR2 is similar to that of ASBR1.

2.4.6 Inter-AS VPN OptionB: Next Hop Changed

Networking Requirements

One VPN user has sites at both ASs. It is required that the VPN sites in different ASs access each other.

Figure 35 OptionB: Next Hop Changed



The configuration scheme is as follows:

PE1-AS1:

The configuration procedure is similar to that of PE1-AS1 in the "Inter-AS VPN OptionB: Next Hop Unchanged" section and is not described here.

P1-AS1:

The configuration procedure is similar to that of P1-AS1 in the "Inter-AS VPN OptionB: Next Hop Unchanged" section and is not described here.

ASBR1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
```

Enable BGP, disable the BGP RT filtering function, establish neighbor relations with the PE and ASBR, and change the next hop of routes to the neighbor PE into the local address.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# no bgp default route-target filter
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 next-hop-self
Qtech(config-router-af)# neighbor 30.30.30.2 activate
Qtech(config-router-af)# end
```

Configure MPLS signaling and enable MPLS on a public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 10.10.10.2
255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
Qtech(config-if-gigabitethernet 1/1)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# end
```

Assign an IP address to the interface connected to ASBR2.

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 30.30.30.1
255.255.255.0
```

Enable label switching on an interface.

```
Qtech(config-if-gigabitethernet 1/0)# label-switching
```

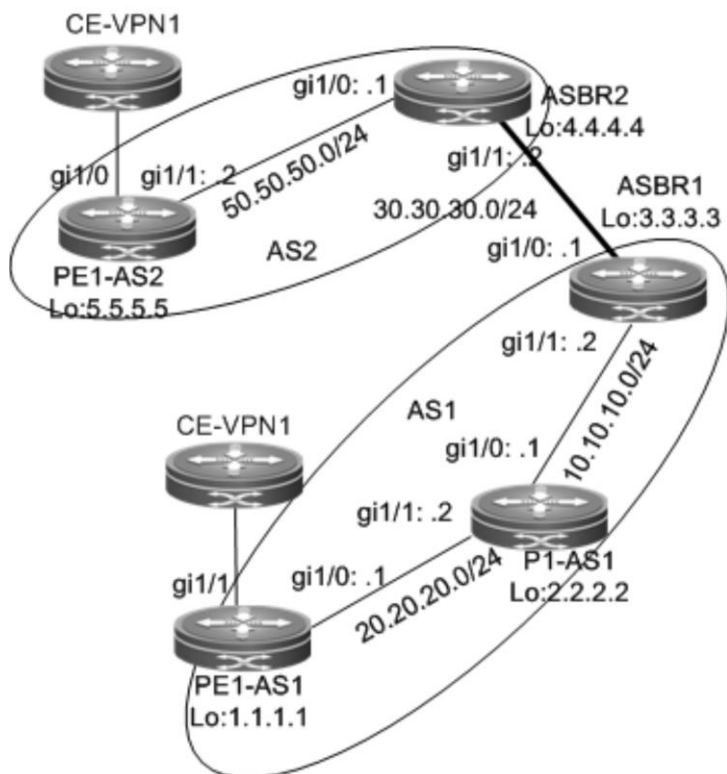
The configuration scheme of ASBR2 is similar to that of ASBR1.

2.4.7 Inter-AS VPN OptionC: Enabling IPv4 Label Switching Between EBGp Neighbors

Networking Requirements

One VPN user has sites at both ASs. It is required that the VPN sites in different ASs access each other.

Figure 36 OptionC: enabling IPv4 label switching between EBGP neighbors



The configuration scheme is as follows:

PE1-AS1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
```

Configure the VRF.

The configuration procedure is similar to that of PE1-AS1 in the "Inter-AS VPN OptionB: Next Hop Unchanged" section and is not described here.

Configure a multi-hop MP-EBGP session and disable IPv4 route exchange for the session.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 5.5.5.5 remote-as 2
Qtech(config-router)# neighbor 5.5.5.5 update-source loopback 0
Qtech(config-router)# neighbor 5.5.5.5 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 5.5.5.5 activate
Qtech(config-router-af)# exit
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 5.5.5.5 activate
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGP.

See the configuration procedure in the "Running BGP Between PEs and CEs to Transmit Route Information" section and the related configurations in the "Intranet Configuration Examples" section.

Configure MPLS signaling and enable MPLS on a public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
```

```
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 20.20.20.1
255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
Qtech(config-if-gigabitethernet 1/1)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# end
```

P1-AS1:

The configuration mainly includes the MPLS signaling protocol and IGP and is not described here. See the P1-AS1 configuration scheme in the "Inter-AS VPN OptionB: Next Hop Unchanged" section.

ASBR1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
```

Configure ACL rules and route map rules to distribute or set labels only for routes that match the rules.

```
Qtech# configure terminal
Qtech(config)# ip access-list extended 101
Qtech(config-ext-nacl)# permit ip host 1.1.1.1 any
Qtech(config-ext-nacl)# exit
Qtech(config)# ip access-list extended 102
Qtech(config-ext-nacl)# permit ip host 5.5.5.5 any
Qtech(config-ext-nacl)# exit
Qtech(config)# route-map set-mpls
Qtech(config-route-map)# match ip address 101
Qtech(config-route-map)# set mpls-label
Qtech(config-route-map)# exit
Qtech(config)# route-map external-pe-route
Qtech(config-route-map)# match ip address 102
Qtech(config-route-map)# end
```

Set up an EBGP session with ASBR2 and configure route map rules to distribute labels for PE routes that match the rules (the route map rules are optional and allow BGP to distribute labels for only certain routes), and configure static routes to PEs in the local AS.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 30.30.30.2 send-label
Qtech(config-router-af)# neighbor 30.30.30.2 route-map set-mpls out
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

Configure MPLS to distribute label for certain BGP routes through ACL rules (the ACL rules are optional and allow you to reduce the number of unnecessary routes).

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes acl 102
```

```
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network to redistribute only BGP routes that match the route map rules (the route map rules are optional and allow you to reduce the number of unnecessary routes).

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# redistribute bgp subnets route-map external-pe-route
Qtech(config-router)# end
```

Assign an IP address to the interface connected to ASBR2.

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 30.30.30.1
255.255.255.0
```

Enable label switching on an interface.

```
Qtech(config-if-gigabitethernet 1/0)# label-switching
```

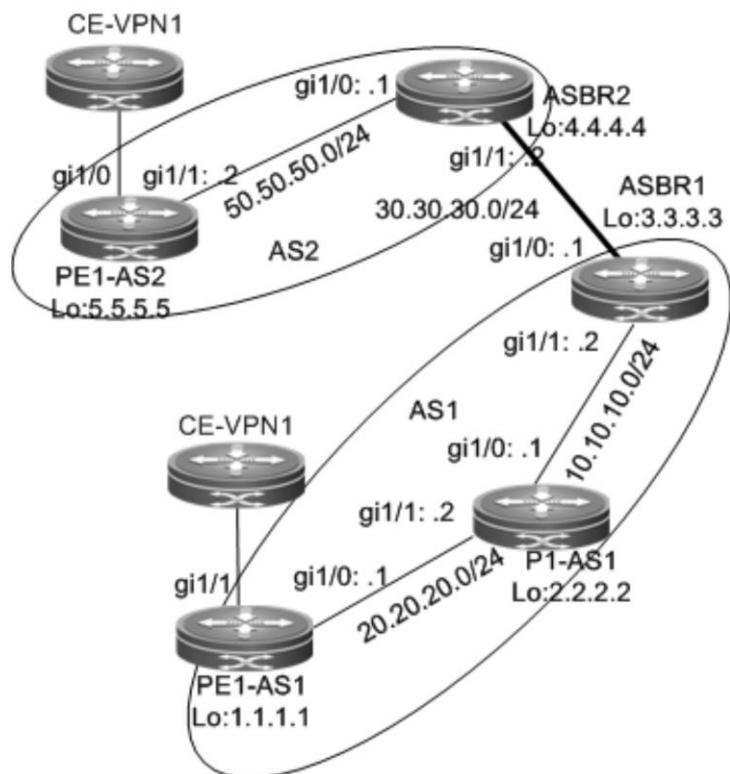
The configuration scheme of ASBR2 is similar to that of ASBR1.

2.4.8 Inter-AS VPN OptionC: Enabling IPv4 Label Switching Between Both EBGP and IBGP Neighbors

Networking Requirements

One VPN user has sites at both ASs. It is required that the VPN sites in different ASs access each other.

Figure 37 OptionC: enabling IPv4 label switching between both EBGP and IBGP neighbors



The configuration scheme is as follows:

PE1-AS1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
```

Configure the VRF.

The configuration procedure is similar to that of PE1-AS1 in the "Inter-AS VPN OptionB: Next Hop Unchanged" section and is not described here.

Configure a multi-hop MP-EBGP session and disable IPv4 route exchange for the session.

The configuration procedure is similar to that of "Inter-AS VPN OptionC: Enabling IPv4 Label Switching Between EBGP Neighbors" and is not described here.

Set up an IBGP session with the ASBR and enable IPv4 label switching.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 3.3.3.3 remote-as 1
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-label
Qtech(config-router-af)# end
```

Configure CE neighbors through EBGP.

See the configuration procedure in the "Running BGP Between PEs and CEs to Transmit Route Information" section and the related configurations in the "Intranet Configuration Examples" section.

Configure MPLS signaling and enable MPLS on a public network interface.

```
Qtech# configure terminal
```

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 20.20.20.1
255.255.255.0
Qtech(config-if-gigabitethernet 1/0)# label-switching
Qtech(config-if-gigabitethernet 1/0)# mpls ip
Qtech(config-if-gigabitethernet 1/0)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# end
```

The configuration of PE1-AS2 is similar to that of PE1-AS1.

P1-AS1:

The configuration mainly includes the MPLS signaling protocol and IGP and is not described here. It is similar to "Example of Configuring Basic MPLS Functions".

ASBR1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
```

Configure ACL rules and route map rules to distribute or set labels only for routes that match the rules.

```
Qtech# configure terminal
Qtech(config)# ip access-list extended 101
Qtech(config)# permit ip host 1.1.1.1 any
Qtech(config)# exit
Qtech(config)# ip access-list extended 102
Qtech(config)# permit ip host 5.5.5.5 any
Qtech(config)# route-map internal-mpls-route permit 10
Qtech(config-route-map)# match ip address 101
Qtech(config-route-map)# set mpls-label
Qtech(config-route-map)# exit
Qtech(config)# route-map external-mpls-route permit 10
Qtech(config-route-map)# match ip address 102
Qtech(config-route-map)# set mpls-label
Qtech(config-route-map)# end
```

Set up an EBGP session with the ASBR and configure route map rules to distribute labels for PE routes that match the rules (the route map rules are optional and allow BGP to distribute labels for only certain routes), and configure static routes to PEs in the local AS.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 30.30.30.2 send-label
Qtech(config-router-af)# neighbor 30.30.30.2 route-map internal-mpls-route out
Qtech(config-router-af)# neighbor 1.1.1.1 send-label
Qtech(config-router-af)# neighbor 1.1.1.1 route-map external-mpls-route out
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```


Configure MPLS signaling and enable MPLS on an interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 255.255.255.0 area 0
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# end
```

Assign an IP address to the interface connected to ASBR2.

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 30.30.30.1
255.255.255.0
```

Enable label switching on an interface.

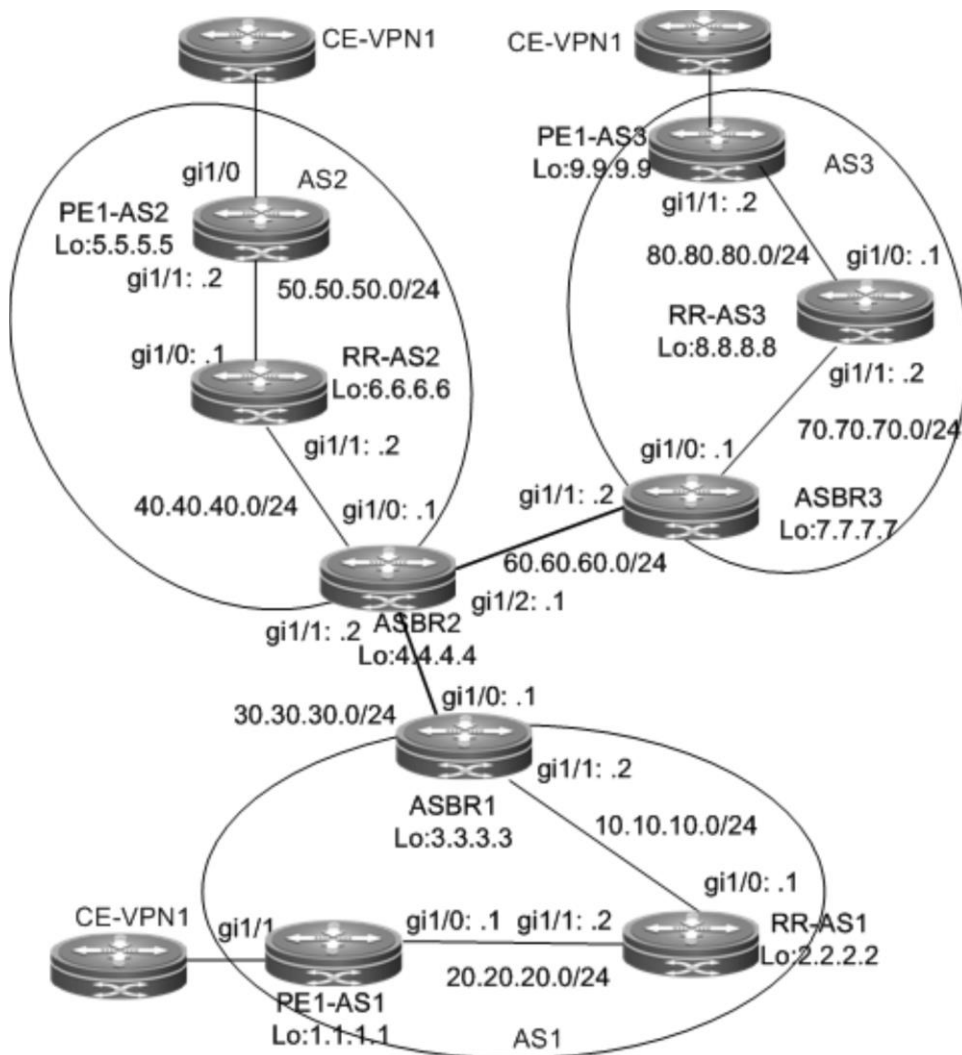
```
Qtech(config-if-gigabitethernet 1/0)# label-switching
```

The configuration scheme of ASBR2 is similar to that of ASBR1.

2.4.9 Inter-AS VPN OptionC: RR Networking Scheme

In the two implementation modes of OptionC, another problem exists. If the sites of the same VPN user are located at different ASs, a common OptionC scheme requires full mesh BGP connections for the inter-AS PEs to ensure the reachability of the VPN sites. As shown in the following figure, the sites of the VPN user are located at three different ASs. If a new VPN site is added, the new site needs to set up BGP connections with the other VPN sites. This restricts the application of the common OptionC scheme. To solve the preceding expansion problem, you can add an RR to each AS in the OptionC scheme. The RRs set up multi-hop MP-EBGP connections to exchange inter-AS VPN routes. At the same time, you can set up MP-IBGP sessions between PEs and the RR in the AS.

Figure 38 Setting up multi-hop MP-EBGP sessions between RRs in the OptionC scheme



The configuration scheme is as follows:

PE1-AS1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
```

Configure the VRF.

The configuration procedure is similar to that of PE1-AS1 in the "Inter-AS VPN OptionB: Next Hop Unchanged" section and is not described here.

Set up an MP-IBGP session with the RR and enable label distribution for IPv4 routes.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 2.2.2.2 remote-as 1
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-label
```

```
Qtech(config-router-af) # end
```

Configure CE neighbors through EBGP.

See the configuration procedure in the "Running BGP Between PEs and CEs to Transmit Route Information" section and the related configurations in the "Intranet Configuration Examples" section.

The configurations of PE1-AS2 and PE1-AS3 are similar to that of PE1-AS1.

RR-AS1

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
```

Set up an MP-IBGP session with the PE, specify the PE as the RR client, and enable label distribution for IPv4 routes.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 route-reflector-client
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-label
Qtech(config-router-af)# neighbor 1.1.1.1 route-reflector-client
Qtech(config-router-af)# end
```

Set up a multi-hop MP-EBGP session with the RR, do not change the next hop of VPN routes exchanged with the RR, and disable the IPv4 route exchange with the RR.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 6.6.6.6 remote-as 2
Qtech(config-router)# neighbor 6.6.6.6 update-source loopback 0
Qtech(config-router)# neighbor 6.6.6.6 ebgp-multihop
Qtech(config-router)# neighbor 8.8.8.8 remote-as 3
Qtech(config-router)# neighbor 8.8.8.8 update-source loopback 0
Qtech(config-router)# neighbor 8.8.8.8 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 6.6.6.6 activate
Qtech(config-router-af)# no neighbor 8.8.8.8 activate
Qtech(config-router-af)# exit-address-family
Qtech(config-router)# address-family vpnv4 unicast
Qtech(config-router-af)# neighbor 6.6.6.6 activate
Qtech(config-router-af)# neighbor 6.6.6.6 next-hop-unchanged
Qtech(config-router-af)# neighbor 8.8.8.8 activate
Qtech(config-router-af)# neighbor 8.8.8.8 next-hop-unchanged
Qtech(config-router-af)# end
```

Set up an IBGP session with the ASBR and enable IPv4 label switching.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 3.3.3.3 remote-as 1
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-label
Qtech(config-router-af)# end
```

Configure MPLS.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
```

```
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 20.20.20.2
255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
Qtech(config-if-gigabitethernet 1/1)# exit
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-gigabitethernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 10.10.10.1
255.255.255.0
Qtech(config-if-gigabitethernet 1/0)# label-switching
Qtech(config-if-gigabitethernet 1/0)# mpls ip
Qtech(config-if-gigabitethernet 1/0)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# end
```

The procedures of RR-AS2 and RR-AS3 are similar to the preceding procedure.

ASBR1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
```

Configure ACL rules and route map rules.

```
Qtech# configure terminal
Qtech(config)# ip access-list extended 101
Qtech(config-ext-nacl)# permit ip host 1.1.1.1 any
Qtech(config-ext-nacl)# exit
Qtech(config)# ip access-list extended 102
Qtech(config-ext-nacl)# permit ip host 5.5.5.5 any
Qtech(config-ext-nacl)# permit ip host 9.9.9.9 any
Qtech(config-ext-nacl)# exit
Qtech(config)# route-map internal-mpls-route permit 10
Qtech(config-route-map)# match ip address 101
Qtech(config-route-map)# set mpls-label
Qtech(config-route-map)# exit
Qtech(config)# route-map external-mpls-route permit 10
Qtech(config-route-map)# match ip address 102
Qtech(config-route-map)# set mpls-label
Qtech(config-route-map)# end
```

Set up an EBGP session with the ASBR, enable label distribution for IPv4 routes, and configure route map rules to distribute labels for PE routes that match the rules (the route map rules are optional and allow the BGP to distribute labels for only certain routes). Set up an IBGP session with the RR, enable label distribution for IPv4 routes, and configure route map rules to distribute labels for inter-AS PE routes that match the rules. Configure static routes to the PEs in the local AS.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# neighbor 2.2.2.2 remote-as 1
```

```
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 30.30.30.2 send-label
Qtech(config-router-af)# neighbor 30.30.30.2 route-map internal-mpls-route out
Qtech(config-router-af)# neighbor 2.2.2.2 send-label
Qtech(config-router-af)# neighbor 2.2.2.2 route-map external-mpls-route out
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

Configure MPLS signaling and enable MPLS on an interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2
255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Run OSPF on the backbone network to transmit route information.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# end
```

Assign an IP address to the interface connected to ASBR2.

```
Qtech(config)# interface gigabitethernet 1/0
```

Use the **no switchport** command to switch the port mode on the switch series to the Routed Port mode. This command is not applicable to routers.

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
Qtech(config-if-gigabitethernet 1/0)# ip address 30.30.30.1
255.255.255.0
```

Enable label switching on an interface.

```
Qtech(config-if-gigabitethernet 1/0)# label-switching
```

The configuration schemes of ASBR2 and ASBR3 are similar to that of ASBR1.

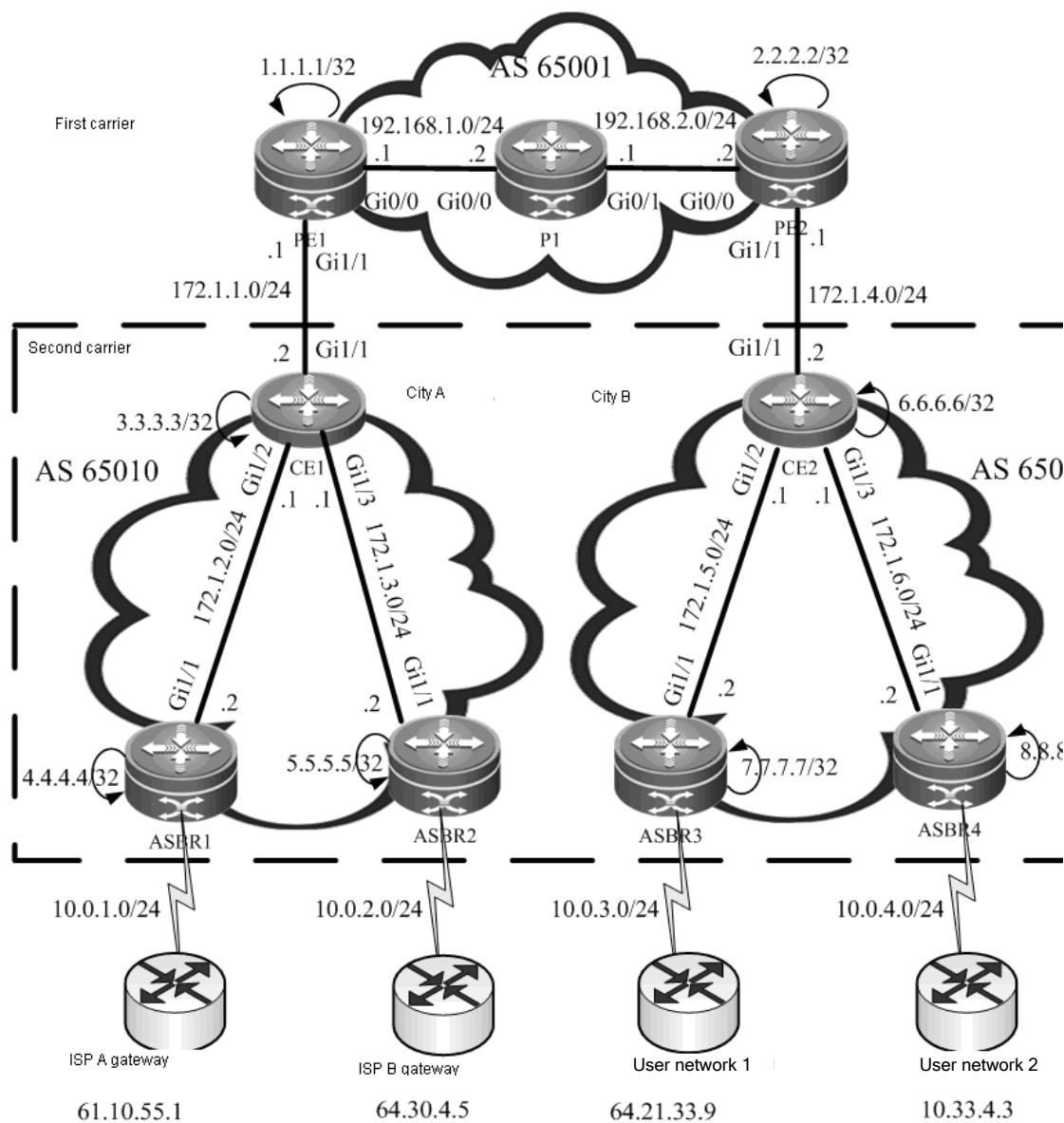
2.4.10 CSC: The Second Carrier Provides Internet Services Based on IP Core

Networking Requirements

A carrier owns an intranet in City A, and this network has the BGP gateways to ISP A and ISP B. This carrier utilizes its intranet to provide Internet services for users in City A. Currently, this carrier expects to expand services to City B, and therefore leases MPLS VPN services from a VPN carrier in the hope of connecting the sites of two cities via VPN, so that users in City B can access the Internet through the existing Internet gateways. The internal routes are exchanged via IGP (OSPF), and the external routes are exchanged via BGP.

Networking Topology

Figure 39 Network topology of scenario I



Configuration Tips

- Configuring basic BGP/MPLS IP VPN functions for the first carrier
- Enabling the CSC function
- Configuring the second carrier
- Configuring user access

Configuration Steps

- Configuring basic BGP/MPLS IP VPN functions for the first carrier

Configure an MPLS network: PE1 is used as an example. The configurations of P1 and PE2 are similar.

Configure a loopback interface.

```
Qtech(config)# interface Loopback 0
Qtech(config-if)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if)# exit
```

Globally enable MPLS and LDP.

```
Qtech(config)# mpls ip
```

```
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface Loopback 0
Qtech(config-mpls-router)# exit
```

Enable MPLS and LDP on the interface.

```
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if)# label-switching
Qtech(config-if)# mpls ip
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
```

Configure IGP (OSPF).

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure an MP-IBGP neighbor: PE1 is used as an example. The configurations of PE2 are similar.

```
Qtech(config)# router bgp 65001
Qtech(config-router)# neighbor 2.2.2.2 remote-as 65001
Qtech(config-router)# neighbor 2.2.2.2 update-source Loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community both
```

Configure a VRF: PE1 is used as an example. The configurations of PE2 are similar.

```
Qtech(config)# ip vrf vpn1
Qtech(config-vrf)# rd 65001:20
Qtech(config-vrf)# route-target both 65001:20
Qtech(config-vrf)# alloc-label per-route
Qtech(config-vrf)# exit
Qtech(config)# interface loopback 1
Qtech(config-if)# ip vrf forwarding vpn1
Qtech(config-if)# ip address 10.1.1.1 255.255.255.255
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip vrf forwarding vpn1
Qtech(config-if)# ip address 172.1.1.1 255.255.255.0
Qtech(config-if)# no shutdown
```

Configure a CE to connect to a PE: CE1 is used as an example. The configurations of CE2 are similar.

```
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.1.2 255.255.255.0
Qtech(config-if)# no shutdown
```

Configure route exchange between PEs and CEs: Route exchange between PE1 and CE1 is used as an example. The configurations of route exchange between PE2 and CE2 are similar.

First, configure PE1.

```
Qtech(config)# router ospf 100 vrf vpn1
Qtech(config-router)# network 172.1.1.0 0.0.0.255 area 0
Qtech(config-router)# redistribute bgp 65001 subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 65001
Qtech(config-router)# address-family ipv4 vrf vpn1
Qtech(config-router-af)# redistribute ospf 100 vrf vpn1
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

Then, configure CE1.

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.1.1.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

■ Enabling the CSC function

Enable CSC on the PE: PE1 is used as an example. The configurations of PE2 are similar.

```
Qtech(config)# mpls router ldp vpn1
Qtech(config-mpls-router)# ldp router-id interface Loopback 1
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# label-switching
Qtech(config-if)# mpls ip
```

Enable MPLS and LDP on the CE: CE1 is used as an example. The configurations of CE2 are similar.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface Loopback 0
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# label-switching
Qtech(config-if)# mpls ip
```

■ Configuring the second carrier

Configure the interface and IGP: CE1 is used as an example. The configurations of CE2, ASBR1, ASBR2, ASBR3 and ASBR4 are similar.

```
Qtech(config)# interface gigabitEthernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.2.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 1/3
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.3.1 255.255.255.0
Qtech(config-if)# no shutdown
```



```
Qtech(config-if)# exit
Qtech(config)# interface Loopback 0
Qtech(config-if)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 172.1.2.0 0.0.0.255 area 0
Qtech(config-router)# network 172.1.3.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

On the ASBR, configure the CE as a BGP neighbor: ASBR1 is used as an example. The configurations of ASBR2, ASBR3 and ASBR4 are similar.

```
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 3.3.3.3 remote-as 65010
Qtech(config-router)# neighbor 3.3.3.3 update-source Loopback 0
Qtech(config-router)# neighbor 3.3.3.3 next-hop-self
```

On the CE, configure the ASBR and a peer CE as the RR client and enable resolution of the next hop of a BGP route to an LSP tunnel: CE1 is used as an example. The configurations of CE2 are similar.

```
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 4.4.4.4 remote-as 65010
Qtech(config-router)# neighbor 4.4.4.4 update-source Loopback 0
Qtech(config-router)# neighbor 4.4.4.4 route-reflector-client
Qtech(config-router)# neighbor 5.5.5.5 remote-as 65010
Qtech(config-router)# neighbor 5.5.5.5 update-source Loopback 0
Qtech(config-router)# neighbor 5.5.5.5 route-reflector-client
Qtech(config-router)# neighbor 6.6.6.6 remote-as 65010
Qtech(config-router)# neighbor 6.6.6.6 update-source Loopback 0
Qtech(config-router)# neighbor 6.6.6.6 route-reflector-client
Qtech(config-router)# exit
Qtech(config)# recursive-route lookup lsp
```

■ Configuring user access

It is assumed that user network 1 is connected to ASBR3. The configurations of other external networks (user network and Internet gateway) are similar.

On ASBR3, use the following command.

```
Qtech(config)# interface gigabitEthernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 10.0.3.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 10.0.3.2 remote-as 100
Qtech(config-router)# exit
```

On the edge router of user network 1, use the following command.

```
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 10.0.3.2 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 0/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```

Qttech(config-if)# ip ref
Qttech(config-if)# ip address 64.21.33.9 255.255.255.0
Qttech(config-if)# no shutdown
Qttech(config-if)# exit
Qttech(config)# router bgp 100
Qttech(config-router)# neighbor 10.0.3.1 remote-as 65010
Qttech(config-router)# network 64.21.33.0 mask 255.255.255.0

```

Verification

Display VRF routes and labels on the PE: PE1 is used as an example. The verification of PE2 is similar.

// In the VRF routing table of the PE, there are only internal routes of the second carrier. There is no external route (for example, 64.30.4.0/24).

```

Qttech# show ip route vrf vpn1
Routing Table: vpn1

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
O   3.3.3.3/32 [110/11] via 172.1.1.2, 00:00:07, gigabitEthernet 1/1
C   172.1.1.0/24 is directly connected, gigabitEthernet 1/1
C   172.1.1.1/32 is local host.
O   172.1.2.0/24 [110/12] via 172.1.1.2, 00:00:07, gigabitEthernet 1/1
B   172.1.4.0/24 [200/0] via 2.2.2.2, 00:00:30
.....
Qttech# show mpls ldp bindings vrf vpn1
VRF vpn1(id 1)
  lib entry: 3.3.3.3/32
    local binding: to lsr: 172.1.1.2:0, label: 1025
    remote binding: from lsr: 172.1.1.2:0, label: imp-null
  lib entry: 172.1.1.0/24
    local binding: to lsr: 172.1.1.2:0, label: imp-null
    remote binding: from lsr: 172.1.1.2:0, label: imp-null
  lib entry 172.1.2.0/24
    local binding: to lsr: 172.1.1.2:0, label: 1026
    remote binding: from lsr: 172.1.1.2:0, label: 1024
.....

```

On the ASBR and user network, display the routing table.

// On the ASBR, there are both external routes and internal routes (using ASBR3 as the example).

```

Qttech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
.....
O   3.3.3.3/24 [110/12] via 172.1.5.1, 00:00:30, gigabitEthernet 1/1
B   61.10.55.0/24 [200/0] via 3.3.3.3, 00:00:40
B   64.21.33.0/24 [200/0] via 10.0.3.2, 00:00:31
.....

```

// In the user network, there are external routes (using the edge device of user network 1 as the example).

```

Qttech# show ip route
Qttech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP

```

```
O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
.....
B   61.10.55.0/24 [200/0] via 10.0.3.1, 00:00:40
C   64.21.33.0/24 is directly connected, gigabitEthernet 0/1
C   64.21.33.9/32 is local host.
.....
```

Verify that the external networks are interconnected.

// On the edge device of user network 1, use the following command.

```
Qtech# ping 61.10.55.1 source 64.21.33.9
Sending 5, 100-byte ICMP Echoes to 61.10.55.1, timeout is 2 seconds:
Packet sent with a source address of 64.21.33.9
 < press Ctrl+C to break >
!!!!!
```

2.4.11 CSC: The Second Carrier Provides Internet Services Based on MPLS Core

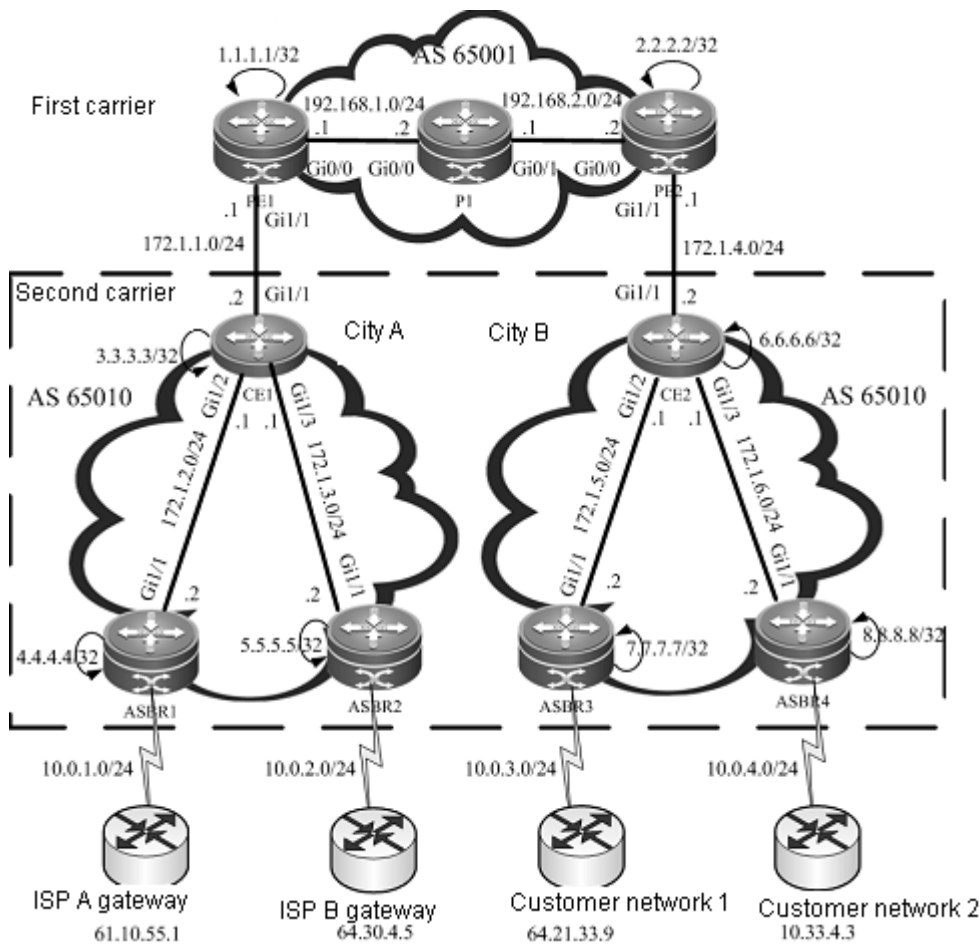
Networking Requirements

A carrier provides Internet services for users in City A. Considering that it may need to provide MPLS services for users in the future, this carrier has deployed MPLS on its backbone network. Now this carrier intends to expand its service to City B, and has built an MPLS network in City B. To interconnect the core networks in the two cities, this carrier leases the VPN service from another MPLS VPN service provider. Therefore, this carrier has become a second carrier, while the MPLS VPN service provider is the first carrier.

The first carrier PE and second carrier CE will exchange (internal) routes via BGP. The second carrier will directly establish BGP neighbors between ASBRs to exchange external routes. The traffic will flow from the external network into the second carrier network and be forwarded on the tunnel until the traffic leaves the second carrier network.

Networking Topology

Figure 40 Network topology of scenario II



Configuration Tips

- Configuring basic BGP/MPLS IP VPN functions for the first carrier
- Enabling the CSC function
- Configuring the second carrier
- Configuring user access

Configuration Steps

- Configuring basic BGP/MPLS IP VPN functions for the first carrier

The configuration steps are similar to those in Scenario I. The difference is that routes are exchanged between PEs and CEs. Only configurations of route exchange between PEs and CEs will be shown below. For other configurations, see "Configuring basic BGP/MPLS IP VPN functions" in the example of "The Second Carrier Provides Internet Services Based on IP Core".

Configure route exchange between PEs and CEs.

First, configure the PE (using PE1 as an example).

```
Qtech(config)# router bgp 65001
Qtech(config-router)# address-family ipv4 vrf vpn1
Qtech(config-router-af)# neighbor 172.1.1.2 remote-as 65010
Qtech(config-router-af)# neighbor 172.1.1.2 as-override
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

Then, configure the CE (using CE1 as an example).

```
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 172.1.1.2 remote-as 65001
Qtech(config-router)# redistribute ospf 1
```

```
Qtech(config-router)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# redistribute bgp 65010 subnets
Qtech(config-router)# exit
```

■ Enabling the CSC function

Enable CSC on the PE: PE1 is used as an example. The configurations of PE2 are similar.

```
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip vrf forwarding vpn1
Qtech(config-if)# ip address 172.1.1.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router bgp 65001
Qtech(config-router)# address-family ipv4 vrf vpn1
Qtech(config-router-af)# neighbor 172.1.1.2 send-label
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

Enable MPLS and BGP label distribution on the CE.

```
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# label-switching
Qtech(config-if)# ip address 172.1.1.2 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 172.1.1.1 send-label
Qtech(config-router)# exit
```

■ Configuring the second carrier

Configure an MPLS network: See "Configuring an MPLS network" in the example of "The Second Carrier Provides Internet Services Based on IP Core". Configuration objects are CE1, CE2 and ASBRs (1 to 4).



Note

You need to enable LDP on the CSC-CE in order to set up sessions with other intra-site devices to build an MPLS network. If the CSC-CE and CSC-PE use BGP to exchange routes, you must use the **advertise-labels for bgp-routes** command on the CSC-CE to allow LDP to distribute labels for BGP routes.

Configure a BGP neighbor: Establish a BGP neighbor relation between two ASBRs.

Configure ASBR2 as the BGP neighbor on ASBR1. The configurations of other ASBRs are similar.

```
Qtech(config)# router bgp 65010
Qtech(config-router)# neighbor 5.5.5.5 remote-as 65010
Qtech(config-router)# neighbor 5.5.5.5 update-source Loopback 0
Qtech(config-router)# neighbor 5.5.5.5 next-hop-self
Qtech(config-router)# exit
Qtech(config)# recursive-route lookup lsp
```

■ Configuring user access

See "Configuring user access" in the example of "The Second Carrier Provides Internet Services Based on IP Core".

Verification

Display VRF routes and labels on the first carrier PE: PE1 is used as an example. The verification of PE2 is similar.

// In the VRF routing table of PE1, there are only internal routes of the second carrier. There is no external routes (for example, 64.30.4.0/24).

```
Qtech# show ip route vrf vpn1
Routing Table: vpn1

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
B   3.3.3.3/32 [200/0] via 172.1.1.2, 00:00:07
C   172.1.1.0/24 is directly connected, gigabitEthernet 1/1
C   172.1.1.1/32 is local host.
B   172.1.2.0/24 [200/0] via 172.1.1.2, 00:00:07
B   172.1.4.0/24 [200/0] via 2.2.2.2, 00:00:30
.....
Qtech# show bgp vpnv4 unicast vrf vpn1 labels
BGP table version is 1, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          In Label/Out Label
Route Distinguisher: 65001:20 (Default for VRF vpn1)
*> 3.3.3.3/32       172.1.1.2         2048/1024
*> 172.1.2.0/24     172.1.1.2         2049/1025
*>i6.6.6.6/32       2.2.2.2           2050/2112
.....
```

On the ASBR and user network, display the routing table.

// On the ASBR (using ASBR3 as an example), use the following command.

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
.....
B   61.10.55.0/24 [200/0] via 4.4.4.4, 00:00:40
B   64.21.33.0/24 [200/0] via 10.0.3.2, 00:00:31
.....
```

// In the user network, use the edge device of user network 1 as an example.

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
.....
B   61.10.55.0/24 [200/0] via 10.0.3.1, 00:00:40
C   64.21.33.0/24 is directly connected, gigabitEthernet 0/1
```

```
C 64.21.33.9/32 is local host.
.....
```

Verify that the external networks are interconnected.

// On the edge device of user network 1, use the following command.

```
Qtech# ping 61.10.55.1 source 64.21.33.9
Sending 5, 100-byte ICMP Echoes to 61.10.55.1, timeout is 2 seconds:
< press Ctrl+C to break >
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 10/20/40 ms
```

2.4.12 CSC: The Second Carrier Provides VPN Services Based on MPLS Core

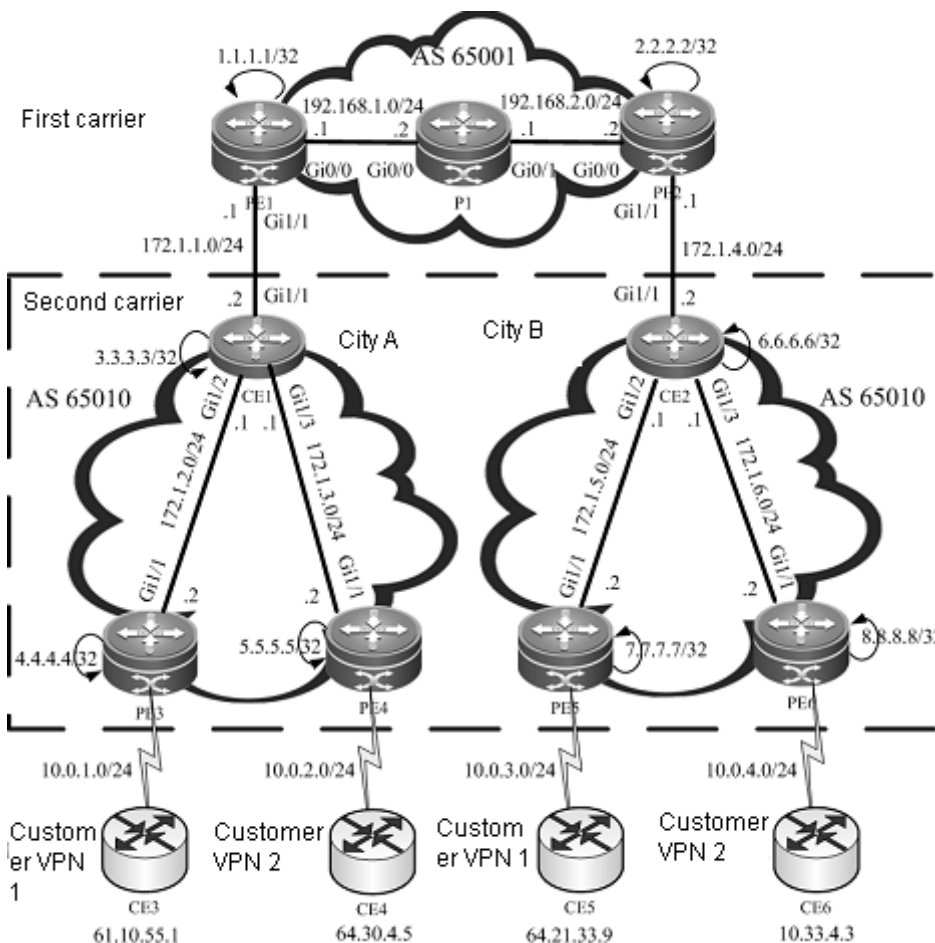
Networking Requirements

A carrier owns an MPLS core network in City A and provides MPLS VPN services for users in this city. Now this carrier intends to expand the service to City B, and has built an MPLS core network in City B. In order to interconnect the core networks in these two cities, this carrier leases the VPN service from another MPLS VPN service provider, thus forming the CSC networking model.

The first carrier PE and second carrier CE will exchange (internal) routes via BGP. An MP-IBGP neighbor relation is established between second carrier PEs to exchange user VPN routes. OSPF is deployed between the second carrier PE and the user VPN CE to exchange routes.

Networking Topology

Figure 41 MPLS core second VPN provider



Configuration Tips

- Configuring basic BGP/MPLS IP VPN functions for the first carrier
- Enabling the CSC function
- Configuring the second carrier
- Configuring user access

Configuration Steps

- Configuring basic BGP/MPLS IP VPN functions for the first carrier

See "Configuring basic BGP/MPLS IP VPN functions" in the example of "The Second Carrier Provides Internet Services Based on MPLS Core".

- Enabling the CSC function

See "Enabling the CSC function" in the example of "The Second Carrier Provides Internet Services Based on MPLS Core".

- Configuring the second carrier

Configure an MPLS network: See "Configuring an MPLS network" in the example of "The Second Carrier Provides Internet Services Based on MPLS Core". Configuration objects are CE1, CE2 and PEs (3 to 6).



Note

You need to enable LDP on the CSC-CE in order to set up sessions with other intra-site devices to build an MPLS network. If the CSC-CE and CSC-PE use BGP to exchange routes, you must run **advertise-labels for bgp-routes** on the CSC-CE to allow LDP to distribute labels for BGP routes.

Configure an MP-IBGP neighbor: See "Configuring an MP-IBGP neighbor" in the example of "The Second Carrier Provides Internet Services Based on IP Core". Configure the MP-IBGP neighbor relations between PE3, PE4, PE5 and PE6.

- Configuring user access

The configurations include configuring a VRF, configuring route exchange between PEs and CEs, and so on. These configurations are the same as those of the BGP/MPLS IP VPN. It is assumed that CE3 is connected to PE3.

On PE3, use the following commands.

```
Qtech(config)# ip vrf customer_vpn1
Qtech(config-vrf)# rd 65010:1
Qtech(config-vrf)# route-target both 65010:1
Qtech(config-vrf)# exit
Qtech(config)# interface gigabitEthernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable MPLS fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip vrf forwarding customer_vpn1
Qtech(config-if)# ip address 10.0.1.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router ospf 10 vrf customer_vpn1
Qtech(config-router)# network 10.0.1.0 0.0.0.255 area 0
Qtech(config-router)# redistribute bgp 65010 subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 65010
Qtech(config-router)# address-family ipv4 vrf customer_vpn1
Qtech(config-router-af)# redistribute ospf 10 vrf customer_vpn1
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

On CE3, use the following command.

```
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
```



```
Qtech(config-if)# ip address 10.0.1.2 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config)# interface gigabitEthernet 0/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 61.10.55.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.0.1.0 0.0.0.255 area 0
Qtech(config-router)# network 61.10.55.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Verification

Display VRF routes and labels on the first carrier PE: PE1 is used as an example. The verification of PE2 is similar.

// In the VRF routing table of PE1, there are only internal routes of the second carrier. There is no VPN route (for example, 64.30.4.0/24).

```
Qtech# show ip route vrf vpn1
Routing Table: vpn1

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
B    3.3.3.3/32 [200/0] via 172.1.1.2, 00:00:07
C    172.1.1.0/24 is directly connected, gigabitEthernet 1/1
C    172.1.1.1/32 is local host.
B    172.1.2.0/24 [200/0] via 172.1.1.2, 00:00:07
B    172.1.4.0/24 [200/0] via 2.2.2.2, 00:00:30
.....
Qtech# show bgp vpnv4 unicast vrf vpn1 labels
BGP table version is 1, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          In Label/Out Label
Route Distinguisher: 65001:20 (Default for VRF vpn1)
*> 3.3.3.3/32       172.1.1.2         2048/1024
*> 172.1.2.0/24     172.1.1.2         2049/1025
*>i6.6.6.6/32       2.2.2.2           2050/2112
.....
```

In the VRF of the second carrier PE and user VPN CE, display the routing table.

// On the PE (using PE3 as an example), use the following command.

```
Qtech# show ip route vrf customer_vpn1
Routing Table: customer_vpn1

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default
```

```
Gateway of last resort is no set
.....
O    61.10.55.0/24 [200/0] via 10.0.1.2, 00:00:40, gigabitEthernet 1/2
B    64.21.33.0/24 [200/0] via 7.7.7.7, 00:00:31
.....
```

// On the user VPN CE (using CE3 as an example), use the following command.

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
.....
C    61.10.55.0/24 is directly connected, gigabitEthernet
C    61.10.55.1/32 is local host.
O    64.21.33.0/24 [200/0] via 10.0.1.1, 00:00:42, gigabitEthernet 0/0
.....
```

Verify that the user VPN networks are interconnected.

//On CE3, use the following command.

```
Qtech# ping 64.21.33.9
Sending 5, 100-byte ICMP Echoes to 64.21.33.9, timeout is 2 seconds:
 < press Ctrl+C to break >
!!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 10/20/40 ms
```

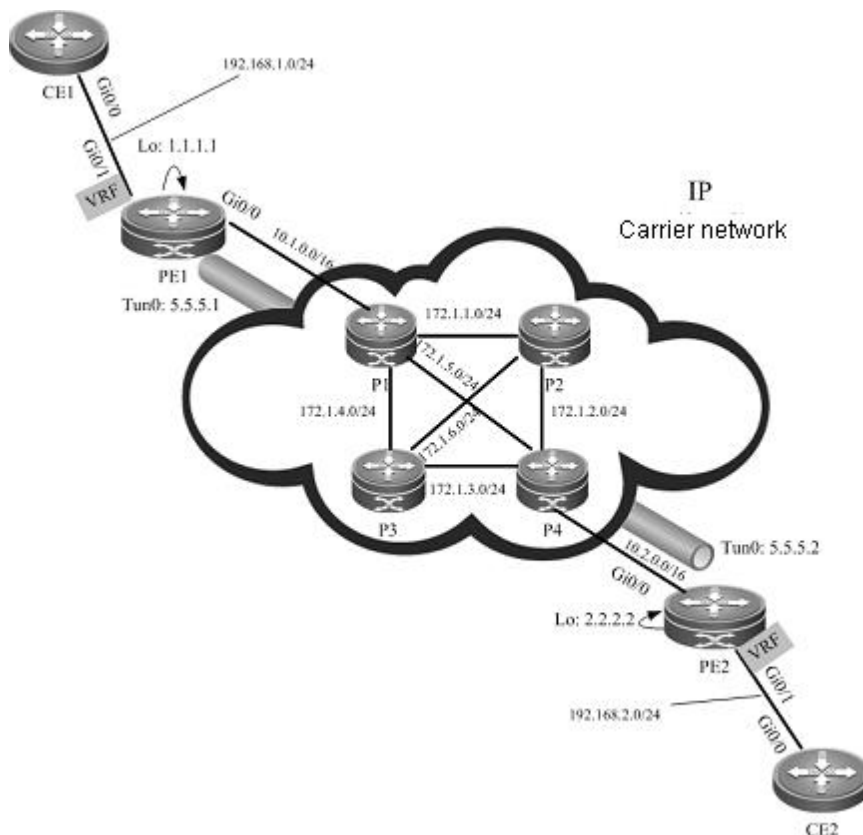
2.4.13 MPLS VPN over GRE

Networking Requirements

In an IP core network, the edge router PE supports the MPLS VPN. Now it is required to use the MPLS VPN over GRE technology to use the IP core network to provide MPLS VPN services for users. The IP core network adopts dual OSPF instances to introduce VPN traffic into the GRE tunnel, while the PE and CE exchange routes via OSPF.

Networking Topology

Figure 42 Network topology



Configuration Tips

- Creating a GRE tunnel
- Configuring an IGP route
- Configuring an MPLS network
- Configuring an MPLS VPN

Configuration Steps

- Configure the P device. P1 is used as an example. The configurations of other devices are similar.

Configure an interface and IP address.

```
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 10.1.0.2 255.255.0.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 0/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.1.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.5.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 0/3
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 172.1.4.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
```

Configure an IGP routing instance.

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.1.1.0 0.0.0.255 area 0
Qtech(config-router)# network 172.1.5.0 0.0.0.255 area 0
Qtech(config-router)# network 172.1.4.0 0.0.0.255 area 0
Qtech(config-router)# network 10.1.0.0 0.0.255.255 area 0
Qtech(config-router)# exit
```

■ Configure the PE device. PE1 is used as an example. The configurations of other devices are similar.

Configure a public network interface and IP address.

```
Qtech(config)# interface Loopback 0
Qtech(config-if)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if)# exit
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 10.1.0.1 255.255.0.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
```

Create a GRE tunnel.

```
Qtech(config)# interface tunnel 0
Qtech(config-if)# ip address 5.5.5.1 255.255.255.0
Qtech(config-if)# tunnel mode gre ip
Qtech(config-if)# tunnel source 10.1.0.1
Qtech(config-if)# tunnel destination 10.2.0.1
Qtech(config-if)# exit
```

Configure an IGP route.

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.1.0.0 0.0.255.255 area 0
Qtech(config-router)# exit
Qtech(config)# router ospf 2
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 5.5.5.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure an MPLS network.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface tunnel 0
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
```

```
Qtech(config-if)# mpls ip
Qtech(config-if)# label-switching
Qtech(config-if)# exit
```

Configure an MPLS VPN.

Configure a VRF.

```
Qtech(config)# ip vrf vpn1
Qtech(config-vrf)# rd 100:1
Qtech(config-vrf)# route-target both 100:1
Qtech(config-vrf)# exit
Qtech(config)# interface gigabitEthernet 0/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip vrf forwarding vpn1
Qtech(config-if)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
```

Configure MP-IBGP.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source Loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 2.2.2.2 active
Qtech(config-router-af)# neighbor 2.2.2.2 send-community both
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4 vrf vpn1
Qtech(config-router-af)# redistribute ospf 10 vrf vpn1
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

Configure route exchange between PEs and CEs.

```
Qtech(config)# router ospf 10 vrf vpn1
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# redistribute bgp 100 subnets
Qtech(config-router)# exit
```

■ Configure the CE. CE1 is used as an example. The configurations of CE2 are similar.

```
Qtech(config)# interface gigabitEthernet 0/0
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if)# ip ref
Qtech(config-if)# ip address 192.168.1.2 255.255.255.0
Qtech(config-if)# no shutdown
Qtech(config-if)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Verification

On the PE, check routing entries. PE1 is used as an example. The next-hop interface of route 2.2.2.2/32 is Tunnel 0.

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
C    10.1.0.0/16 is directly connected, gigabitEthernet 0/0
```

```

C 10.1.0.1/32 is local host.
C 1.0.0.0/8 is subnetted
C 1.1.1.1/32 is local host.
O 2.0.0.0/8 is subnetted
O 2.2.2.2/32 [110/11] via 5.5.5.2, 00:00:40, Tunnel 0
.....

```

Verify the VPN route on PE. PE1 is used as an example.

```

Qtech# show ip route vrf vpn1
Routing Table: vpn1

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
C 192.168.1.0/24 is directly connected, gigabitEthernet 0/1
C 192.168.1.1/32 is local host.
B 192.168.2.0/24 [200/0] via 2.2.2.2, 00:00:41
.....

```

Check MPLS forwarding entries on the PE. PE1 is used as an example.

```

Qtech# show mpls forwarding-table
Label Operation Code:
PH--PUSH label
PP--POP label
SW--SWAP label
SP--SWAP topmost label and push new label
DP--DROP packet
PC--POP label and continue lookup( IP or Label )
PI--POP label and do ip lookup forward
PN--POP label and forward to nexthop
PM--POP label and do MAC lookup forward
PV--POP label and output to VC attach interface
IP--IP lookup forward
Local  Outgoing  OP  FEC          Outgoing      Next Hop
label  label                interface
--    3           PH 2.2.2.2/32  Tunnel 0      5.5.5.2
--    21        PH 192.168.2.0/24(V) Tunnel 0 Point2point
.....

```

Verify the routing table on the CE.

```

Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
C 192.168.1.0/24 is directly connected, gigabitEthernet 0/1
C 192.168.1.2/32 is local host.
O 192.168.2.0/24 [112/11] via 192.168.1.1, 00:00:41
.....

```

Verify the intercommunication between CEs. On CE1, use the following command.

```

Qtech# ping 192.168.2.2
Sending 5, 100-byte ICMP Echoes to 192.168.2.2, timeout is 2 seconds:
 < press Ctrl+C to break >
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 10/20/40 ms

```

2.4.14 OSPF VPN Configuration Examples

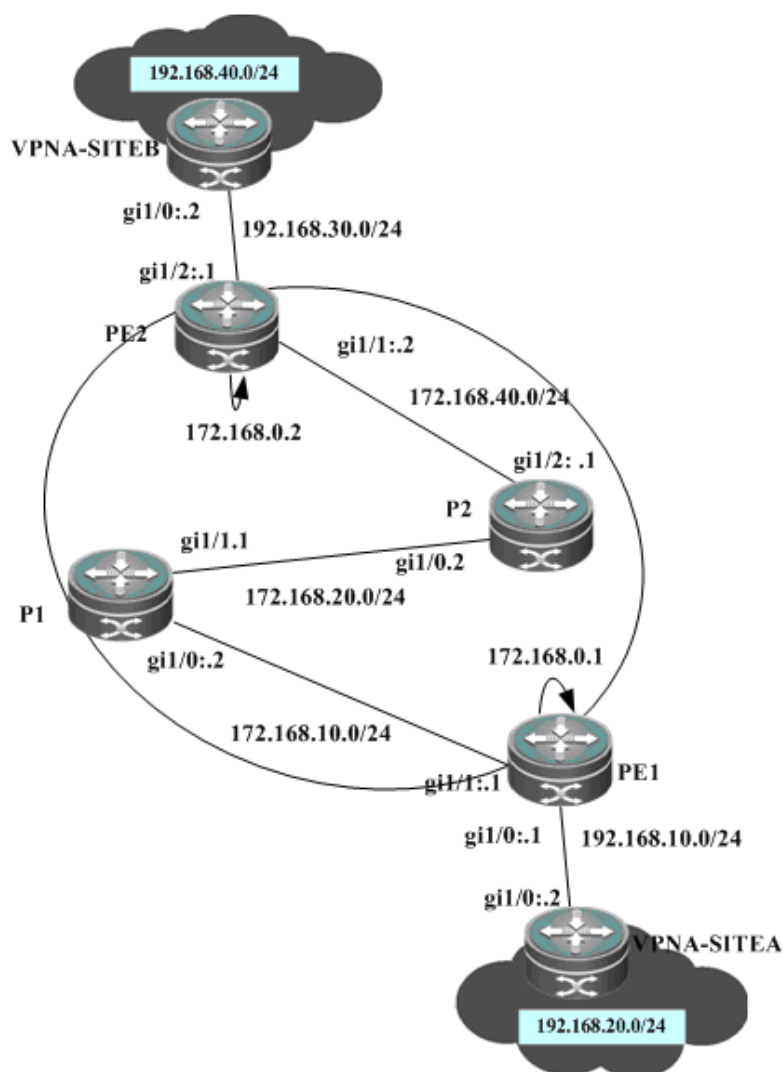
2.4.14.1 Domain-id Configuration Example

Networking Requirements

Two different sites of a customer exchange VPN routes via an MPLS backbone network. The customer's sites are connected to a PE via OSPF. It is required that the customer's OSPF routes can be restored to the OSPF routes of original sites after being exchanged over the MPLS backbone network.

Networking Topology

Figure 43



To meet the requirements, configure two VRF OSPF instances with the same domain ID on two PEs, as shown below:

Configuration Steps

SITEA:

Configure the OSPF protocol between the PE and the CE.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
```

PE1:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure a VRF.

Create a VRF named VPNA, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
```

Associate the CE-connecting interface with the VRF.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# end
```

Configure the BGP protocol to set up an MP-IBGP session with PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# end
```

Exchange routes with the CE via OSPF; set the domain ID of the OSPF instance to 10.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPNA
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# domain-id 10
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# end
```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
```



```
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qtech(config-router)# end
```

P1 and P2: The configuration steps are similar to the configuration steps of P in the MPLS backbone network.

SITEB:

Run OSPF with PE2.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
```

PE2:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.2 255.255.255.255
```

Configure a VRF.

Create a VRF named VPNA, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# exit
```

Associate the CE-connecting interface with the VRF.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/2)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/2)# ip address 192.168.30.1
255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# exit
```

Configure the BGP protocol to set up an MP-IBGP session with PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.1 activate
Qtech(config-router-af)# end
```

Exchange VPN routes with the CE via OSPF; set the domain ID to 10.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPNA
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# domain-id 10
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
```

```
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# exit
```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.40.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.40.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
Qtech(config-router)# end
```

Verification

■ VPNA-SITEB:

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
O IA   192.168.10.0/24 [110/2] via 192.168.30.1, 00:00:36, GigabitEthernet 1/0
O IA   192.168.20.0/24 [110/2] via 192.168.30.1, 00:00:36, GigabitEthernet 1/0
C      192.168.30.0/24 is directly connected, GigabitEthernet 1/0
O      192.168.40.0/24 [110/101] via 192.168.24.2, 00:56:23, GigabitEthernet 1/1
```

■ PE2:

```
Qtech# show ip route vrf VPNA
Routing Table: VPNA

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
B      192.168.10.0/24 [110/2] via 172.168.0.1, 00:00:36
B      192.168.20.0/24 [110/2] via 172.168.0.1, 00:00:36
C      192.168.30.0/24 is directly connected, GigabitEthernet 1/2
O      192.168.40.0/24 [110/101] via 192.168.30.2, 00:56:23, GigabitEthernet 1/2
```

■ PE1:

```
Qtech# show ip route vrf VPNA
Routing Table: VPNA
```

```
Codes: C - connected, S - static, R - RIP, B - BGP
O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
C    192.168.10.0/24 is directly connected, GigabitEthernet 1/0
O    192.168.20.0/24 [110/101] via 192.168.10.2, 00:56:23, GigabitEthernet 1/0
B    192.168.30.0/24 [110/2] via 172.168.0.2, 00:00:36
B    192.168.40.0/24 [110/2] via 172.168.0.2, 00:00:36
```

■ VPNA-SITEA:

```
Qtech# show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
C    192.168.10.0/24 is directly connected, GigabitEthernet 1/0
O    192.168.20.0/24 [110/101] via 192.168.23.2, 00:56:23, GigabitEthernet 1/1
O IA  192.168.30.0/24 [110/2] via 192.168.10.1, 00:00:36, GigabitEthernet 1/0
O IA  192.168.40.0/24 [110/2] via 192.168.10.1, 00:00:36, GigabitEthernet 1/0
```

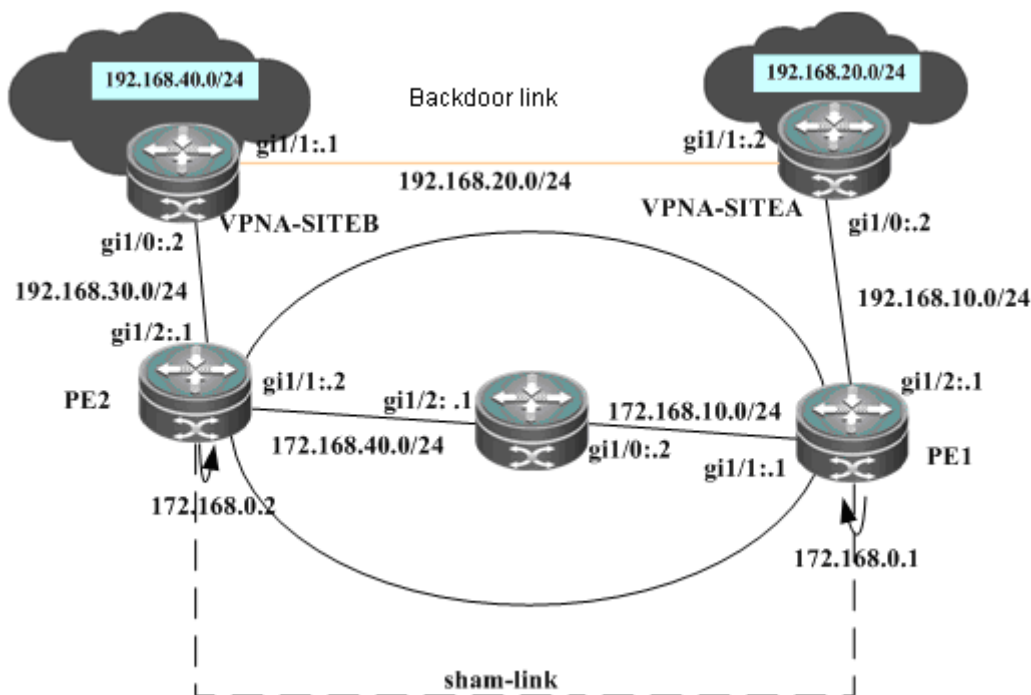
2.4.14.2 Sham Link Configuration Example

Networking Requirements

Two different sites of a customer exchange VPN routes via an MPLS backbone network. At the same time, a "backdoor link" is also established between these two sites to ensure that information can still be exchanged between both sites through this backup link when the MPLS backbone network fails.

Networking Topology

Figure 44



Configuration Steps

SITEA:

Run the OSPF protocol with PE1 and SITEB. The OSPF protocol runs over the backdoor link with SITEB.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# network 192.168.20.0 255.255.255.0 area 0
```

Configure the OSPF cost on an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/0)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/0)# ip ref
Qtech(config-if-GigabitEthernet 1/0)# ip address 192.168.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0)# ip ospf cost 1
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# ip ospf cost 200
```

PE1:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
```

```
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure a VRF.

Create a VRF named VPNA, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
```

Associate the CE-connecting interface with the VRF.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/2)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/2)# ip address 192.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# end
```

Configure the VRF loopback interface to establish a sham link.

```
Qtech# configure terminal
Qtech(config)# interface loopback 10
Qtech(config-if-Loopback 10)# ip vrf forwarding VPNA
Qtech(config-if-Loopback 10)# ip address 192.168.0.1 255.255.255.255
```

Configure the BGP protocol to set up an MP-IBGP session with PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# end
```

Exchange routes with the CE via OSPF, and establish a sham link with the OSPF instance on PE2.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPNA
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# area 0 sham-link 192.168.0.1 192.168.0.2
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# redistribute connected
Qtech(config-router-af)# end
```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
```

```
Qtech(config-if-GigabitEthernet 1/1) # end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qtech(config-router) # end
```

P1:

The configuration steps are similar to the configuration steps of P in the MPLS backbone network.

SITEB:

Run the OSPF protocol with PE2 and SITEA. The OSPF protocol runs over the backup link with SITEA.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
Qtech(config-router)# network 192.168.20.0 255.255.255.0 area 0
```

Configure the OSPF cost on an interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/0) # no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/0) # ip ref
Qtech(config-if-GigabitEthernet 1/0) # ip address 192.168.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/0) # ip ospf cost 1
Qtech(config) # interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1) # no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1) # ip ref
Qtech(config-if-GigabitEthernet 1/1) # ip address 192.168.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1) # ip ospf cost 200
```

PE2:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0) # ip address 172.168.0.2 255.255.255.255
```

Configure a VRF.

Create a VRF named VPNA, set the RD and RT values, and associate the VRF with the corresponding interface.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPNA
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf) # exit
```

Associate the CE-connecting interface with the VRF.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/2
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/2) # no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/2) # ip ref
Qtech(config-if-GigabitEthernet 1/2) # ip vrf forwarding VPNA
Qtech(config-if-GigabitEthernet 1/2) # ip address 192.168.30.1
255.255.255.0
```

```
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the VRF loopback interface to establish a sham link.

```
Qtech# configure terminal
Qtech(config)# interface loopback 10
Qtech(config-if-Loopback 10)# ip vrf forwarding VPNA
Qtech(config-if-Loopback 10)# ip address 192.168.0.2 255.255.255.255
```

Configure the BGP protocol to set up an MP-IBGP session with PE2 and PE3.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.1 activate
Qtech(config-router-af)# end
```

Exchange VPN routes with the CE via OSPF, and establish a sham link with PE1.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPNA
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# area 0 sham-link 192.168.0.2 192.168.0.1
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# redistribute connected
Qtech(config-router-af)# exit
```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.40.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.40.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
Qtech(config-router)# end
```

Verification

■ PE1

```
Qtech# show ip ospf 10 sham-links
Sham Link OSPF_SL0 to address 192.168.0.2 is up
Area 0 source address 192.168.0.1
Run as demand circuit
DoNotAge LSA allowed. Cost of using 1 State POINT_TO_POINT,
Timer intervals configured, Hello 10, Dead 40, Wait 40,
Hello due in 00:00:06
Adjacency State FULL (Hello suppressed)
Index 2/2, retransmission queue length 0, number of retransmission 0
```

```

First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
Last retransmission scan length is 0, maximum is 0
Last retransmission scan time is 0 msec, maximum is 0 msec
Qtech# show ip ospf 10 neighbor
Neighbor ID      Pri   State           Dead Time   Address        Interface
192.168.0.2      0    FULL/ -         -           192.168.0.2    OSPF_SL0
Qtech# show ip route vrf VPNA
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default
C      192.168.10.0/24 is directly connected, Gi1/2
O      192.168.20.0/24 [110/101] via 192.168.1.2, 00:56:23, Gi1/2
O      192.168.40.0/24 [110/2] via 172.168.0.2, 00:00:36

```

PE2

```

Qtech# show ip ospf 10 sham-links
Sham Link SLINK0 to address 192.168.0.1 is up
Area 0.0.0.0 source address 192.168.0.2, Cost: 1
Output interface is GigabitEthernet 1/1
Next hop address 172.16.10.1
Transmit Delay is 1 sec, State Point-To-Point,
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
Hello due in 00:00:01
Adjacency state Full

Qtech# show ip ospf 10 neighbor

OSPF process 10, 1 Neighbors, 1 is Full:
Neighbor ID      Pri   State           BFD State   Dead Time   Address
Interface
192.168.0.1      1    Full/ -         -           00:00:34    192.168.0.1
SLINK0

Qtech# show ip route vrf VPNA
Routing Table: VPNA

Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default

Gateway of last resort is no set
O      192.168.10.0/24 [110/2] via 172.168.0.1, 00:00:36
O      192.168.20.0/24 [110/2] via 172.168.0.1, 00:00:36
C      192.168.30.0/24 is directly connected, GigabitEthernet 1/2
O      192.168.40.0/24 [110/101] via 192.168.30.2, 00:56:23, GigabitEthernet 1/2

```

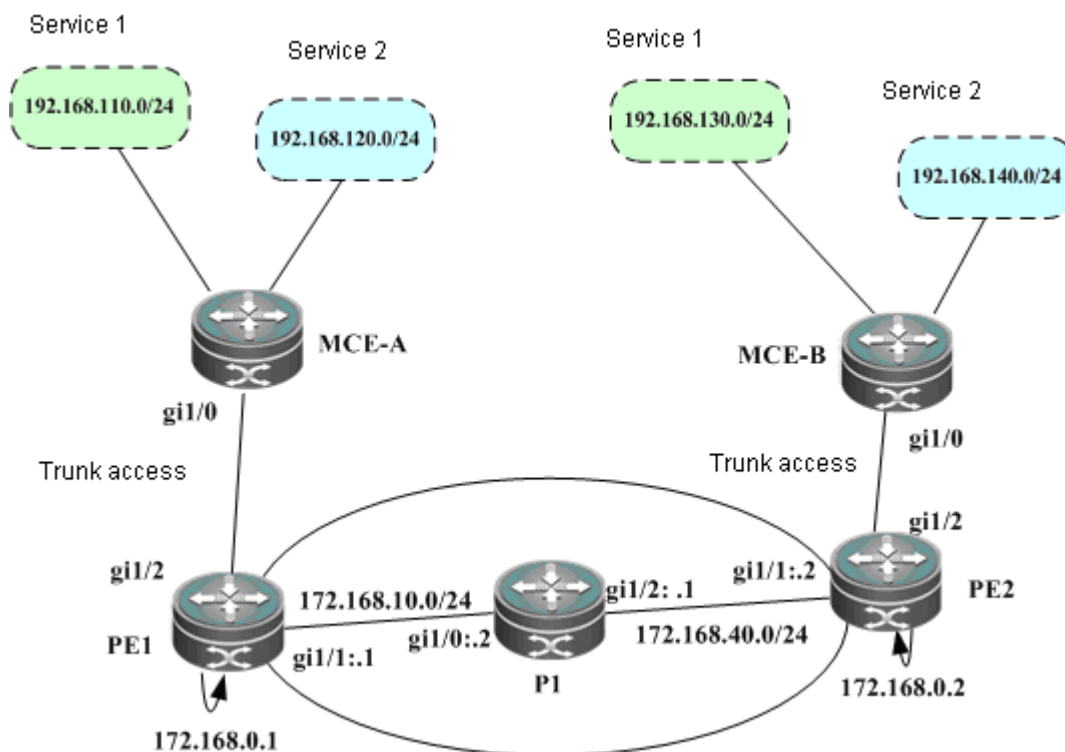
2.4.14.3 Configuring Multiple OSPF Instances on an MCE

Networking Requirements

A customer site involves multiple services. The same services communicate with each other over an MPLS backbone network and different services are isolated from each other.

Networking Topology

Figure 45



Configuration Steps

MCE-A:

Configure a trunk link between a PE and a CE.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the routing interface to connect to the PE.

```
Qtech(config-if-GigabitEthernet 1/0)# switchport mode trunk
Qtech(config-if-GigabitEthernet 1/0)# end
```

Configure two VRFs to represent different services and bind respective interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN1
Qtech(config-vrf)# exit
Qtech(config)# VLAN 10
Qtech(config)# interface vlan 10
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 10)# ip vrf forwarding VPN1
Qtech(config-if-vlan 10)# ip address 192.168.10.2 255.255.255.0
Qtech(config)# ip vrf VPN2
Qtech(config-vrf)# exit
Qtech(config)# VLAN 20
Qtech(config)# interface vlan 20
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 20)# ip vrf forwarding VPN2
Qtech(config-if-vlan 20)# ip address 192.168.20.2 255.255.255.0
```

Run the OSPF protocol with the PE for two VRFs.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPN1
```

```
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# capability vrf-lite
```

```
Qtech(config)# router ospf 10 VPN2
Qtech(config-router)# network 192.168.20.0 255.255.255.0 area 0
Qtech(config-router)# capability vrf-lite
```

PE1:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.1 255.255.255.255
```

Configure the trunk link between the PE and the CE.

```
Qtech(config)# interface gigabitethernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# switchport mode trunk
Qtech(config-if-GigabitEthernet 1/2)# end
```

Configure VRFs.

Create two VRFs named VPN1 and VPN2 to represent different services, and associate the VRFs with the corresponding interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN1
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
Qtech# configure terminal
Qtech(config)# ip vrf VPN2
Qtech(config-vrf)# rd 1:200
Qtech(config-vrf)# route-target both 1:200
Qtech(config-vrf)# end
```

Associate the CE-connecting interface with the VRF.

```
Qtech(config)# VLAN 10
Qtech(config)# interface vlan 10
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 10)# ip vrf forwarding VPN1
Qtech(config-if-vlan 10)# ip address 192.168.10.1 255.255.255.0
```

```
Qtech(config)# VLAN 20
Qtech(config)# interface vlan 20
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 20)# ip vrf forwarding VPN1
Qtech(config-if-vlan 20)# ip address 192.168.20.1 255.255.255.0
```

Configure the BGP protocol to set up an MP-IBGP session with PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.2 remote-as 1
Qtech(config-router)# neighbor 172.168.0.2 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.2 activate
Qtech(config-router-af)# end
```

Exchange routes with the CE via OSPF.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPN1
Qtech(config-router)# network 192.168.10.0 255.255.255.0 area 0
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPNA
```

```

Qttech(config-router-af)# redistribute ospf 10
Qttech(config-router-af)# redistribute connected
Qttech(config-router-af)# end

Qttech# configure terminal
Qttech(config)# router ospf 20 VPN2
Qttech(config-router)# network 192.168.20.0 255.255.255.0 area 0
Qttech(config-router)# redistribute bgp subnets
Qttech(config-router)# exit
Qttech(config)# router bgp 1
Qttech(config-router)# address-family ipv4 vrf VPN2
Qttech(config-router-af)# redistribute ospf 20
Qttech(config-router-af)# redistribute connected
Qttech(config-router-af)# end

```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```

Qttech# configure terminal
Qttech(config)# mpls ip
Qttech(config)# mpls router ldp
Qttech(config-mpls-router)# ldp router-id interface loopback 0 force
Qttech(config-mpls-router)# exit
Qttech(config)# interface gigabitethernet 1/1

```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```

Qttech(config-if-GigabitEthernet 1/1)# no switchport

```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```

Qttech(config-if-GigabitEthernet 1/1)# ip ref
Qttech(config-if-GigabitEthernet 1/1)# ip address 172.168.10.1 255.255.255.0
Qttech(config-if-GigabitEthernet 1/1)# label-switching
Qttech(config-if-GigabitEthernet 1/1)# mpls ip
Qttech(config-if-GigabitEthernet 1/1)# end

```

Configure a routing protocol on the backbone network.

```

Qttech# configure terminal
Qttech(config)# router ospf 1
Qttech(config-router)# network 172.168.10.0 0.0.0.255 area 0
Qttech(config-router)# network 172.168.0.1 0.0.0.0 area 0
Qttech(config-router)# end

```

P1:

The configuration steps are similar to the configuration steps of P in the MPLS backbone network.

SITEB:

Configure the trunk link between the PE and the CE.

```

Qttech# configure terminal
Qttech(config)# interface gigabitethernet 1/0

```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the routing interface to connect to the PE.

```

Qttech(config-if-GigabitEthernet 1/0)# switchport mode trunk
Qttech(config-if-GigabitEthernet 1/0)# end

```

Configure two VRFs to represent different services and bind respective interfaces.

```

Qttech# configure terminal
Qttech(config)# ip vrf VPN1
Qttech(config-vrf)# exit
Qttech(config)# VLAN 10
Qttech(config)# interface vln 30

```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```

Qttech(config-if-vlan 10)# ip vrf forwarding VPN1
Qttech(config-if-vlan 10)# ip address 192.168.30.2 255.255.255.0

```

```
Qtech(config)# ip vrf VPN2
Qtech(config-vrf)# exit
Qtech(config)# VLAN 40
Qtech(config)# interface vlan 40
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 20)# ip vrf forwarding VPN2
Qtech(config-if-vlan 20)# ip address 192.168.40.2 255.255.255.0
```

Run the OSPF protocol with the PE for two VRFs.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPN1
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
Qtech(config-router)# capability vrf-lite

Qtech(config)# router ospf 10 VPN2
Qtech(config-router)# network 192.168.40.0 255.255.255.0 area 0
Qtech(config-router)# capability vrf-lite
```

PE2:

Configure a loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 172.168.0.2 255.255.255.255
```

Configure the trunk link between the PE and the CE.

```
Qtech(config)# interface gigabitethernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# switchport mode trunk
Qtech(config-if-GigabitEthernet 1/2)# end
```

Configure VRFs.

Create two VRFs named VPN1 and VPN2 to represent different services, and associate the VRFs with the corresponding interfaces.

```
Qtech# configure terminal
Qtech(config)# ip vrf VPN1
Qtech(config-vrf)# rd 1:100
Qtech(config-vrf)# route-target both 1:100
Qtech(config-vrf)# end
Qtech# configure terminal
Qtech(config)# ip vrf VPN2
Qtech(config-vrf)# rd 1:200
Qtech(config-vrf)# route-target both 1:200
Qtech(config-vrf)# end
```

Associate the CE-connecting interface with the VRF.

```
Qtech(config)# VLAN 30
Qtech(config)# interface vlan 30
```

VLAN is a configuration command used on switch products, and is not applicable to routers (except for the switching card interface). Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 10)# ip vrf forwarding VPN1
Qtech(config-if-vlan 10)# ip address 192.168.30.1 255.255.255.0

Qtech(config)# VLAN 40
Qtech(config)# interface vlan 40
```

VLAN is a configuration command used on switch products, and is not applicable to routers. Routers can use the sub-interface to bind the VRF.

```
Qtech(config-if-vlan 20)# ip vrf forwarding VPN2
Qtech(config-if-vlan 20)# ip address 192.168.40.1 255.255.255.0
```

Configure the BGP protocol to set up an MP-IBGP session with PE2.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 172.168.0.1 remote-as 1
```

```
Qtech(config-router)# neighbor 172.168.0.1 update-source loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 172.168.0.1 activate
Qtech(config-router-af)# end
```

Exchange routes with the CE via OSPF.

```
Qtech# configure terminal
Qtech(config)# router ospf 10 VPN1
Qtech(config-router)# network 192.168.30.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPN1
Qtech(config-router-af)# redistribute ospf 10
Qtech(config-router-af)# redistribute connected
Qtech(config-router-af)# end
```

```
Qtech# configure terminal
Qtech(config)# router ospf 20 VPN2
Qtech(config-router)# network 192.168.40.0 255.255.255.0 area 0
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# address-family ipv4 vrf VPN2
Qtech(config-router-af)# redistribute ospf 20
Qtech(config-router-af)# redistribute connected
Qtech(config-router-af)# end
```

Configure MPLS signaling on the backbone network. Enable MPLS on the public network interface.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

In case of a switch, configure the interface to a RoutedPort interface (not applicable to a router).

```
Qtech(config-if-GigabitEthernet 1/1)# no switchport
```

In case of a router, enable fast forwarding on the interface (not applicable to a switch).

```
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 172.168.40.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
```

Configure a routing protocol on the backbone network.

```
Qtech# configure terminal
Qtech(config)# router ospf 1
Qtech(config-router)# network 172.168.40.0 0.0.0.255 area 0
Qtech(config-router)# network 172.168.0.2 0.0.0.0 area 0
Qtech(config-router)# end
```

Verification

■ MCEA

```
Qtech# show ip route vrf VPN1
Codes: C - connected, S - static, R - RIP, B - BGP
O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default
C
192.168.10.0/24 is directly connected, VLAN 10
O
192.168.110.0/24 [110/101] via 192.168.21.2, 00:56:23, Gi1/1
O E2
192.168.130.0/24 [110/2] via 192.168.10.1, 00:00:36, VLAN 10
```

```
Qtech# show ip route vrf VPN2
Codes: C - connected, S - static, R - RIP, B - BGP
        O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default
C       192.168.20.0/24 is directly connected, VLAN 20
O       192.168.120.0/24 [110/101] via 192.168.22.2, 00:56:23, Gi1/2
O E2    192.168.140.0/24 [110/2] via 192.168.20.1, 00:00:36, VLAN 20
```

■ MCEB

```
Qtech# show ip route vrf VPN1
Codes: C - connected, S - static, R - RIP, B - BGP
        O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default
C       192.168.30.0/24 is directly connected, VLAN 30
O       192.168.130.0/24 [110/101] via 192.168.23.2, 00:56:23, Gi1/1
O E2    192.168.110.0/24 [110/2] via 192.168.30.1, 00:00:36, VLAN 30
```

```
Qtech# show ip route vrf VPN2
Codes: C - connected, S - static, R - RIP, B - BGP
        O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default
C       192.168.40.0/24 is directly connected, VLAN 40
O       192.168.140.0/24 [110/101] via 192.168.24.2, 00:56:23, Gi1/2
O E2    192.168.140.0/24 [110/2] via 192.168.40.1, 00:00:36, VLAN 40
```

3 CONFIGURING L2VPN

- ☑ For the router with the L2VPN service enabled, the L2VPN service can be properly forwarded if the fast forwarding function is enabled both on the interfaces connected to the user and the public network.

3.1 Understanding L2VPN

Similar to an MPLS/BGP L3VPN, an L2VPN also uses the existing public network to extend the private network of a user. For an MPLS L2VPN, Layer 2 user data (such as ATM cells, FR frames, and Ethernet frames) is transparently transmitted on an MPLS network. As far as the user is concerned, the MPLS network is a Layer 2 switching network where different sites set up Layer 2 connections on the MPLS network.

Compared with L3VPN, L2VPN has the following advantages:

- Supports various link layer protocols. On an MPLS network, you can provide Layer 2 VPN services based on various protocols including ATM, FR, VLAN, Ethernet, PPP, and HDLC. L2VPN also supports multiple network layer protocols, including IP, IPv6, IPX, and SNA.
- A provider edge (PE) does not store the information about user VPNs, reducing the overhead on the PE. This largely lessens the burden of PEs and the entire service provider (SP) network and allows the carriers to support more VPNs and access more users.
- Allows a user to control the advertising of VPN routes and frees the PE from managing VPN routes. This guarantees reliability and confidentiality of user routes and lessens the management burden of carriers.

At present, an MPLS L2VPN has the following two service models:

- Virtual Private Wire Service (VPWS)

You can set up a Pseudo Wire (PW), also called Virtual Circuit (VC), on an IP/MPLS network to simulate Layer 2 point-to-point services, including Ethernet, PPP, HDLC, AAL5 frames, ATM cells, FR, and SONET/SDH. For a user, the VPWS resembles a physical line provided for the user on the carrier's network.

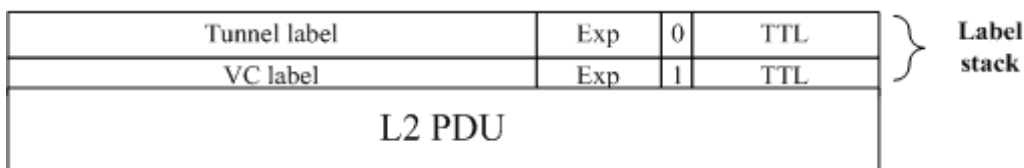
- Virtual Private LAN Service (VPLS)

Simulate LAN services on an IP/MPLS network to implement Ethernet connections on the WAN. For a user, its Layer 2 devices are connected to each other across the IP/MPLS core network and the core network is like a virtual switch.

3.1.1 Frame Format of an MPLS L2VPN Packet

As shown in the following figure, an MPLS L2VPN packet is generally encapsulated in two layers of labels. The outer layer is a public label that is responsible for forwarding the packet on the public network. The inner layer is the VC label that is used to identify a VC instance on a PE.

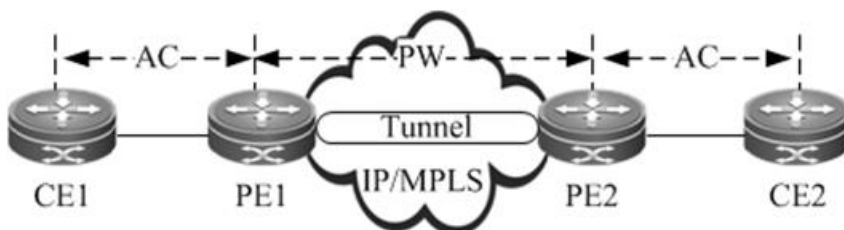
Figure 46



3.1.2 Basic Concepts

The following figure shows the components of an L2VPN.

Figure 47



3.1.2.1 CE

A custom edge (CE) is a user device directly connected to the SP.

3.1.2.2 PE

A PE, an edge device on the SP network, is connected to CEs and is responsible for the access of VPN services. It forwards packets from a private network to a public tunnel and from the public tunnel to the private network.

On a hierarchical VPLS network, PEs are classified into User Facing Provider Edge devices (U-PEs) and Network Facing Provider Edge devices (N-PEs).

■ U-PE

A U-PE is a PE next to the user side as the hierarchical VPLS network. It is an aggregation device for users to access a VPN.

■ N-PE

An N-PE is a core PE device on the hierarchical VPLS network. It is located at the edge of core VPLS domains to provide transparent transmission of VPLS services between core networks.

3.1.2.3 AC

On an L2VPN of any type (VPWS/VPLS), CEs must be connected to PEs through physical lines or virtual lines. These physical or virtual lines are referred to as the ACs. For example, an AC can be an Ethernet cable, a VLAN, or an MPLS LSP. All user packets on the AC are generally forwarded to the peer CE without any changes.

3.1.2.4 PW

A PW is responsible for setting up and maintaining the signaling protocol between PEs. The AC transmits frames from a CE to a PE and the PW sends user frames from one PE to another PE.

On a hierarchical VPLS network, PWs are classified into Hub PWs and Spoke PWs.

■ Hub PW

A Hub PW indicates a PW set up between N-PEs.

■ Spoke PW

A Spoke PW indicates a PW set up between a U-PE and an N-PE, or a PW with which a user accesses the PE on a basic VPLS network.

3.1.2.5 Forwarder

On an L2VPN, every frame received by a PE from the AC must be forwarded to the corresponding PW. Similarly, the frames received by the PE from the PW are sent to the corresponding AC. This process of making forwarding decisions is called the forwarder.

In VPWS, the forwarder performs the one-to-one mapping between ACs and PWs.

In VPLS, the forwarder is also called the Virtual Switch Instance (VSI) or Virtual Forwarding Instance (VFI), which is the VPLS forwarding table. Through the VFI, you can map the ACs of actual VPLS users to PWs.

3.1.2.6 Tunnel

The traffic of PWs between PEs is transmitted over the tunnel. One tunnel can carry multiple PWs. The tunnels mentioned in this chapter refer to MPLS LSPs.

3.1.2.7 Encapsulation

The L2VPN payload is transmitted over PWs. The PWE3 defines the encapsulation formats and transmission technologies of various packets transmitted over PWs. The PW supports two encapsulation modes: raw and tag. In raw mode, the service distinguishers are removed from the PDUs transmitted on PWs. In tag mode, the service distinguishers are included in the PDUs transmitted on PWs. For Ethernet emulated services, the service distinguisher is generally a VLAN tag. Encapsulation and transmission methods of PPP and HDLC packets are defined in the RFC4618.

3.1.2.8 PW Signaling

PW signaling protocols include LDP and BGP. They are responsible for creating and maintaining PWs.

- When using LDP sessions to set up PWs

When using LDP sessions to set up PWs, you should set up two types of LDP sessions: LDP sessions set up through the basic discovery mechanism and LDP sessions set up through the extended discovery mechanism. The former is used to set up public LSPs and the latter to transmit the label mapping messages of PWs. The setup and disconnection of a PW are as follows:

- PEs exchange Hello packets through the target LDP session (through the extended LDP discovery mechanism) and set up the LDP session.
- When the status of the AC at one PE end is Up, the PE assigns a label to the corresponding PW.
- The PE encodes the label value and the PW ID into the FEC TLV and sends a label mapping message to the peer PE through the target LDP session.
- Upon receipt of the label mapping message, the peer PE decodes the PW ID and label value and checks whether the interface parameters (such as MTU) and PW types are consistent.
- The PW is set up after both ends exchange their label values and verify the validity of PW IDs and interface parameters.
- To disconnect a PW, a PE sends a label withdrawal message to the peer PE. Then the PW is disconnected.



Caution

The following conditions must be met when you set up a PW through LDP; otherwise, the PW cannot be set up:

- 1) The MTUs and PW types on the devices at both ends of the PW must be consistent.
- 2) The PW IDs on the devices at both ends of the PW must be consistent.

- Using BGP signaling to set up PWs

Unlike using LDP signaling, this method does not require static configuration of the connection between CEs. Instead, the entire carrier network is divided into different VPNs and CEs are numbered globally in VPN sites. Similar to BGP/MPLS L3VPN, BGP signaling uses VPN Target to identify CE sites that belong to the same VPN. The process of discovering VPN sites by using VPN Target is called the automatic discovery. If BGP is used as the signaling protocol, there will be two stages. The first stage is automatic discovery and the second stage is to set up bidirectional PWs between PEs based on the result of the automatic discovery.

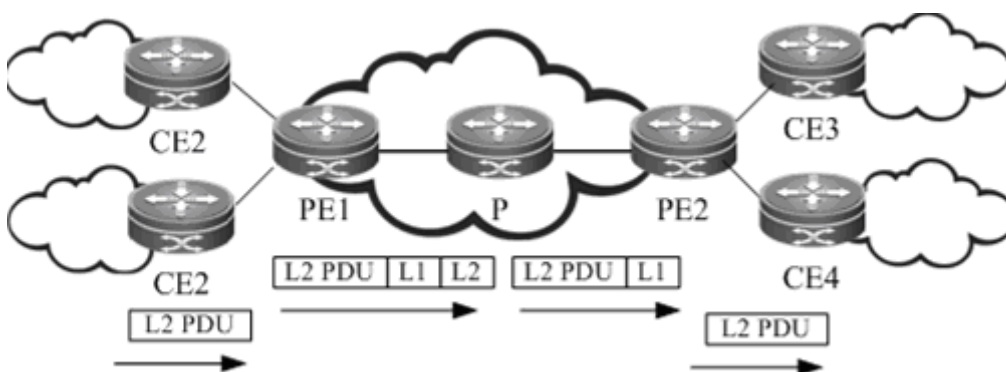
The method of establishing PWs by using BGP has brought in a concept of the label blocks. It uses the label block to allocate labels for multiple links at a time. Users can specify the site range for a local CE, indicating the number of remote CEs that can be connected with the CE. The system allocates one label block to the CE at a time. The label block's size is equal to the site range. In this way, users can allocate extra labels for VPN. This may cause waste of the label resource in a short term but can reduce the configuration workload for VPN expansion.

Given the BGP's characteristics, such as the route reflector's characteristics, this method of setting up PWs can reduce the full inter-connection of BGP sessions, facilitating the expansion of capacity.

3.1.3 Basic Forwarding Process

An L2VPN adopts the two-layer label stack to transmit services on the backbone network. The outer label is used to forward packets on the backbone network and the inner VC label is used to identify VC instances on PEs. Based on the inner VC label, a PE determines the CE to which the packets needs to be sent. The following figure shows the forwarding process.

Figure 48



3. Configuring L2VPN

After receiving a Layer 2 packet from CE2, PE1 searches for the PW forwarding entry based on the PW associated with the AC and learns that the next hop is PE2 and the PW label is L1. PE1 then searches for the public LSP based on the next hop (PE2) and obtains the outer label L2. As a result, PE1 encapsulates an MPLS header and pushes the inner label L1 and outer label L2 to the Layer packet and sends the packet to P. P forwards the MPLS packet based on the label and the penultimate hop popping (PHP) P pops out the outer label and sends the packet to PE2. Upon receipt of the packet, PE2 searches for the PW ID entry based on the inner label L1, learns the output interface (that is, the egress AC), pops out the inner label, and directly sends the Layer 2 packet to the destination CE4.

3.1.4 VCCV

Virtual circuit connectivity verification (VCCV) is a PW end-to-end connectivity fault detection and diagnosis mechanism. In brief, VCCV sends VCCV packets from the ingress node to the egress node of the PW to verify the end-to-end data plane connectivity of the PW and locate a connectivity fault in the PW. VCCV defines a series of messages to verify the connectivity of the PW. The VCCV packets must be encapsulated in the same way and pass the same tunnel as the PW packets to ensure that the VCCV packets are transmitted in the same path as the PW data packets. Therefore, VCCV needs to create a control channel that is associated with the PW and has the same path as the PW data if possible. The VCCV packets are transmitted in this control channel. The data in the control channel is not forwarded to the CE device, but is intercepted and processed on the PE device.

There are two VCCV modes: VCCV ping and VCCV traceroute. The VCCV ping mode can detect the PW connectivity. The VCCV traceroute mode can track the PW path to locate a connectivity fault in the PW.

3.1.4.1 VCCV Control Channel Type

VCCV packets are transmitted on the same PW bidirectional virtual circuit (VC) as PW service data packets, and have the same public network tunnel label and VC label encapsulated as common PW data packets. In addition, VCCV packets are transmitted in the same path as the PW data packets. The channel that transmits VCCV packets is called the control channel, and VCCV supports the following three types of control channels:

- Type 1: control word control channel.

VCCV packets that are transmitted in the control word control channel carry a control word. The first nibble of the control word carried in a VCCV packet is 0001b, indicating that this packet is a VCCV packet, which is different from the first nibble 0000b of the control word of a PW data packet. The control word can be used to distinguish the VCCV packet from common PW data packets and instruct the outbound PE router to process the VCCV packet.

- Type 2: router alert label control channel.

A control channel of this type is also referred to as router alert (RA) label control channel. An RA label is added to the PW label of a VCCV packet to force the outbound PE router to process the VCCV packet.

- Type 3: TTL timeout control channel.

For a single-segment PW, the time to live (TTL) of the PW label of a VCCV packet is set to 1. The TTL will expire on the outbound PE router, and as a result, the packet will be delivered to the CPU, which is forced to process the VCCV packet.

For a multi-segment pseudo wire (MS-PW), the TTL of the PW label of a VCCV packet is set according to the number of the PW segments. The TTL of the first segment is set to 1, the TTL of the second segment set to 2, and so on. The TTL will expire on the outbound PE router (S-PE or T-PE) in the PW segment, and as a result, the VCCV packet will be delivered to the CPU, which is forced to process the VCCV packet.



Caution

Qtech products do not support Type 1 and only support Types 2 and 3.

3.1.4.2 VCCV Ping

VCCV ping is used to verify the PW data plane connectivity. It is an extension of MPLS LSP ping. A PE device sends a VCCV ping request packet to the peer PE by running the user command. If no connectivity fault exists on the PW, the packet is forwarded to the egress PE device on the PW and delivered to the control plane. Otherwise, the packet will be discarded by the intermediate label switch router (LSR), which is also called transit LSR, or sent to its control plane. When receiving the packet on the control plane, the LSR verifies whether itself is the egress PE device of the PW based on the PW FEC information carried in the packet and responds to the source PE device. The VCCV response packet contains the relevant return code, which indicates the network status of the LSR. With VCCV ping, the source LSR possibly obtains a series of results based on the return code (indicating that the packet reaches the target PW egress and a response is returned successfully, the packet reaches a wrong PW egress, the PW path is disconnected, the transmission times out, and so on.), so as to check the PW connectivity.

3. Configuring L2VPN

3.1.4.3 VCCV Traceroute

VCCV traceroute is used to track the PW path and check the consistency between the control plane and data plane of all LSRs on the PW. VCCV traceroute is an extension of MPLS LSP traceroute.

VCCV traceroute also uses the MPLS echo request packets and response packets to track the PW path. In VCCV traceroute mode, multiple MPLS echo request packets are successively sent and the TTLs of the VC labels of these packets increase progressively. The TTL of the tunnel label of the first VCCV traceroute packet is 255, and the TTL value of the VC label is 1. The TTL of the VC label of each subsequent echo request packet increases by 1 compared with the previous one.

For a single-segment PW, if no connectivity fault exists on the PW, the packet is forwarded to the egress PE device on the PW and delivered to the control plane. The egress PE device verifies itself as the outbound PE device and directly returns a response packet as the egress PE device. Otherwise, the packet will be discarded by the intermediate LSR or sent to its control plane. When receiving the packet on the control plane, the LSR performs verification based on the information carried in the packet and responds to the source PE device.

For a MS-PW, if no connectivity fault exists on the MS-PW, the echo request packet sent in VCCV traceroute mode is forwarded to the intermediate S-PE device and the egress PE device and to the control plane. The intermediate S-PE device verifies the forwarding as an intermediate S-PE forwarding behavior and returns L to indicate that itself is the intermediate S-PE device on the MS-PW. The egress PE device verifies itself as the egress PE and returns a response packet as the egress PE device. Otherwise, the packet will be discarded by the intermediate LSR or sent to its control plane for processing. The intermediate LSR implements verification based on the information carried in the packet and then responds to the source PE device.

3.2 VPWS

3.2.1 Understanding VPWS

As an end-to-end bearer technology of Layer 2 services, VPWS is a P2P L2VPN. VPWS provides MPLS network-based L2VPN services so that carriers can provide L2VPN services based on various protocols including ATM, FR, VLAN, Ethernet and PPP over a unified MPLS network. Moreover, the MPLS network can provide traditional IP, MPLS L3VPN and other services. Simply speaking, MPLS L2VPN is to transmit users' layer-2 data transparently on the MPLS network.

- Signaling protocol of VPWS

VPWSs can be divided into Martini and Kompella VPWSs by signaling protocol. Martini VPWSs use LDP as the signaling protocol while Kompella VPWSs use BGP as the signaling protocol.


- Intercommunication of heterogeneous media of VPWSs

If CEs on two ends of the same L2VPN feature different link types, L2VPN's feature of heterogeneous media intercommunication are needed. According to the suggestion of draft-kompella-ppvpn-l2vpn, the encapsulation type of the L2VPN interface of PEs needs to be ip-interworking during the establishment of the L2VPN connection. Users' layer-3 data (IP packets) is transmitted on the MPLS network transparently.

3.2.2 Configuring Martini VPWS

3.2.2.1 Configuring a Public Tunnel

You must set up an LSP on the public network to carry VC services. To run MPLS on the backbone network, you must enable LDP on Ps and PEs to establish a public network tunnel. This means that you have to configure LDP on the routers and enable MPLS forwarding on each interface. The configuration procedure is as follows:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
	Enables MPLS globally.
Qtech(config)# mpls ip	 Caution This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP and enters MPLS routing configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback id [force]	Configures the LDP router ID. The IP address of the loopback interface is generally used as the router ID.
Qtech(config-mpls-router)# exit	Exits MPLS routing configuration mode.

Qtech(config)# interface <i>type ID</i>	Enters public network interface configuration mode.
Qtech(config-if- <i>type ID</i>)# ip address <i>ip-address mask</i>	Assigns an IP address to the interface.
Qtech(config-if- <i>type ID</i>)# label-switching	Enables MPLS forwarding on the interface at the public network side.
Qtech(config-if- <i>type ID</i>)# mpls ip	Enables LDP on the interface.
Qtech(config-if- <i>type ID</i>)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches.
Qtech(config-if- <i>type ID</i>)# show running-config	Displays all configuration information.

Configure an MPLS network.

```
Qtech# configure terminal
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# )# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 1/1
```

The **no switchport** command is used on switches to switch the port mode to routed port mode. It does not apply to routers and does not need to be used on routers.

```
Qtech(config-if-gigabitethernet 1/1)# no switchport
# Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.
Qtech(config-if-gigabitethernet 1/1)# no switchport
Qtech(config-if-gigabitethernet 1/1)# ip address 192.168.10.1 255.255.255.0
Qtech(config-if-gigabitethernet 1/1)# label-switching
Qtech(config-if-gigabitethernet 1/1)# mpls ip
```

3.2.2.2 Configuring Remote LDP Peers

A PW is set up and maintained by the extended LDP. If other LSRs exist between two PEs, use the extended LDP discovery mechanism to set up a remote LDP session between the PEs and assign PW labels in the session. The procedures for configuring a remote LDP peer and setting up a remote LDP session are as follows:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# neighbor ip-address	Configures a remote LDP session.
Qtech(config-mpls-router)# show running-config	Displays all configuration information.

Configure a remote LDP peer at 3.3.3.3.

```
Qtech# configure terminal
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config)# exit
```



Caution

The PW label messages of the LDP are not affected by the LDP label distribution mode or label retention mode. The LDP is forced to work in DU and liberal label retention mode.

3.2.2.3 Configuring User Access VPWS

VPWS Access Modes for Switches

Only Ethernet VPWS services are provided on switches. According to whether the packet carries a VLAN tag, user access can be divided into the following modes:

- 59) Access interface access
- 60) Trunk interface access
- 61) Dot1q Tunnel interface access

**Caution**

VPWS services are supported by only VLAN interfaces (that is, SVI interfaces on switches). In addition, the VLAN can have only one member interface. You have trouble in enabling both IP and VPWS services on VLAN interfaces at the same time.

One VLAN interface can be bound to only one VC instance. The same VC instance cannot be bound to different VLAN interfaces.

When the **xconnect** command is used to specify the neighbor address of the VC peer end, you must use the router ID of this peer end as the peer address. The router ID of this peer end must be the 32-bit address of the loopback interface.

After the port protection mode is enabled on the member ports of the AC end of L2VPN, the port protection mode does not take effect for non-Tunk member ports.

These access modes are described in details as follows:

- VLAN access interface access

This mode applies when user packets transmitted on ACs are not encapsulated through 802.1Q (that is, packets without VLAN tags). Use the following commands to configure VLAN access interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport mode access	Enables the interface to work in access mode.
Qtech(config-if-type ID)# switchport access vlan vlan-id	Sets the interface as a member interface of a VLAN.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan vlan-id	Creates and enters VLAN interface configuration mode.
Qtech(config-if-type ID)# xconnect vc_id vc_peer encapsulation mpls {ethernet ethernetvlan} raw	Creates a VC and configures the raw encapsulation mode.
Qtech(config-if-type ID)# show running-config	Displays all configuration information.

Configure **GigabitEthernet 1/1** as an access interface and configure VPWS services for the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-gigabitEthernet 1/1)# switchport mode access
Qtech(config-if-gigabitEthernet 1/1)# switchport access vlan 2
Qtech(config-if-gigabitEthernet 1/1)# exit
Qtech(config)# interface vlan 2
Qtech(config-if-vlan 2)# xconnect 2 2.2.2.2 encapsulation mpls ethernet raw
```

**Caution**

In access interface access mode, we recommend setting the PW type to Ethernet, and the PW encapsulation mode must be raw.

- VLAN trunk interface access

This mode applies to the transmission of VPWS services from multiple users on the same AC. The PE determines the VPWS services for user packets based on their VLAN tags to provide the multiplexing of access interfaces.

Use the following commands to configure VLAN trunk interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport mode trunk	Enables the interface to work in trunk mode.
Qtech(config-if-type ID)# switchport trunk allow vlan add vlan-list	Enables the trunk link to allow VLAN traffic.
Qtech(config-if-type ID)# exit	Exits the interface configuration mode.

Command	Function
Qtech(config)# interface <i>vlan</i> <i>vlan-id</i>	Creates and enters VLAN interface configuration mode.
Qtech(config-if-type ID)# xconnect <i>vc_peer</i> <i>vc_id</i> encapsulation <i>mpls</i> ethernetvlan <i>tagged</i>	Creates a VC and configures the tagged encapsulation mode.
Qtech(config-if-type ID)# show running-config	Displays all configuration information.

Configure **GigabitEthernet** 1/1 as a trunk port and configure VPWS services for the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-gigabitEthernet 1/1)# switchport mode trunk
Qtech(config-if-gigabitEthernet 1/1)# switchport trunk allowed vlan add 2 3
Qtech(config-if-gigabitEthernet 1/1)# exit
Qtech(config)# interface vlan 2
Qtech(config-if-vlan 2)# xconenct 2 2.2.2.2 encapsulation mpls ethernetvlan tagged
Qtech(config-if-vlan 2)# exit
Qtech(config)# interface vlan 3
Qtech(config-if-vlan 2)# xconenct 3 2.2.2.2 encapsulation mpls ethernetvlan tagged
```



Caution

In trunk interface access mode, we recommend setting the PW type to **ethernetvlan**, and the PW encapsulation mode must be tagged.
The L2VPN service cannot be bound to the Native VLAN of the Trunk interface.

■ VLAN tunnel interface access

This mode applies when user service packets transmitted on ACs carry private VLAN tags if users access VPWS services. In this mode, the PE forwards all packets received from the VLAN tunnel interface without any changes. This mode requires the VLAN member interfaces that connect PEs with CEs to work in tunnel mode.

Use the following commands to configure VLAN tunnel interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface <i>type</i> <i>ID</i>	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport access <i>vlan-id</i>	Sets the interface as a VLAN member interface.
Qtech(config-if-type ID)# switchport mode dot1q-tunnel	Sets the interface to work in tunnel mode.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# interface <i>vlan</i> <i>vlan-id</i>	Creates and enters VLAN interface configuration mode.
Qtech(config-if-type ID)# xconnect <i>vc_id</i> <i>vc_peer</i> encapsulation <i>mpls</i> ethernet raw	Creates a VC and configures the raw encapsulation mode.
Qtech(config-if-type ID)# show running-config	Displays all configuration information.

Configure **GigabitEthernet** 1/1 as a VLAN tunnel interface and configure VPWS services for the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-gigabitEthernet 1/1)# switchport mode dot1q-tunnel
Qtech(config-if-gigabitEthernet 1/1)# switchport access 2
Qtech(config-if-gigabitEthernet 1/1)# exit
Qtech(config)# interface vlan 2
Qtech(config-if-vlan 2)# xconenct 2 2.2.2.2 encapsulation mpls ethernet raw
Qtech(config-if-vlan 2)# exit
```

**Caution**

For the access mode of the VLAN tunnel port, we recommend setting the PW type to **ethernet** and the encapsulation mode must be raw.
For the access mode of the VLAN tunnel interface, only the basic QinQ is supported.

VPWS Access Modes for Routers

There are several ways for users to access VPWS services provided by routers. Users can choose access modes according to actual application needs. Services provided by the VPWS depend on the link protocol adopted by the interface that connects the PE with the CE. Currently, the following four point-to-point L2VPN services are supported:

- 1) Simulative Ethernet line service
- 2) Simulative 802.1Q line service
- 3) Simulative PPP line service
- 4) Simulative HDLC line service

For the PE, the four L2VPN line services correspond to four access modes.

**Caution**

You have trouble in enabling both IP and VPWS services on VLAN interfaces at the same time. One VLAN interface can be bound to only one VC instance. The same VC instance cannot be bound to different VLAN interfaces.

- For the router product, VPWS services can be properly forwarded only when the fast forwarding function is enabled on the interfaces connected to the access user VPWS and to the public network.

**Caution**

When the **xconnect** command is used to specify the neighbor address of the VC peer end, you must use the router ID of this peer end as the peer address. The router ID of this peer end must be the 32-bit address of the loopback interface.

■ Ethernet access

In this mode, the interface between a PE and a CE encapsulates the Ethernet link protocol and provides VPWS services. The CE connects to the PE through the Ethernet link and requests Ethernet frames transmitted transparently by the PE. The Ethernet interface access mode applies when user service packets transmitted on ACs carry private VLAN tags or do not carry VLAN tags in the case of VPWS service access. In this mode, all packets received by PEs from the interface are forwarded without any changes.

Use the following commands to configure Ethernet access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# xconnect vc_peer vc_id encapsulation mpls ethernet raw	Creates a VC, and configure the Ethernet PW type and the raw encapsulation mode.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches.
Qtech(config-if-type ID)# show running-config	Displays all configuration information.

Configure VPWS services for the Ethernet access interface **Gigabitethernet 1/1**.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 0/1
```

Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 1/1)# ip ref
Qtech(config-if-gigabitethernet 0/1)# xconnect 2.2.2.2 2 encapsulation mpls ethernet raw
Qtech(config-if-gigabitethernet 0/1)# exit
```

■ Ethernet sub-interface access

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In this mode, the interface between a PE and a CE encapsulates the 802.1Q link protocol and provides VPWS services. The CE connects to the PE through the Ethernet sub-interface and requests Ethernet frames transmitted transparently by the PE. The Ethernet sub-interface access mode applies when several VPWS services for multiple users are transmitted on an access physical link. The PE matches packets with VPWS services according to dot1q tags carried by the user packets to provide the multiplexing of access interfaces. In this access mode, packets sent by CEs to PEs must carry VLAN tags.

Use the following commands to configure Ethernet sub-interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# xconnect vc_peer vc_id encapsulation mpls ethernetvlan tagged	Creates a VC, and configures the Ethernet VLAN PW type and the tagged encapsulation mode.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches. Use the command to configure the sub-interface's fast forwarding function on its master interface.
Qtech(config-if-type ID)# show running-config	Displays all configuration information.

Configure **GigabitEthernet 1/1** as an access interface and configure VPWS services for the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitEthernet 0/1.1
Qtech(config-if-gigabitEthernet 0/1.1)#encapsulation dot1Q 1
```

Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitEthernet 1/1)# ip ref
Qtech(config-if-gigabitEthernet 0/1.1)# xconnect 2.2.2.2 2 encapsulation mpls
ethernetvlan tagged
Qtech(config-if-gigabitEthernet 0/1.1)# exit
```

**Caution**

If the VPWS service is enabled on both the master interface and sub-interface, or is enabled on one of them, packets without VLAN tags received by the Ethernet interface belong to the service provided by the master interface. If they carry VLAN tags and match with the sub-interface's VLAN ID, they belong to the service provided by the sub-interface.

To enable the sub-interface to support the fast forwarding function, use the **ip ref** command to enable the fast forwarding function on its master interface.

Users can use **mpls mtu** command to modify the **mpls mtu** value. By default, the value is equal to the **mtu** value of the interface.

■ PPP access

In this mode, the interface that connects a PE with a CE encapsulates the PPP link protocol and provides VPWS services. The CE connects to the PE in PPP mode and requests the PPP frames transmitted transparently by the PE. The interface that encapsulates the PPP protocol is bound with the L2VPN service and its PE-end PPP protocol will be disabled. Therefore, the LCP and NCP of one CE will not interact with each other. The PE will transparently transmit the PPP negotiation controlling packet sent by CE. The PPP negotiation will be conducted between CEs.

Use the following commands to configure PPP access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# encapsulation ppp	Enables the interface to encapsulate PPP.
Qtech(config-if-type ID)# xconnect vc_peer vc_id encapsulation mpls ppp	Creates the VC and configures the PW type as PPP.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches.

Qtech(config-if-type ID)# show running-config	Displays the existing configuration information.
--	--

Configure **serial 1/0** to provide the VPWS service of transparently transmitting PPP frames.

```
Qtech# configure terminal
Qtech(config)# interface serial 1/0
Qtech(config-if-serial 1/0)# encapsulation ppp
Qtech(config-if-serial 1/0)# xconnect 2.2.2.2 2 encapsulation mpls ppp
Qtech(config-if-serial 1/0)# exit
```

■ HDLC access

In this mode, the interface that connects a PE with a CE encapsulates the HDLC link protocol and provides VPWS services. The CE connects to the PE in HDLC mode and requests the HDLC frames transmitted transparently by the PE.

Use the following commands to configure HDLC access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# encapsulation hdlc	Enables the interface to encapsulate HDLC.
Qtech(config-if-type ID)# xconnect vc_peer vc_id encapsulation mpls hdlc	Creates the VC and configures the PW type as HDLC.
Qtech(config-if-type ID)# show running-config	Disables the existing configuration information.

Configure **serial 1/0** to provide the VPWS service of transparently transmitting HDLC.

```
Qtech# configure terminal
Qtech(config)# interface serial 1/0
```

Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.

```
Qtech(config-if-serial 1/0)# ip ref
Qtech(config-if-serial 1/0)# encapsulation hdlc
Qtech(config-if-serial 1/0)# xconnect 2.2.2.2 2 encapsulation mpls ppp
Qtech(config-if-serial 1/0)# exit
```

3.2.2.4 Configuring Heterogeneous Media Communication VPWS

If CEs on two ends of the same L2VPN feature different link types, the L2VPN's feature of heterogeneous media intercommunication is needed. According to the suggestion of draft-kompella-ppvnp-l2vpn, the encapsulation type of the L2VPN interface of PEs needs to be ip-interworking during the establishment of the L2VPN connection. Users' IP packets are transmitted on the MPLS network transparently. When the L2VPN's heterogeneous media communication function is used, VPWS service interfaces of PEs on both ends must encapsulate ip-interworking. After PW connection is set up, packets are processed as follows:

- 62) After a PE receives packets from a CE and decapsulates the link layer, the PE transmits IP packets to the MPLS network.
- 63) IP packets are transmitted transparently through the MPLS network to the peer PE.
- 64) The peer PE re-encapsulates the IP packets according to its link layer protocol type and sends them to the CE connected to it.
- 65) The link layer control packet (such as PPP's IPCP) sent by the CE are processed by the PE without being transmitted on the MPLS network.
- 66) Non-IP packets (such as MPLS packets) are discarded and do not enter the MPLS network.
- Among the Ethernet interfaces on the PE, the following L2VPN interfaces can be encapsulated in ip-interworking mode:
 - 67) Ethernet interface or sub-interface
 - 68) GigabitEthernet interface or sub-interface

Note the following points:

- 69) After being encapsulated as ip-interworking, the PE's Ethernet interface processes only ARP and IP packets received by the local CE and discards the others including IPv6 packets.
- 70) When the PE receives IP packets from the CE, the dynamic MAC is not updated.
- 71) If the VPWS inbound interface that encapsulates ip-interworking on the PE receives the CE's ARP request packets, the VPWS inbound interface uses the PE's MAC address to reply regardless of the destination IP address.
- 72) Each Ethernet interface or sub-interface of the PE can be connected to only one CE and cannot be connected to multiple CEs or other devices through a hub or a layer-2 switch. Otherwise, MAC addresses learned by the PE will be covered, obstructing the forwarding.
- If a CE uses the PPP link protocol to access a PE, pay attention to the following points:

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73) Unlike the negotiation that provides the homogeneous media L2VPN PPP simulative line service, the negotiation of PPP is conducted between the CE and the PE, rather than CEs; the address of the negotiation between PE and CE will not generate the corresponding route.

74) It supports PAP and CHAP authentication. The authentication method is the same as the common situation.

75) It does not support IPHC compression.

76) It supports transparent transmission of IP packets from the local CE to the peer CE and does not support transparent transmission though protocols such as MPLS and IPv6.

77) The **ppp ipcp address proxy** command must be used on the PE to specify the remote CE's IP address, which is the same as the IPCP proxy address of the PE as the remote CE. The address will not generate a route on the PE.

Use the following commands to configure the heterogeneous media communication VPWS access service in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# ppp ipcp address proxy remote-ce-ip-addr	(Optional) When the interface that connects the PE to the CE encapsulates the PPP link protocol, configure the remote CE's IP address on the PE as the proxy address for the remote CE to conduct IPCP negotiation with the local CE.
Qtech(config-if-type ID)# xconnect vc_peer vc_id encapsulation mpls ip-interworking [local-ce mac mac]	Creates VC and configures the PW type as the heterogeneous media communication. (Optional) local-ce mac mac : When the interface that connects PE to CE encapsulates the Ethernet protocol, the local CE's MAC address must be configured.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches.
Qtech(config-if-type ID)# show running-config	Displays the existing configuration information.

Configure **serial 1/0** to provide the heterogeneous media VPWS service of the PPP access mode.

```
Qtech# configure terminal
Qtech(config)# interface serial 1/0
Qtech(config-if-serial 1/0)# encapsulation ppp
```

Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 1/1)# ip ref
Qtech(config-if-serial 1/0)# ppp ipcp address proxy 192.168.1.1
Qtech(config-if-serial 1/0)# xconnect 2.2.2.2 2 encapsulation mpls ip-interworking
Qtech(config-if-serial 1/0)# exit
```

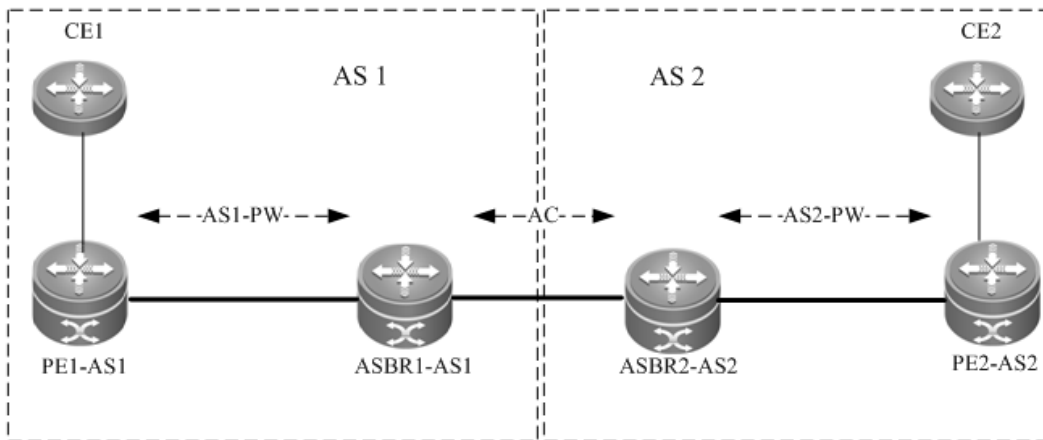
3.2.2.5 Configuring Inter-AS VPWS

There are two solutions for configuring Inter-AS Martini VPWS:

- Inter-AS Option A: This solution is simple and can be adopted when the number of inter-AS L2VPNs on ASBR is small.
- Inter-AS Option C: You do not need to create or maintain any VCs on ASBR. When each AS has numerous inter-AS L2VPNs, this solution can be applied to solve the bottleneck of the ASBR's scalability.

Inter-AS Option A

Figure 49 Option A Inter-AS VPWS



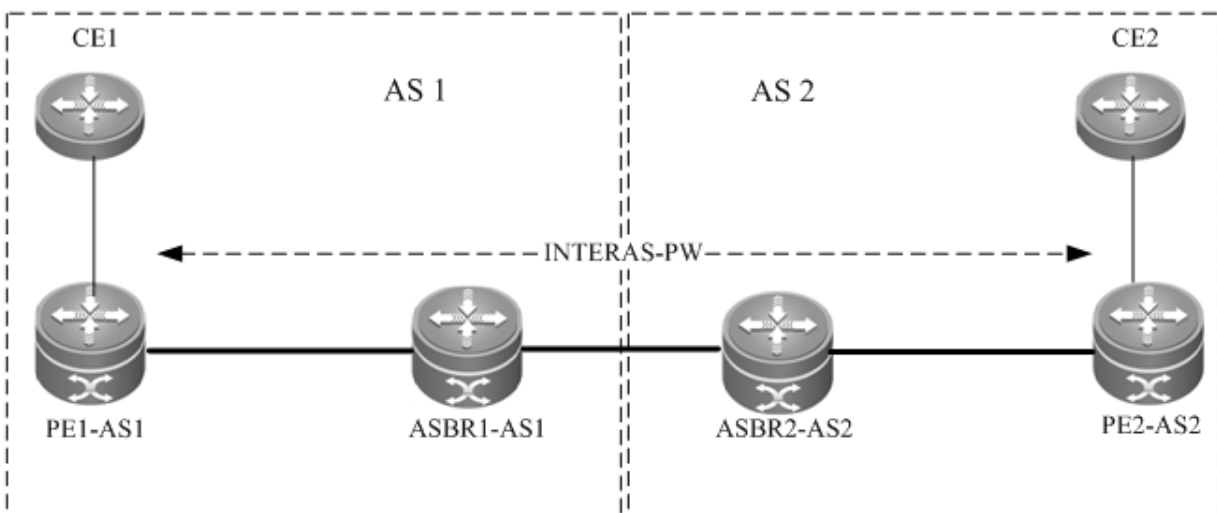
In the solution, ASBRs of two ASs are connected with each other and are PEs of their respective autonomous systems. Each ASBR considers the peer ASBR as its CE device. As shown in the preceding figure, for ASBR1-AS1 of AS1, ASBR2-AS2 of AS2 is only an accessed CE device; for ASBR2-AS2 of AS2, ASBR1-AS1 is also only an accessed CE device.

The Option A solution is easy to implement. You do not need to especially configure two PEs that serve as ASBRs or configure an IP address for the interface between ASBRs. For each inter-AS L2VPN or each Inter-AS PW, a logical or physical link must be allocated between ASBRs of two ASs. When there are numerous inter-AS PWs, great pressure is caused to ASBRs, hindering the expansion.

The solution's configuration is similar to the aforementioned basic VPWS configuration.

Inter-AS Option C

Figure 50 Option C Inter-AS VPWS



As shown in the preceding figure, Option C solution is to set up an inter-AS PW on two ASs directly and exchange PW tags. The principle is described as follows:

By sending tag IPv4 routes to the PE in respective ASs and sending tag IPv4 routes received by PEs in respective ASs to the ASBR peers of peer ASs, ASBRs connect the tunnel between two ASs and set up an LSP tunnel between the ingress PE and egress PE. Then, the inter-AS LDP remote session are set up between PEs in different ASs and PW information are exchanged.

3. Configuring L2VPN

In the solution, ASBRs do not need to maintain inter-AS L2VPN information or prepare a physical or logical interface for the inter-AS L2VPN. However, it needs to provide an MPLS tunnel. The L2VPN information is directly exchanged between PEs, decreasing the pressure on ASBRs and facilitating the scalability.

The configuration procedure is as follows:

- 78) Configure MPLS signaling.
- 79) Configure PEs.
- 80) Configure ASBRs.
- 81) Configure the remote LDP session.
- 82) Configure the user access VPWS.
- Configure MPLS signaling.

In each AS, enable the MPLS and LDP functions on PE and P devices and the interface that connects to the P or PE device in AS of the ASBR to set up a basic MPLS network. For the configuration procedures, see the chapter about basic MPLS configuration.

■ Configuring PEs

Configure the PEs in ASs, set up an IBGP session between the PE and the AS, and exchange IPv4 routes that carry tags.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-number</i>	Configures BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>asbr-address</i> remote-as <i>asbr-asn-number</i>	Sets up IBGP sessions between the PE and ASBR.
Qtech(config-router)# neighbor <i>asbr-address</i> update-source <i>interface-name</i>	Uses the loopback address as the source address of the BGP session set up between peers.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# neighbor <i>asbr-address</i> send-label	Enables IPv4 route tag switching.
Qtech(config-router-af)# show running-config	Displays configuration information.

Set up the IBGP session with the ASBR device 10.10.10.2 and enable the IPv4 route tag switching function.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.2 remote-as 1
Qtech(config-router)# neighbor 10.10.10.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.2 activate
Qtech(config-router-af)# neighbor 10.10.10.2 send-label
Qtech(config-router-af)# exit
```

■ Configuring ASBRs

Configure ASBRs to set up the IBGP session with the PE in the same AS and with the ASBR in the other AS. Enable the IPv4 route tag switching function on both sessions. Configure the PE address to be transmitted to another ASBR on the ASBR.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls ip	Enables the device to support MPLS forwarding. This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP globally.
Qtech(config-mpls-router)# ldp router-id interface Loopback <i>id</i> force	Configures the IP address of the loopback interface as the router ID.
Qtech(config-mpls-router)# advertise-labels for bgp-routes	Allocates tags for BGP's route.
Qtech(config-mpls-router)# exit	Returns to config mode.
Qtech(config)# router bgp <i>asn-number</i>	Configures BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor <i>asbr-address</i> remote-as <i>asbr-asn-number</i>	Sets up EBGP session with ASBRs.
Qtech(config-router)# neighbor <i>pe-address</i> remote-as <i>asn-number</i>	Sets up EBGP session with PEs.
Qtech(config-router)# neighbor <i>pe-address</i> update-source loopback <i>id</i>	Uses the loopback address as the source address of the BGP session set up between PE peer.

Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# network <i>pe-address</i> mask <i>mask-value</i>	(Optional) Uses the network command to import the PE route received to BGP. The IGP protocol can be re-distributed to import the route.
Qtech(config-router-af)# neighbor asbr-address send-label	Enables the IPv4 route tag switching function on BGP that is set up with the ASBR in another AS.
Qtech(config-router-af)# neighbor pe-address send-label	Enables the IPv4 route tag switching function on BGP that is set up with the PE in the same AS.
Qtech(config-router-af)# neighbor asbr-ip-address route-map <i>name</i> out	(Optional) Configures the route allocation policy. You can define route map rules (routemap) to control allocation of routes to neighbors and control whether these routes carry tags when they are sent.
Qtech(config-router-af)# neighbor asbr-ip-address route-map <i>name</i> in	(Optional) Configures the route allocation policy. You can define route map rules (routemap) to control only routes that carry tags.
Qtech(config-router-af)# show running-config	Displays configuration information.

In the following example, the configured ASBR sets up an EBGP session with the ASBR in another AS (30.30.30.2) and the tag switching function is enabled for IPv4 routes. The IBG neighbor is created between the ASBR and the PE in the same AS (10.10.10.1) and the tag switching function is enabled for IPv4 routes.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 30.30.30.2 activate
Qtech(config-router-af)# neighbor 30.30.30.2 send-label
Qtech(config-router-af)# exit
Qtech(config-router)# neighbor 10.10.10.1 remote-as 1
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.1 send-label
Qtech(config-router-af)# exit
```



Caution

For the IBGP session set up between ASBR and the PE in the same AS, the **neighbor peer-address update-source** *loopback id* command must be used on the ASBR and PE to configure the address of the device's loopback interface as the source address of the session. Otherwise, the inter-AS LSP tunnel cannot be established.

The direct EBGP session established between ASBRs usually uses the direct connection interface's address as the source address of the BGP session to ensure that both ASBRs have routes that lead to each other. Therefore, you are not advised to use the **neighbor peer-address update-source** *loopback id* command on the EBGP session established based on direct connection to configure the address of the device's loopback interface as the source address of the session. If necessary, use the **neighbor ebgp-multihop** command to enable the multi-hop EBGP function, configure the static route on ASBR to ensure that the route can lead to the peer, and configure the static FTN to ensure that the inter-AS LSP's tunnel is available.

The **label-switching** command must be used on the interface between ASBRs to enable the interface's MPLS packet forwarding capability.

■ Configuring the LDP remote session

Set up an inter-AS LDP remote session between PEs in two ASs. See the Configuring LDP Remote Peer chapter.

■ Configuring the user access VPWS

For detailed configuration, see the Configuring User Access VPWS chapter.

■ Checking the configuration result

Command	Function
show bgp ipv4 unicast labels	Displays label information allocated by BGP for IPv4 routes.
show mpls ldp neighbor	Displays neighbor information of LDP.

Command	Function
<code>show mpls l2transport vc [detail]</code>	Displays VC status information.

View route and label information on an ASBR or a PE.

```
Qtech # show bgp ipv4 unicast labels
Network      Next Hop      In Label/Out Label
1.1.1.1/32    192.167.1.1   17/18
1.1.1.2/32    192.167.1.1   noLabel/19
```

Field	Definition
Network	Route prefix
NextHop	Route's next hop
In Label	Label (if any) allocated by the router
Out Label	Label (if any) learned from the next-hop router of the route

View LDP session information on a PE.

```
Qtech # show mpls ldp neighbor
Default VRF:
Peer LDP Ident: 10.20.10.10:0; Local LDP Ident: 8.8.8.8:0
TCP connection: 10.20.10.10.62488 - 8.8.8.8.646
State: OPERATIONAL; Msgs sent/recvd: 42/45; UNSOLICITED
Up time: 00:33:49
LDP discovery sources:
  Link Peer on GigabitEthernet 2/1, Src IP addr: 192.168.201.220
  Targeted Hello 8.8.8.8 -> 10.20.10.10
Addresses bound to peer LDP Ident:
10.20.10.10 192.168.201.220 192.168.198.1 10.5.0.1
```

Field	Definition
Peer LDP Ident	LDP identifier of the peer neighbor of the LDP session
Local LDP Identifier	Router's LDP identifier
TCP connection	TCP connection that supports the LDP session
State	Status of the LDP session
Msgs sent/recvd	Quantity of LDP messages sent to/received by the session peer
UNSOLICITED and ONDEMAND	Label allocation mode

View VC status information.


```
Qtech # show mpls l2transport vc detail
Local interface : VLAN 2, AC state: up
Peer address: 192.168.0.1 ,VC ID: 2, VC status: up
VC type: vlan      VC mode:tagged
Group id: 0      MTU: 1500
Control Word not support
Output interface: VLAN 300 , imposed label stack {22 ,501 }
MPLS VC label: local 22, remote 22
```

Field	Definition
Local interface	Local interface bound to VC
AC state	AC status, up or down
Peer address	Peer IP address
VC ID	VC's unique identifier
VC status	VC status, up or down
VC type	VC type
VC mode	VC mode, tagged or raw (only applies to the Ethernet access mode)
Group id	VC's local group ID
MTU	MTU of the locally configured VC
Control Word	Whether the control word is supported
Output interface	Output interface on the public network used to transmit the VC process
imposed label stack	Added label stack
MPLS VC label	Local indicates the label locally allocated for the VC while Remote indicates the label allocated by the peer for the VC.

3.2.3 Configuring Kompella VPWS

3.2.3.1 Configuring the Public Network Tunnel

The LSP tunnel must be set up on the public network to carry the VC service. To run MPLS on the backbone network, LDP must be run on Ps and PEs to establish the public network tunnel. This includes configuring the label allocation protocol for MPLS devices and enabling the MPLS forwarding on each interface. The configuration procedure is as follows:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
	Enables MPLS forwarding globally.
Qtech# mpls ip	 Caution This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback id [force]	Configures LDP's router ID, which is usually the IP address of the loopback interface.
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Qtech(config)# interface type ID	Enters public network interface configuration mode.
Qtech(config-if-type ID)# label-switching	Enables the interface's MPLS forwarding function.
Qtech(config-if-type ID)# mpls ip	Enables the interface's LDP function and MPLS forwarding function.
Qtech(config-if-type ID)# ip ref	Enables the fast forwarding function for routers. You do not need to be enable the function for switches.
Qtech(config-if-type ID)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure the public network tunnel between PEs.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# end
Qtech# copy running-config startup-config
```



Caution

The LDP is a topology-driven protocol. To ensure the normal working of the LDP, enable IPv4 routing protocols and ensure their normal operations.

3.2.3.2 Configuring the L2VPN Address Family

Kompella VPWS uses MP-BGP4 as the signaling protocol to transmit layer-2 information and VC labels, realizing point-to-point VPN. In addition, the MP-BGP4 protocol can be used as the auto-discovery protocol and connect remote CEs. The procedure for enabling the L2VPN address family is as follows:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-num	Creates BGP and enters BGP configuration mode.
Qtech(config)# neighbor peer-address remote-as asn-number	Sets up the IBGP session.

Qtech(config)# neighbor peer-address update-source interface-name	Enables the IBGP session to use the address of the loopback interface as the session's source address.
Ruijie(config-router)# address-family l2vpn vpws	Enters the L2VPN VPWS address family.
Qtech(config-router-af)# neighbor ip-address activate	Activates switching of L2VPN information on the BGP session.
Qtech(config-router-af)# neighbor { ip-address peer-group-name } send-community [both standard extended]	Specifies the extended community attribute to be sent to BGP neighbors.
Qtech(config-router-af)# end	Returns from address family configuration mode to privileged mode.
Qtech# show bgp l2vpn vpws { all [id:offset neighbor ip-address summary] }	Displays L2VPN address family information.

Configure the L2VPN address family and enable VPWS information switching.

```
Qtech# configure terminal
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 10.10.10.1 remote-as 1
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 10.10.10.1 activate
Qtech(config-router-af)# neighbor 10.10.10.1 send-community extended
Qtech(config-router-af)# end
Qtech# show bgp l2vpn vpws all
```

3.2.3.3 Configuring the Kompella VPWS Instance

The **l2 vfi** command can be used to create Kompella VPWS instances or enter Kompella VPWS configuration mode. The **no l2 vfi** command can be used to delete VFI instances. The unique local VFI instance name and the unique local device VPN ID must be specified when the instance is being created. The auto-discovery function must be enabled for the specified VFI instance. One VFI name must correspond to one VPN ID.

The **label-saving** command can be used to enable the label saving mode and allocate a label for the specified remote site. In label saving mode, **site range** does not take effect.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id point-to-point	Creates the Kompella VPWS instance and enters VPWS configuration mode.
Qtech(config-vfi)# rd rd_value	Configures the RD value. Configure the RD first.
Qtech(config-vfi)# encapsulation mpls [ethernet ethernetvlan ppp hdlc ip-interworking]	Specifies the encapsulation type of Kompella L2VPN PWs, which is Ethernet by default.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RTs. Multiple RTs can be configured.
Qtech(config-vfi)# site-id id [site-range size]	Configures the CE ID of a site and the site range. If the site range is not configured, the default value 16 will be adopted. Multiple site IDs can be configured for Kompella VPWS.
Qtech(config-vfi-site)# xconnect interface interface-type interface-number remote-ce-id id	Binds the local interface and specifies the ID of the remote CE to be connected.
Qtech(config-vfi-site)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure a Kompella VPWS instance.

```
Qtech#configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 4500:2
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gi 2/2 remote-ce-id 2
Qtech(config-vfi-site)#end
Qtech# copy running-config startup-config
```


**Caution**

The **point-to-point** keyword must be specified after the **I2 vfi** command to create a Kompella VPWS instance.

VFI instances of one VPN must be configured with the same ID to facilitate management.

Each site's ID is globally unique in VFI instances.

VFI instances of all PEs on one VPN must be configured with the same VPWS PW type. Otherwise, BGP signaling cannot be used to establish PWs.

We recommend specifying the PW type as Ethernet VLAN for VPWS connected through the sub-interface and as Ethernet for VPWS connected through the Ethernet. If the interface type is different from the specified PW type, although PWs can be established, two PW types adopt different ways to process tags of user packets, causing problems to communication between CEs. VLAN tags carried by user packets are processed as p-tags in Ethernet VLAN PWs while are transmitted transparently as c-tags in Ethernet PWs.

3.2.3.4 Configuring User Access VPWS

A created VFI instance takes effect only after the user configured with the VFI instance is connected with the link. Multiple point-to-point VCs can be configured in one VFI.

Switch VPWS access mode

Switches can provide only Ethernet VPWS services. The user access mode can be divided into the following modes according to whether packets carry VLAN tags:

- 83) Access interface access
- 84) Trunk interface access
- 85) VLAN tunnel interface access

**Caution**

Only the VLAN interface (SVI interface of switches) can provide the VPWS service. IP and VPWS services cannot be enabled concurrently on the VLAN interface at the same time.

One VLAN interface can bind only one VC instance and one VC instance cannot be bound on different VLAN interfaces.

When the port protection mode is enabled on the AC-end member port of L2VPN, the port protection mode does not take effect on the member port if the corresponding member port is not a Trunk interface.

These access modes are described in details as follows:

- VLAN access interface access

This mode applies when user packets transmitted on ACs are not encapsulated by 802.1Q (that is, the packets do not carry VLAN tags). Use the following commands to configure VLAN access interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport mode access	Sets the interface in access mode.
Qtech(config-if-type ID)# switchport access vlan vlan-id	Sets the interface as a member port of a VLAN port.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# I2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ethernet	Configures the encapsulation method of VFI as Ethernet.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface vlan vlan-id remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

**Caution**

In VLAN access interface access mode, we recommend setting the PW encapsulation mode to **ethernet**, and the encapsulation modes on two ends of a PW must be the same.

Configure **gigabitethernet 1/1** to be connected through the access interface and configure VPWS services under the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/1
Qtech(config-if-gigabitethernet 1/1)# switchport mode access
Qtech(config-if-gigabitethernet 1/1)# switchport access vlan 2
Qtech(config-if-gigabitethernet 1/1)# exit
Qtech(config)# 12 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 2 remote-ce-id 2
```

■ **VLAN trunk interface access**

This mode applies when several VPWS services for multiple users are transmitted on an AC. PE devices can match packets with VPWS services according to VLAN tags carried by the user packets to provide the multiplexing of access interfaces.

Use the following commands to configure VLAN trunk interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport mode trunk	Sets the interface in trunk working mode.
Qtech(config-if-type ID)# switchport trunk allow vlan add vlan-list	Sets the VLAN flows allowed to be transmitted on the trunk link.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# 12 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ethernetvlan	Configures the encapsulation method of VFI as Ethernet VLAN.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface vlan vlan-id remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

**Caution**

In trunk access interface access mode, we recommend setting the PW encapsulation mode to **ethernetvlan**, and the encapsulation modes on two ends of a PW must be the same. The L2 VPN service cannot be bound to the Native VLAN of the Trunk interface.

Configure **gigabitethernet 1/1** to be connected through the trunk interface and configure VPWS under the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/1
Qtech(config-if-gigabitethernet 1/1)# switchport mode trunk
Qtech(config-if-gigabitethernet 1/1)# switchport trunk allowed vlan add 2 3
Qtech(config-if-gigabitethernet 1/1)# exit
Qtech(config)# 12 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 2 remote-ce-id 2
```

■ VLAN tunnel interface access

This mode applies when user service packets transmitted on an AC carry private VLAN tags if users access the VPWS service. In this mode, all packets received by PEs from the interface are forwarded without any changes. This mode requires the VLAN member ports between PEs with CEs to work in tunnel mode.

Use the following commands to configure VLAN tunnel interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# switchport access vlan-id	Sets the VLAN member port of the interface.
Qtech(config-if-type ID)# switchport mode dot1q-tunnel	Sets the interface to work in tunnel mode.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ethernetvlan	Configures the encapsulation method of VFI as Ethernet VLAN.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface vlan vlan-id remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.



Caution

In VLAN tunnel interface access mode, we recommend setting the PW encapsulation mode to **ethernet**, and the encapsulation modes on two ends of a PW must be the same. For the VLAN tunnel interface access mode, only the basic QinQ is supported.

Configure **gigabitethernet 1/1** to be connected through the VLAN tunnel interface and configure VPWS under the corresponding VLAN interface.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/1
Qtech(config-if-gigabitethernet 1/1)# switchport mode dot1q-tunnel
Qtech(config-if-gigabitethernet 1/1)# switchport access 2
Qtech(config-if-gigabitethernet 1/1)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 2 remote-ce-id 2
```

Router VPWS access mode

There are several ways for users to connect to VPWS services provided by routers. Users can choose access modes according to actual application needs. Services provided by the VPWS depend on the link protocol adopted by the interface that connects the PE with the CE. Currently, the following four point-to-point L2VPN services are supported:

- 86) Simulative Ethernet line service
- 87) Simulative 802.1Q line service
- 88) Simulative PPP line service
- 89) Simulative PPP line service
- Ethernet interface access

This mode applies when user service packets transmitted on ACs carry private VLAN tags or do not carry VLAN tags in the case of VFI service access. In this mode, all packets received by PEs from the interface are forwarded without any changes and the private tags are considered part of the data.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.

Qtech(config-if-type ID)# ip ref	Enables fast forwarding of the Ethernet interface.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ethernet	Configures the encapsulation mode of VFI as Ethernet.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface type ID remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

Configure **gigabitethernet 1/0** to provide the VPWS service of transparently transmitting Ethernet frames.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
Qtech(config-if-gigabitethernet 1/0)# ip ref
Qtech(config-if-gigabitethernet 1/0)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitethernet 1/0 remote-ce-id 2
```



Caution

In Ethernet interface access mode, we recommend setting the PW encapsulation mode to **ethernet**, and the encapsulation modes on two ends of a PW must be the same. The remote CE ID must be specified to establish the Kompella VPWS.

■ Ethernet sub-interface access

In this mode, the interface between a PE and a CE is encapsulated by the 802.1Q link protocol and provides VPWS services. The CE connects to the PE through the Ethernet sub-interface and requests Ethernet frame transmitted transparently by the PE. The Ethernet sub-interface access mode applies when several VPWS services for multiple users are transmitted on a physical access link. PE devices can match packets with VPWS services according to dot1q tags carried by the user packets to provide the multiplexing of access interfaces. In this mode, packets sent by the CE to the PE must carry VLAN tags.

Use the following commands to configure Ethernet sub-interface access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters sub-interface configuration mode.
Qtech(config-if-type ID)# encapsulation dot1Q vlan-id	Configures the VLAN ID to be encapsulated.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ethernetvlan	Configures the encapsulation mode of VFI as Ethernet VLAN.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface type ID remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

Configure **gigabitethernet 1/0.100** to provide the VPWS service of transparently transmitting Ethernet frames.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/0
Qtech(config-if-gigabitethernet 1/0)# ip ref
```

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```

Qtech(config-if-gigabitethernet 1/0)# exit
Qtech(config)# interface gigabitethernet 1/0.100
Qtech(config-if-serial 1/0.100)# encapsulation dot1q 100
Qtech(config-if-serial 1/0.100)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitethernet 1/0.100 remote-ce-id 2

```



Caution

In sub-interface access mode, we recommend setting the PW encapsulation mode to **ethernetvlan**, and the encapsulation modes on two ends of a PW must be the same.

The **ip ref** command must be used to enable the fast forwarding function on the master interface of the sub-interface.

- PPP access

In this mode, the interface between a PE and a CE encapsulates the PPP link protocol and provides VPWS services. The CE connects to the PE in PPP mode and requests the PPP frames transmitted transparently by the PE. The interface that encapsulates the PPP protocol is bound with the L2VPN service and its PE-end PPP protocol will be disabled. Therefore, the LCP and NCP of one CE will not interact with each other. The PE will transparently transmit the PPP negotiation control packet sent by the CE. The PPP negotiation will be conducted between CEs.

Use the following commands to configure PPP access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# ip ref	Enables fast forwarding of the sub-interface.
Qtech(config-if-type ID)# encapsulation ppp	Configures the PPP encapsulation protocol.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls ppp	Configures the encapsulation mode of VFI as PPP.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface type ID remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

Configure **serial 1/0** to provide the VPWS service of transparently transmitting PPP frames.

```

Qtech# configure terminal
Qtech(config)# interface serial 1/0
Qtech(config-if-serial 1/0)# encapsulation ppp
Qtech(config-if-serial 1/0)# ip ref
Qtech(config-if-serial 1/0)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ppp
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface serial 1/0 remote-ce-id 2

```

- HDLC access

In this mode, the interface between a PE and a CE encapsulates the HDLC link protocol and provides VPWS services. The CE connects to the PE in HDLC mode and requests the HDLC frames transmitted transparently by the PE.

Use the following commands to configure HDLC access in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.

Command	Function
Qtech(config-if-type ID)# ip ref	Enables fast forwarding of the sub-interface.
Qtech(config-if-type ID)# encapsulation hdlc	Configures the HDLC encapsulation protocol.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id point-to-point	Enters VFI configuration mode.
Qtech(config-vfi)# rd rd_value	Defines the RD value of the Kompella VPWS instance.
Qtech(config-vfi)# route-target { import export both } rt_value	Configures RT.
Qtech(config-vfi)# encapsulation mpls hdlc	Configures the encapsulation mode of VFI as PPP.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface type ID remote-ce-id id	Connects the interface that binds VFI locally with the VFI's remote CEs.

Configure serial 1/0 to provide the VPWS service of transparently transmitting HDLC frames.

```
Qtech# configure terminal
Qtech(config)# interface serial 1/0
Qtech(config-if-serial 1/0)# encapsulation hdlc
Qtech(config-if-serial 1/0)# ip ref
Qtech(config-if-serial 1/0)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 point-to-point
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls hdlc
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface serial 1/0 remote-ce-id 2
```

3.2.3.5 Configuring Heterogeneous Media Communication VPWS

If CEs on two ends of the same L2VPN feature different link types, the L2VPN's feature of heterogeneous media intercommunication is needed. According to the suggestion of draft-kompella-ppvnp-l2vpn, the encapsulation type of the L2VPN interface of PEs needs to be ip-interworking during the establishment of L2VPN connection. Users' IP packets are transmitted on the MPLS network transparently. When the L2VPN's heterogeneous media communication function is used, VPWS service interfaces of PEs on both ends must encapsulate ip-interworking. After PW connection is set up, packets are processed as follows:

- 90) After a PE receives packets from a CE and decapsulates the link layer, the PE transmits IP packets to the MPLS network.
- 91) IP packets are transmitted transparently through the MPLS network to the peer PE.
- 92) The peer PE re-encapsulates the IP packets according to its link layer protocol type and sends them to the CE connected to it.
- 93) The link layer control packet (such PPP's IPCP) sent by the CE are processed by the PE without being transmitted on the MPLS network.
- 94) Non-IP packets (such as MPLS packets) are discarded and do not enter the MPLS network.
 - Among the Ethernet interfaces on the PE, the following L2VPN interfaces can be encapsulated in ip-interworking mode:
 - 95) Ethernet interface or sub-interface
 - 96) GigabitEthernet interface or sub-interface

Note the following points:

- 97) After being encapsulated as ip-interworking, the PE's Ethernet interface processes only ARP and IP packets received by the local CE and discards the others including IPv6 packets.
- 98) When the PE receives IP packets from the CE, the dynamic MAC is not updated;
- 99) If the VPWS inbound interface that encapsulates ip-interworking on the PE receives the CE's ARP request packets, the VPWS inbound interface uses the PE's MAC address to reply regardless of the destination IP address.
- 100) Each Ethernet interface or sub-interface of the PE can be connected to only one CE and cannot be connected to multiple CEs or other devices through a hub or a layer-2 switch. Otherwise, MAC addresses learned by the PE will be covered, obstructing the forwarding.
 - If a CE uses the PPP link protocol to access a PE, pay attention to the following points:
 - 101) Unlike the negotiation that provides the homogeneous media L2VPN PPP simulative line service, the negotiation of PPP is conducted between the CE and the PE, rather than CEs; the address of the negotiation between PE and CE will not generate the corresponding route.
 - 102) It supports PAP and CHAP authentication. The authentication method is the same as the common situation.

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- 103) It does not support IPHC compression.
- 104) It supports transparent transmission of IP packets from the local CE to the peer CE and does not support transparent transmission though protocols such as MPLS and IPv6.
- 105) The **ppp ipcp address proxy** command must be used on the PE to specify the remote CE's IP address, which is the same as the IPCP proxy address of the PE as the remote CE. The address will not generate a route on the PE.

**Caution**

If both ends of the CE is configured with the address of the same network segment, they can be connected no matter which IP address is configured for the PE-end PPP proxy as the CE has a network segment route that leads to the peer CE and the next-hop output interface can be obtained. If two ends of the CE are configured with addresses of different network segments, the PE-end PPP proxy must be specified as the peer CE address and a route that leads to the peer CE's network segment must be configured statically in the CE.

Use the following commands to configure the heterogeneous media communication VPWS access service in privileged mode.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# l2 vfi <i>vpws-name</i> vpnid <i>vpn-id</i> point-to-point	Creates the Kompella VPWS instance and enters VPWS configuration mode.
Qtech(config-vfi)# rd <i>rd_value</i>	Configures the RD value. Configure the RD first.
Qtech(config-vfi)# encapsulation mpls ip-interworking	Specifies ip-interworking as the encapsulation type of Kompella L2VPN PW.
Qtech(config-vfi)# route-target { import export both } <i>rt_value</i>	Configures RTs. Multiple RTs can be configured.
Qtech(config-vfi-site)# xconnect interface <i>interface-type interface-number remote-ce-id id</i>	Configures the local interface to be bound and specifies the ID of the CE to be connected remotely.
Qtech(config-vfi-site)# local-ce mac <i>mac</i>	Specifies the CE's static MAC address.
Qtech(config-vfi-site)# exit-site-mode	Returns to VFI configuration mode.
Qtech(config-vfi)# exit	Returns to global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters interface configuration mode.
Qtech(config-if-type ID)# ppp ipcp address proxy <i>remote-ce-ip-addr</i>	(Optional) When the interface that connects the PE to the CE encapsulates the PPP link protocol, configure the remote CE's IP address on the PE as the proxy address for the remote CE to conduct IPCP negotiation with the local CE.
Qtech(config-if-type ID)# ip ref	<input checked="" type="checkbox"/> For routers, the fast forwarding function of the interface must be enabled. You do not need to use this command on switches.
Qtech(config-if-type ID)# show running-config	Displays the existing configuration information.

Configure **serial 1/0** to provide the heterogeneous media VPWS service of the PPP access mode.

```
Qtech(config)# interface serial 1/0
Qtech(config-if-serial 1/0)# encapsulation ppp
```

Enable the fast forwarding function of the interface on routers. You do not need to use this command on switches.

```
Qtech(config-if-serial 1/0)# ip ref
Qtech(config-if-serial 1/0)# ppp ipcp address proxy 192.168.1.1
Qtech(config-if-serial 1/0)# exit
```

```
Qtech# configure terminal
Qtech# l2 vfi vpws1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# encapsulation mpls ip-interworking
Qtech(config-vfi)# route-target both 100:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface serial 1/0 remote-ce-id 2
```

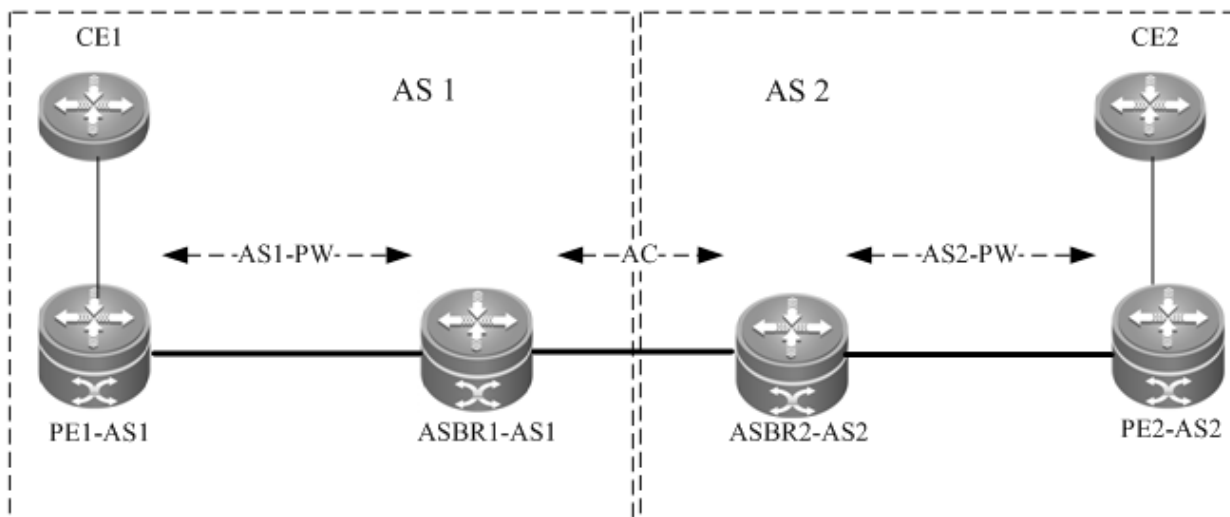
3.2.3.6 Configuring Inter-AS VPWS

In real application, multiple sites of a user's VPN may be connected to multiple SPs using different ASs or multiple ASs of an SP. The application mode in which the VPN crosses multiple ASs is called the inter-AS VPN. There are two solutions for configuring inter-AS VPWS:

- Inter-AS Option A: This solution is simple and can be adopted when the number of inter-AS L2VPNs on ASBR is small.
- Inter-AS Option C: You do not need to create or maintain any VCs on ASBR. When each AS has numerous inter-AS L2VPNs, this solution can be applied to solve the bottleneck of the ASBR's scalability.

Option A

Figure 51 Option A Inter-AS VPWS



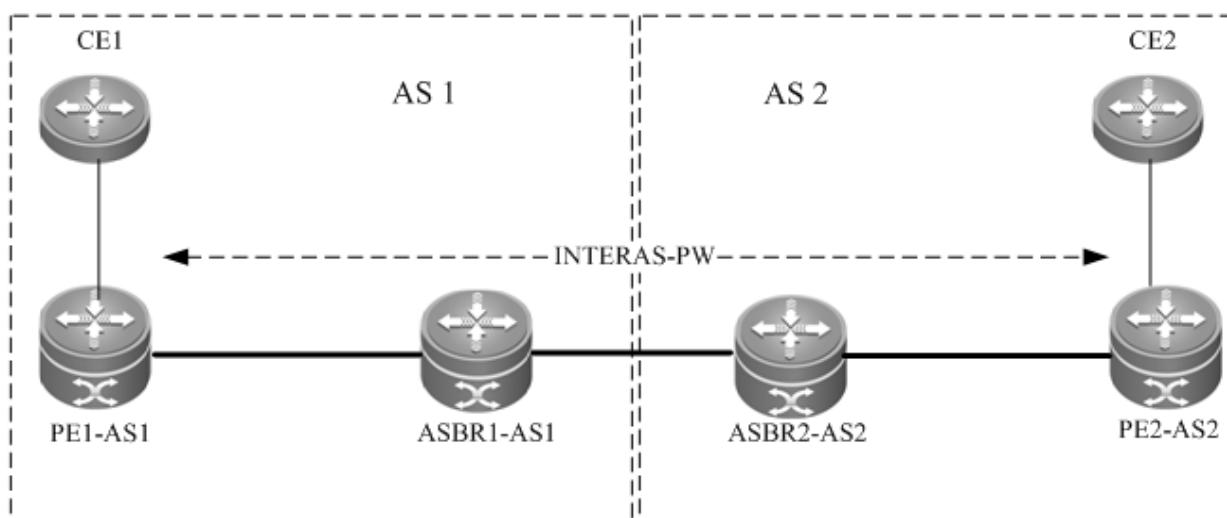
In the solution, ASBRs of two ASs are connected with each other and are PEs of their respective autonomous systems. Each ASBR considers the peer ASBR as its CE device. As shown in the preceding figure, for ASBR1-AS1 of AS1, ASBR2-AS2 of AS2 is only an accessed CE device; for ASBR2-AS2 of AS2, ASBR1-AS1 is also only an accessed CE device.

Option A is easy to implement. You do not need to especially configure two PEs that serve as ASBRs or configure an IP address for the interface between ASBRs. For each inter-AS L2VPN or each Inter-AS PW, a logical or physical link must be allocated between ASBRs of two ASs. When there are numerous inter-AS PWs, great pressure is caused to ASBRs, hindering the expansion.

The solution's configuration is similar to the aforementioned basic VPWS configuration.

Option C

Figure 52 Option C Inter-AS VPWS



As shown in the preceding figure, Option C is to set up an inter-AS PW on two ASs directly and switch PW labels. The principle is described as follows:

By sending tag IPv4 routes to the PE in respective ASs and sending tag IPv4 routes received by PEs in respective ASs to the ASBR peers of peer ASs, ASBRs connect the tunnel between two ASs and set up an LSP tunnel between the ingress PE and egress PE. Then, the Inter-AS LDP remote session are set up between PEs in different ASs and PW information are switched.

In the solution, ASBRs do not need to maintain inter-AS L2VPN information or prepare a physical or logical interface for the inter-AS L2VPN. However, it needs to provide an MPLS tunnel. The L2VPN information is directly switched between PEs, decreasing the pressure on ASBRs and facilitating the scalability.

The configuration procedure is as follows:

- 106) Configure MPLS signaling.
- 107) Configure PEs.
- 108) Configure ASBR.
- 109) Configure the L2VPN address family.
- 110) Configure a Kompella VPWS instance.
- 111) Configure the user access VPWS.
- 112) Check the configuration result.

In each AS, enable the MPLS and LDP functions on PE and P devices and the interface that connects to the P or PE device in AS of the ASBR to set up a basic MPLS network. For the configuration procedures, see the chapter about basic MPLS configuration.

■ Configuring PEs

Configure the PEs in ASs, set up an IBGP session between the PE and the AS, and exchange IPv4 routes that carry tags.

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp asn-number	Configures BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor asbr-address remote-as asbr-asn-number	Sets up IBGP sessions between the PE and ASBR.
Qtech(config-router)# neighbor asbr-address update-source interface-name	Uses the loopback address as the source address of the BGP session set up between peers.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# neighbor asbr-address send-label	Enables IPv4 route tag switching.
Qtech(config-router-af)# show running-config	Displays configuration information.

Set up the IBGP session with the ASBR device 10.10.10.2 and enable the IPv4 route tag switching function.


— Qtech# configure terminal

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```
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 10.10.10.2 remote-as 1
Qtech(config-router)# neighbor 10.10.10.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.2 activate
Qtech(config-router-af)# neighbor 10.10.10.2 send-label
Qtech(config-router-af)# exit
```

■ Configuring ASBRs

Configure ASBRs to set up the IBGP session with the PE in the same AS and with the ASBR in the other AS. Enable the IPv4 route tag switching function on both sessions and enable MPLS globally. Configure the PE address to be transmitted to another ASBR on the ASBR.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls ip	Enables the device to support MPLS forwarding.  Caution This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP protocol globally.
Qtech(config-mpls-router)# ldp router-id interface loopback id force	Configures the IP address of the loopback interface as the router ID.
Qtech(config-mpls-router)# advertise-labels for bgp-routes	Allocates labels for BGP's route.
Qtech(config-mpls-router)# exit	Returns to config mode.
Qtech(config)# router bgp asn-number	Configures BGP and enters BGP configuration mode.
Qtech(config-router)# neighbor asbr-address remote-as asbr-asn-number	Sets up EBGP session with ASBRs.
Qtech(config-router)# neighbor pe-address remote-as asn-number	Sets up EBGP session with PEs.
Qtech(config-router)# neighbor pe-address update-source loopback id	Uses the loopback address as the source address of the BGP session set up between PE peer.
Qtech(config-router)# address-family ipv4	Enters the IPv4 address family.
Qtech(config-router-af)# network pe-address mask mask-value	(Optional) Uses the network command to import the PE route received to BGP. The IGP protocol can be re-distributed to import the route
Qtech(config-router-af)# neighbor asbr-address send-label	Enables the IPv4 route label switching function on BGP that is set up with the ASBR in another AS.
Qtech(config-router-af)# neighbor pe-address send-label	Enables the IPv4 route label switching function on BGP that is set up with the PE in the same AS.
Qtech(config-router-af)# neighbor asbr-ip-address route-map name out	(Optional) Configures the route allocation policy. You can define route map rules (routemap) to control allocation of routes to neighbors and control whether these routes carry labels when they are sent.
Qtech(config-router-af)# neighbor asbr-ip-address route-map name in	(Optional) Configures the route allocation policy. You can define route map rules (routemap) to control only routes that carry labels.
Qtech(config-router-af)# show running-config	Displays configuration information.

In the following example, the configured ASBR sets up an EBGP session with the ASBR in another AS (30.30.30.2) and the label switching function is enabled for IPv4 routes. The IBG neighbor is created between the ASBR and the PE in the same AS (10.10.10.1) and the label switching function is enabled for IPv4 routes.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
```

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```
Qtech(config-mpls-router)# exit
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 30.30.30.2 remote-as 2
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 30.30.30.2 activate
Qtech(config-router-af)# neighbor 30.30.30.2 send-label
Qtech(config-router-af)# exit
Qtech(config-router)# neighbor 10.10.10.1 remote-as 1
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 10.10.10.1 send-label
Qtech(config-router-af)# exit
```



Caution

For the IBGP session set up between ASBR and the PE in the same AS, the **neighbor peer-address update-source loopback id** command must be used on the ASBR and PE to configure the address of the device's loopback interface as the source address of the session. Otherwise, the inter-AS LSP tunnel cannot be established.

The direct EBGP session established between ASBRs usually uses the direct connection interface's address as the source address of the BGP session to ensure that both ASBRs have routes that lead to each other. Therefore, you are not advised to use the **neighbor peer-address update-source loopback id** command on the EBGP session established based on direct connection to configure the address of the device's loopback interface as the source address of the session. If necessary, use the **neighbor ebgp-multihop** command to enable the multi-hop EBGP function, configure the static route on ASBR to ensure that the route can lead to the peer, and configure the static FTN to ensure that the inter-AS LSP's tunnel is available.

The **label-switching** command must be used on the interface between ASBRs to enable the interface's MPLS packet forwarding capability.

■ Configuring the L2VPN address family

Configure L2VPN address families between PEs of ASs. For detailed configuration, see the Configuring L2VPN Address Family chapter.

■ Configuring a Kompella VPWS instance

Configure L2VPN address families between PEs of ASs. For detailed configuration, see the Configuring Kompella VPWS Instance chapter.

■ Configuring the user access VPWS

For detailed configuration, see the Configuring User Access VPWS chapter.

■ Checking the configuration result

Command	Function
show bgp ipv4 unicast labels	Displays label information allocated by BGP for IPv4 routes.
show bgp l2vpn vpws all connections	Displays Kompella VPWS connection information.
show mpls l2transport vc [detail]	Displays VC status information.

View route and label information on an ASBR or a PE.

```
Qtech # show bgp ipv4 unicast labels
Network      Next Hop      In Label/Out Label
1.1.1.1/32    192.167.1.1  17/18
1.1.1.2/32    192.167.1.1  no-label/19
```

Field	Definition
Network	Route prefix
Nexthop	Route's next-hop
In Label	Label (if any) allocated by the router
Out Label	Label (if any) learned from the next-hop router of the route

View VC status information.

```
Qtech # show mpls l2transport vc detail
Local interface : VLAN 2, AC state: up
Peer address: 192.168.0.1 ,VC ID: 2, VC status: up
VC type: vlan      VC mode:tagged
Group id: 0        MTU: 1500
```

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```
Control Word not support
Output interface: VLAN 300 , imposed label stack {22 ,501 }
MPLS VC label: local 22, remote 22
```

Field	Definition
Local interface	Local interface bound by VC
AC state	AC status, up or down
Peer address	VC's peer IP address
VC ID	VC's unique identifier
VC status	VC status, up or down
VC type	VC type
VC mode	VC mode, tagged or raw (only applies to the Ethernet access mode)
Group id	VC's local group ID
MTU	MTU of the locally configured VC
Control Word	Whether the control word is supported
Output interface	Output interface on the public network used to transmit the VC process
imposed label stack	Added label stack
MPLS VC label	Local and peer private labels bound for the VC

3.2.3.7 Other Parameters for Configuring Kompella VPWS**Configuring VPWS Instance Descriptors (Optional)**

You can configure the descriptive information of each VPWS instance.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi vfi-name	Enters VFI configuration mode.
Qtech(config-vfi)# description vfi-description	(Optional) Configures VFI's descriptive information.
Qtech(config-vfi)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configuring VPWS's Compatibility (Optional)

By default, the PW's mtu value provided by L2VPN is 1500 bytes. If the same PW's mtu values on two PEs are different, PW connection cannot be set up between the two PEs. Some manufacturers' devices do not support configuring mtu in L2VPN instances. When such devices perform Kompella communication with devices of other manufacturers, the **ignore match l2-extcommunity** command can be used to ignore received mtu and matching detection of **EncapsType** and **Control Flag**, ensuring that the VC link is UP.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id autodiscovery	Creates the Kompella VPWS instance and enters VPWS configuration mode.
Qtech(config-vfi)# ignore match l2-extcommunity	Configures ignoring detection of L2VPN expanded community attribute members.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

This command only takes effect on Kompella L2VPN.

Configuring mtu of a VPWS Instance (Optional)

You can configure each VFI instance's mtu value, which is **1500** by default. The mtu value of VFI indicates the length of the packet that can be transmitted by the PW, or the length of the user's layer-2 packet plus the length of the PW-encapsulated packet. By default, if the PW does not enable the control word, assuming that two labels are encapsulated, the length of an Ethernet packet that can be transmitted is 1492 bytes, of which 8 bytes are encapsulated by the PW (2 labels).

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi name	Enters VFI configuration mode.

Qtech(config-vfi)# mtu <i>mtu</i>	(Optional) Configures the mtu value of the VFI.
Qtech(config-vfi)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

The mtu values of one VFI instance on different PEs must be the same. Otherwise, the signaling protocol cannot establish PWs.

If the PW signaling protocol negotiation's mtu is modified, the mtu of the user access service interface must be adjusted (generally adjusted to the PW mtu length minus the encapsulated length); the PW's public-network-end output interface's mtu, MPLS mtu and PW mtu must be the same to ensure proper forwarding. The **mtu** command can be used on an interface to modify the interface's mtu. Use the **mpls mtu** command to modify the interface's MPLS mtu.

3.2.4 Configuring Static VC FTN and ILM Entries (Optional)

There are two methods to add VC FTN and ILM entries: by switching VC labels through the extended LDP and static configurations. These two methods cannot be applied to a VC instance at the same time. That is, if you add a VC FTN or ILM entry through the extended LDP, you cannot use the CLI command to add entries for the VC. Similarly, if you use the CLI command to add a VC FTN or ILM entry, you cannot add VC FTN or ILM entry by using the VPWS signaling protocol.

The procedure for configuring a VC FTN entry is as follows:

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls static l2vc-ftn <i>vc-id vc-peer-ip out-label out-label</i>	Configures an FTN entry for a static VC instance.
Qtech(config)# show running-config	Displays all configuration information.

The procedure for configure a VC ILM entry is as follows:

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls static ilm in-label <i>in_label forward-action pop-l2vc-destport</i> <i>vc-id vc_peer_addr</i>	Configures an ILM entry for a static VC instance.
Qtech(config)# show running-config	Displays all configuration information.

**Caution**

We do not recommend configuring static VC FTN and ILM when using the VPWS dynamic signaling protocol to establish PW. For configured static VC forwarding table entries, the static public network LSP must be configured. VC is only effective when the corresponding public network LSP tunnel exists. Static VC FTN and ILMF are not needed for heterogeneous media communication. Static VC FTN and ILM do not take effect on a Kompella VPWS VC instance but only on a Martini VC instance. That is, they are generated by static forwarding table entries, not by LDP signaling.

3.2.5 Configuring Static PW (Optional)

When you can access the Martini VPWS via CLI configuration, you can specify the mode as the static mode, and then configure the outgoing label and incoming label of the VC manually instead of adding the FTN and ILM options of the VC through Label Distribution Protocol (LDP).

Run the following commands to configure a VPWS static PW:

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Configures and enters the VLAN interface configuration mode.
Qtech(config-if-type ID)# xconnect <i>vc_peer</i> <i>vc_id encapsulation mpls ethernet raw</i> manual	Creates a VC and configures the raw encapsulation mode.
Qtech(config-if-type ID)# exit	Exits the interface configuration mode.

Qtech(config)# mpls static-l2vc <i>ipv4-address vc-id out-label out-label-value in-label in-label-value</i>	Configures the outgoing label and incoming label of the static PW.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

The static PW does not apply to heterogeneous media interconnection. The outgoing and incoming labels of the static PW do not take effect on the VC instances of the Kompella VPWS. They only apply to the VC instances of the Martini VPWS, that is, the static forwarding entry instead of LDP signaling is adopted.

3.2.6 Maintaining PW Connectivity of VPWS

Configuration Prerequisites

When using VCCV to check the PW connectivity of VPWS, you must ensure that the VPWS network is already correctly configured.

3.2.6.1 Checking PW Connectivity

Command	Function
Qtech# ping mpls pseudowire { <i>ip-address vc-id [segment segment-number] kompella vfi_name local_site_id remote_site_id rd remote_rd</i> } { label-alert ttl-expiry } [repeat repeat] [timeout timeout] [size size] [interval mseconds] [source ip-address] [destination ip-address] [pad pattern] [reply mode { ipv4 router-alert control-channel }] [verbose]	Checks the PW connectivity.

Example: Check the connectivity of the PW whose peer PE IPv4 address is 10.10.10.3 and PW ID is 100.

```
Qtech#ping mpls pseudowire 10.10.10.3 100 label-alert

Sending 5, 112-byte MPLS Echoes on Pseudowire, peer address 10.10.10.3, VC ID 100,
    timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0

Press Ctrl+C to break.
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 ms
```

3.2.6.2 Locating Data Plane Fault of PW

Command	Function
Qtech# traceroute mpls pseudowire { <i>ip-address vc-id [segment segment-number] kompella vfi_name local_site_id remote_site_id rd remote_rd</i> } { label-alert ttl-expiry } [timeout timeout] [source ip-address] [destination ip-address] [reply mode { ipv4 router-alert control-channel }] [verbose]	Traces the PW path.

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Example: Track the path of the PW whose VFI name is vpn-1, local VE ID is 1, remote VE ID is 2, and remote RD is 200:1 to locate the fault.

```
Qtech#traceroute mpls pseudowire kompella vpn-1 1 2 label-alert rd 200:1
Tracing Pseudowire Label Switched Path, VFI name vpn-1, local site id 1, remote site
id 2, timeout is 2 seconds.
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0

Press Ctrl+C to break.
 0 192.168.1.10      MRU 1500 [Labels: router-alert/1538 Exp: 0/0]
! 1 192.168.1.11    20 ms
```

3.2.7 Verifying VPWS Configuration

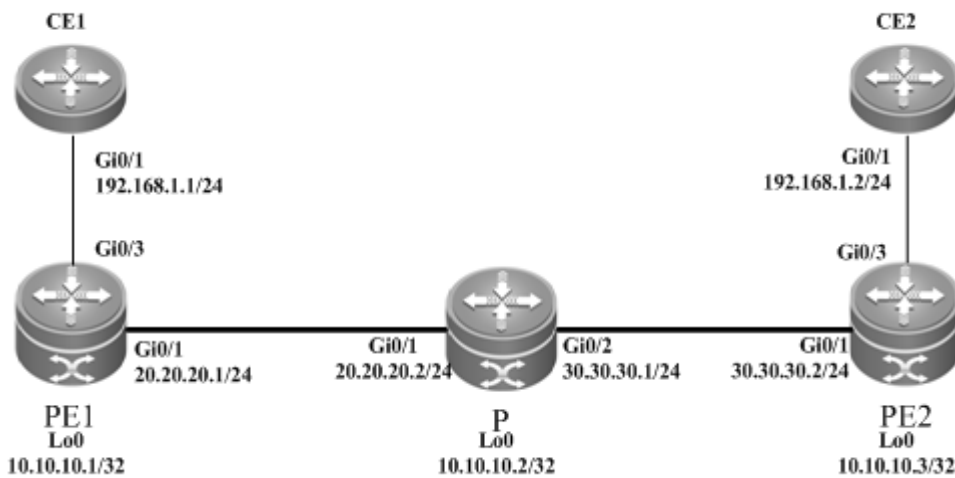
Command	Function
show bgp l2vpn vpws all	Displays NLRI information about all Kompella VPWS instances.
show bgp l2vpn vpws all connections	Displays Kompella VPWS signaling information.
show mpls l2transport vc [vc_id [ip-address]] [interface interface_name] [detail]	Displays VC information established by VPWS.
show mpls vfi [name]	Displays VFI instance information of Kompella VPWS.
show mpls ldp vc	Displays VC signaling information of Martini VPWS.

3.2.8 Martini VPWS Router Configuration Instance

3.2.8.1 Connecting CEs to PEs Through Ethernet

As shown in the following network topology, the interface between PEs and CEs is an Ethernet interface. That is, CEs are connected to PEs through the Ethernet interface, through which L2VPN service is provided between CE1 and CE2.

Figure 53



The configuration procedure is as follows:

- Configuring CE1:

Configure the interface that connects CE1 and PE1.

```
Qtech(config)# interface gigabitethernet 0/1
```

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```
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.1.1 255.255.255.0
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# end
```

■ Configuring PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)# xconnect 10.10.10.3 2 encapsulation mpls ethernet
raw
Qtech(config-if-GigabitEthernet 0/3)# exit
```

■ Configuring P:

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

■ Configuring PE2:

The configuration is similar to that of PE1.

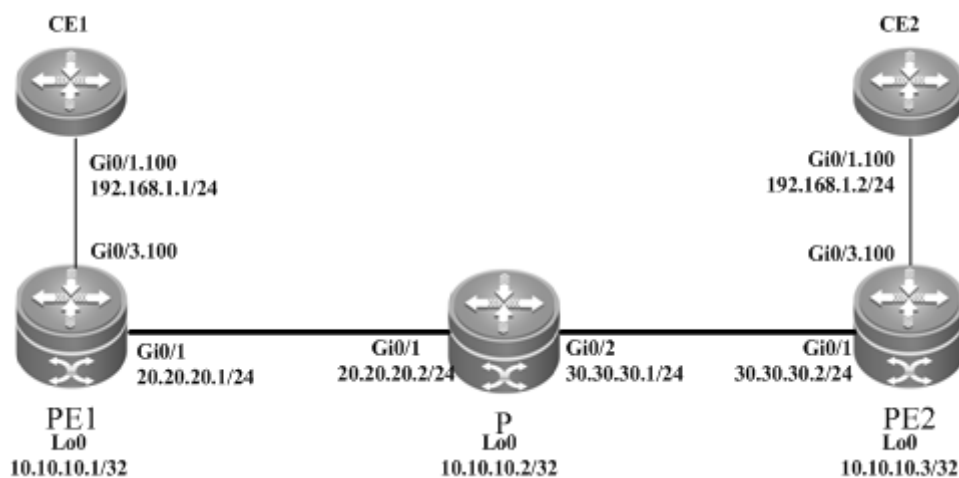
■ Configuring CE2:

The configuration is similar to that of CE1.

3.2.8.2 Connecting CEs to PEs Through VLAN

As shown in the following network topology, the interface between PEs and CEs is an Ethernet sub-interface. That is, CEs are connected to PEs through the Ethernet sub-interface, through which L2VPN service is provided between CE1 and CE2.

Figure 54



The configuration procedure is as follows:

■ Configuring CE1:

Configure the interface that connects CE1 and PE2.

```
Qtech(config)# interface gigabitethernet 0/1
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-gigabitethernet 0/1)# exit
Qtech(config)# interface gigabitethernet 0/1.100
Qtech(config-if-Gigabitethernet 0/1.100)# encapsulation dot1Q 100
Qtech(config-if-Gigabitethernet 0/1.100)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1.100)# end
```

■ Configuring PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 0/3
Qtech(config-if-Gigabitethernet 0/3)# ip ref
Qtech(config-if-Gigabitethernet 0/3)# exit
Qtech(config)# interface gigabitethernet 0/3.100
Qtech(config-if-Gigabitethernet 0/3.100)# encapsulation dot1Q 100
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 0/3.100)# xconnect 10.10.10.3 2 encapsulation mpls
ethernetvlan tagged
Qtech(config-if-GigabitEthernet 0/3.100)# exit
```

■ **Configuring P:**

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

■ **Configuring PE2:**

The configuration is similar to that of PE1.

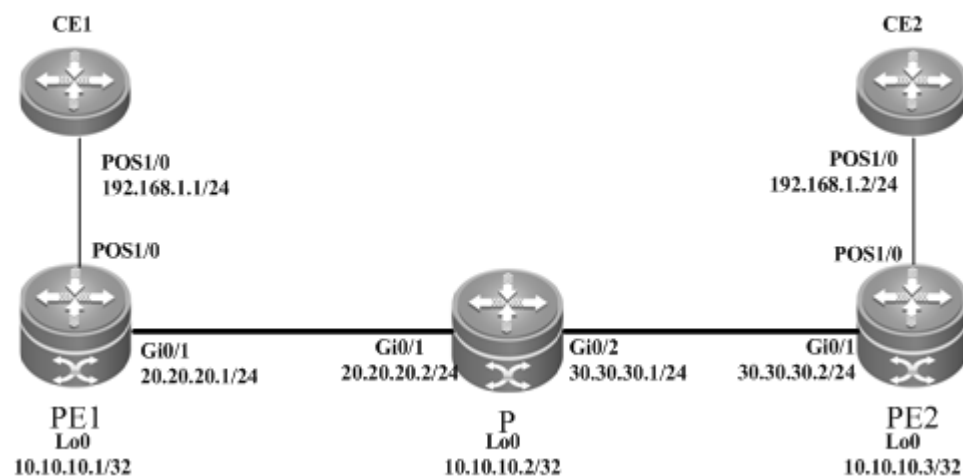
■ **Configuring CE2:**

The configuration is similar to that of CE1.

3.2.8.3 Connecting CEs to PEs Through PPP

As shown in the following network topology, the interface between PEs and CEs is a POS interface. That is, the PPP link protocol is encapsulated and CEs are connected to PEs through PPP, through which L2VPN service is provided between CE1 and CE2.

Figure 55



The configuration procedure is as follows:

■ **Configuring CE1:**

Configure the interface that connects CE1 and PE2.

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# encapsulation ppp
Qtech(config-if-pos 1/0)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-pos 1/0)# clock internal
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-pos 1/0)# ip ref
Qtech(config-if-pos 1/0)# end
```

■ **Configuring PE1:**

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 0/1
```

```
Qtech(config-if-GigabitEthernet 0/1)# ip address 20.20.20.1 255.255.255.0
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# encapsulation ppp
Qtech(config-if-pos 1/0)# clock internal
Qtech(config-if-pos 1/0)# xconnect 10.10.10.3 2 encapsulation mpls ppp
Qtech(config-if-pos 1/0)# end
```

- **Configuring P:**

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

- **Configuring PE2:**

The configuration is similar to that of PE1.

- **Configuring CE2:**

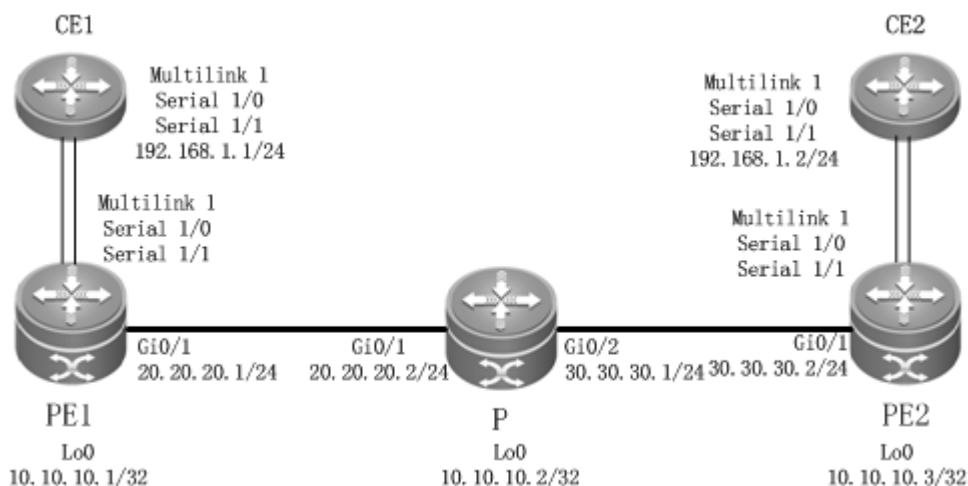
The configuration is similar to that of CE1.

3.2.8.4 Connecting CEs to PEs Through MultiPPP

As shown in the following network topology, PEs and CEs are connected through the Serial interface and the PPP protocol is encapsulated. PEs and CEs bind two Serial interfaces, which work in MultiPPP mode. Therefore, CEs are connected to PEs through MultiPPP to establish the L2VPN service between CE1 and CE2.

CEs are connected to PEs through MultiPPP by enabling the heterogeneous media access mode on the PE-end multilink interface. The mode does not support the homogeneous media access mode.

Figure 56



The configuration procedure is as follows:

- **Configuring CE1:**

Configure the multilink interface that connects CE1 and PE2.

```
Qtech(config)# interface mutilink 1
Qtech(config-multilink 1)# ip address 192.168.1.1 255.255.255.0
```

Enable the fast forwarding function of routers on the interface for routers. You do not use this command on switches.

```
Qtech(config-multilink 1)# ip ref
Qtech(config-multilink 1)# end
```

3. Configuring L2VPN

Configure the serial interface bound with the multilink interface.

```
Qtech(config)# interface serial 1/0
Qtech(config-serial 1/0)# encapsulation ppp
Qtech(config-serial 1/0)# ppp multilink
Qtech(config-serial 1/0)# ppp multilink group 1
Qtech(config-serial 1/0)# end
Qtech(config)# interface serial 1/1
Qtech(config-serial 1/1)# encapsulation ppp
Qtech(config-serial 1/1)# ppp multilink
Qtech(config-serial 1/1)# ppp multilink group 1
Qtech(config-serial 1/1)# end
```

- **Configuring PE1:**

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

Configure the multilink interface.

```
Qtech(config)# interface mutilink 1
Qtech(config-multilink 1)# ip ref
Qtech(config-multilink 1)# xconnect 10.10.10.3 2 encapsulation mpls ip-interworking
Qtech(config-multilink 1)# ppp ipcp address proxy 192.168.1.2
```

Configure the serial interface bound with the multilink interface.

```
Qtech(config)# interface serial 1/0
Qtech(config-serial 1/0)# encapsulation ppp
Qtech(config-serial 1/0)# ppp multilink
Qtech(config-serial 1/0)# ppp multilink group 1
Qtech(config-serial 1/0)# end
Qtech(config)# interface serial 1/1
Qtech(config-serial 1/1)# encapsulation ppp
Qtech(config-serial 1/1)# ppp multilink
Qtech(config-serial 1/1)# ppp multilink group 1
Qtech(config-serial 1/1)# end
```

- **Configuring P:**

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

- **Configuring PE2:**

The configuration procedure is similar to that of PE1.

- **Configuring CE2:**

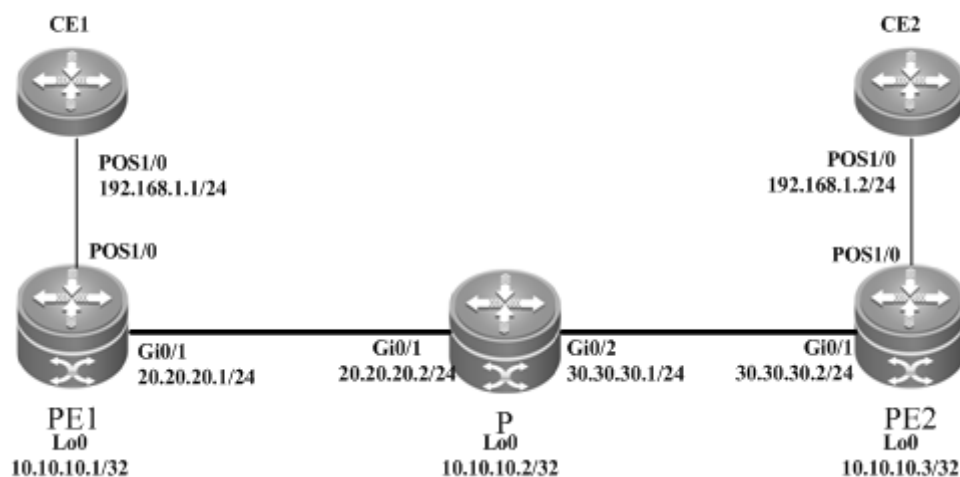
The configuration procedure is similar to that of CE1.

3. Configuring L2VPN

3.2.8.5 Connecting CEs to PEs Through HDLC

As shown in the following network topology, the interface that connects PEs and CEs is a POS interface and the HDLC link protocol is encapsulated. That is, CEs are connected to PEs through a HDLC interface, through which L2VPN service is provided between CE1 and CE2.

Figure 57



The configuration procedure is as follows:

- Configuring CE1:

Configure the interface that connects CE1 and PE2.

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# encapsulation hdlc
Qtech(config-if-pos 1/0)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-pos 1/0)# clock internal
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-pos 1/0)# ip ref
Qtech(config-if-pos 1/0)# end
```

- Configuring PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

3. Configuring L2VPN

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# encapsulation hdlc
Qtech(config-if-pos 1/0)# clock internal
Qtech(config-if-pos 1/0)# xconnect 10.10.10.3 2 encapsulation mpls hdlc
Qtech(config-if-pos 1/0)# end
```

■ **Configuring P:**

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

■ **Configuring PE2:**

The configuration is similar to that of PE1.

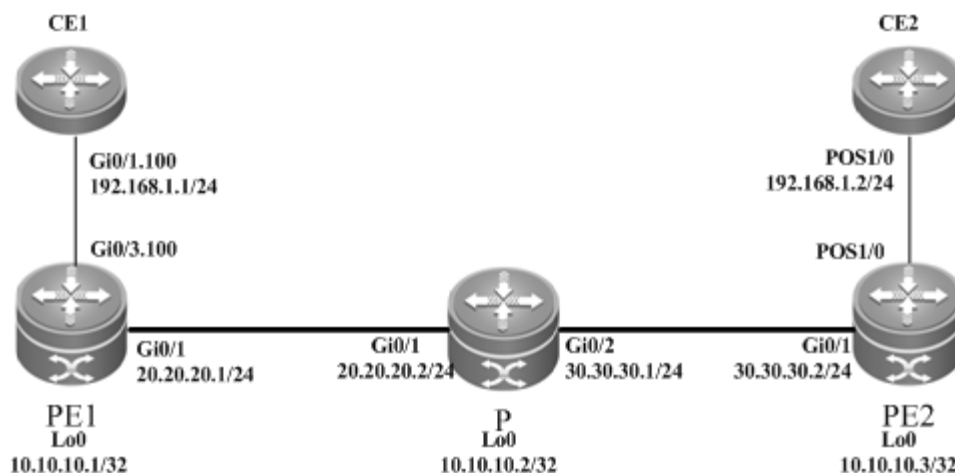
■ **Configuring CE2:**

The configuration is similar to that of CE1.

3.2.8.6 VLAN and PPP Heterogeneous Media Communication

As shown in the following network topology, the interface that connects PE1 and CE1 is an Ethernet sub-interface and the encapsulated link protocol is 802.1Q. PE2 and CE2 are connected through the POS interface and the encapsulated link protocol is PPP, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.

Figure 58



The configuration procedure is as follows:

Configure the interface that connects CE1 and PE1.

```
Qtech(config)# interface gigabitethernet 0/1
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-gigabitethernet 0/1)# exit
Qtech(config)# interface gigabitethernet 0/1.100
Qtech(config-if-gigabitethernet 0/1.100)# encapsulation dot1Q 100
Qtech(config-if-gigabitethernet 0/1.100)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-gigabitethernet 0/1.100)# end
```

■ **Configuring PE1:**

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
```

3. Configuring L2VPN

```
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 0/3
Qtech(config-if-Gigabitethernet 0/3)# ip ref
Qtech(config-if-Gigabitethernet 0/3)# exit
Qtech(config)# interface gigabitethernet 0/3.100
Qtech(config-if-Gigabitethernet 0/3.100)# encapsulation dot1Q 100
Qtech(config-if-Gigabitethernet 0/3.100)# xconnect 10.10.10.3 2 encapsulation mpls ip-
interworking local-ce mac 00d0.f811.2111
Qtech(config-if-Gigabitethernet 0/3.100)# exit
```

- **Configuring P:**

Configure the public network route protocol and LSP tunnel.

The configuration procedures is similar to the aforementioned MPLS basic function configuration instance.

- **Configuring PE2:**

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.3 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.1
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.3 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface pos 1/0
Qtech(config-if-pos1/0)# ip ref
Qtech(config-if-pos1/0)# encapsulation ppp
Qtech(config-if-pos1/0)# ppp ipcp address proxy 192.168.1.1
Qtech(config-if-pos1/0)# xconnect 10.10.10.3 2 encapsulation mpls ip-interworking
Qtech(config-if-pos1/0)# exit
```

- **Configuring CE2:**

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# ip ref
Qtech(config-if-pos 1/0)# encapsulation ppp
Qtech(config-if-pos 1/0)# ip address 192.168.1.2 255.255.255.0
```

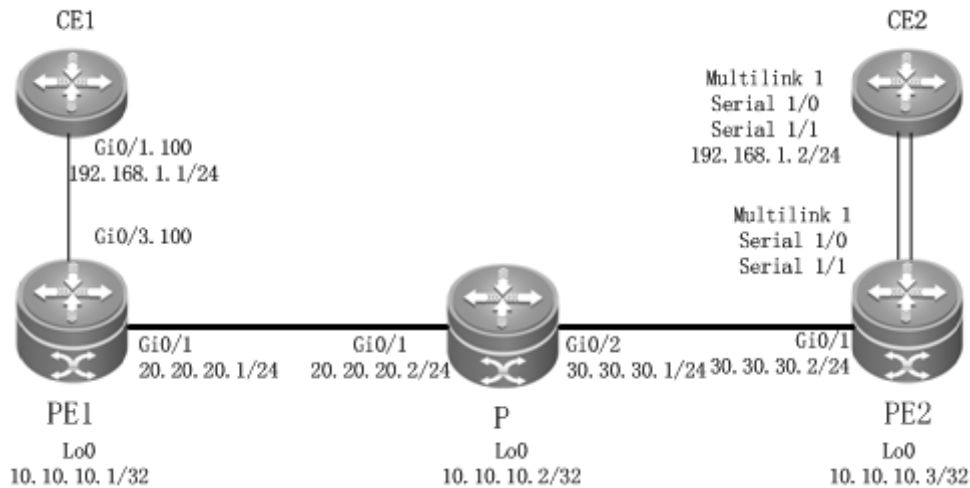
3. Configuring L2VPN

```
Qtech(config-if-pos 1/0)# clock internal
Qtech(config-if-pos 1/0)# end
```

3.2.8.7 VLAN and MultiPPP Heterogeneous Media Communication

As shown in the following network topology, the interface that connects PE1 and CE1 is an Ethernet sub-interface and the encapsulated link protocol is 802.1Q. PE2 and CE2 are connected through the Serial interface and the encapsulated link protocol is PPP. PPP is bound by two physical lines in the MultiPPP working mode, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.

Figure 59



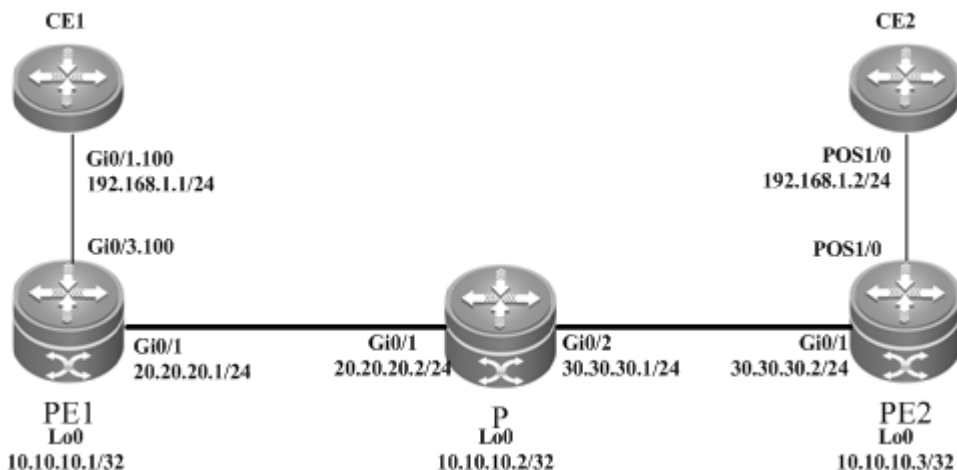
The configuration of CE1 and PE1 is generally the same as the configuration of VLAN and PPP heterogeneous media communication.

The configuration of CE2 and PE2 is generally the same as the configuration of a CE when it is connected to a PE through MultiPPP.

3.2.8.8 VLAN and HDLC Heterogeneous Media Communication

As shown in the following network topology, the interface between PE1 and CE1 is an Ethernet sub-interface and the encapsulated link protocol is 802.1Q. PE2 and CE2 are connected through the POS interface and the encapsulated link protocol is HDLC, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.

Figure 60



The configuration procedure is as follows:

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Configure the interface that connects CE1 and PE1.

```
Qtech(config)# interface gigabitethernet 0/1
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-gigabitethernet 0/1)# exit
Qtech(config)# interface gigabitethernet 0/1.100
Qtech(config-if-Gigabitethernet 0/1.100)# encapsulation dot1Q 100
Qtech(config-if-Gigabitethernet 0/1.100)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1.100)# end
```

■ Configuring PE1:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.3
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 0/3
Qtech(config-if-Gigabitethernet 0/3)# ip ref
Qtech(config-if-Gigabitethernet 0/3)# exit
Qtech(config)# interface gigabitethernet 0/3.100
Qtech(config-if-Gigabitethernet 0/3.100)# encapsulation dot1Q 100
Qtech(config-if-Gigabitethernet 0/3.100)# xconnect 10.10.10.3 2 encapsulation mpls ip-
interworking local-ce mac 00d0.f811.2111
Qtech(config-if-Gigabitethernet 0/3.100)# exit
```

■ Configuring P:

Configure the public network route protocol and LSP tunnel.

The configuration procedure is similar to the aforementioned MPLS basic function configuration instance.

■ Configuring PE2:

Configure the loopback interface.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.3 255.255.255.255
```

Configure the public network LSP tunnel and remote LDP neighbor.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 10.10.10.1
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-Gigabitethernet 0/1)# mpls ip
Qtech(config-if-Gigabitethernet 0/1)# label-switching
```

3. Configuring L2VPN

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# exit
Qtech(config)# router ospf 10
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.3 0.0.0.0 area 0
Qtech(config-router)# end
```

Configure the interface that connects PEs and CEs to enable the VPWS service.

```
Qtech# configure terminal
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# ip ref
Qtech(config-if-pos1/0)# encapsulation hdlc
Qtech(config-if- pos1/0)# xconnect 10.10.10.3 2 encapsulation mpls ip-interworking
Qtech(config-if-pos1/0)# exit
```

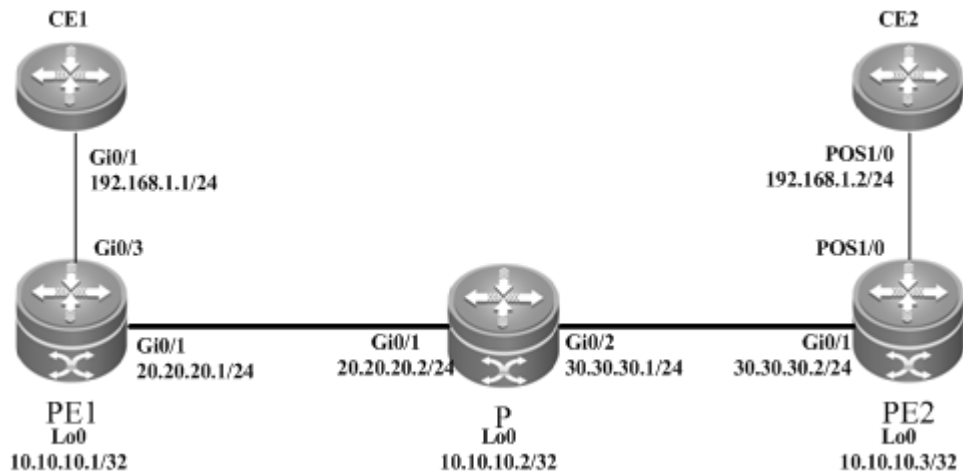
- **Configuring CE2:**

```
Qtech(config)# interface pos 1/0
Qtech(config-if-pos 1/0)# ip ref
Qtech(config-if-pos 1/0)# encapsulation hdlc
Qtech(config-if-pos 1/0)# ip address 192.168.1.2 255.255.255.0
Qtech(config-if-pos 1/0)# clock internal
Qtech(config-if-pos 1/0)# end
```

3.2.8.9 Ethernet and PPP Heterogeneous Media Communication

As shown in the following network topology, the interface between PE1 and CE1 is an Ethernet interface and the encapsulated link protocol is EthernetII. PE2 and CE2 are connected through the POS interface and the encapsulated link protocol is PPP, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.

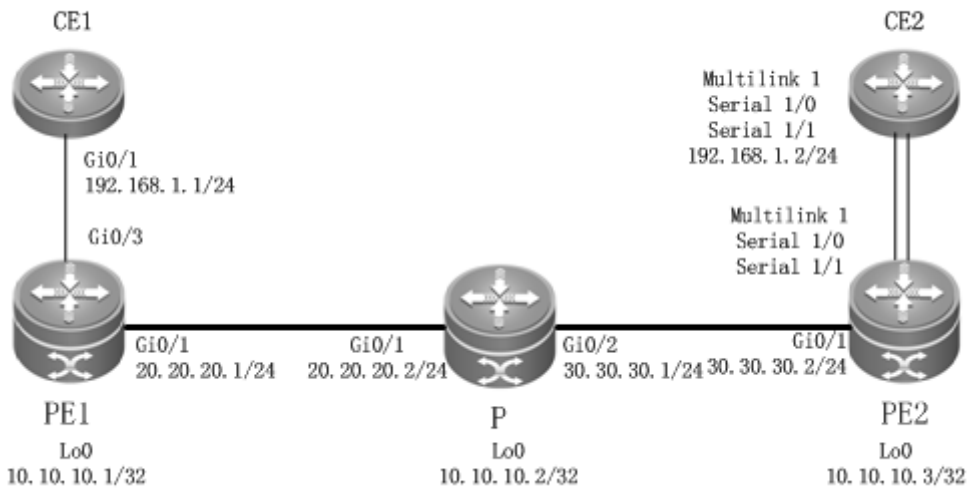
Figure 61



The configuration is generally the same as that for VLAN and PPP heterogeneous media communication, except the access modes of PE1 and CE1.

3.2.8.10 Ethernet and MultiPPP Heterogeneous Media Communication

As shown in the following network topology, the interface between PE1 and CE1 is an Ethernet interface and the encapsulated link protocol is EthernetII. PE2 and CE2 are connected through the Serial interface and the encapsulated link protocol is PPP. PPP is bound by two physical lines in the MultiPPP working mode, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.



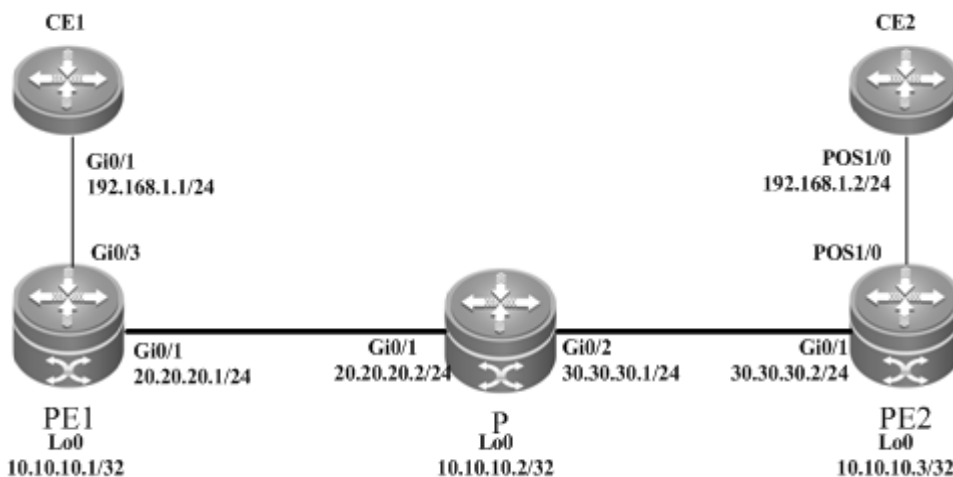
The configuration of CE1 and PE1 is generally the same as that for VLAN and PPP heterogeneous media communication, except the access mode of PE1 and CE1.

The configuration of CE2 and PE2 is generally the same as the configuration of a CE when it is connected to a PE through MultiPPP.

3.2.8.11 Ethernet and HDLC Heterogeneous Media Communication

As shown in the following network topology, the interface between PE1 and CE1 is an Ethernet interface and the encapsulated link protocol is EthernetII. PE2 and CE2 are connected through the POS interface and the encapsulated link protocol is HDLC, through which the L2VPN service is established between CE1 and CE2. VPWS provides the heterogeneous media communication L2VPN service.

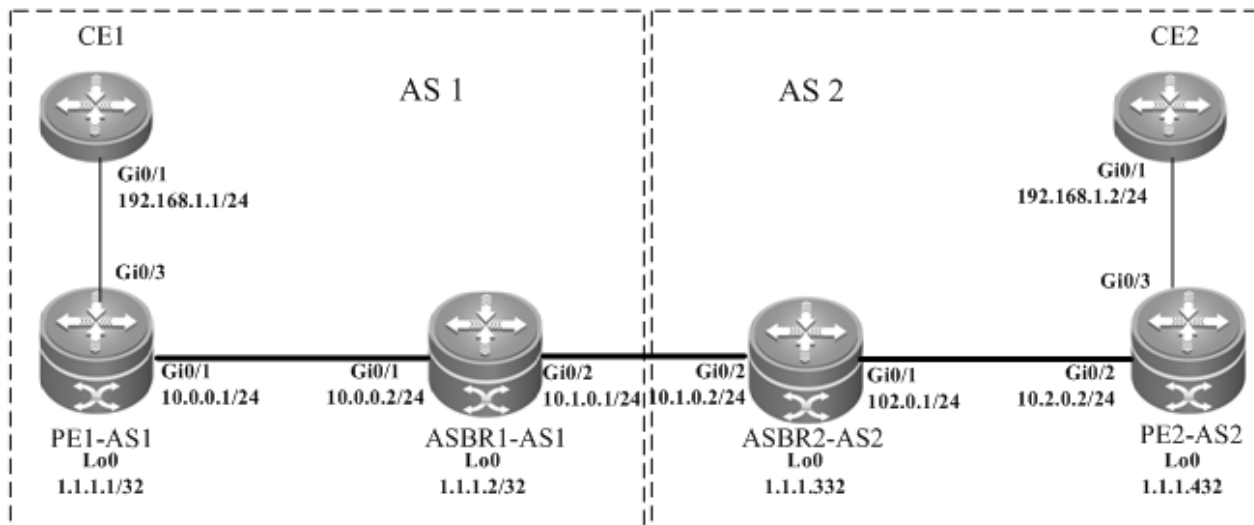
Figure 63



The configuration is generally the same as the configuration of VLAN and HDLC heterogeneous media communication, except the access modes of PE1 and CE1.

3.2.8.12 Option C Inter-AS VPWS

Figure 64 Option C: Inter-AS VPWS



The preceding figure shows how to realize inter-AS VPWS by using the Option C solution. To set up a PW between PEs of different ASs, PW information is not maintained on ASBR and OSPF is used in each AS as IGP to realize inter-AS communication. Assuming that CE1 is connected to a PE through the master port, it is required to establish L2VPN communication between CE1 and CE2. Configuration of devices is described as follows (only configuration related to the function is included):

■ Configuring CE1:

```
Qtech# configure terminal
Qtech(config)# interface GigabitEthernet 0/1
```

The **no switchport** command is used on switches to switch the port mode to the Routed Port mode. It does not apply to routers and does not need to be used on routers.

```
Qtech(config-if-GigabitEthernet 0/1)# no switchport
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.1.1 255.255.255.0
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# end
```

The configuration of CE2 is similar to that of CE1.

■ Configuring PE1-AS1:

Configure the public network route protocol, MPLS signaling, and remote neighbors.

```
Qtech# configure terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.4
Qtech(config-mpls-router)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.0.0.0 0.0.0.255 area 0
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# exit
Qtech(config)# interface GigabitEthernet 0/1
```

The **no switchport** command is used on switches to switch the port mode to the Routed Port mode. It does not apply to routers and does not need to be used on routers.

```
Qtech(config-if-GigabitEthernet 0/1)# no switchport
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 10.0.0.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# end
```

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Configure BGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.2 remote-as 1
Qtech(config-router)# neighbor 1.1.1.2 update-source loopback 0
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 1.1.1.2 activate
Qtech(config-router-af)# neighbor 1.1.1.2 send-label
Qtech(config-router-af)# end
```

Configure the user access VPWS.

```
Qtech# configure terminal
Qtech(config)# interface GigabitEthernet 0/3
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/3)# ip ref
Qtech(config-if-GigabitEthernet 0/3)# xconnect 1.1.1.1 1 encapsulation mpls ethernet
Qtech(config-if-GigabitEthernet 0/3)# end
```

The configuration of PE2-AS2 is similar to that of PE1-AS1.

■ Configuring ASBR1-AS1:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure the public network route protocol and MPLS signaling.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface GigabitEthernet 0/1
```

The **no switchport** command is used on switches to switch the port mode to the Routed Port mode. It does not apply to routers and does not need to be used on routers.

```
Qtech(config-if-GigabitEthernet 0/1)# no switchport
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/3)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 10.0.0.2 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.0.0.0 0.0.0.255 area 0
Qtech(config-router)# network 1.1.1.2 0.0.0.0 area 0
Qtech(config-router)# exit
```

Configure the IP address of the interface connected to ASBR2.

```
Qtech(config)# interface GigabitEthernet 0/2
```

The **no switchport** command is used on switches to switch the port mode to the Routed Port mode. It does not apply to routers and does not need to be used on routers.

```
Qtech(config-if-GigabitEthernet 0/2)# no switchport
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/2)# ip ref
Qtech(config-if-GigabitEthernet 0/2)# ip address 10.1.0.1 255.255.255.0
```

Enable the interface's label packet forwarding capability.

```
Qtech(config-if-GigabitEthernet 0/2)# label-switching
Qtech(config-if-GigabitEthernet 0/2)# exit
```

Configure BGP.

```
Qtech# configure terminal
Qtech(config)# router bgp 1
Qtech(config-router)# neighbor 1.1.1.1 remote-as 1
```

3. Configuring L2VPN

```
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 10.1.0.2 remote-as 2
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-label
Qtech(config-router-af)# neighbor 10.1.0.2 activate
Qtech(config-router-af)# neighbor 10.1.0.2 send-label
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

The configuration of ASBR2-AS2 is similar to that of ASBR1-AS1.

The configuration of PE2-AS2 is similar to that of PE1-AS1.

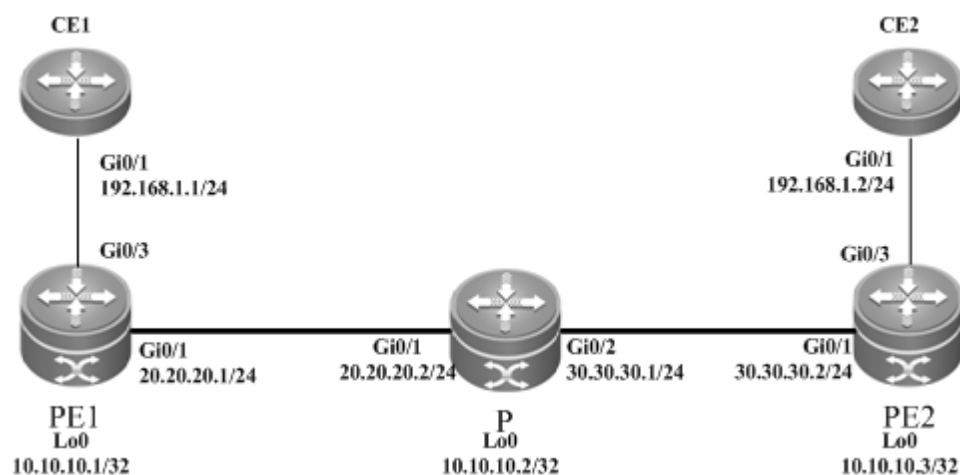
The configuration of CE2 is similar to that of CE1.

3.2.9 Kompella VPWS Router Configuration Instance

3.2.9.1 Connecting CEs to PEs Through Ethernet

As shown in the following network topology, the interface between PEs and CEs is an Ethernet interface. That is, CEs are connected to PEs through the Ethernet interface, through which the L2VPN service is provided between CE1 and CE2.

Figure 65



The configuration procedure is as follows:

Configuring CE1:

Configure the interface between CE1 and PE1.

```
Qtech(config)# interface gigabitethernet 0/1
Qtech(config-if-Gigabitethernet 0/1)# ip address 192.168.1.1 255.255.255.0
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitethernet 0/1)# ip ref
Qtech(config-if-Gigabitethernet 0/1)# end
```

Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
```

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```
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 10.10.10.3 remote-as 100
Qtech(config-router)# neighbor 10.10.10.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 10.10.10.3 activate
Qtech(config-router-af)# neighbor 10.10.10.3 send-community extended
Qtech(config-router-af)# exit
```

Configure a VFI instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 0/3 remote-ce-id 2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Enable the interface to connect to remote CEs.

```
Qtech(config)# interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)# ip ref
Qtech(config-if-GigabitEthernet 0/3)# exit
```

Configuring P:

Configure the public network route protocol and LSP tunnel.

The configuration is similar to the aforementioned MPLS basic function configuration instance.

Configuring PE2:

The configuration is similar to that of PE1.

Configuring CE2:

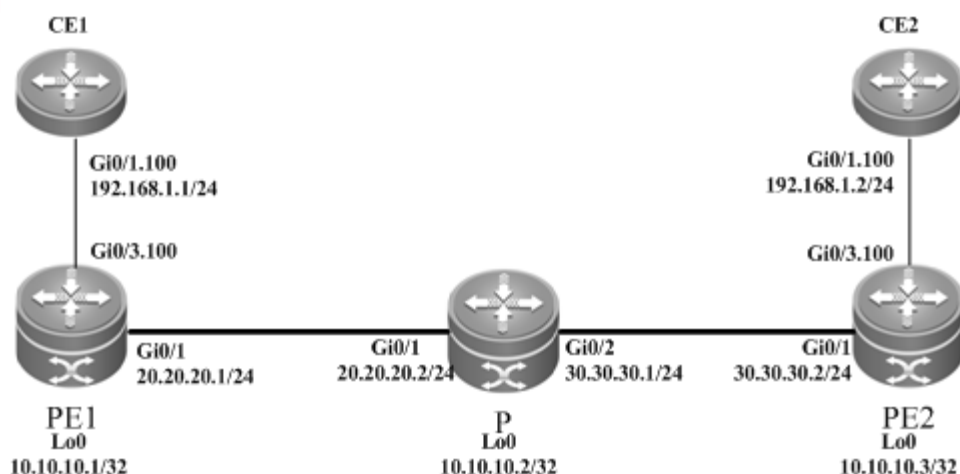
The configuration is similar to that of CE1.

3.2.9.2 Connecting CEs to PEs Through VLAN

As shown in the following network topology, the interface that connects PEs and CEs is an Ethernet sub-interface. That is, CEs are connected to PEs through the Ethernet sub-interface, through which L2VPN service is provided between CE1 and CE2.

Figure 66

3. Configuring L2VPN



The configuration procedure is as follows:

Configuring CE1:

Configure the interface between CE1 and PE1.

```
Qtech(config)# interface gigabitEthernet 0/1
```

Enable the fast forwarding function of routers on the interface for routers. You do not need to use this command on switches.

```
Qtech(config-if-gigabitEthernet 0/1)# ip ref
Qtech(config-if-gigabitEthernet 0/1)# exit
Qtech(config)# interface gigabitEthernet 0/1.100
Qtech(config-if-GigabitEthernet 0/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 0/1.100)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1.100)# end
```

Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 10.10.10.3 remote-as 100
Qtech(config-router)# neighbor 10.10.10.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 10.10.10.3 activate
Qtech(config-router-af)# neighbor 10.10.10.3 send-community extended
Qtech(config-router-af)# exit
```


3. Configuring L2VPN

Configure the interface to connect with remote CEs.

```
Qtech(config-if-GigabitEthernet 0/3.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 0/3)# exit
```

Configure a VFI instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 0/3.100 remote-ce-id 2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configuring P:

Configure the public network route protocol and LSP tunnel.

The configuration is similar to the aforementioned MPLS basic function configuration instance.

Configuring PE2:

The configuration procedure is similar to that of PE1.

Configuring CE2:

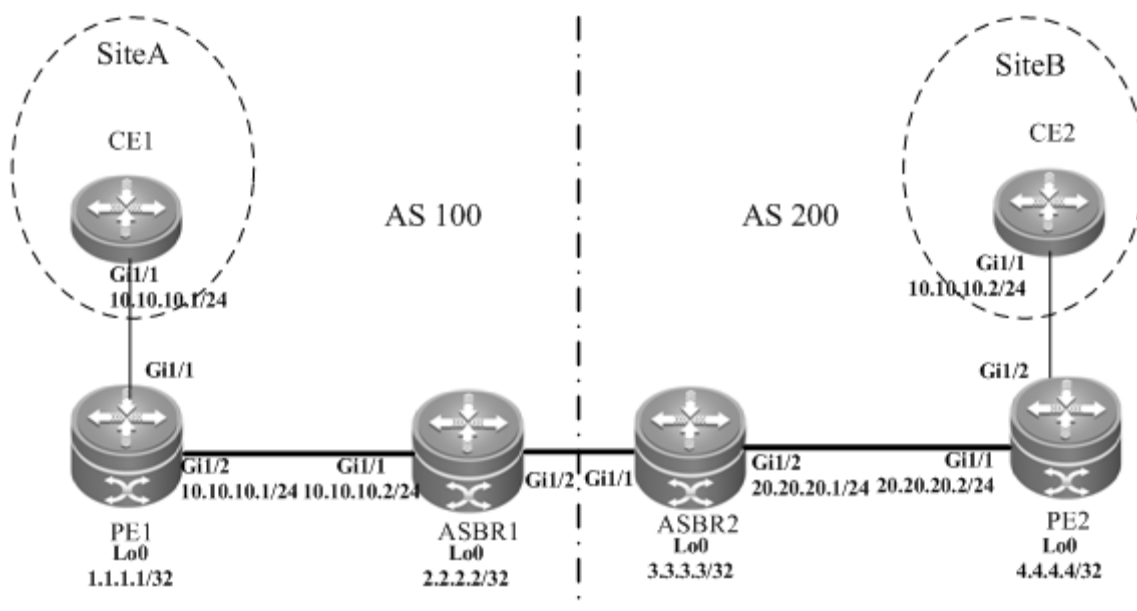
The configuration procedure is similar to that of CE1.

3.2.9.3 Option A Inter-AS VPWS**Networking Requirements**

- CEs of customer S in site A and site B are connected with each other through the carrier's PE1 in AS 100 and PE2 in AS 200, realizing layer-2 point-to-point connection.
- PE1 and PE2 are in different autonomous ASs. ASBR1 and ASBR2 are considered CEs by each other, which means that the interface between ASBRs connects the AC to the VFI instance.

Networking Topology

Figure 67 Kompella VPWS inter-AS networking topology



The preceding figure shows the structure of the Kompella VPLS inter-AS networking topology in Option A. The intermediate interface is considered by ASBRs as AC access.

Configuration Tips

Before configuring Kompella VPWS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between PE and ASBR devices.

3. Configuring L2VPN

- Establish the MP-IBGP peer relationship between PEs and intra-AS ASBRs.
- Obtain Kompella VPWS configuration information including VPWS instance descriptive information, RT value, CE ID, maximum planned site number, ID deviation, and interface information from the network administrator.

Configuration Steps

- Configuring CE1

See "Configuring CE1" in basic configuration examples.

- Configuring PE1

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Ruije(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community extended
Qtech(config-router-af)# exit
```

Configure a VFI instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1 remote-ce-id 2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configure the interface between CEs and PEs and specify the remote CE ID.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

- Configuring ASBR1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF protocol, establish public network routes so that PEs can ping with ASBRs in the same domain.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
```

3. Configuring L2VPN

```
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# exit
```

Configure a VPWS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpws-1 vpid 2 point-to-point
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2 remote-ce-id 1
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

■ Configure ASBR2:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF protocol, establish public network routes so that PEs can ping with ASBRs in the same domain.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
```

3. Configuring L2VPN

```
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure a VPWS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 3
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1 remote-ce-id 4
Qtech(config-vfi-site)#exit-site-mode
Qtech Networks(config-vfi)#exit
```

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

■ Configuring PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 3.3.3.3 remote-as 200
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)# exit
```

Configure a VPWS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpws-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 4
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2 remote-ce-id 3
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configure the interface between PE2 and a CE.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

3. Configuring L2VPN

■ Configuring CE2:

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPWS, use the following commands to check the operation of VPWS.

Command	Function
Qtech# show bgp l2vpn vpws all	Displays all the VPWS information.
Qtech# show mpls l2transport vc [<i>vc_id</i> [<i>ip-address</i>]] [interface <i>interface_name</i>] [detail]	Displays information about the PW (including VPWS PW and VPLS PW).
Qtech# show bgp l2vpn { vpls vpws } all connections [neighbor <i>address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

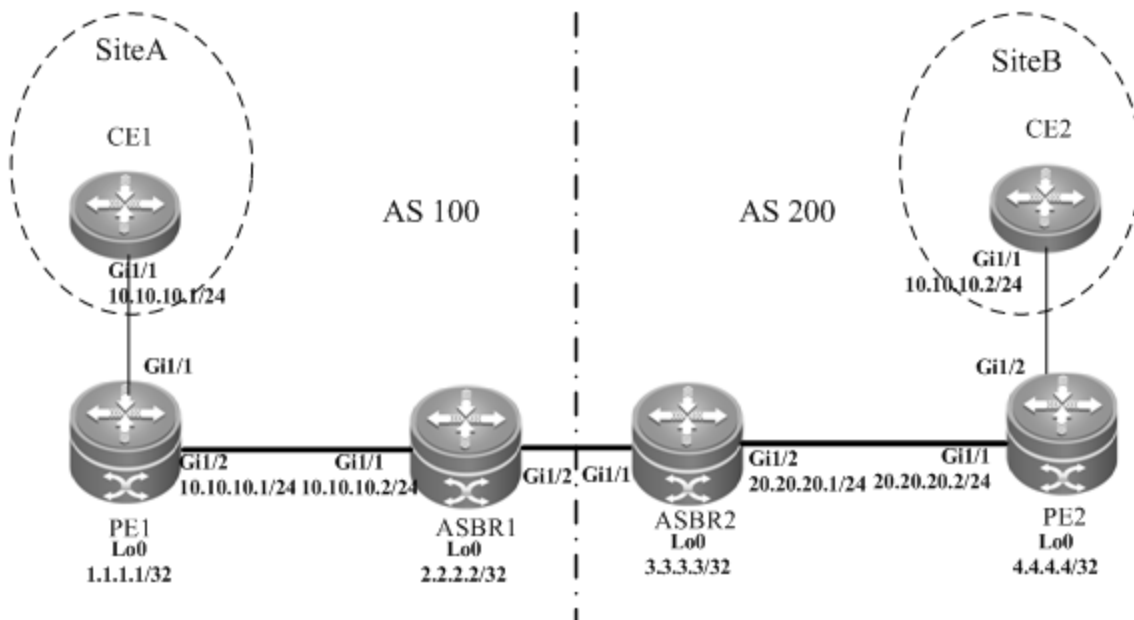
3.2.9.4 Option C Inter-AS VPWS

Networking Requirements

- CEs of customer S in site A and site B are connected with each other through the carrier's PE1 in AS 100 and PE2 in AS 200, realizing layer-2 point-to-point connection.
- PE1 and PE2 are in different ASs and can automatically detect PE devices involved in the VFI instance.
- ASBR is not responsible for maintaining VPWS label block messages.
- VPWS label block messages are directly switched between PEs.

Networking Topology

Figure 68 Kompella VPWS Option C inter-AS networking topology



The above figure shows the structure of Kompella VPWS Option C Inter-AS networking topology. Customer S's CE devices in Site A and Site B are connected to each other through PE1 in AS100 and PE2 in AS200, thus realizing layer-2 point-to-point connection.

Configuration Tips

Before configuring Kompella VPWS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between PE and ASBR devices in the same AS.
- Establish a public network tunnel between PE and ASBR devices in the same AS and enable MPLS on the ASBR interface.
- Establish IBGP between PE and ASBR in the same AS.

3. Configuring L2VPN

- Establish EBGP between ASBR devices and enable send-label.
- Obtain Kompella VPWS configuration information including VPWS instance descriptive information, RT value, CE, planned site number, ID deviation, and interface information from the network administrator.

Configuration Steps

- Configuring CE1

See "Configuring CE1" in basic configuration examples.

- Configuring PE1

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Qtech(config-router)# neighbor 4.4.4.4 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 4.4.4.4 activate
Qtech(config-router-af)# exit
Ruije(config-router)# address-family l2vpn vpws
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure a VPWS instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1 remote-ce-id 2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configure the interface that connects CEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

- Configuring ASBR1

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

3. Configuring L2VPN

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the interface that connects ASBR.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure ASBR to allocate labels for PEs' routes.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 192.168.1.2 remote-as 200
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.2 send-label
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ Configuring ASBR2

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the interface that connects ASBR.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/1)# label-switching
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure ASBR to allocate labels for PE's routes.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 192.168.1.1 remote-as 100
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.1 send-label
Qtech(config-router-af)# network 4.4.4.4 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ Configuring PE2

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PE's.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 1.1.1.1 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 1.1.1.1 activate
Qtech(config-router-af)# exit
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure a Kompella VPWS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# mtu 1500
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2 remote-ce-id 1
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

Configure the interface between PE's and CE's.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

■ Configuring CE2

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, GE1 can ping with GE2.

3. Configuring L2VPN

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPWS:

Command	Function
Qtech# show bgp l2vpn vpws all	Displays all the VPWS information.
Qtech# show mpls l2transport vc [<i>vc_id</i>] [<i>ip-address</i>] [interface <i>interface_name</i>] [detail]	Displays information about the PW (including VPWS PW and VPLS PW).
Qtech# show bgp l2vpn { vpls vpws } all connections [<i>neighbor address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

3.2.10 Examples of Maintaining PW Connectivity of VPWS

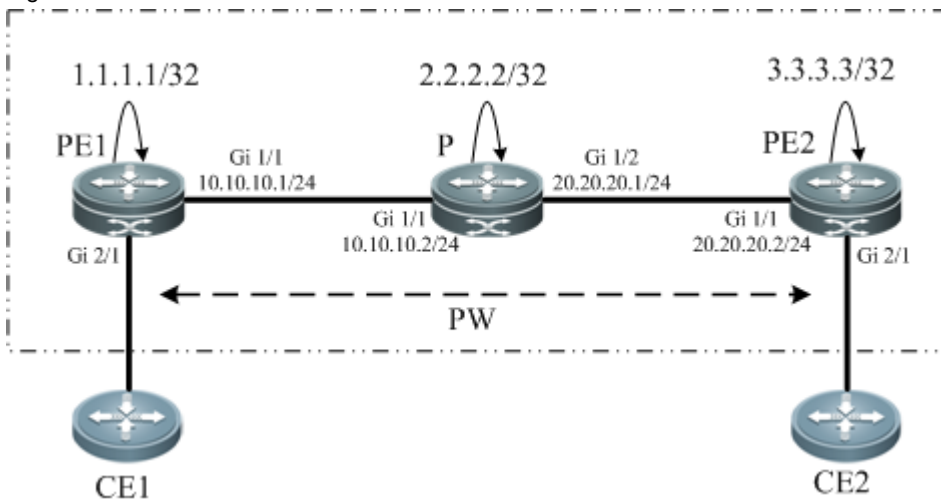
3.2.10.1 Verifying PW Connectivity and Fault of Martini VPWS

Networking Requirements

- The CE devices play the role of the customer network to connect to the PE devices via the AC.
- PE1 and PE2 establish a PW between them via LDP.
- PE1, P, and PE2 set up the public tunnel and LSP path via LDP.

Network Topology

Figure 33



Configuration Key Points

The configuration key points for PE1, P, and PE2 are as follows:

- Configure the IP address of the interface of each device and configure the Open Shortest Path First (OSPF) protocol.
- Configure the global MPLS capability and the interface MPLS capability of each device.
- Configure LDP to enable the network to forward MPLS traffic.
- Configure PWE3.
- Check the PW connectivity.
- Locate the PW fault.

Configuration Steps

- (1) Configure the IP address of the interface of each node and configure the OSPF protocol.

#Configure PE1.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)#exit
PE1 config-if-GigabitEthernet 1/1)#
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
```

3. Configuring L2VPN

```
Qtech(config-router)#network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
```

Qtech(config-router)#exit#Configure P.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure PE2.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

- (2) Configure the global MPLS capability and the interface MPLS capability of each node and enable the LDP function on the interfaces.

#Configure PE1.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#neighbor 3.3.3.3.
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

#Configure P.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#mpls ip
Qtech(config-if-GigabitEthernet 1/2)#label-switching
Qtech(config-if-GigabitEthernet 1/2)#exit
```

#Configure PE2.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#neighbor 1.1.1.1
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

3. Configuring L2VPN

(3) Configure VPWS instances between PE1 and PE2 and enable CE1 and CE2 to access the VPWS.

#Configure PE1.

```
Qtech(config)#interface gigabitethernet 2/1
Qtech(config-if-Gigabitethernet 2/1)#xconnect 3.3.3.3 100 encapsulation mpls ethernet
Qtech(config-if-Gigabitethernet 2/1)#exit
```

#Configure PE2.

```
Qtech(config)#interface gigabitethernet 2/1
Qtech(config-if-Gigabitethernet 2/1)#xconnect 1.1.1.1 100 encapsulation mpls ethernet
Qtech(config-if-Gigabitethernet 2/1)#exit
```

(4) Verify the PW connectivity.

```
Qtech#ping mpls pseudowire 3.3.3.3 100 label-alert
Sending 5, 112-byte MPLS Echoes on Pseudowire, peer address 3.3.3.3, VC ID 100,
timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' -labeled output interface, 'B' -unlabeled output interface,
'D' -DS Map mismatch, 'F' -no FEC mapping, 'f' -FEC mismatch,
'M' -malformed request, 'm' -unsupported tlvs, 'N' -no label entry,
'P' -no rx intf label prot, 'p' -premature termination of LSP,
'R' -transit router, 'I' -unknown upstream index,
'X' -unknown return code, 'x' -return code 0
Press Ctrl+C to break.
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 ms
```

(5) Locate the PW fault.

```
Qtech#traceroute mpls pseudowire 3.3.3.3 100 segment 1 ttl-expiry
Tracing Pseudowire Label Switched Path, peer address 3.3.3.3, VC ID 100, timeout is 2
seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0

Press Ctrl+C to break.
 0 10.10.10.2      MRU 1500 [Labels: 1025 Exp: 0]
! 1 20.20.20.2    60 ms [Labels: 1025 Exp: 0]
local 1.1.1.1 remote 3.3.3.3 vc id 100
```

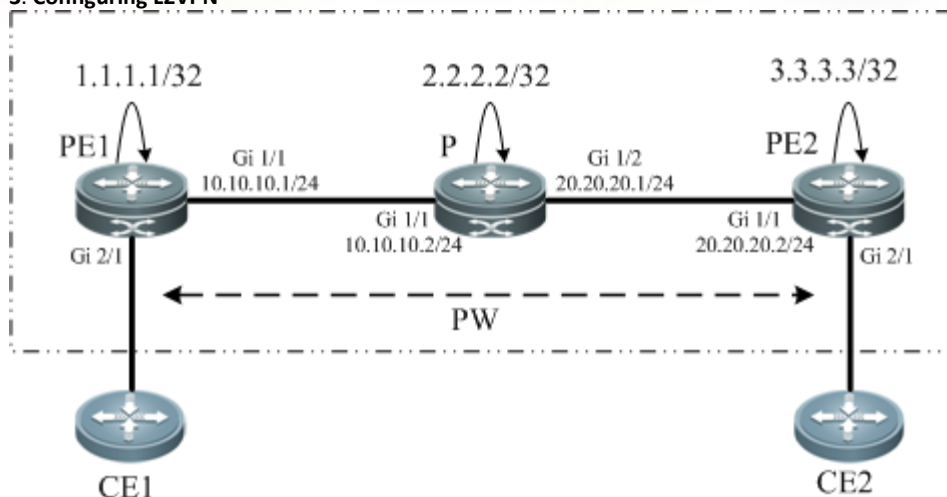
3.2.10.2 Verifying PW Connectivity of Kompella VPWS**Networking Requirements**

As shown in Figure 3-25, PE1, P, and PE2 belong to the same MPLS domain, and CE1 and CE2 belong to the same VPN instance. PE1 and PE2 establish a PW between them and use the ping or traceroute command to check the PW connectivity to ensure services on the links.

Network Topology

Figure 34

3. Configuring L2VPN



Configuration Key Points

The configuration key points for each node are as follows:

- (1). Configure the IP address of the interface of each node and configure the OSPF protocol.
- (2). Configure the global MPLS capability and the interface MPLS capability of each node.
- (3). Enable the L2VPN on PE1 and PE2 and create a VC connection.
- (4). Check the PW connectivity.
- (5). Locate the PW fault.

Configuration Steps

- (1) Configure the IP address of the interface of each node and configure the OSPF protocol.

#Configure PE1.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure P.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure PE2.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
```

3. Configuring L2VPN

```
Qtech(config-router)#exit
```

- (2) Configure the global MPLS capability and the interface MPLS capability of each node and enable the LDP function on the interfaces.

#Configure PE1.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

#Configure P.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#mpls ip
Qtech(config-if-GigabitEthernet 1/2)#label-switching
Qtech(config-if-GigabitEthernet 1/2)#exit
```

#Configure PE2.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

- (3) Configure a L2VPN address family.

#Configure PE1.

```
Qtech(config)#router bgp 100
Qtech(config-router)#neighbor 3.3.3.3 remote-as 100
Qtech(config-router)#neighbor 3.3.3.3 update-source loopback 0
Ruijie(config-router)#address-family l2vpn vpws
Qtech(config-router-af)#neighbor 3.3.3.3 activate
Qtech(config-router-af)#neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)#exit
```

#Configure PE2.

```
Qtech(config)#router bgp 100
Qtech(config-router)#neighbor 1.1.1.1 remote-as 100
Qtech(config-router)#neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)#address-family l2vpn vpws
Qtech(config-router-af)#neighbor 1.1.1.1 activate
Qtech(config-router-af)#neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)#exit
```

- (4) Configure a VFI instance.

#Configure PE1.

```
Qtech(config)#l2 vfi vpws-1 vpnid 1 point-to-point
Qtech(config-vfi)#rd 1:1
Qtech(config-vfi)#encapsulation mpls ethernet
Qtech(config-vfi)#route-target both 10000:1
Qtech(config-vfi)#site-id 1
Qtech(config-vfi-site)#xconnect interface gigabitEthernet 2/1 remote-ce-id 2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

#Configure PE2.

```
Qtech(config)#l2 vfi vpws-1 vpnid 1 point-to-point
```

3. Configuring L2VPN

```
Qtech(config-vfi)#rd 1:1
Qtech(config-vfi)#encapsulation mpls ethernet
Qtech(config-vfi)#route-target both 10000:1
Qtech(config-vfi)#site-id 2
Qtech(config-vfi-site)#xconnect interface gigabitEthernet 2/1 remote-ce-id 1
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

(5) Verify the PW connectivity.

```
Qtech#ping mpls pseudowire kompella vpws-1 1 2 rd 1:1 label-alert
Sending 5, 112-byte MPLS Echoes on Pseudowire, VFI name vpws-1, local site id, 1,
remote site id 2,
    timeout is 2 seconds, send interval is 0 msec:
```

```
Codes: '.' - success, 'Q' - request not sent, '.' - timeout,
'L'-labeled output interface, 'B'-unlabeled output interface,
'D'-DS Map mismatch, 'F'-no FEC mapping, 'f'-FEC mismatch,
'M'-malformed request, 'm'-unsupported tlvs, 'N'-no label entry,
'P'-no rx intf label prot, 'p'-premature termination of LSP,
'R'-transit router, 'I'-unknown upstream index,
'X'-unknown return code, 'x'-return code 0
```

Press Ctrl+C to break.

!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 ms

(6) Locate the PW fault.

```
Qtech#traceroute mpls pseudowire kompella vpws-1 1 2 rd 1:1 label-alert
Tracing Pseudowire Label Switched Path, VFI name vpws-1, local site id 1, remote site
id 2, timeout is 2 seconds.
```

```
Codes: '.' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
```

Press Ctrl+C to break.

```
0 10.10.10.2    MRU 1500 [Labels: router-alert/1538 Exp: 0/0]
! 1 20.20.20.2    20 ms
```

3.3 VPLS**3.3.1 Introduction to VPLS**

The Virtual Private LAN Service (VPLS) is a technology that provides virtual and dedicated Ethernet services on an IP/MPLS network. By using VPLS, you can set up PWs in full mesh mode between PEs to forward encapsulated Layer 2 Ethernet frames between the PEs on the MPLS network. In this manner, you can create a P2MP Ethernet VPN. With a VPLS VPN, the user Layer 2 devices are connected to each other across the IP/MPLS core network and the core network is like a virtual switch for the user.

Compared with VPWS, VPLS can provide P2MP solutions. Compared with L3VPN, VPLS has the advantages of L2VPN to provide better network scalability and maintenance.

The terms used in this document are as follows:

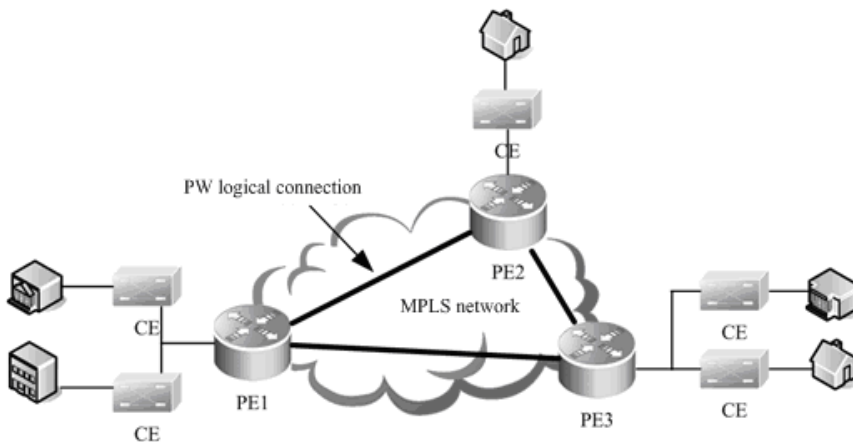
- PW: Pseudo Wire
- VPLS: Virtual Private LAN Service
- H-VPLS: Hierarchical VPLS
- MTU: Multi-Tenant Unit indicates corporate users at office buildings and business districts.
- As small edge devices at gathering places, the MTU is responsible for accessing corporate customers and aggregating users who require VPLS services to a PE through VCs.
- Spoke Connection: indicates the connection of a U-PE to an N-PE in H-VPLS. You can use a PW or QinQ.
- Spoke PW: indicates the Spoke connection between an N-PE and a U-PE when a PW is adopted, or the PW between a CE and PE when a user accesses the CE through PWs.

3.3.2 VPLS Network Structure

3.3.2.1 Basic VPLS

The following figure shows a typical VPLS model.

Figure 69



As shown in the VPLS networking in the preceding figure, PW logical connections are set up between PEs and the CEs are connected to the PEs enabled with VPLS. These VPLS PEs form P2MP services for the CEs. In this manner, the PEs are like a Layer 2 switch for the CEs to connect to.

The VPLS model in the dual-IGP instance has the following defects:

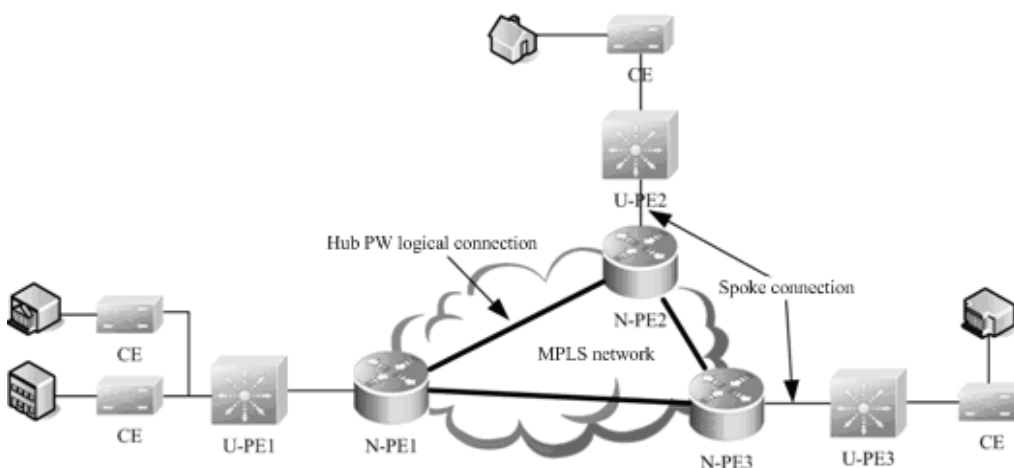
- Packets forwarded on the PWs between PEs are horizontally partitioned to avoid loops. That is, the packets received from a Hub PW are not forwarded to the Hub PW. Therefore, PWs must be set up between every two PEs. This incurs large system overheads and is not applicable to networks of large scales.
- The broadcast and multicast packets must be replicated at every PW, leading to low efficiency.

To address these problems, the hierarchical VPLS is introduced.

3.3.2.2 Hierarchical VPLS

The following figure shows a typical hierarchical VPLS (H-VPLS) model.

Figure 70



H-VPLS classifies the VPLS network into layers and sets up Hub PWs only between N-PEs on the core network. This addresses the problems on a common VPLS network. The Spoke connections between U-PEs and N-PEs are formed through PWs or QinQ tunnels. The U-PE can support VPWS or QinQ and is not required to support VPLS.

Using H-VPLS can reduce the burden on the VPLS core devices, decrease the overheads of the signaling protocol, reduce the number of packets that are replicated, and greatly strengthen the scalability of the VPLS network.

3. Configuring L2VPN

3.3.3 VPLS Signaling Protocol

VPLSs can be divided into Martini and Kompella VPLSs according to different VPLS signaling protocols. These two types of signaling are defined respectively in RFC4762 and RFC4761 of IETF. The Martini VPLS is based on the LDP signaling protocol and Kompella VPLS is based on the BGP signaling protocol. Given the BGP protocol's characteristics, such as the route reflector's characteristics, the Kompella VPLS can reduce the full inter-connection of BGP sessions, therefore facilitating the expansion of capacity. The Martini VPLS applies to small-sized and simple environment deployment.

3.3.4 VPLS Inter-AS


Both Martini and Kompella VPLSs can be inter-AS through Option A solution. In the inter-AS VPLS networking environment, the type of link between ASBRs must be the same as the type of VC. A sub-interface must be prepared for each inter-AS VC on ASBR. This solution can be adopted when the number of inter-AS VCs is small.

Option C is another solution to realize inter-AS VPLS. The SP network device only needs external tunnels on PEs in different ASs. ASBR does not maintain inter-AS VPLS information and does not need to prepare an interface for the inter-AS VPLS. VSI information of the VPLS can only be exchanged between PEs, reducing resource consumption without adding configuration tasks. The solution applies when the number of inter-AS VPLSs is large.

3.3.5 Configuring Martini VPLS

3.3.5.1 Configuring a Public Tunnel Between PEs

You must set up an LSP on the public network to carry VPLS services. To run MPLS on the backbone network, you must enable LDP on Ps and PEs at the same time to set up a public tunnel. This means that you have to configure LDP on MPLS devices and enable MPLS forwarding on each interface. The configuration procedure is as follows:

Command	Function
Qtech# config terminal	Enters global configuration mode.
	Enables MPLS globally.
Qtech(config)# mpls ip	 Caution This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback id [force]	Configures the LDP router ID. The IP address of the loopback interface is generally used as the router ID.
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Qtech(config)# interface type ID	Enters public network interface configuration mode.
Qtech(config-if-type ID)# label-switching	Enables MPLS on the interface at the public network side.
Qtech(config-if-type ID)# mpls ip	Enables LDP and MPLS forwarding for the interface.
Qtech(config-if-type ID)# ip ref	The interface's fast forwarding function must be enabled for routers.
Qtech(config-if-type ID)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

LDP is a topology-driven protocol. To ensure normal working of the LDP, enable IPv4 routing protocols and ensure their normal operations.

3.3.5.2 Configuring Remote LDP Peers

A PW is set up and maintained by the extended LDP. If other LSRs exist between two PEs, use the extended LDP discovery mechanism to set up a remote LDP session between the PEs and assign PW labels in the session. The procedures for configuring a remote LDP peer and setting up a remote LDP session are as follows:

Command	Function
Qtech# config terminal	Enters global configuration mode.

Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# neighbor ip_address	Configures remote LDP peers.
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Qtech(config)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

The PW label messages of the LDP are not affected by the LDP label distribution mode or label retention mode. The LDP is forced to work in DU and liberal label retention mode.

3.3.5.3 Martini VPLS Configuration Example

The **l2 vfi** command is used to create a VPLS instance and enter VPLS mode. The **no l2 vfi** command is used to delete a VPLS instance. When creating a VPLS instance, you must specify a name that is unique on the local device and specify a unique VPN ID. Each VPLS name corresponds to a VPN ID.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id	Creates a VPLS instance and enters VPLS configuration mode.
Qtech(config-vfi)# neighbor ip-address encapsulation mpls [vc-id vc-id] [hub-vc spoke-vc] [ethernet ethernetvlan]	Configures a VPLS peer. The default PW type is Ethernet. We recommend using the PW type for access interface access and VLAN tunnel interface access on switches and Ethernet interface access on routers. <input checked="" type="checkbox"/> We recommend setting the PW type as Ethernet VLAN if switchers use Trunk interface access or routers use sub-interface access VPLS service.
Qtech(config-vpls)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

The VPLS peer must be unique in the VPLS instance scope. To facilitate management, you must configure VPLS instances of one VPN with the same ID.
A PW's key is the PW ID and the VPLS peer's LSR ID. It must be unique globally, including VPWS PW. Each configuration of the same peer by using the **neighbor** command will cover the previous one.
The **mtu** parameter and PW type of interfaces on two ends of a PW must be the same. The default PW type of the VPLS is Ethernet. PW IDs on two ends of PEs(that is, the VC IDs) must be the same.
When using the **neighbor** command to specify the address of the VC's peer neighbor, you must use the peer router ID as the peer address and the 32-bit address of the loopback interface as the peer router ID.

- For switches, DHCP packets cannot be transmitted transparently after **ip dhcp snooping** is enabled globally.

3.3.5.4 Configuring User Access VPLS

- For switches, each VPLS can bind only one interface. For routers, multiple interfaces can be bound.

Configuring VPLS access mode for switches

A VPLS instance takes effect only after the user of the VPLS instance accesses the VPLS. At present, there are three modes of user access VPLS services:

- For switches, a VPLS can bind only one SVI interface because VPLS is supported only by the SVI interface.

**Caution**

When the port protection mode is enabled on the AC-end member port of a L2VPN, the port protection mode does not take effect on the member port if the corresponding member port is not a trunk interface.

- VLAN access interface access

The VLAN access interface is applicable to the transmission of user packets that are not encapsulated through 802.1Q (that is, packets without VLAN tags) on VPLS ACs.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters interface mode of the specified physical interface.
Qtech(config-if- <i>type ID</i>)# switchport mode access	Enables the interface to work in access mode.
Qtech(config-if- <i>type ID</i>)# switchport access <i>vlan-id</i>	Sets the interface as a VLAN member interface.
Qtech(config-if- <i>type ID</i>)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if- <i>type ID</i>)# xconnect vfi <i>vpls-name</i>	Binds the VLAN to a VPLS instance.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

For the access interface access mode, we recommend setting the PW type to **ethernet**, and the two ends of PW must be set in the same type.

- VLAN trunk interface access

The VLAN trunk interface access is applicable to the transmission of multiple VPLS services on the same physical AC. Each VLAN corresponds to a VPLS instance. The PE determines the VPLS instance for user packets based on their VLAN tags to provide the multiplexing of access interfaces.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters interface mode of the specified physical interface.
Qtech(config-if- <i>type ID</i>)# switchport mode trunk	Enables the interface to work in trunk mode.
Qtech(config-if- <i>type ID</i>)# switchport trunk allow vlan <i>vlan-list</i>	Enables the trunk link to allow VLAN traffic.
Qtech(config-if- <i>type ID</i>)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if- <i>type ID</i>)# xconnect vfi <i>vpls-name</i>	Binds the VLAN to a VPLS instance.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

For the Trunk interface access mode, we recommend setting the PW type as **ethernetvlan**, and the two ends of PW must be set in the same type.

The L2 VPN service cannot be bound to the Native VLAN of the Trunk interface.

- VLAN tunnel interface access

The VLAN tunnel interface access is applicable to the transmission of user service packets that carry private VLAN tags on the ACs when a user accesses VPLS services. In this mode, the PE forwards all packets received from the VLAN tunnel interface without any changes. This mode requires the VLAN member interfaces between PEs and CEs to work in tunnel mode.

Command	Function
Qtech# config terminal	Enters global configuration mode.

Qtech(config)# interface <i>type ID</i>	Enters interface mode of the specified physical interface.
Qtech(config-if- <i>type ID</i>)# switchport access <i>vlan-id</i>	Sets the interface as a VLAN member interface.
Qtech(config-if- <i>type ID</i>)# switchport mode dot1q-tunnel	Enables the interface to work in tunnel mode.
Qtech(config-if- <i>type ID</i>)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if- <i>type ID</i>)# xconnect vfi <i>vpls-name</i>	Binds the VLAN to a VPLS instance.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

For the VLAN tunnel interface access mode, we recommend setting the PW type as **Ethernet**, and the two ends of PW must be set in the same type.

For the VLAN tunnel interface access mode, only the basic QinQ is supported.

- PW access

The PW access is applicable to user access networks that are enabled with MPLS. In addition, the user is not directly connected to any VPLS PE link. In the H-VPLS model, the PW access mode can be used to access the N-PE if the U-PE has no bridging capability so that the VPLS access service can be provided on the U-PE for the user.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi <i>name</i>	Enters VPLS configuration mode.
Qtech(config-vpls)# neighbor ip-address encapsulation mpls [<i>vc-id</i>] spoke-vc [ethernet ethernetvlan]	Configures a PW for user access.
Qtech(config-vpls)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

For one VPLS instance, you can configure multiple PWs for user access.

**Caution**

When accessing VPLS services through PWs, you must specify the **spoke-vc** keyword in the **neighbor** command to configure PWs, enable the **label-switching** command on the Spoke PW access interface, and enable fast forwarding for routers.

Configuring VPLS access mode for routers

A created VPLS instance takes effect only after the user configured with the VPLS instance is connected with the link.

- Ethernet interface access

This mode applies when the user service packets transmitted on ACs carry private VLAN tags or do not carry VLAN tags in the case of VPLS service access. In this mode, all packets received by PEs from the interface are forwarded according to the destination MAC address and the private tags are considered part of the data. In such case, PEs provide port-based VPLS service. The address learning mode of the VPLS instance of the bound port is the free mode. MAC address overlapping in the user VLAN is not supported.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters the specified physical interface.
Qtech(config-if- <i>type ID</i>)# ip ref	The interface's fast forwarding function must be enabled for routers.
Qtech(config-if- <i>type ID</i>)# xconnect vfi <i>vpls-name</i>	Binds VLAN to the VPLS instance.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

For the VPLS service of the Ethernet interface access mode, we recommend setting the PW type to **ethernet**, and both ends of the PW in the same PW type.

The same VPLS instance can be bound to different interfaces to realize local connection.

If a VPLS instance is configured on different PEs with Ethernet interface and sub-interface access modes, we recommend setting all PWs of the VPLS instance to the **ethernetvlan** type.

■ Sub-interface access

This mode applies when multiple VPLS services are transmitted on a physical AC. Each sub-interface corresponds to a VPLS instance. PE devices can match packets with VPLS instances according to VLAN tags carried by the user packets to provide the multiplexing of access interfaces.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters the specified physical interface.
Qtech(config-if-type ID)# encapsulation dot1Q	Sets the VIP encapsulated by the sub-interface.
Qtech(config-if-type ID)# ip ref	The interface's fast forwarding function must be enabled for routers.
Qtech(config-if-type ID)# xconnect vfi vpls-name	Binds VLAN to the VPLS instance.
Qtech(config-if-type ID)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

If a VPLS instance is used to transmit flows of multiple VLANs of the user, MAC address overlapping between VLANs of the user is not supported.

The same VPLS instance can be bound to different interfaces to realize local connection.

For the VPLS service of the sub-interface access mode, we recommend setting the PW type to **ethernetvlan**, and both ends of the PW in the same PW type.

■ PW access

This mode applies when the user's access network is the MPLS network and no direct link is set up between the user and VPLS PEs. In the H-VPLS model, the PW access mode can be used to access the N-PE when the U-PE has no bridging capability so that the VPLS access service can be provided on the U-PE for the user.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi name	Enters VPLS configuration mode.
Qtech(config-vfi)# neighbor ip-address encapsulation mpls [vc-id vc-id] spoke-vc [ethernet ethernetvlan]	Configures the PW to be accessed by user.
Qtech(config-vfi)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

One VPLS instance can be configured with multiple PWs for user access.

When accessing VPLS services through PWs, you must specify the **spoke-vc** keyword in the **neighbor** command to configure PWs.

- For routers, the **label-switching** and **ip ref** commands must be enabled on the interface where Spoke PW is located.

**Caution**

If the Ethernet access mode is adopted, the PW type must be **ethernet**. If the Ethernet sub-interface access mode is adopted, the PW type must be **ethernetvlan**.

3.3.5.5 Verifying Martini VPLS Configuration

After completing the configuration of the VPLS, use the following commands to check the operation of VPLS.


Command	Function
---------	----------

Qtech# show mpls vfi	Displays VPLS information.
Qtech# show mpls l2transport vc [[<i>vc_id</i> [<i>ip-address</i>]] [interface <i>interface-name</i>]] [detail]	Displays information about the PW (including VPWS PW and VPLS PW).
Qtech# show ip ref mpls forwarding-table vfi [<i>vpls_name</i>] [mac-address-table [<i>H.H.H</i>]] [statistics]	Displays all MAC addresses under the VPLS instance including static MAC addresses learned from PWs and ACs and configured by the user, and statistics of VPLS forwarding.
Qtech# show mpls forwarding-table	Displays PW-related ILM and FTN forwarding table entries.
Qtech# show mpls ldp neighbor	Displays all LDP neighbor information.
Qtech# show mpls ldp vc	Displays all LDP VC information.

3.3.6 Configuring Kompella VPLS

3.3.6.1 Configuring the Public Network Tunnel Between PEs

You must set up an LSP tunnel must be set up on the public network to provide VPLS services. To run MPLS on the backbone network, you must enable LDP on Ps and PEs to establish a public network tunnel. This means that you have to configure LDP for MPLS devices and enable MPLS forwarding on each interface. The configuration procedure is as follows:

Command	Function
Qtech# config terminal	Enters global configuration mode.
	Enables MPLS forwarding globally.
Qtech# mpls ip	 Caution This command is not applicable to switch chip forwarding.
Qtech(config)# mpls router ldp	Enables LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id interface loopback id [force]	Configures LDP's router ID, which is usually the IP address of the loopback interface.
Qtech(config-mpls-router)# exit	Exits the LDP configuration mode.
Qtech(config)# interface type ID	Enters public network interface configuration mode.
Qtech(config-if-type ID)# label-switching	Enables the interface's MPLS forwarding function.
Qtech(config-if-type ID)# mpls ip	Enables the interface's LDP function and MPLS forwarding function.
Qtech(config-if-type ID)# ip ref	Enables the fast forwarding function for routers.
Qtech(config-if-type ID)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure the public network tunnel between PEs.

```
Qtech# configure terminal
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# end
Qtech# copy running-config startup-config
```

**Caution**

LDP is a topology-driven protocol. To ensure normal working of the LDP, enable IPv4 routing protocols and ensure their normal operations.

3.3.6.2 Configuring L2VPN VPLS Address Family

Kompella VPLS uses MP-BGP4 as signaling and auto-discovery mechanism. PE devices in one VPLS instance must exchange VPLS information through the L2VPN address family. By default, the L2VPN VPLS address family is not supported. The procedure for enabling the L2VPN address family is as follows:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# router bgp <i>asn-num</i>	Creates the BGP and enters BGP configuration mode.
Qtech(config)# neighbor <i>peer-address</i> remote-as <i>asn-number</i>	Sets up an IBGP session.
Qtech(config)# neighbor <i>peer-address</i> update-source <i>interface-name</i>	Enables the IBGP session to use the address of the loopback interface as the session's source address.
Ruijie(config-router)# address-family <i>l2vpn vpls</i>	Enters the L2VPN VPLS address family.
Qtech(config-router-af)# neighbor <i>ip-address</i> activate	Activates switching of VPLS information on the BGP session.
Qtech(config-router-af)# neighbor { <i>ip-address</i> <i>peer-group-name</i> } send-community [both standard extended]	Specifies the extended community attribute to be sent to BGP neighbors.
Qtech(config-router-af)# end	Returns from address family configuration mode to privileged mode.
Qtech# show bgp <i>l2vpn vpls</i> { all [id:offset neighbor ip-address summary] }	Displays L2VPN VPLS address family information.

Configure the L2VPN address family and enable VPLS information switching.

```
Qtech# configure terminal
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 10.10.10.1 remote-as 100
Qtech(config-router)# neighbor 10.10.10.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 10.10.10.1 activate
Qtech(config-router-af)# neighbor 10.10.10.1 send-community extended
Qtech(config-router-af)# end
Qtech# show bgp l2vpn vpls all
```

3.3.6.3 Configuring Kompella VPLS Instance

The **l2 vfi** command can be used to create Kompella VPLS instances or enter Kompella VPLS configuration mode. The **no l2 vfi** command can be used to delete VPLS instances. The unique local VPLS instance name and the unique local device VPN ID must be specified when the instance is being created. The auto-discovery function must be enabled for the specified VPLS instance. Each VPLS name corresponds to a VPN ID. In auto-discovery mode, BGP is the default signaling.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi <i>vpls-name</i> vpnid <i>vpn-id</i> autodiscovery	Creates the Kompella VPLS instance and enters VPLS configuration mode.
Qtech(config-vfi)# signal bgp	Configures the VPLS instance signaling, which is BGP by default.
Qtech(config-vfi)# rd <i>rd_value</i>	Configures the RD value. Configure the RD first.
Qtech(config-vfi)# encapsulation mpls [ethernet ethernetvlan]	Specifies the encapsulation mode of Kompella VPLS PWs, which is Ethernet (that is, raw mode) by default. If the sub-interface VPLS access mode is adopted, we recommend the ethernetvlan encapsulation mode (that is, tag mode).

Command	Function
Qtech(config-vfi)# route-target { import export both } <i>rt_value</i>	Configures RTs. Multiple RTs can be configured.
Qtech(config-vfi)# site-id <i>id</i> [site-range <i>size</i>]	Configures VE IDs of VPLS sites and the site range. If the site range is not configured, the default value 16 will be adopted.
Qtech(config-vfi-site)# xconnect interface <i>interface-id</i>	Configures the interface bound by the site.
Qtech(config-vfi-site)# end	Exits site configuration mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure a Kompella VPLS instance.

```
Qtech#configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# route-target both 4500:2
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitethernet 1/1
Qtech(config-vfi-site)#end
Qtech# copy running-config startup-config
```



Caution

The **autodiscovery** keyword must be specified after the **l2 vfi** command to create a Kompella VPLS instance.

The auto-discovery between PEs in a VPLS instance is based on MP-BGP. To configure the Kompella VPLS, specify the VPLS PW signaling protocol as BGP.

VPLS instances of one VPN must be configured with the same ID to facilitate management.

PEs on one VPLS must be configured with the same VPLS PW encapsulation mode. Otherwise, VPLS packets cannot be forwarded. Assuming that a VPLS-X exists, if the VPLS-X encapsulation mode on PE1 is **ethernet** (that is, raw mode), the VPLS encapsulation mode on PE2 must not be **ethernetvlan** (that is, tag mode).

- For switches, DHCP packets cannot be transmitted transparently after **ip dhcp snooping** is enabled globally.

3.3.6.4 Configuring User Access VPLS

Configuring VPLS Access Mode for Switches

A created VPLS instance takes effect only after the user configured with the VPLS instance is connected to the link. Currently, there are the following three ways for switch users to access VPLS services:

- For switches, a VPLS instance can bind only one SVI interface because VPLS is supported only by the SVI interface.



Caution

When the port protection mode is enabled on the AC-end member port of L2VPN, the port protection mode does not take effect on the member port if the corresponding member port is not a Trunk interface.

- VLAN access interface access

This mode applies when user packets transmitted on the VPLS AC are not encapsulated by 802.1Q (that is, the packets do not carry VLAN tags).

3.3.6.5 Command	3.3.6.6 Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters the specified physical interface.
Qtech(config-if- <i>type ID</i>)# switchport mode access	Enables the interface to work in access mode.

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Qtech(config-if-type ID)# switchport access <i>vlan-id</i>	Sets the interface as a VLAN member port.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if-type ID)# exit	Returns to global configuration mode.
Qtech(config)# I2 vfi <i>vfi_name</i> vpnid <i>vpn_id</i> autodiscovery	Enters VFI configuration mode.
Qtech(config-vfi)# site-id <i>id</i> [site-range <i>size</i>]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface vlan <i>id</i>	Configures the AC interface bound by the VPLS site.
Qtech(config-vfi-site)# end	Returns to privileged configuration mode.
Qtech# copy running-config startup-config	Saves configuration.



Caution

For the access interface access mode, we recommend setting the VPLS PW encapsulation mode to **ethernet** (that is, raw mode).
VLAN trunk interface access

This mode applies when multiple VPLS services are transmitted on a physical AC. Each VLAN corresponds to a VPLS instance. PE devices can match packets with VPLS instances according to VLAN tags carried by the user packets to provide the multiplexing of access interfaces.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters the specified physical interface.
Qtech(config-if-type ID)# switchport mode trunk	Enables the interface to work in trunk mode.
Qtech(config-if-type ID)# switchport trunk allow vlan add <i>vlan-list</i>	Sets the VLAN flows allowed to be transmitted on the trunk link.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if-type ID)# exit	Returns to global configuration mode.
Qtech(config)# I2 vfi <i>vfi_name</i> vpnid <i>vpn_id</i> autodiscovery	Enters VFI configuration mode.
Qtech(config-vfi)# site-id <i>id</i> [site-range <i>size</i>]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface vlan <i>id</i>	Configures the AC interface bound by the VPLS site.
Qtech(config-vfi-site)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.



Caution

For the Trunk interface access mode, we recommend setting the VPLS PW encapsulation mode to **ethernetvlan** (that is, tag mode).
The L2 VPN service cannot be bound to the Native VLAN of the trunk interface.

■ VLAN tunnel interface access

This mode applies when user service packets transmitted on ACs carry private VLAN tags if the user is connected to the VPLS service. In this mode, all packets received by PEs from the interface are forwarded without being processed. This mode requires the VLAN member port between PEs and CEs to work in tunnel mode.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters the specified physical interface.
Qtech(config-if-type ID)# switchport access <i>vlan-id</i>	Sets the interface as a VLAN member port.
Qtech(config-if-type ID)# switchport mode dot1q-tunnel	Enable the interface to work in tunnel mode.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# interface vlan <i>vlan-id</i>	Enters VLAN interface mode.
Qtech(config-if-type ID)# exit	Returns to global configuration mode.
Qtech(config)# I2 vfi <i>vfi_name</i> vpnid <i>vpn_id</i> autodiscovery	Enters VFI configuration mode.

Qtech(config-vfi)# site-id <i>id</i> [site-range <i>size</i>]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface <i>vlan id</i>	Configures the AC interface bound by the VPLS site.
Qtech(config-vfi-site)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

For the VLAN tunnel interface access mode, we recommend setting the VPLS PW encapsulation mode to **ethernet** (that is, raw mode).
For the VLAN tunnel interface access mode, only the basic QinQ is supported.

Configuring VPLS Access Mode for Routers

A created VPLS instance takes effect only after the user configured with the VPLS instance is connected with the link.

There are the following two ways to access VPLS services:

- Ethernet interface access

This mode applies user service packets transmitted on ACs carry private VLAN tags or do not carry VLAN tags in the case of VPLS service access. In this mode, all packets received by PEs from the interface are forwarded according to the destination MAC address and the private tags are considered part of the data. In such case, PEs provide port-based VPLS services. The address learning mode of the VPLS instance of the bound port is the free mode. MAC address overlapping in the user VLAN is not supported.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters the specified physical interface.
Qtech(config-if- <i>type ID</i>)# ip ref	Enables the fast forwarding function for routers.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech(config-if- <i>type ID</i>)# exit	Returns to global configuration mode.
Qtech(config)# l2 vfi <i>vfi_name</i> vpnid <i>vpn_id</i> autodiscovery	Enters VFI configuration mode.
Qtech(config-vfi)# site-id <i>id</i> [site-range <i>size</i>]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface <i>interface-id</i>	Configures the AC interface bound by the VPLS site.
Qtech(config-vfi-site)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure Ethernet interface VPLS access.

```
Qtech# configure terminal
Qtech(config)# interface gigabitethernet 1/2
```

Enable the fast forwarding function of the interface for routers.

```
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
Qtech(config)# l2 vfi vfiA vpnid 1 autodiscovery
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitethernet 1/2
Qtech(config-vfi-site)#end
Qtech# copy running-config startup-config
```

**Caution**

For the Ethernet access mode, we recommend using the **encapsulation mpls ethernet** command to specify the Kompella VPLS PW encapsulation mode as **ethernet** (that is, raw mode). If the packets of imported PEs carry VLAN tags, the tags will be transmitted transparently as private tags.

- For routers, a VPLS instance can be configured with mixed access modes. For example, PEs in a VPLS instance are configured with both Ethernet and sub-interface access modes. In such case, we recommend setting the VPLS PW encapsulation mode on the PEs to **ethernetvlan** (that is, tag mode).

- Sub-interface access

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PE devices can access a VPLS instance through sub-interfaces.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters the specified physical interface.
Qtech(config-if-type ID)# ip ref	For routers, the fast forwarding function must be enabled on the master interface of the sub-interface.
Qtech(config-if-type ID)# end	Returns to privileged mode.
Qtech(config-if-type ID)# exit	Returns to global configuration mode.
Qtech(config)# l2 vfi vfi_name vpnid vpn_id autodiscovery	Enters VFI configuration mode.
Qtech(config-vfi)# site-id id [site-range size]	Configures site information of the VFI.
Qtech(config-vfi-site)# xconnect interface interface-id	Configures the AC interface bound by the VPLS site.
Qtech(config-vfi-site)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.

Configure sub-interface VPLS access.

```
Qtech# configure terminal
```

Enable the fast forwarding function of the sub-interface for routers.

```
Qtech(config)# interface gigabitethernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
Qtech(config)# interface gigabitethernet 1/2.10
Qtech(config-if-GigabitEthernet 1/2.10)# encapsulation dot1q 10
Qtech(config-if-GigabitEthernet 1/2.10)#exit
Qtech(config)# l2 vfi vfiA vpnid 1 autodiscovery
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# route-target both 2:2
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitethernet 1/2.10
Qtech(config-vfi-site)#end
Qtech# copy running-config startup-config
```

**Caution**

For the sub-interface access mode, we recommend using the **encapsulation mpls ethernetvlan** command to specify the Kompella VPLS PW encapsulation mode as **ethernetvlan** (that is, tag mode).

3.3.6.7 Configuring Kompella VPLS's Compatibility (Optional)

By default, the PW's mtu value provided by L2VPN is 1500 bytes. If the same PW's mtu values on two PEs are different, PW connection cannot be set up between the two PEs. Some manufacturers' devices do not support configuring mtu in L2VPN instances. When such devices perform Kompella communication with devices of other manufacturers, the **ingore match l2-extcommunity** command can be used to ignore received mtu and matching detection of **Control Flag**, ensuring that the VC link is UP.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id autodiscovery	Creates the Kompella VPLS instance and enters VPLS configuration mode.
Qtech(config-vfi)# ingore match l2-extcommunity	Configures ignoring detection of L2VPN expanded community attribute members.
Qtech# copy running-config startup-config	Saves configuration.

**Caution**

This command takes effect only on Kompella L2VPN.

3.3.6.8 Verifying Kompella VPLS Configuration

Command	Function
<code>show bgp l2vpn vpls all</code>	Displays NLRI information about all VPWS instances.
<code>show bgp l2vpn vpls all connections</code>	Displays all connection information of Kompella VPLS.
<code>show mpls l2transport vc [vc_id [ip-address]] [interface interface_name] [detail]</code>	Displays VC information established by Kompella VPLS.
<code>show mpls vfi [name]</code>	Displays VPLS instance information.
Qtech# <code>show ip ref mpls forwarding-table vfi [vpls_name] [mac-address-table [H.H.H] statistics]</code>	Displays all MAC addresses under the VPLS instance including static MAC addresses learned from PWs and ACs and configured by the user, and statistics of VPLS forwarding.
Qtech# <code>show mpls forwarding-table</code>	Displays PW-related ILM and FTN forwarding table entries.

3.3.7 Configuring Other VPLS Parameters

3.3.7.1 Configuring VPLS Instance Descriptors (Optional)

You can configure the descriptive information of each VPLS instance.

Command	Function
Qtech# <code>config terminal</code>	Enters global configuration mode.
Qtech(config)# <code>l2 vfi vpls-name</code>	Enters VPLS configuration mode.
Qtech(config-vfi)# <code>description vpls-description</code>	(Optional) Configures descriptive information of the VPLS.
Qtech(config-vfi)# <code>end</code>	Returns to privileged mode.
Qtech# <code>copy running-config startup-config</code>	Saves configuration.

3.3.7.2 Configuring mtu of VPLS Instance (Optional)

You can configure each VPLS instance's mtu value, which is **1500** by default. The mtu value of VPLS indicates the length of the packet that can be transmitted by the PW, or the length of the user's layer-2 packet plus the length of the PW-encapsulated packet. By default, if the PW does not enable the control word, assuming that two labels are encapsulated, the length of an Ethernet packet that can be transmitted is 1492 bytes, of which 8 bytes are encapsulated by the PW (2 labels).

Command	Function
Qtech# <code>config terminal</code>	Enters global configuration mode.
Qtech(config)# <code>l2 vfi vpls-name</code>	Enters VPLS configuration mode.
Qtech(config-vfi)# <code>mtu mtu</code>	(Optional) Configures the mtu value of the VPLS.
Qtech(config-vfi)# <code>end</code>	Returns to privileged mode.
Qtech# <code>copy running-config startup-config</code>	Saves configuration.



Caution

The mtu values of one VPLS instance on different PEs must be the same. Otherwise, the signaling protocol cannot establish PWs. Currently, transmission of VPLS fragments is not supported. If the PW signaling protocol negotiation's mtu is modified, the mtu of the user access service interface must be adjusted (generally adjusted to the PW mtu length minus the encapsulated length); the PW's public-network-end output interface's mtu, MPLS mtu and PW mtu must be the same to ensure proper forwarding. The **mtu** command can be used on an interface to modify the interface's mtu. Use the **mpls mtu** command to modify MPLS mtu of the interface.

3.3.7.3 Configuring VPLS Transparent Transmission Bridge Protocol Control Packet (Optional)

You can control whether the VPLS interface transparently transmits bridge protocol control packets to meet application needs.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# interface <i>type ID</i>	Enters specified interface mode.
Qtech(config-if- <i>type ID</i>)# l2 vfi tunnel-protocol stp	Enables the interface to transparently transmit STP packets.
Qtech(config-if- <i>type ID</i>)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.



Caution

Generally, BPDU packets do not carry VLAN Tag. If CEs access PEs through a trunk interface or sub-interface and the BPDU transparent transmission function is enabled on the access interface, the BPDU packets sent by CEs must carry corresponding VLAN tags so that the BPDU packets can be identified by the corresponding VPLS instances and transmitted transparently in the VPLS instances.

3.3.7.4 Configuring MAC Address Aging Time (Optional)

You can configure each VPLS instance's address aging time, which is 300 seconds by default.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi <i>vpls-name</i>	Enters VPLS configuration mode.
Qtech(config-vfi)# mac-address aging-time interval	(Optional) Configures the address aging time of the VPLS.
Qtech(config-vfi)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.



Caution

If the aging time of MAC addresses is changed, all the MAC addresses will be aged according to the new aging time. If the aging time is set to *m*, MACs that have not performed communication will be aged after *m*.

Configuring MAC Address Capacity Volume Limit (Optional)

You can configure each VPLS instance's MAC address capacity limit and behavior to be performed when the limit is exceeded.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# l2 vfi <i>vpls-name</i>	Enters VPLS configuration mode.
Qtech(config-vfi)# mac-limit { action { discard forward } alarm { disable enable } maximum count	(Optional) Configures each VPLS instance's MAC address capacity limit and behavior to be performed when the limit is exceeded.
Qtech(config-vfi)# end	Returns to privileged mode.
Qtech# copy running-config startup-config	Saves configuration.



Caution

By default, the message warning of exceeding the capacity is disabled. If it is enabled, the Log message will be displayed when the MAC capacity of the VPLS instance is exceeded for the first time. The Log message will be displayed again when the VPLS MAC capacity drops to below the limit.

3.3.7.5 Configuring Static MAC Addresses (Optional)

You can configure static MAC addresses for VPLS instances. When conflicts exist in static MAC addresses and dynamically learned ones, dynamically learned MAC addresses are overwritten.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech(config)# mpls static vfi vpls-name mac-address H.H.H neighbor ip-address	Configures MAC addresses for a VPLS instance.
Qtech(config)# end	Returns to the privileged mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

Static MAC addresses configured through configuration of relate PWs of neighbor addresses can work properly only in the following scenario: The L2VPN instance has only a PW for the neighbor configured. If the L2VPN instance is configured with multiple PWs for the neighbor, the configured static MAC address will bind with a PW randomly, leading to incorrect forwarding.

3.3.7.6 Clearing Dynamic MAC Addresses (Optional)

A VPLS instance can dynamically learn MAC addresses from ACs and PWs. You can clear the MAC addresses learned dynamically by VPLS instances, including the local and remote VPLS instances.

Command	Function
Qtech# config terminal	Enters global configuration mode.
Qtech# clear l2 vfi vpls-name mac-address local	Clears the MAC addresses learned dynamically by the local (local PE) VPLS instance.
Qtech# clear l2 vfi vpls-name mac-address remote	Clears the MAC addresses learned dynamically by the remote (another PE) VPLS instance.

**Caution**

Clearing MAC addresses of remote PEs is effective for Martini VPLS only.

3.3.7.7 Applying Tunnel Policy (Optional)

Configuring Tunnel Policy

For details, see Section 3.2.2.6.

Applying Tunnel Policy to Martini VPLS

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id	Creates a VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# neighbor ip-address encapsulation mpls [vc-id vc-id] [hub-vc spoke-vc] [ethernet ethernetvlan] [tnl-policy policy-name]	Configures a VPLS peer and applies the tunnel policy.

#Example: Apply the tunnel policy to the Martini VPLS.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1
Qtech(config-vfi)# neighbor 2.2.2.2 encapsulation mpls vc-id 1 tnl-policy pol
Qtech(config-vfi)# exit
```

Applying Tunnel Policy to Kompella VPLS

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# l2 vfi vpls-name vpnid vpn-id autodiscovery	Creates a Kompella VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# neighbor peer-address tnl-policy policy-name	Applies the tunnel policy to the VFI.

#Example: Apply the tunnel policy to the Kompella VPLS.

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```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-2 vpnid 2 autodiscovery
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# neighbor 2.2.2.2 tnl-policy pol
Qtech(config-vfi)# exit
```

3.3.7.8 Configuring PW Class (Optional)

Configure the PW class instance to be referenced by the VPLS. Use the **pw-class** command to create a PW template instance and enter the PW template instance. Use the **no** form of this command to delete the PW template instance. You must specify a locally unique name for the PW template instance when you create it.

Command	Function
Qtech# configure terminal	Enters the global configuration mode.
Qtech(config)# pw-class <i>pwclass</i>	Creates a PW class instance and enters the PW class configuration mode.
Qtech(config-pw-class)# backup neighbor <i>ip-address</i> [vc-id <i>vc_id</i>] [manual]	Configures the IP address and VC identifier of the remote neighbor of the backup PW. If no VC identifier is configured, reuse the VC identifier of the primary PW. The other attributes of the standby PW also use the attributes of the primary PW.
Qtech(config-pw-class)# vccv bfd [primary backup] enable	Enables the PW connectivity check. The PW connectivity check is enabled on the primary and backup PWs by default. The PW connectivity check in BFD mode is supported.
Qtech(config-pw-class)# fast-reroute [delay <i>delay-time</i> immediately never]	Configures the switchback policy for switching from the backup PW back to primary PW. The switchback to the primary PW is delayed for 300s by default.
Qtech(config-pw-class)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.

3.3.7.9 Configuring VPLS Referencing PW Class (Optional)

Run the following commands to enable the VPLS to reference the PW class instance.

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# l2 vfi <i>vpls-name</i> vpnid <i>vpn-id</i>	Creates a VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# neighbor <i>ip-address</i> encapsulation mpls [vc-id <i>vc-id</i>] [hub-vc spoke-vc] [ethernet ethernetvlan] [manual] [tnl-policy <i>policy-name</i>] [pw-class <i>class-name</i>]	Configures a VPLS peer and reference the PW class instance.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.

**Caution**

You must create a PW class instance before it can be referenced.

#Example: Enable the Martini VPLS to reference the PW class instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vfi_frr vpnid 1
Qtech(config-vfi)# neighbor 2.2.2.2 encapsulation mpls pw-class pwclass
Qtech(config-vfi)# exit
```

3. Configuring L2VPN

3.3.7.10 Configuring MAC Address Learning of VPLS (Optional)

The VPLS can dynamically learn the MAC addresses of the AC and the PW. You can control the MAC address learning function on the VPLS, including enabling or disabling learning of the AC MAC address and learning of the PW MAC address.

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# I2 vfi name vpnid vpn-id	Creates a VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# mac-learning [ac pw] disable	Controls MAC address learning. The MAC addresses of the AC and the PW are learned concurrently by default.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.



Caution

This command is available to both the Martini VPLS and the Kompella VPLS.

3.3.7.11 Configuring MAC Address Withdrawal of VPLS (Optional)

You can withdraw the remote MAC address dynamically learned by the VPLS and forward the MAC address withdrawal message to other PE devices.

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# I2 vfi name vpnid vpn-id	Creates a VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# mac-withdraw enable	Enables the MAC address withdrawal message sending function. If this function is disabled, the local spoke PW is invalid or the AC is invalid. In this case, no MAC address withdrawal message is sent to the remote peer. Upon receiving the MAC address withdrawal message from the hub PW, the PE device withdraws the MAC address and sends the MAC address withdrawal message other PEs.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.



Caution

Withdrawing the MAC address of the remote PE is available to the Martini VPLS only.

3.3.7.12 Configuring Action on Unknown Unicast Packets Received by VPLS Instance (Optional)

Run the following commands to configure the forwarding action on the unknown unicast packets received by the VPLS instance.

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# I2 vfi name vpnid vpn-id	Creates a VPLS instance and enters the VPLS configuration mode.
Qtech(config-vfi)# unknown-frame unicast [ac-ac ac-pw pw-ac] discard	Configures the forwarding action on the unknown unicast and broadcast packets.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.

3.3.8 Maintaining PW Connectivity of VPLS

Configuration Prerequisites

When using VCCV to detect the PW connectivity of the VPLS, you must ensure that the PWE3 network is already correctly configured.

3.3.8.1 Checking PW Connectivity

Command	Function
<pre>Qtech#ping mpls pseudowire { ip- address vc-id [segment segment- number] kompella vfi_name local_site_id remote_site_id rd remote_rd } { label-alert ttl-expiry } [repeat repeat] [timeout timeout] [size size] [interval mseconds] [source ip-address] [destination ip- address] [pad pattern] [reply mode { ipv4 router-alert control- channel }] [verbose]</pre>	Checks the PW connectivity.

Example: Check the connectivity of the PW whose peer PE IPv4 address is 10.10.10.10 and PW ID is 100.

```
Qtech#ping mpls pseudowire 10.10.10.3 100 label-alert
Sending 5, 112-byte MPLS Echoes on Pseudowire, peer address 10.10.10.3, VC ID 100,
timeout is 2 seconds, send interval is 0 msec:
```

```
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
```

Press Ctrl+C to break.

!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 ms

3.3.8.2 Locating Data Plane Fault of PW

Command	Function
<pre>Qtech#traceroute mpls pseudowire { ip-address vc-id {segment segment- number} kompella vfi_name local_site_id remote_site_id rd remote_rd } { label-alert ttl-expiry } [repeat repeat] [timeout timeout] [size size] [interval mseconds] [source ip-address] [destination ip- address] [pad pattern] [reply mode { ipv4 router-alert }] [verbose]</pre>	Tracks the PW path to locate the connectivity fault.

Example: Track the path of the PW whose VFI name is vpn-1, local VE ID is 1, remote VE ID is 2, and remote RD is 200:1 to locate the fault.

```
Qtech#traceroute mpls pseudowire kompella vpn-1 1 2 rd 200:1 label-alert
Tracing Pseudowire Label Switched Path, VFI name vpn-1, local site id 1, remote site
id 2, timeout is 2 seconds.
```

```
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
```

Press Ctrl+C to break.

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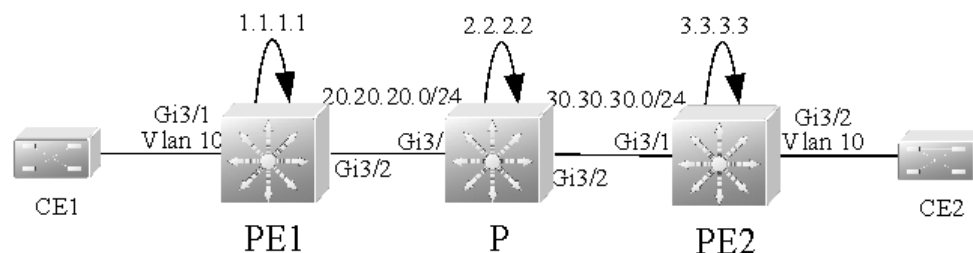
```
0 192.168.1.10    MRU 1500 [Labels: router-alert/1538 Exp: 0/0]
! 1 192.168.1.11    20 ms
```

3.3.9 Typical Examples of Martini VPLS Configuration for Switches

3.3.9.1 Basic VPLS

As shown in the following figure, CE1 and CE2 access the same VPLS network through PE1 and PE2. PE1, P, and PE2 form a public MPLS network that provides VPLS services. On PE1 and PE2, bind VLAN 10 to the VPLS instance.

Figure 71



The configuration procedure is as follows:

Configuring PE1:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# no switchport
Qtech(config-if-GigabitEthernet 3/2)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the VLAN interface to the VPLS instance.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 10
Qtech(config-if-Vlan 10)# xconnect vfi vfi_a
Qtech(config-if-Vlan 10)# exit
```

Configure the interface between PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configuring P:

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Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# no switchport
Qtech(config-if-GigabitEthernet 3/1)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# no switchport
Qtech(config-if-GigabitEthernet 3/2)# ip address 30.30.30.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configuring PE2:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# no switchport
Qtech(config-if-GigabitEthernet 3/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# 12 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the VLAN interface to the VPLS instance.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 10
Qtech(config-if-Vlan 10)# xconnect vfi vfi_a
Qtech(config-if-Vlan 10)# exit
```

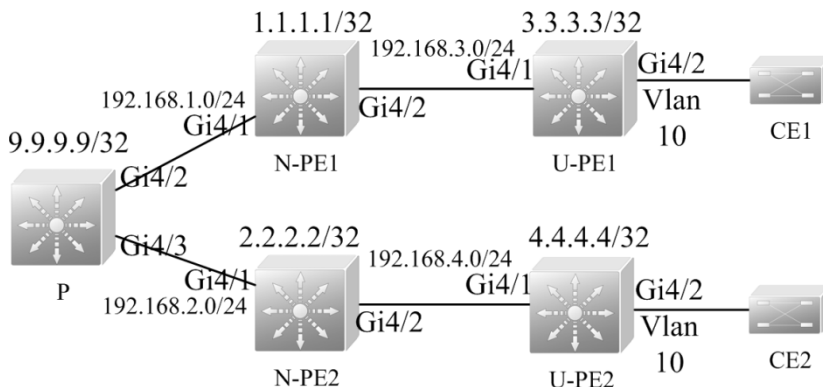
3. Configuring L2VPN

Configure the interface between PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/2)# exit
```

3.3.9.2 H-VPLS (PW Access)

Figure 72



As shown in the preceding figure, CE1 and CE2 access the same H-VPLS network through U-PE1 and U-PE2, which are connected to N-PE1 and N-PE2 respectively. The N-PEs and U-PEs are connected through PWs. All U-PEs and N-PEs belong to the MPLS network and work together to provide VPLS services.

When setting up PWs between N-PEs and U-PEs, you must specify the PW of the N-PEs with the U-PEs as a Spoke PW. On the U-PE end, the PW type is not restricted. If U-PEs support VPLS, the PW between U-PEs and N-PEs can be either a Hub PW or a Spoke PW. If the U-PEs do not support VPLS, the VPWS PW can also be configured.

In this example, U-PE1 and N-PE1 are connected through a Hub PW whereas U-PE2 and N-PE2 are connected through a VPWS PW.

■ Configuring U-PE1:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 192.168.3.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1)# no switchport
Qtech(config-if-GigabitEthernet 4/1)# ip address 192.168.3.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1)# mpls ip
Qtech(config-if-GigabitEthernet 4/1)# label-switching
Qtech(config-if-GigabitEthernet 4/1)# exit
```

Configure a VPLS instance and enable a PW to connect the peer N-PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the VLAN interface to the VPLS instance.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 10
```

3. Configuring L2VPN

```
Qtech(config-if-Vlan 10)# xconnect vfi vfi_a
Qtech(config-if-Vlan 10)# exit
```

Configure the interface between PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 4/2)# exit
```

■ **Configuring N-PE1:**

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.3.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 2.2.2.2
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1)# no switchport
Qtech(config-if-GigabitEthernet 4/1)# ip address 192.168.1.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1)# mpls ip
Qtech(config-if-GigabitEthernet 4/1)# label-switching
Qtech(config-if-GigabitEthernet 4/1)# exit
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# no switchport
Qtech(config-if-GigabitEthernet 4/2)# ip address 192.168.3.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/2)# mpls ip
Qtech(config-if-GigabitEthernet 4/2)# label-switching
Qtech(config-if-GigabitEthernet 4/2)# exit
```

Configure a VPLS instance, a Hub PW to connect another N-PE, and the Spoke PW to connect the peer U-PE.

```
Qtech(config)# 12 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 2.2.2.2 encapsulation mpls
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls spoke-vc
Qtech(config-vpls)# exit
```

■ **Configuring P:**

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 9.9.9.9 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 9.9.9.9 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# no switchport
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 4/2)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/2)# mpls ip
Qtech(config-if-GigabitEthernet 4/2)# label-switching
Qtech(config-if-GigabitEthernet 4/2)# exit
Qtech(config)# interface gigabitEthernet 4/3
Qtech(config-if-GigabitEthernet 4/3)# no switchport
Qtech(config-if-GigabitEthernet 4/3)# ip address 192.168.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/3)# mpls ip
Qtech(config-if-GigabitEthernet 4/3)# label-switching
Qtech(config-if-GigabitEthernet 4/3)# exit
```

■ **Configuring N-PE2:**# **Configure the loopback interface.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.4.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# neighbor 4.4.4.4
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1)# no switchport
Qtech(config-if-GigabitEthernet 4/1)# ip address 192.168.2.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1)# mpls ip
Qtech(config-if-GigabitEthernet 4/1)# label-switching
Qtech(config-if-GigabitEthernet 4/1)# exit
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# no switchport
Qtech(config-if-GigabitEthernet 4/2)# ip address 192.168.4.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/2)# mpls ip
Qtech(config-if-GigabitEthernet 4/2)# label-switching
Qtech(config-if-GigabitEthernet 4/2)# exit
```

Configure a VPLS instance, enable a Hub PW to connect another N-PE, and enable the Spoke PW to connect the peer U-PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# neighbor 4.4.4.4 encapsulation mpls spoke-vc
Qtech(config-vpls)# exit
```

■ **Configuring U-PE2:**# **Configure the loopback interface.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 192.168.4.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 2.2.2.2
```

```
Qtech(config-mpls-router) # exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config) # interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1) # no switchport
Qtech(config-if-GigabitEthernet 4/1) # ip address 192.168.4.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1) #mpls ip
Qtech(config-if-GigabitEthernet 4/1) # label-switching
Qtech(config-if-GigabitEthernet 4/1) # exit
```

Configure a VPWS PW for a VLAN interface.

```
Qtech(config) # vlan 10
Qtech(config-vlan) # exit
Qtech(config) # interface vlan 10
Qtech(config-if-Vlan 10) # xconnect 2.2.2.2 1 encapsulation mpls ethernet
Qtech(config-if-Vlan 10) # exit
```

Configure the interface between PEs and CEs.

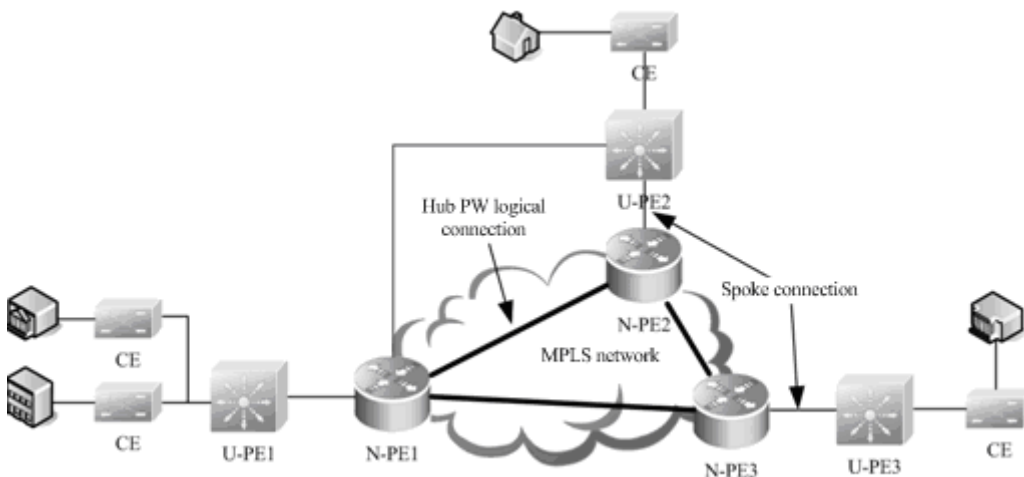
```
Qtech(config) # interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2) # switchport access vlan 10
Qtech(config-if-GigabitEthernet 4/2) # exit
```

3.3.9.3 H-VPLS (QinQ Access and Dual-Homed)

If the U-PE and N-PE are connected through only one Spoke, the U-PE communication with the external network is discontinued if the Spoke connection fails. To solve this problem, you can connect the U-PE to N-PEs in dual-homed mode. In this mode, the U-PE is connected to different N-PEs, which belong to the same VPLS network, through two (or more) Spoke connections. In normal situations, only one of the Spoke connections is working. It is called the active connection and the others are backup ones. If the active connection fails, one backup connection is chosen to take over the task.

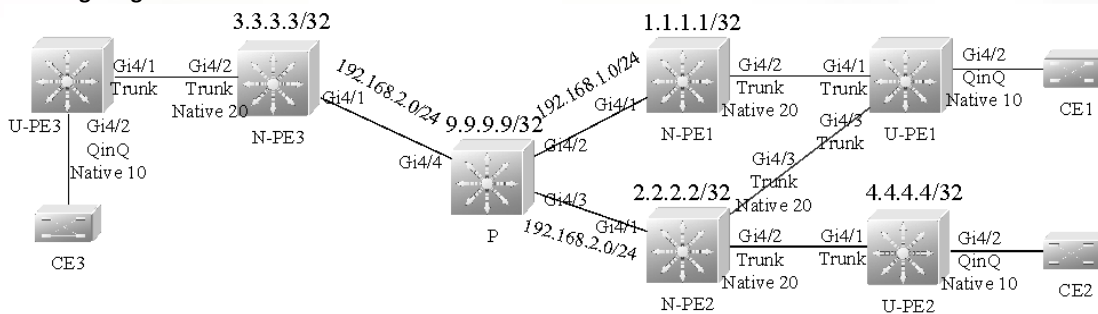
The following shows a schematic diagram of an H-VPLS network in dual-homed mode.

Figure 73



On an H-VPLS network in QinQ and dual-homed access mode, you can use the STP to switch over the active and standby connections. The STP, however, does not belong to users and is transmitted only over the carrier's network (U-PEs and N-PEs). To avoid the impact of STP protocol packets (BPDUs) on user packets, you must create a special VPLS instance on the N-PE to transparently transmit BPDU packets in dual-homed mode.

Figure 40



The preceding figure shows an H-VPLS topology in dual-homed mode. The CE is connected to U-PEs on the same H-VPLS network and the U-PEs are connected to N-PEs through the QinQ tunnel. The N-PEs belong to the MPLS network and the U-PEs do not run MPLS, but the N-PEs and U-PEs work together to provide VPLS services. The upstream interface on the U-PE works in trunk mode and allows the traffic of the VLAN to which the U-PE interface connected to the CE belongs to pass through. Enable QinQ on the interfaces that connect U-PEs and CEs. This QinQ native VLAN cannot be the same as the native VLAN on the U-PE1 interface connected to the N-PE or the native VLAN on the N-PE interface connected to the U-PE. This is because the QinQ native VLAN on the interfaces that connect U-PEs and CEs is used to identify VPLS instances provided for a user whereas the native VLAN on the N-PE trunk interface connected to the U-PE is used to identify the VPLS instance for transparently transmitting BPDU packets in dual-homed mode. Set up Hub PWs between N-PEs. Enable dual-homed mode on U-PE1 and you can find that U-PE1 is connected to both N-PE1 and N-PE2.

As shown in Figure 1-27, only one VPLS instance is provided for the user. You are required to create a special VPLS instance to transparently transmit BPDU packets in dual-homed mode. You only need to enable this VPLS instance on the N-PEs to which the U-PE is connected.

Configuring U-PE1:

Configure a Spoke connection to the peer N-PE1.

```
Qtech(config)# interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1)# switchport mode trunk
Qtech(config-if-GigabitEthernet 4/1)# exit
```

Configure a Spoke connection to the peer N-PE2.

```
Qtech(config)# interface gigabitEthernet 4/3
Qtech(config-if-GigabitEthernet 4/3)# switchport mode trunk
Qtech(config-if-GigabitEthernet 4/3)# exit
```

Configure the interface between PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 4/2)# switchport mode dot1q-tunnel
Qtech(config-if-GigabitEthernet 4/2)# exit
```

Enable STP only on the U-PEs that adopt the dual-homed access mode.

```
Qtech(config)# spanning-tree
```

Configuring N-PE1:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 2.2.2.2
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 4/1
```

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```
Qtech(config-if-GigabitEthernet 4/1)# no switchport
Qtech(config-if-GigabitEthernet 4/1)# ip address 192.168.1.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1)# mpls ip
Qtech(config-if-GigabitEthernet 4/1)# label-switching
Qtech(config-if-GigabitEthernet 4/1)# exit
```

Configure the N-PE interface connected to the U-PE.

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# switchport mode trunk
Qtech(config-if-GigabitEthernet 4/2)# switchport trunk native vlan 20
Qtech(config-if-GigabitEthernet 4/2)# exit
```

Configure a VPLS instance for the user and enable Hub PWs to connect the N-PEs in the same VPLS instance.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 2.2.2.2 encapsulation mpls
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the QinQ VLAN interface to the VPLS instance.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 10
Qtech(config-if-Vlan 10)# xconnect vfi vfi_a
Qtech(config-if-Vlan 10)# exit
```

Configure the VPLS instance to transparently transmit BPDUs and enable Hub PWs to connect other N-PEs in dual-homed mode.

```
Qtech(config)# l2 vfi vfi_bpdu vpnid 100
Qtech(config-vpls)# neighbor 2.2.2.2 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the native VLAN interface, which is used to transparently transmit BPDUs, to the VPLS instance.

```
Qtech(config)# vlan 20
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 20
Qtech(config-if-Vlan 20)# xconnect vfi vfi_bpdu
Qtech(config-if-Vlan 20)# l2 vfi tunnel-protocol stp
Qtech(config-if-Vlan 20)# exit
```

Configuring P:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 9.9.9.9 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 9.9.9.9 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# no switchport
Qtech(config-if-GigabitEthernet 4/2)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/2)# mpls ip
Qtech(config-if-GigabitEthernet 4/2)# label-switching
Qtech(config-if-GigabitEthernet 4/2)# exit
Qtech(config)# interface gigabitEthernet 4/3
Qtech(config-if-GigabitEthernet 4/3)# no switchport
Qtech(config-if-GigabitEthernet 4/3)# ip address 192.168.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 4/3)# mpls ip
Qtech(config-if-GigabitEthernet 4/3)# label-switching
Qtech(config-if-GigabitEthernet 4/3)# exit
```

Configuring N-PE2:

Configure the loopback interface.

```
Qtech(config)# interface loopback 0
```


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```
Qtech(config-if-Loopback 0)# # ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 4/1
Qtech(config-if-GigabitEthernet 4/1)# no switchport
Qtech(config-if-GigabitEthernet 4/1)# ip address 192.168.2.2 255.255.255.0
Qtech(config-if-GigabitEthernet 4/1)# mpls ip
Qtech(config-if-GigabitEthernet 4/1)# label-switching
Qtech(config-if-GigabitEthernet 4/1)# exit
```

Configure the N-PE interface connected to U-PEs (to two U-PEs at the same time).

```
Qtech(config)# interface gigabitEthernet 4/2
Qtech(config-if-GigabitEthernet 4/2)# switchport mode trunk
Qtech(config-if-GigabitEthernet 4/2)# switchport trunk native vlan 20
Qtech(config-if-GigabitEthernet 4/2)# exit
Qtech(config)# interface gigabitEthernet 4/3
Qtech(config-if-GigabitEthernet 4/3)# switchport mode trunk
Qtech(config-if-GigabitEthernet 4/3)# switchport trunk native vlan 20
Qtech(config-if-GigabitEthernet 4/3)# exit
```

Configure a VPLS instance for the user and enable Hub PWs to connect the N-PEs in the same VPLS instance.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the QinQ VLAN interface to the VPLS instance.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 10
Qtech(config-if-Vlan 10)# xconnect vfi vfi_a
Qtech(config-if-Vlan 10)# exit
```

Enable the VPLS instance to transparently transmit BPDU packets and enable Hub PWs to connect other N-PEs in dual-homed mode.

```
Qtech(config)# l2 vfi vfi_bpdu vpnid 100
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# exit
```

Bind the native VLAN interface, which is used to transparently transmit BPDU packets, to the VPLS instance.

```
Qtech(config)# vlan 20
Qtech(config-vlan)# exit
Qtech(config)# interface vlan 20
Qtech(config-if-Vlan 20)# xconnect vfi vfi_bpdu
Qtech(config-if-Vlan 20)# l2 vfi tunnel-protocol stp
Qtech(config-if-Vlan 20)# exit
```

Configuring U-PE2:

Refer to U-PE1. Since U-PE2 is connected to only one N-PE, STP is not required.

Configuring U-PE3:

Refer to U-PE2.

Configuring N-PE3:

Refer to N-PE1.

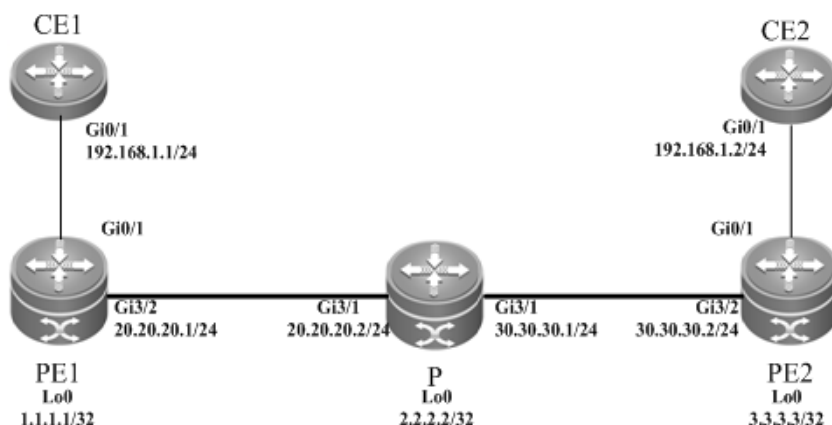
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3.3.10 Typical Examples of Martini VPLS Configuration for Routers

3.3.10.1 Basic VPLS (Ethernet Interface Access)

As shown in the following figure, CE1 and CE2 access the same VPLS network through PE1 and PE2. PE1, P, and PE2 form a public MPLS network to provide VPLS services. Gi0/1 is bound on PE1 and PE2 to the VPLS instance.

Figure 41



The configuration procedure is as follows:

Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip ref
Qtech(config-if-GigabitEthernet 3/2)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls ethernet
Qtech(config-vpls)# exit
```

Configure the interface that connects PEs and CEs to bind the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# xconnect vfi vfi_a
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configuring P:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
```

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```
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# ip ref
Qtech(config-if-GigabitEthernet 3/1)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip ref
Qtech(config-if-GigabitEthernet 3/2)# ip address 30.30.30.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configuring PE2:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# ip ref
Qtech(config-if-GigabitEthernet 3/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls ethernet
Qtech(config-vpls)# exit
```

Configure the interface that connects PEs and CEs to bind the VPLS instance.

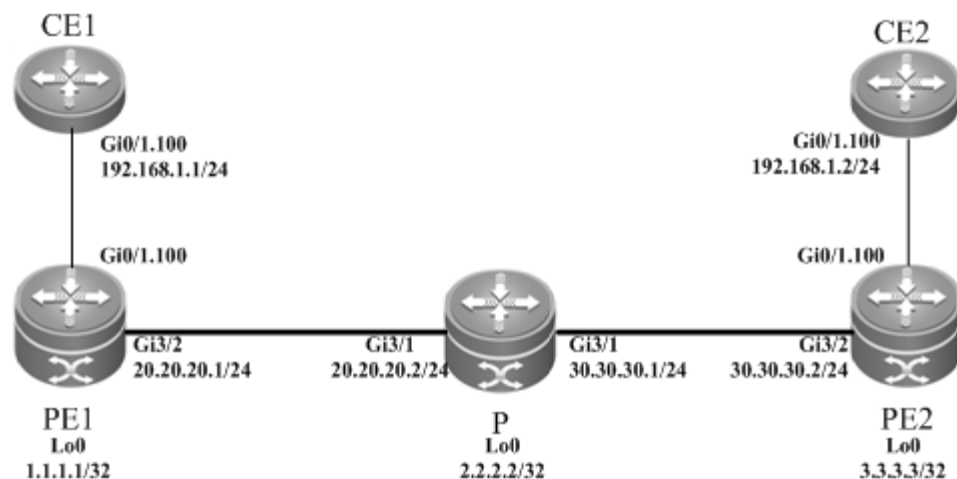
```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# xconnect vfi vfi_a
Qtech(config-if-GigabitEthernet 0/1)# exit
```

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3.3.10.2 Basic VPLS (Ethernet Sub-interface Access)

As shown in the following figure, CE1 and CE2 access the same VPLS network through PE1 and PE2. PE1, P, and PE2 form a public MPLS network to provide VPLS services. VLAN 10 is bound on PE1 and PE2 to the VPLS instance.

Figure 74



The configuration procedure is as follows:

Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip ref
Qtech(config-if-GigabitEthernet 3/2)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls ethernetvlan
Qtech(config-vpls)# exit
```

Configure the interface that connects PEs and CEs to bind the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# interface gigabitEthernet 0/1.100
Qtech(config-if-GigabitEthernet 0/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 0/1.100)# xconnect vfi vfi_a
Qtech(config-if-GigabitEthernet 0/1.100)# exit
```

Configuring P:

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Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# ip ref
Qtech(config-if-GigabitEthernet 3/1)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip ref
Qtech(config-if-GigabitEthernet 3/2)# ip address 30.30.30.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configuring PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# ip ref
Qtech(config-if-GigabitEthernet 3/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configure a VPLS instance and specify the peer PE.

```
Qtech(config)# 12 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls ethernetvlan
Qtech(config-vpls)# exit
```

Configure the interface that connects PEs and CEs to bind the VPLS instance.

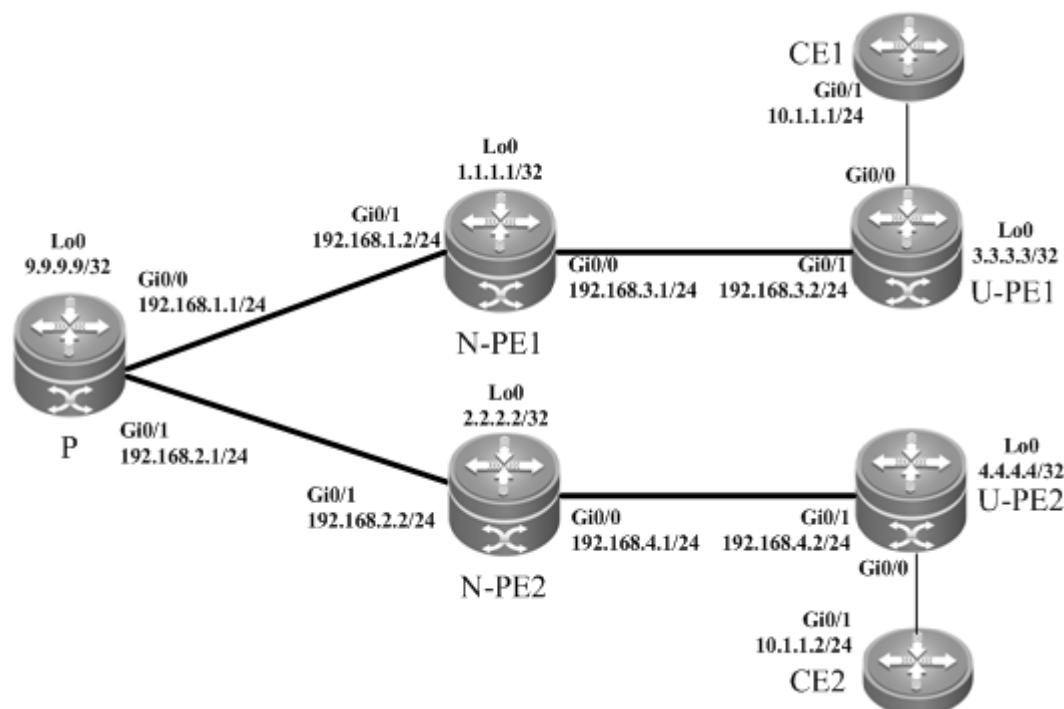
```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# interface gigabitEthernet 0/1.100
Qtech(config-if-GigabitEthernet 0/1.100)# encapsulation dot1Q 100
```

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```
Qtech(config-if-GigabitEthernet 0/1.100)# xconnect vfi vfi_a
Qtech(config-if-GigabitEthernet 0/1.100)# exit
```

3.3.10.3 H-VPLS (PW Access)

Figure 75



As shown in the preceding figure, CE1 and CE2 access the same H-VPLS network through U-PE1 and U-PE2, which are connected to N-PE1 and N-PE2 respectively. The N-PEs and U-PEs are connected through PWs. All U-PEs and N-PEs belong to the MPLS network and work together to provide VPLS services.

When setting up PWs between N-PEs and U-PEs, you must specify the PW of the N-PEs with the U-PEs as a Spoke PW. On the U-PE end, the PW type is not restricted. If U-PEs support VPLS, the PW between U-PEs and N-PEs can be either a Hub PW or a Spoke PW. If the U-PEs do not support VPLS, the VPWS PW can also be configured.

In this example, U-PE1 and N-PE1 are connected through a Hub PW whereas U-PE2 and N-PE2 are connected through a VPWS PW.

Configuring U-PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 192.168.3.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.3.2 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
```

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```
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configure a VPLS instance and enable PWs to connect to the peer N-PE

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# exit
```

Configure the interface that connects PEs and CEs to bind the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 0/0
Qtech(config-if-GigabitEthernet 0/0)# ip ref
Qtech(config-if-GigabitEthernet 0/0)# exit
```

Configuring N-PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.3.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 2.2.2.2
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.1.2 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# interface gigabitEthernet 0/0
Qtech(config-if-GigabitEthernet 0/0)# ip ref
Qtech(config-if-GigabitEthernet 0/0)# ip address 192.168.3.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/0)# mpls ip
Qtech(config-if-GigabitEthernet 0/0)# label-switching
Qtech(config-if-GigabitEthernet 0/0)# exit
```

Configure a VPLS instance, enable a Hub PW to connect another N-PE, and enable a Spoke PW to connect the peer U-PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 2.2.2.2 encapsulation mpls
Qtech(config-vpls)# neighbor 3.3.3.3 encapsulation mpls spoke-vc
Qtech(config-vpls)# exit
```

Configuring P:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 9.9.9.9 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 9.9.9.9 0.0.0.0 area 0
Qtech(config-router)# network 192.168.1.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
```

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```
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

```
Qtech(config)# interface gigabitEthernet 0/0
Qtech(config-if-GigabitEthernet 0/0)# ip ref
Qtech(config-if-GigabitEthernet 0/0)# ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/0)# mpls ip
Qtech(config-if-GigabitEthernet 0/0)# label-switching
Qtech(config-if-GigabitEthernet 0/0)# exit
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configuring N-PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 192.168.2.0 0.0.0.255 area 0
Qtech(config-router)# network 192.168.4.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# neighbor 4.4.4.4
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.2.2 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
Qtech(config)# interface gigabitEthernet 0/0
Qtech(config-if-GigabitEthernet 0/0)# ip ref
Qtech(config-if-GigabitEthernet 0/0)# ip address 192.168.4.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/0)# mpls ip
Qtech(config-if-GigabitEthernet 0/0)# label-switching
Qtech(config-if-GigabitEthernet 0/0)# exit
```

Configure a VPLS instance, enable a Hub PW to connect another N-PE, and enable a Spoke PW to connect the peer U-PE.

```
Qtech(config)# l2 vfi vfi_a vpnid 1
Qtech(config-vpls)# neighbor 1.1.1.1 encapsulation mpls
Qtech(config-vpls)# neighbor 4.4.4.4 encapsulation mpls spoke-vc
Qtech(config-vpls)# exit
```

Configuring U-PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
```


3. Configuring L2VPN

```
Qtech(config-router)# network 192.168.4.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 2.2.2.2
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)# ip ref
Qtech(config-if-GigabitEthernet 0/1)# ip address 192.168.4.2 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)# mpls ip
Qtech(config-if-GigabitEthernet 0/1)# label-switching
Qtech(config-if-GigabitEthernet 0/1)# exit
```

Configure the interface that connects PEs and CEs to enable VPWS.

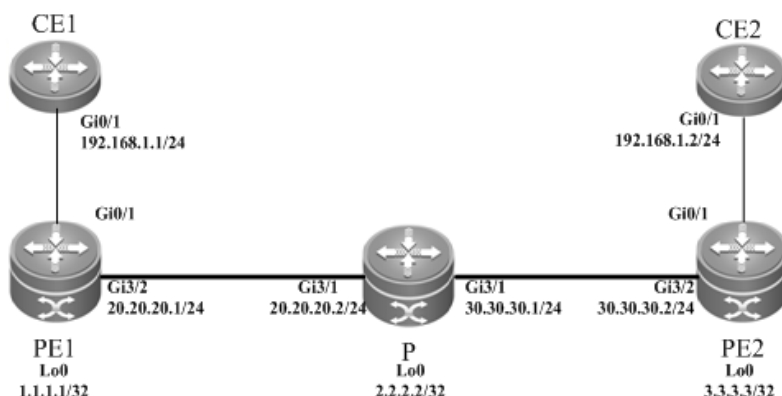
```
Qtech(config)# interface gigabitEthernet 0/0
Qtech(config-if-GigabitEthernet 0/0)# ip ref
Qtech(config-if-GigabitEthernet 0/0)# xconnect 2.2.2.2 1 encapsulation mpls ethernet
Qtech(config-if-GigabitEthernet 0/0)# exit
```

3.3.11 Typical Examples of Kompella VPLS Configuration for Switches**3.3.11.1 Basic VPLS****Networking Requirements**

- CE1 and CE2 access the same VPLS network through PE1 and PE2.
- PE1, P and PE2 form the public MPLS network.
- VLAN 10 is bound on PE1 and PE2 to the VPLS instance.

Networking Topology

Figure 76

**Configuration Tips**

Before configuring Kompella VPLS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between PE1 and PE2.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, maximum planned site number, VE ID deviation, and interface information from the network administrator.

Configuration Steps

Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

3. Configuring L2VPN**# Configure OSPF and establish public network routes.**

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 3.3.3.3
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# no switchport
Qtech(config-if-GigabitEthernet 3/2)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 3.3.3.3 remote-as 100
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface that connects PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)# eixt
```

Configuring P:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on an interface.

3. Configuring L2VPN

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# no switchport
Qtech(config-if-GigabitEthernet 3/1)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# no switchport
Qtech(config-if-GigabitEthernet 3/2)# ip address 30.30.30.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configuring PE2:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 30.30.30.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# neighbor 1.1.1.1
Qtech(config-mpls-router)# exit
```

Enable LDP and MPLS on the public network interface.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# no switchport
Qtech(config-if-GigabitEthernet 3/1)# ip address 30.30.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the interface that connects PEs and CEs.

```
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)# exit-site-mode
Qtech(config-vfi)# exit
```

3. Configuring L2VPN

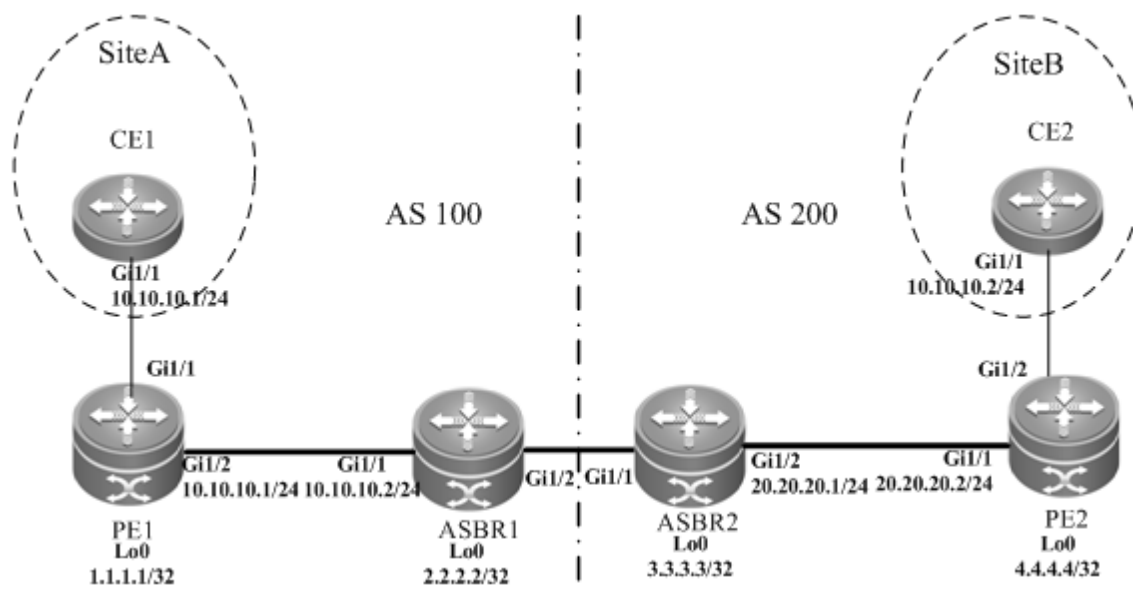
3.3.11.2 Inter-AS Configuration Examples – Option A Solution

Networking Requirements

- LAN segments of customer S in site A and site B are connected with each other through the carrier's PE1 in AS100 and PE2 in AS 200, forming a virtual and simulative LAN service, or VPLS service.
- PE1 and PE2 are in different ASs. ASBR1 and ASBR2 are considered CE devices by each other, which means that the interface between ASBRs connects the AC to the VPLS instance;

Networking Topology

Figure 77 Kompella VPLS inter-AS networking topology



The preceding figure shows the structure of the Kompella VPLS inter-AS networking topology in Option A. The intermediate interface is considered by ASBRs as AC connection.

Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between PE and ASBR devices.
- Establish the MP-IBGP peer relationship between PEs and intra-AS ASBRs.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, maximum planned site number, VE ID deviation, and interface information from the network administrator.

Configuration Steps

- Configuring CE1

See "Configuring CE1" in basic configuration examples.

- Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
```

■ Configuring ASBR1:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF protocol and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

3. Configuring L2VPN

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# mtu 1500
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring ASBR2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 3
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
```

3. Configuring L2VPN

```
Qtech(config-vfi)#exit
```

- **Configuring PE2:**

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 3.3.3.3 remote-as 200
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the interface that connects PE2 and a CE.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 4
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

- **Configuring CE2:**

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

Command	Function
Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [vc_id [ip-address]] [interface interface_name] [detail]	Displays information about the PW (including VPWS PW and VPLS PW).

Qtech# show bgp l2vpn { vpls vpws } all connections [neighbor address] [interface interface_name] [site-id id] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [name]	Displays all the configured or specified VFI information.

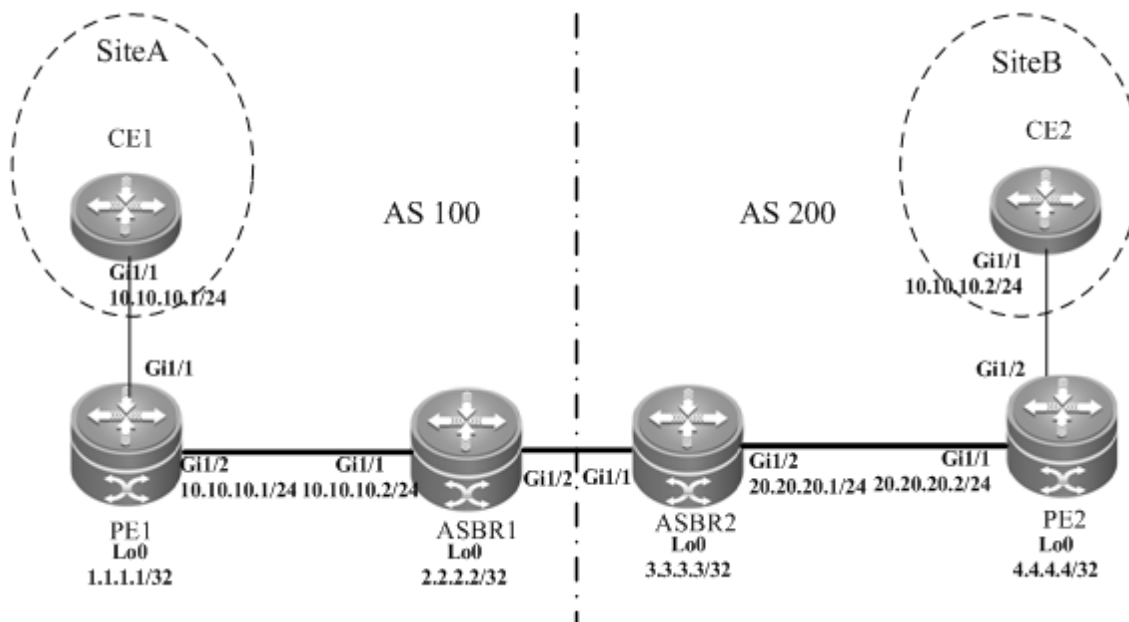
3.3.11.3 Inter-AS Configuration Examples – Option C Solution

Networking Requirements

- LAN segments of customer S in site A and site B are connected with each other through the carrier's PE1 in AS 1 and PE2 in AS 2, forming a virtual and simulative LAN service or VPLS service.
- PE1 and PE2 are in different ASs and can automatically detect PE devices involved in the VPLS instance.
- ASBR is not responsible for maintaining VPLS label block messages.
- VPLS label block messages are directly exchanged between PEs.

Networking Topology

Figure 78 Kompella VPLS Option C inter-AS networking topology



The preceding figure shows the structure of Kompella VPLS Option C inter-AS networking topology. Customer S's LAN segments in site A and site B are connected to each other through PE1 in AS 100 and PE2 in AS200 as one LAN.

Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between VPLS-PE and ASBR devices in the same AS.
- Establish a public network tunnel between PE and ASBR devices in the same AS and enable MPLS on the ASBR interface.
- Establish IBGP between PE and ASBR in the same AS.
- Establish EBGP between ASBR devices and enable send-label.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, planned site number, VE ID deviation, and interface information from the network administrator.



Caution

When Option C (multihop MP-EBGP) is applied to realize inter-AC Kompella L2VPN applications, the next hop will be changed to itself by default when such information is sent to the peer EBGP if the MP-EBGP connection is set up by the route reflector between ASs to switch NLRI information of L2VPN. To realize the Kompella L2VPN through Option C solution, the **neighbor next-hop-unchanged** command must be configured on the route reflector so that the reflector does not change the next hop when NLRI information is sent. Otherwise, the inter-AS forwarding fails.

Configuration Steps

3. Configuring L2VPN

■ Configuring CE1:

See "Configuring CE1" in basic configuration examples.

■ Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Qtech(config-router)# neighbor 4.4.4.4 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 4.4.4.4 activate
Qtech(config-router-af)# exit
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Configure the interface that connects CEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring ASBR1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
```

3. Configuring L2VPN

```
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the interface that connects ASBRs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Enable ASBRs to allocate labels for PEs' routes.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 192.168.1.2 remote-as 200
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.2 send-label
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ Configuring ASBR2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the interface that connects ASBRs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Enable ASBRs to allocate labels for PEs' routes.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 192.168.1.1 remote-as 100
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.1 send-label
```

3. Configuring L2VPN

```
Qtech(config-router-af)# network 4.4.4.4 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ **Configuring PE2:**# **Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 200
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 1.1.1.1 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 1.1.1.1 activate
Qtech(config-router-af)# exit
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure a VLAN interface.

```
Qtech(config)# vlan 10
Qtech(config-vlan)# exit
```

Enable the interface that connects PEs and CEs to bind the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# mtu 1500
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface vlan 10
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ **Configuring CE2:**

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

Command**Function**

3. Configuring L2VPN

Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [<i>vc_id</i>] [<i>ip-address</i>] [interface <i>interface_name</i>] [detail]	Displays information about the PW (including VPWS PW and VPLS PW)
Qtech# show bgp l2vpn { vpls vpws } all connections [<i>neighbor address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

3.3.12 Typical Examples of Kompella VPLS Configuration for Routers

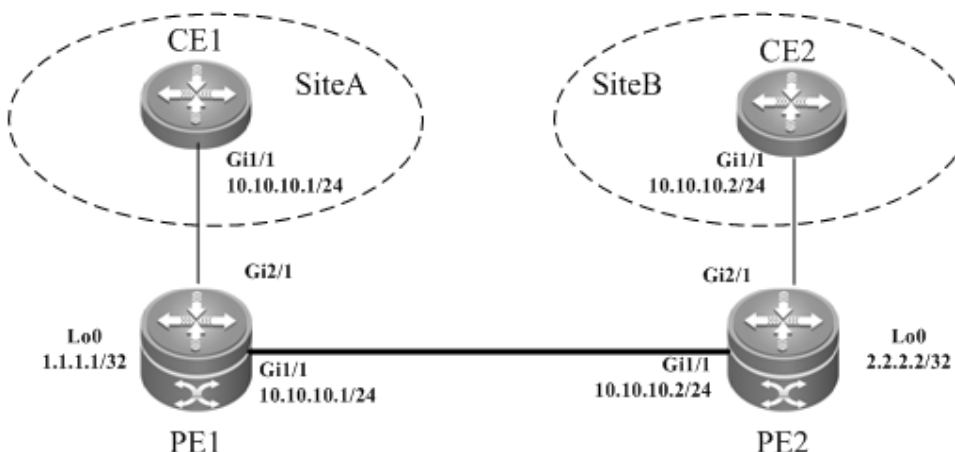
3.3.12.1 Basic Configuration Examples (Ethernet Access)

Networking Requirements

- LAN segments of customer S in site A and site B are connected with each other through the carrier's network devices, PE1 and PE2, forming a virtual and simulative LAN service or VPLS service.
- PE1 and PE2 are in the same AS and can automatically detect PE devices involved in the VPLS instance.
- Customer S's long-term network deployment plan is to connect LANs in five sites at most.
- The signaling protocol adopted by the carrier is the MP-BGP4 protocol.
- PEs are connected to CEs through the Ethernet interface.

Networking Topology

Figure 79 Basic Kompella VPLS configuration networking topology



Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Configure the public network tunnel that transmits data frames between VPLS PEs.
- Enable the L2VPN address family on PEs.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, planned site number, VE ID deviation, and interface information from the network administrator, and configure the Kompella VPLS instance.
- Configure the user access VPLS.

Configuration Steps

- Configuring CE1:

Configure OSPF.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.1 255.255.255.0
Qtech(config-router)# exit
```

■ Configuring PE1**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community extended
Qtech(config-router-af)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# 12 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 2/1
Qtech(config-vfi-site)#exit-site-id
Qtech(config-vfi)# exit
```

Configure the interface.

```
Qtech(config)# interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)# ip ref
Qtech(config-if-GigabitEthernet 2/1)# exit
```

■ Configuring PE2:**# Configure the loopback interface address.**

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
```

3. Configuring L2VPN

```
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 2/1
Qtech(config-vfi-site)#exit-site-id
Qtech(config-vfi)#exit
```

Configure the interface.

```
Qtech(config)# interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)# ip ref
Qtech(config-if-GigabitEthernet 2/1)# exit
```

■ Configuring CE2:**# Configure OSPF.**

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-router)# exit
```

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

Command	Function
Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [<i>vc_id</i> [<i>ip-address</i>]] [interface <i>interface_name</i>] [detail]	Displays information about PW (including VPWS PW and VPLS PW)
Qtech# show bgp l2vpn { vpls vpws } all connections [<i>neighbor address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

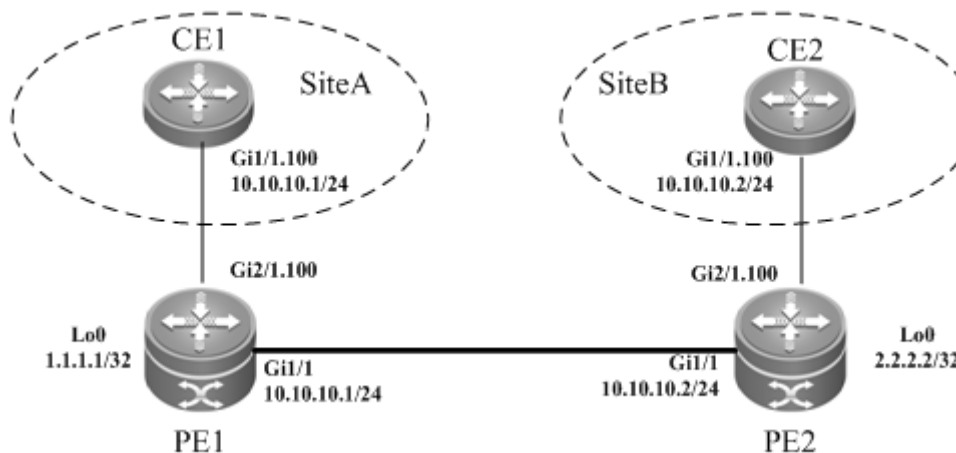
3.3.12.2 Basic Configuration Examples (Ethernet Sub-interface Access)**Networking Requirements**

3. Configuring L2VPN

- LAN segments of customer S in site A and site B are connected with each other through the carrier's network devices, PE1 and PE2, forming a virtual and simulative LAN service or VPLS service.
- PE1 and PE2 are in the same AS and can automatically detect PE devices involved in the VPLS instance.
- Customer S's long-term network deployment plan is to connect LANs in five sites at most.
- The signaling protocol adopted by the carrier is the MP-BGP4 protocol.
- PEs are connected to CEs through the Ethernet sub-interface.

Networking Topology

Figure 80 Basic Kompella VPLS configuration networking topology



Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Configure the public network tunnel that transmits data frames between VPLS PEs.
- Enable the L2VPN address family on PEs.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, planned site number, VE ID deviation, and interface information from the network administrator, and configure the Kompella VPLS instance.
- Configure the user access VPLS.

Configuration Steps

- Configuring CE1:

Configure OSPF.

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
Qtech(config)# interface gigabitEthernet 1/1.100
Qtech(config-if-GigabitEthernet 1/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 1/1.100)# ip address 10.10.10.1 255.255.255.0
Qtech(config-router)# exit
```

- Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
```

3. Configuring L2VPN

```
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community extended
Qtech(config-router-af)# exit
```

Configure an interface.

```
Qtech(config)# interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)# ip ref
Qtech(config-if-GigabitEthernet 2/1)# exit
Qtech(config)# interface gigabitEthernet 2/1.100
Qtech(config-if-GigabitEthernet 2/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 2/1.100)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 1:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 2/1.100
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
```


3. Configuring L2VPN

```
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Bind the interface to the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)# ip ref
Qtech(config-if-GigabitEthernet 2/1)# exit
Qtech(config)# interface gigabitEthernet 2/1.100
Qtech(config-if-GigabitEthernet 2/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 2/1.100)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 2:2
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernetvlan
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 2/1.100
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring CE2:**# Configure OSPF.**

```
Qtech# configure terminal
Qtech(config)# router ospf 10
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1.100
Qtech(config-if-GigabitEthernet 1/1.100)# encapsulation dot1Q 100
Qtech(config-if-GigabitEthernet 1/1.100)# ip ref
Qtech(config-if-GigabitEthernet 1/1.100)# ip address 10.10.10.2 255.255.255.0
Qtech(config-router)# exit
```

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

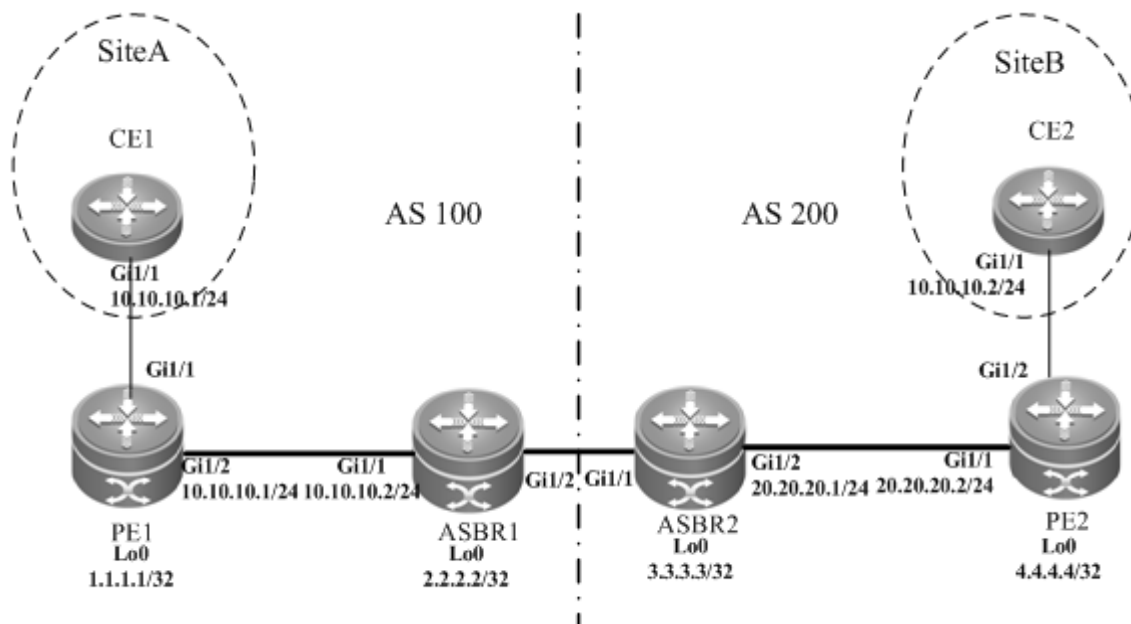
Command	Function
Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [<i>vc_id</i>] [<i>ip-address</i>] [interface <i>interface_name</i>] [detail]	Displays information about the PW (including VPWS PW and VPLS PW).
Qtech# show bgp l2vpn { vpls vpws } all connections [<i>neighbor address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

3.3.12.3 Inter-AS Configuration Examples – Option A Solution**Networking Requirements**

- LAN segments of customer S in site A and site B are connected with each other through the carrier's PE1 in AS 100 and PE2 in AS 200, forming a virtual and simulative LAN service or VPLS service;
- PE1 and PE2 are in different ASs. ASBR1 and ASBR2 are considered CE devices by each other, which means that the interface between ASBRs connects the AC to the VPLS instance.

Networking Topology

Figure 81 Kompella VPLS inter-AS networking topology



The preceding figure shows the structure of the Kompella VPLS inter-AS networking topology in Option A. The intermediate interface is considered by ASBRs as AC connection.

Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between PE and ASBR devices.
- Establish the MP-IBGP peer relationship between PEs and intra-domain ASBRs in the domain.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, maximum planned site number, VE ID deviation, and interface information from the network administrator.

Configuration Steps

- Configuring CE1:

See "Configuring CE1" in basic configuration examples.

- Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

3. Configuring L2VPN

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 2.2.2.2 remote-as 100
Qtech(config-router)# neighbor 2.2.2.2 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 2.2.2.2 activate
Qtech(config-router-af)# neighbor 2.2.2.2 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface between CEs and PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1
Qtech(config-vfi-site)#exit-site-mode
```

■ Configuring ASBR1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 100
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
```

3. Configuring L2VPN

```
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# mtu 1500
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring ASBR2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface between ASBR1 and ASBR2.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 3
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes so that PEs can ping with ASBRs in the same AS.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
```

3. Configuring L2VPN

```
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 3.3.3.3 remote-as 200
Qtech(config-router)# neighbor 3.3.3.3 update-source loopback 0
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 3.3.3.3 activate
Qtech(config-router-af)# neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface that connects PE2 and a CE.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 4
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring CE2:

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

Command	Function
Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [<i>vc_id</i> [<i>ip-address</i>]] [interface <i>interface_name</i>] [detail]	Displays information about PW (including VPWS PW and VPLS PW)
Qtech# show bgp l2vpn { vpls vpws } all connections [neighbor <i>address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

3.3.12.4 Inter-AS Configuration Examples – Option C Solution**Networking Requirements**

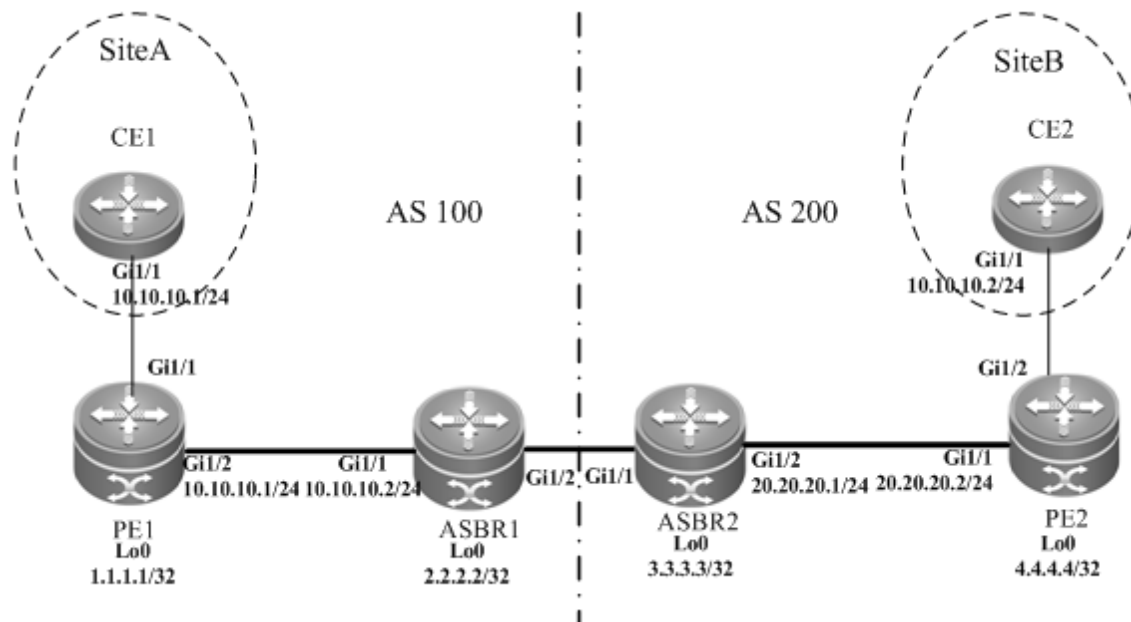
- LAN segments of customer S in site A and site B are connected with each other through the carrier's PE1 in AS 1 and PE2 in AS 2, forming a virtual and simulative LAN service or VPLS service.
- PE1 and PE2 are in different ASs and can automatically detect PE devices involved in the VPLS instance.

3. Configuring L2VPN

- ASBR is not responsible for maintaining VPLS label block messages.
- VPLS label block messages are directly exchanged between PEs.

Networking Topology

Figure 50 Kompella VPLS Option C inter-AS networking topology



The preceding figure shows the structure of Kompella VPLS Option C inter-AS networking topology. Customer S's LAN segments in site A and site B are connected to each other through PE1 in AS 100 and PE2 in AS 200 as one LAN.

Configuration Tips

Before configuring Kompella VPLS, complete the following tasks:

- Run IGP in the carrier's network to realize connection between VPLS-PE and ASBR devices in the same AS.
- Establish a public network tunnel between PE and ASBR devices in the same AS and enable MPLS on the ASBR interface.
- Establish IBGP between PE and ASBR devices in the same AS.
- Establish EBGP between ASBR devices and enable send-label.
- Obtain Kompella VPLS configuration information including VPLS instance descriptive information, RT value, VE ID, planned site number, VE ID deviation, and interface information from the network administrator.



Caution

When Option C (multihop MP-EBGP) is applied to realize Inter-AC Kompella L2VPN applications, the next hop will be changed to itself by default when such information is sent to the peer EBGP if the MP-EBGP connection is set up by the route reflector between ASs to switch NLRI information of L2VPN. To realize the Kompella L2VPN through Option C solution, the **neighbor next-hop-unchanged** command must be configured on the route reflector so that the reflector does not change the next hop when NLRI information is sent. Otherwise, inter-AS forwarding fails.

Configuration Steps

- Configuring CE1:

See "Configuring CE1" in basic configuration examples.

- Configuring PE1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

3. Configuring L2VPN

```
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 4.4.4.4 remote-as 200
Qtech(config-router)# neighbor 4.4.4.4 update-source loopback 0
Qtech(config-router)# neighbor 4.4.4.4 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 4.4.4.4 activate
Qtech(config-router-af)# exit
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 4.4.4.4 activate
Qtech(config-router-af)# neighbor 4.4.4.4 send-community extended
Qtech(config-router-af)# exit
```

Configure the interface that connects CEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 100:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# site-id 1
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/1
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring ASBR1:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 10
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)# network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

#Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
```

3. Configuring L2VPN

```
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the interface that connects ASBRs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Enable ASBRs to allocate labels for PE's routes.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 192.168.1.2 remote-as 200
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.2 send-label
Qtech(config-router-af)# network 1.1.1.1 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ Configuring ASBR2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# redistribute bgp subnets
Qtech(config-router)# network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# advertise-labels for bgp-routes
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure the interface that connects ASBRs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Enable ASBRs to allocate labels for PE's routes.

```
Qtech(config)# router bgp 200
Qtech(config-router)# neighbor 192.168.1.1 remote-as 100
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# neighbor 192.168.1.1 send-label
Qtech(config-router-af)# network 4.4.4.4 mask 255.255.255.255
Qtech(config-router-af)# end
```

■ Configuring PE2:

Configure the loopback interface address.

```
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 4.4.4.4 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

Configure OSPF and establish public network routes.

```
Qtech(config)# router ospf 20
Qtech(config-router)# network 4.4.4.4 0.0.0.0 area 0
Qtech(config-router)# network 20.20.20.0 0.0.0.255 area 0
```



```
Qtech(config-router)# exit
```

Configure LDP and globally enable MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure the public network tunnel between PEs.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip ref
Qtech(config-if-GigabitEthernet 1/1)# ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
```

Configure the L2VPN address family.

```
Qtech(config)# router bgp 100
Qtech(config-router)# neighbor 1.1.1.1 remote-as 200
Qtech(config-router)# neighbor 1.1.1.1 update-source loopback 0
Qtech(config-router)# neighbor 1.1.1.1 ebgp-multihop
Qtech(config-router)# address-family ipv4
Qtech(config-router-af)# no neighbor 1.1.1.1 activate
Qtech(config-router-af)# exit
Ruijie(config-router)# address-family l2vpn vpls
Qtech(config-router-af)# neighbor 1.1.1.1 activate
Qtech(config-router-af)# neighbor 1.1.1.1 send-community extended
Qtech(config-router-af)# exit
```

Enable the interface that connects PEs and CEs to bind the VPLS instance.

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip ref
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure a VPLS instance.

```
Qtech# configure terminal
Qtech(config)# l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi)# rd 200:1
Qtech(config-vfi)# signal bgp
Qtech(config-vfi)# encapsulation mpls ethernet
Qtech(config-vfi)# route-target both 10000:1
Qtech(config-vfi)# mtu 1500
Qtech(config-vfi)# site-id 2
Qtech(config-vfi-site)# xconnect interface gigabitEthernet 1/2
Qtech(config-vfi-site)#exit-site-mode
Qtech(config-vfi)#exit
```

■ Configuring CE2:

See "Configuring CE2" in basic configuration examples.

Verification

After the configuration, CE1 can ping with CE2.

After completing the configuration of Kompella VPLS, use the following commands to check the operation of VPLS.

Command	Function
Qtech# show bgp l2vpn vpls all	Displays all the VPLS information.
Qtech# show mpls l2transport vc [<i>vc_id</i> [<i>ip-address</i>]] [interface <i>interface_name</i>] [detail]	Displays information about the PW (including VPWS PW and VPLS PW)
Qtech# show bgp l2vpn { vpls vpws } all connections [<i>neighbor address</i>] [interface <i>interface_name</i>] [site-id <i>id</i>] [detail]	Displays VPLS PW information.
Qtech# show mpls vfi [<i>name</i>]	Displays all the configured or specified VFI information.

3.3.13 Examples of Maintaining PW Connectivity of VPLS

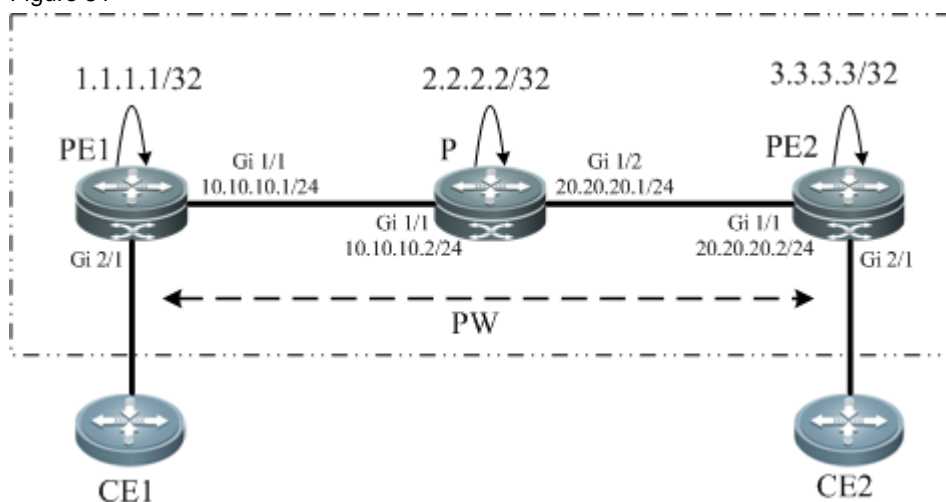
3.3.13.1 Verifying PW Connectivity and Fault of Martini VPLS

Networking Requirements

- The CE devices play the role of the customer network to connect to the PE devices via the AC.
- PE1 and PE2 establish a PW between them via LDP.
- PE1, P, and PE2 set up the public tunnel and LSP path via LDP.

Network Topology

Figure 51



Configuration Key Points

The configuration key points for PE1, P, and PE2 are as follows:

- Configure the IP address of the interface of each device and configure the OSPF protocol.
- Configure the global MPLS capability and the interface MPLS capability of each device.
- Configure LDP to enable the network to forward MPLS traffic.
- Configure the VPLS.
- Check the PW connectivity.
- Locate the PW fault.

Configuration Steps

- (1) Configure the IP address of the interface of each node and configure the OSPF protocol.

#Configure PE1.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure P.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
```

```
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure PE2.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

- (2) Configure the global MPLS capability and the interface MPLS capability of each node and enable the LDP function on the interfaces.

#Configure PE1.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#neighbor 3.3.3.3
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

#Configure P.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#mpls ip
Qtech(config-if-GigabitEthernet 1/2)#label-switching
Qtech(config-if-GigabitEthernet 1/2)#exit
```

#Configure PE2.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#neighbor 1.1.1.1
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

- (3) Configure VPLS instances between PE1 and PE2 and enable CE1 and CE2 to access the VPLS.

#Configure PE1.

```
Qtech(config)# l2 vfi vfi-a vpnid 1
Qtech(config-vfi)# neighbor 1.1.1.1 vc-id 100 encapsulation mpls
Qtech(config-vfi)# exit
```

```

Qttech(config)# vlan 10
Qttech(config-vlan)# exit
Qttech(config)# interface vlan 10
Qttech(config-if-Vlan 10)# xconnect vfi vfi-a
Qttech(config-if-Vlan 10)# exit
Qttech(config)# interface gigabitEthernet 3/2
Qttech(config-if-GigabitEthernet 3/2)# switchport access vlan 10
Qttech(config-if-GigabitEthernet 3/2)# exit

```

#Configure PE2.

```

Qttech(config)# l2 vfi vfi-a vpnid 1
Qttech(config-vfi)# neighbor 3.3.3.3 vc-id 100 encapsulation mpls
Qttech(config-vfi)# exit
Qttech(config)# vlan 10
Qttech(config-vlan)# exit
Qttech(config)# interface vlan 10
Qttech(config-if-Vlan 10)# xconnect vfi vfi-a
Qttech(config-if-Vlan 10)# exit
Qttech(config)# interface gigabitEthernet 1/3
Qttech(config-if-GigabitEthernet 1/3)# switchport access vlan 10
Qttech(config-if-GigabitEthernet 1/3)# exit

```

(4) Verify the PW connectivity.

```

Qttech#ping mpls pseudowire 3.3.3.3 100 label-alert
Sending 5, 112-byte MPLS Echoes on Pseudowire, peer address 3.3.3.3, VC ID 100,
  timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
Press Ctrl+C to break.
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 m

```

(5) Locate the PW fault.

```

Qttech#traceroute mpls pseudowire 3.3.3.3 100 segment 1 ttl-expiry
Tracing Pseudowire Label Switched Path, peer address 3.3.3.3, VC ID 100, timeout is
2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0

Press Ctrl+C to break.
 0 10.10.10.2      MRU 1500 [Labels: 1025 Exp: 0]
! 1 20.20.20.2    60 ms [Labels: 1025 Exp: 0]
   local 1.1.1.1 remote 3.3.3.3 vc id 100

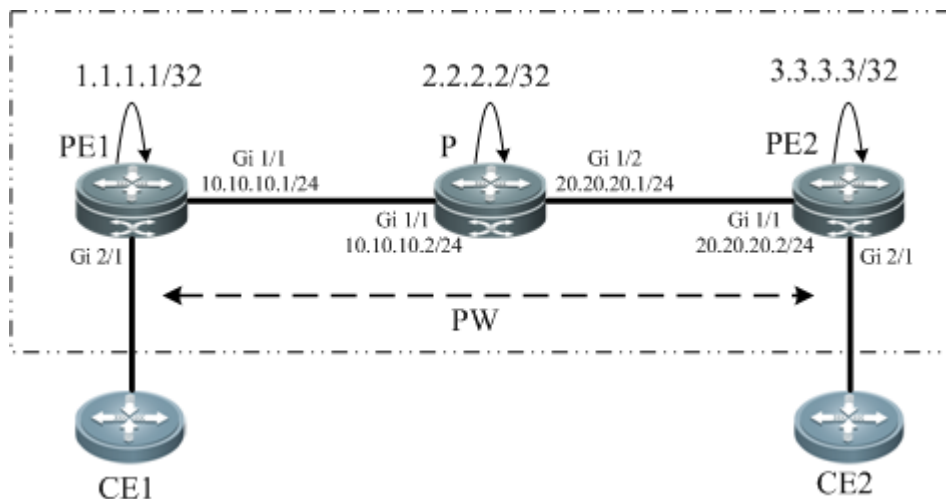
```

3.3.13.2 Verifying PW Connectivity of Kompella VPLS**Networking Requirements**

As shown in Figure 3-36, PE1, P, and PE2 belong to the same MPLS domain, and CE1 and CE2 belong to the same VPN instance. PE1 and PE2 establish a PW between them and use the ping or traceroute command to check the PW connectivity to ensure services on the links.

Network Topology

Figure 52Ошибка! Не указана последовательность.



Configuration Key Points

The configuration key points for each node are as follows:

- Configure the IP address of the interface of each node and configure the OSPF protocol.
- Configure the global MPLS capability and the interface MPLS capability of each node.
- Enable the L2VPN on PE1 and PE2 and create a VC connection.
- Check the PW connectivity.
- Locate the PW fault.

Configuration Steps

(1) Configure the IP address of the interface of each node and configure the OSPF protocol.

#Configure PE1.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 1.1.1.1 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 1.1.1.1 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure P.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 2.2.2.2 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 10.10.10.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 2.2.2.2 0.0.0.0 area 0
Qtech(config-router)#network 10.10.10.0 0.0.0.255 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

#Configure PE2.

```
Qtech(config)#interface loopback 0
Qtech(config-if-Loopback 0)#ip address 3.3.3.3 255.255.255.255
Qtech(config-if-Loopback 0)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#router ospf 10
Qtech(config-router)#network 3.3.3.3 0.0.0.0 area 0
Qtech(config-router)#network 20.20.20.0 0.0.0.255 area 0
Qtech(config-router)#exit
```

- (2) Configure the global MPLS capability and the interface MPLS capability of each node and enable the LDP function on the interfaces.

#Configure PE1.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

#Configure P.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#mpls ip
Qtech(config-if-GigabitEthernet 1/2)#label-switching
Qtech(config-if-GigabitEthernet 1/2)#exit
```

#Configure PE2.

```
Qtech(config)#mpls ip
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
Qtech(config-mpls-router)#exit
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#exit
```

- (3) Configure a L2VPN address family.

#Configure PE1.

```
Qtech(config)#router bgp 100
Qtech(config-router)#neighbor 3.3.3.3 remote-as 100
Qtech(config-router)#neighbor 3.3.3.3 update-source loopback 0
Ruije(config-router)#address-family l2vpn vpws
Qtech(config-router-af)#neighbor 3.3.3.3 activate
Qtech(config-router-af)#neighbor 3.3.3.3 send-community extended
Qtech(config-router-af)#exit
```

#Configure PE2.

```
Qtech(config)#router bgp 100
Qtech(config-router)#neighbor 1.1.1.1 remote-as 100
Qtech(config-router)#neighbor 1.1.1.1 update-source loopback 0
Ruije(config-router)#address-family l2vpn vpws
Qtech(config-router-af)#neighbor 1.1.1.1 activate
Qtech(config-router-af)#neighbor 1.1.1.1 send-community extended
```

```
Qtech(config-router-af) #exit
```

(4) Configure a VFI instance.**#Configure PE1.**

```
Qtech(config) # vlan 10
Qtech(config-vlan) # exit
Qtech(config) # interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2) # switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/2) # exit
Qtech(config) # l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi) # rd 1:1
Qtech(config-vfi) # signal bgp
Qtech(config-vfi) # encapsulation mpls ethernet
Qtech(config-vfi) # route-target both 10000:1
Qtech(config-vfi) # site-id 1
Qtech(config-vfi-site) # xconnect interface vlan 10
Qtech(config-vfi-site) #exit-site-mode
Qtech(config-vfi) # eixt
```

#Configure PE2.

```
Qtech(config) # vlan 10
Qtech(config-vlan) # exit
Qtech(config) # interface gigabitEthernet 1/3
Qtech(config-if-GigabitEthernet 1/3) # switchport access vlan 10
Qtech(config-if-GigabitEthernet 1/3) # exit
Qtech(config) # l2 vfi vpls-1 vpnid 1 autodiscovery
Qtech(config-vfi) # rd 1:1
Qtech(config-vfi) # signal bgp
Qtech(config-vfi) # encapsulation mpls ethernet
Qtech(config-vfi) # route-target both 10000:1
Qtech(config-vfi) # site-id 1
Qtech(config-vfi-site) # xconnect interface vlan 10
Qtech(config-vfi-site) #exit-site-mode
Qtech(config-vfi) # eixt
```

(5) Verify the PW connectivity.

```
Qtech#ping mpls pseudowire kompella vpls-1 1 2 rd 1:1 label-alert
Sending 5, 112-byte MPLS Echoes on Pseudowire, VFI name vpls-1, local site id, 1,
remote site id 2,
    timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
Press Ctrl+C to break.
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max=20/36/60 ms
```

(6) Locate the PW fault.

```
Qtech#traceroute mpls pseudowire kompella vpls-1 1 2 rd 1:1 label-alert
Tracing Pseudowire Label Switched Path, VFI name vpls-1, local site id 1, remote
site id 2, timeout is 2 seconds.
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0

Press Ctrl+C to break.
0 10.10.10.2 MRU 1500 [Labels: router-alert/1538 Exp: 0/0]
```

! 1 20.20.20.2 20 ms

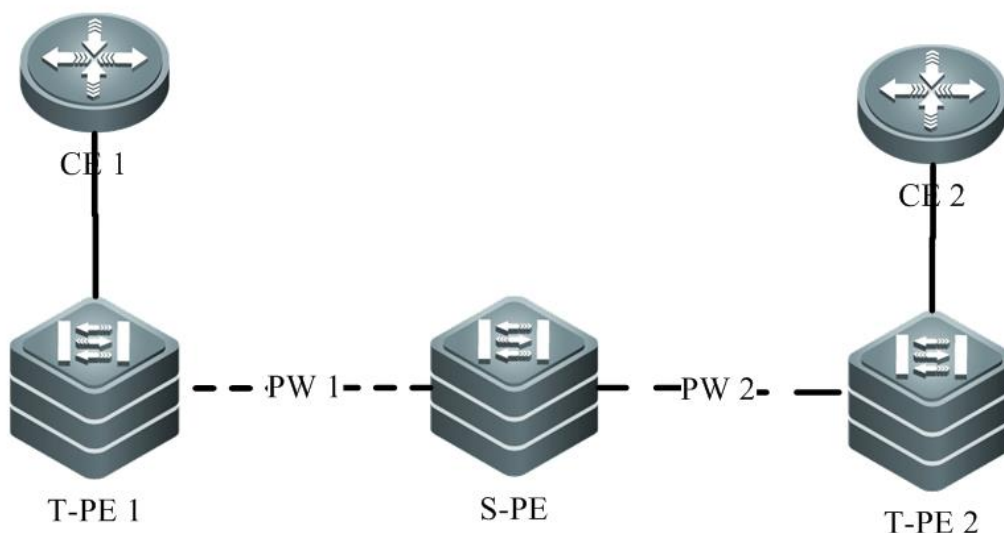
3.4 MS-PW

3.4.1 Introduction

MS-PW is an intra-domain or cross-domain end-to-end pseudo wire in the IP/MPLS network, and is set up between two user-oriented T-PE devices of the operator and passes through one or more PE devices (switches). It is used to simulate Layer 2 point-to-point services. The MS-PW allows you to carry the specific services from the AC across domains on the paths or tunnels between the ingress and egress of the PW and to manage the information such as the service-related signaling, statuses, and alarms on the border of the PW.

3.4.1.1 Overview

Figure 53 Basic MS-PW Topology



Involved devices are as follows:

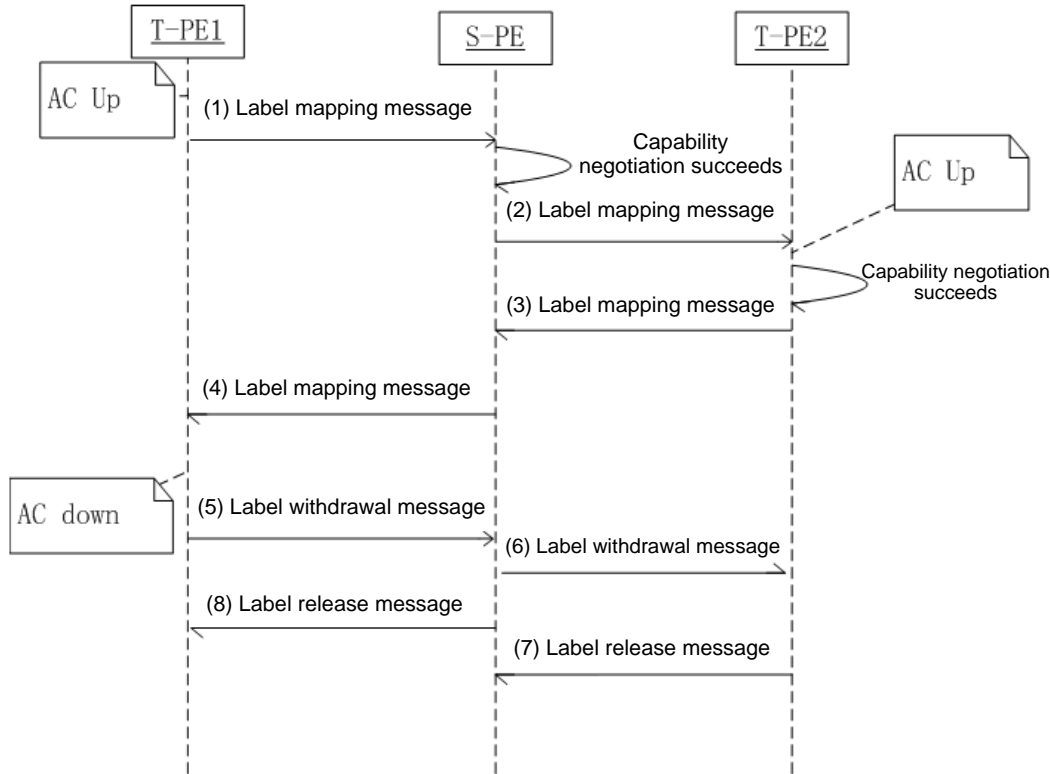
- CE (customer edge): the device directly connected to the user network and operator network. It can be a router, a bridge device, or a host. The customer edge is the start point and end point of the simulation service. It does not participate in the establishment and maintenance of the PW. Therefore, it cannot perceive whether the end-to-end PW exists.
- T-PE (PW terminating provider edge): the device connected to the customer edge via the access circuit. This type of device mainly processes the data from the CE devices and forwards it to the peer PE devices. In addition, T-PE needs to process the simulation data from the peer end-to-end PW of the PW.
- S-PE (switching provider edge): a key device in the establishment of a MS-PW. It serves as the joint of the control plane and data plane of the MS-PW between two T-PEs and connects the adjacent segments of the MS-PW based on the PW identifier. On the data plane, the S-PE handles the multiplex layer of the PW and exchanges PW packets between adjacent PW segments. On the control plane, the S-PE participates in the establishment and maintenance of the PW. In addition, it participates in the VCCV and operation, administration, and management (OAM). You can also pre-configure the PW segments on the S-PE and bind the two PW segments on both sides of the S-PE.

3.4.1.2 Working Principle

The connection of multiple PW segments is not directly set up between two T-PE devices, but via an S-PE. For example, as shown in Figure 3-38, T-PE1 and T-PE2 set up a connection with the S-PE separately. The S-PE is responsible for connecting the PW segments on both sides of it. During establishment signaling negotiation, one of the T-PE devices sends a mapping packet that carries parameters to the S-PE, and the S-PE processes the packet and then forwards the processed packet to the other T-PE. After the parameters of both T-PE devices are

negotiated, the PW is established. Same with the mapping packets, the release, withdrawal, and notification packets are also transmitted segment by segment.

Figure 54 MS-PW Signaling Interworking



Implementation of the MS-PW solution is described in detail as follows:

- A PW segment connecting T-PE1 with the S-PE and a PW segment connecting T-PE2 with the S-PE are configured. During the signaling connection, T-PE1 and T-PE2 play the active role and the S-PE plays the passive role. However, if the S-PE is configured in static mode, it serves as the T-PE.
- The S-PE connects the two PW segments. During the signaling negotiation, the parameters of T-PE1 and T-PE2 are negotiated through the S-PE. If the parameters of both ends are consistent, the PW is established via the S-PE. Otherwise, the S-PE does not send label mapping messages to the downstream devices.
- Same with the mapping packets, the release, withdrawal, and notification packets are also transmitted segment by segment, so that the packets can be forwarded to each segment or one of the MS-PW segments can be removed without affecting others.

The figure above shows that T-PE1 initiates a delete or reset message. However, any PE device (T-PE or S-PE) on the MS-PW can possibly initiate the delete or reset message for certain reasons, causing the removal of the MS-PW. Similarly, the PE devices only need to send related messages to each PW segment of the MS-PW.

3.4.1.3 Protocols and Standards

- RFC5254: Requirements for Multi-Segment Pseudo-wire Emulation Edge-to-Edge (PWE3)
- RFC 6073: Segmented Pseudowire
- RFC 5659: An Architecture for Multi-Segment Pseudowire Emulation Edge-to-Edge
- RFC 5085: Pseudowire Virtual Circuit Connectivity Verification (VCCV): A Control Channel for Pseudowire

3.4.2 Defaults

The default PW value of the T-PE is the same as that of a common Martini VPWS and static VPWS. For the S-PE, when the PW is dynamically established, the related PW attributes of the default PW value are obtained via negotiation with the T-PE.

3.4.3 Configuring MS-PW

Perform the following steps to configure a MS-PW:

- (Mandatory) Configure the MPLS.
- (Mandatory) Configure PW segments.
- (Mandatory) Configure the PW switching point.
- Display the configuration.

3.4.3.1 Configuring MPLS

Enable the MPLS on the T-PEs and S-PE. The configuration is similar to the configuration of public network tunnels described in Section 3.2 "VPWS".

3.4.3.2 Configuring PW Segments

Configure the PW segments on both T-PE devices. The configuration is the same as that of the Martini VPWS and static VPWS. For details, see related sections.

3.4.3.3 Configuring PW Switching Point

Run the following commands to configure the PW switching point on S-PE:

Command	Function
Qtech# config terminal	Enters the global configuration mode.
Qtech(config)# l2 vfi name switching	Creates a switching VFI instance.
Qtech(config-vfi)# neighbor ip-address vc-id encapsulation mpls [manual] [no-switching-tlv] [tnl-policy policy-name]	Joins the PWs located on both sides of the VFI.
Qtech(config-vfi)# end	Returns to the privileged EXEC mode.
Qtech# copy running-config startup-config	Saves the configuration.



Caution

The MS-PW can be established only after the PWs are configured successfully on both sides of S-PE.

3.4.3.4 Displaying Configuration

After the configuration is completed, run the following commands to display the information of the switching VFI:

Command	Function
Qtech# show mpls switching vfi [name]	Displays the information of the switching VFI.
Qtech# show mpls l2transport switching vfi [name]	Displays the switching information of the switching VFI.

3.4.4 Examples of Configuring MS-PW

3.4.4.1 Configuring Static MS-PW

Networking Requirements

You need to connect CE1 on Site A and CE2 on Site B to T-PE1 and T-PE2 respectively. The requirements are as follows:

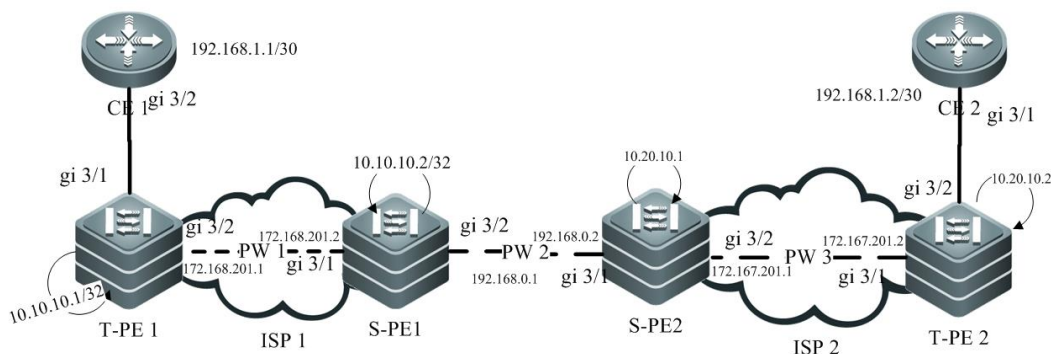
- (1) T-PE1 and S-PE1 establish PW1.

(2) S-PE2 and T-PE2 establish PW3.

(3) Join PW1 and PW2 (from S-PE1 to S-PE2) on the switching node S-PE1 and join PW2 and PW3 (from S-PE1 to S-PE2) on the switching node S-PE2 to establish a cross-domain MS-PW.

Network Topology

Figure 55 Cross-domain MS-PW



Configuration Key Points

The configuration key points are as follows:

- The CE device is connected to the PE device through an Ethernet interface. The PW operates in Ethernet mode.
- The MPLS is configured on the backbone network to establish a label switched path (LSP) statically.
- PW segments are configured between T-PE1 and S-PE1 and between T-PE2 and S-PE2 separately.
- The PWs on both sides of the two switching node device are statically joined to form a MS-PW.

Configuration Steps

■ Configure CE-1.

#Configure the IP address.

```
Qtech# config terminal
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip address 192.168.1.1 255.255.255.252
Qtech(config-if-GigabitEthernet 3/2)# exit
```

■ Configure CE-2.

■ The configuration of CE-2 is similar to that of CE-1. Configure T-PE1.

#Configure the IP address.

```
Qtech# config terminal
Qtech(config)# interface loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.1 255.255.255.255
Qtech(config-if-Loopback 0)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# ip address 172.168.201.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)# exit
```

Qtech(config)##Configure the routing protocol.

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.10.10.1 0.0.0.0 area 0
Qtech(config-router)# network 172.168.201.0 0.0.0.255 area 0
Qtech(config-router)# exit
Qtech(config)#
```

#Configure the MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-router)# ldp router-id interface loopback 0 force
Qtech(config-router)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# label-switching
```

```
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# exit
Qtech(config)#
```

#Bind the interface to the VPWS.

```
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# xconnect 10.10.10.2 10 encapsulation mpls
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)#
```

#Configure the LDP extension peer.

```
Qtech(config)# mpls router ldp
Qtech(config-router)# neighbor 10.10.10.2
```

■ Configure S-PE1.

#Configure the IP address. The configuration is similar to that of T-PE1:

#Configure the routing protocol.

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 10.10.10.2 0.0.0.0 area 0
Qtech(config-router)# network 172.168.201.0 0.0.0.255 area 0
Qtech(config-router)# exit
```

#Configure the MPLS.

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-router)# ldp router-id interface loopback 0 force
Qtech(config-router)# exit
Qtech(config)# interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)# label-switching
Qtech(config-if-GigabitEthernet 3/1)# mpls ip
Qtech(config-if-GigabitEthernet 3/1)# exit
Qtech(config)# interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)# label-switching
Qtech(config-if-GigabitEthernet 3/2)# mpls ip
Qtech(config-if-GigabitEthernet 3/2)# exit
Qtech(config)#
```

#Configure the switching VFI.

```
Qtech(config)# l2 vfi ms-pw switching
Qtech(config-vfi)# neighbor 10.10.10.1 10 encapsulation mpls
Qtech(config-vfi)# neighbor 10.20.10.1 20 encapsulation mpls manual
Qtech(config-vfi)# exit
Qtech(config)#
```

#Configure the label information of the static PW.

```
Qtech(config)# mpls static-l2vc 10.20.10.1 20 out-label 200 in-label 100
```

■ Configure S-PE2.

The configuration is similar to that of S-PE1.

■ Configure T-PE2.

The configuration is similar to that of T-PE1.

Displaying

Display the status of the MS-PW on S-PE1 and S-PE2. You can find that the MS-PW is in the up state.

```
Qtech# show mpls switching vfi ms-pw
VFI name: ms-pw, Admin State: up
VFI Type: Switching, MTU: 1500
PW Encapsulation type: ethernet
Segment 1:
Peer-Address   VC-ID   State   Local-label   Remote-label   Signal
10.10.10.1     10      up      1500          1600           LDP
Segment 2:
Peer-Address   VC-ID   State   Local-label   Remote-label   Signal
10.20.10.1     20      up      100           200            Static
```

4 CONFIGURING MPLS GR

**Note**

Routers and router icons contained in this chapter refer to routers and layer-3 switches with the routing protocol enabled.

4.1 LDP GR

4.1.1 Overview

The Internet Engineering Task Force (IETF) has extended the Label Distribution Protocol (LDP), which is a signaling protocol of Multiprotocol Label Switching (MPLS), so that a device may instruct neighbors to keep related MPLS forwarding entries and set an "old" flag for these MPLS forwarding entries when the LDP is restarted on the device. After the LDP is restarted, neighbors assist the device to implement information synchronization so that the device is restored to the status before the LDP restart within the shortest possible time. The packet forwarding path does not change and data forwarding is not interrupted in the system throughout the LDP restart, guaranteeing the high reliability of MPLS application services.

4.1.1.1 Basic Concepts

GR Routers Classified by Capability

GR routers are classified by capability into GR-capable routers, GR-aware routers, and GR-unaware routers.

■ GR-Capable Router

A GR-capable router is a router that has GR capability. In general, a GR-capable router is equipped with two management boards which work in 1+1 master/slave mode. The GR-capable router can send an advertisement packet to neighboring routers during master/slave switchover of the management boards, so that neighboring routers keep forwarding entries related to the GR-capable router. After master/slave switchover, routing tables are re-established without causing route flapping or changing the packet forwarding path, guaranteeing uninterrupted data forwarding in the system.

■ GR-Aware Router

A GR-aware router is a router that has GR detection capability. It may be not equipped with two management boards but can detect that its neighbors are experiencing GR and can assist its neighbors to complete GR.

■ GR-Unaware Router

A GR-unaware router is a router that does not have GR detection capability. It cannot detect that its neighbors are experiencing GR, cannot assist its neighbors to complete GR, and does not have GR capability. Generally, if a router has no awareness capability, it is because the system software does not provide the GR feature or the GR feature is disabled.

GR Routers Classified by Role

GR routers are classified by role during router restart into GR restarters and GR helpers.

■ GR Restarter

The GR restarter has GR capability and its restart is triggered by administrators or faults.

■ GR Helper

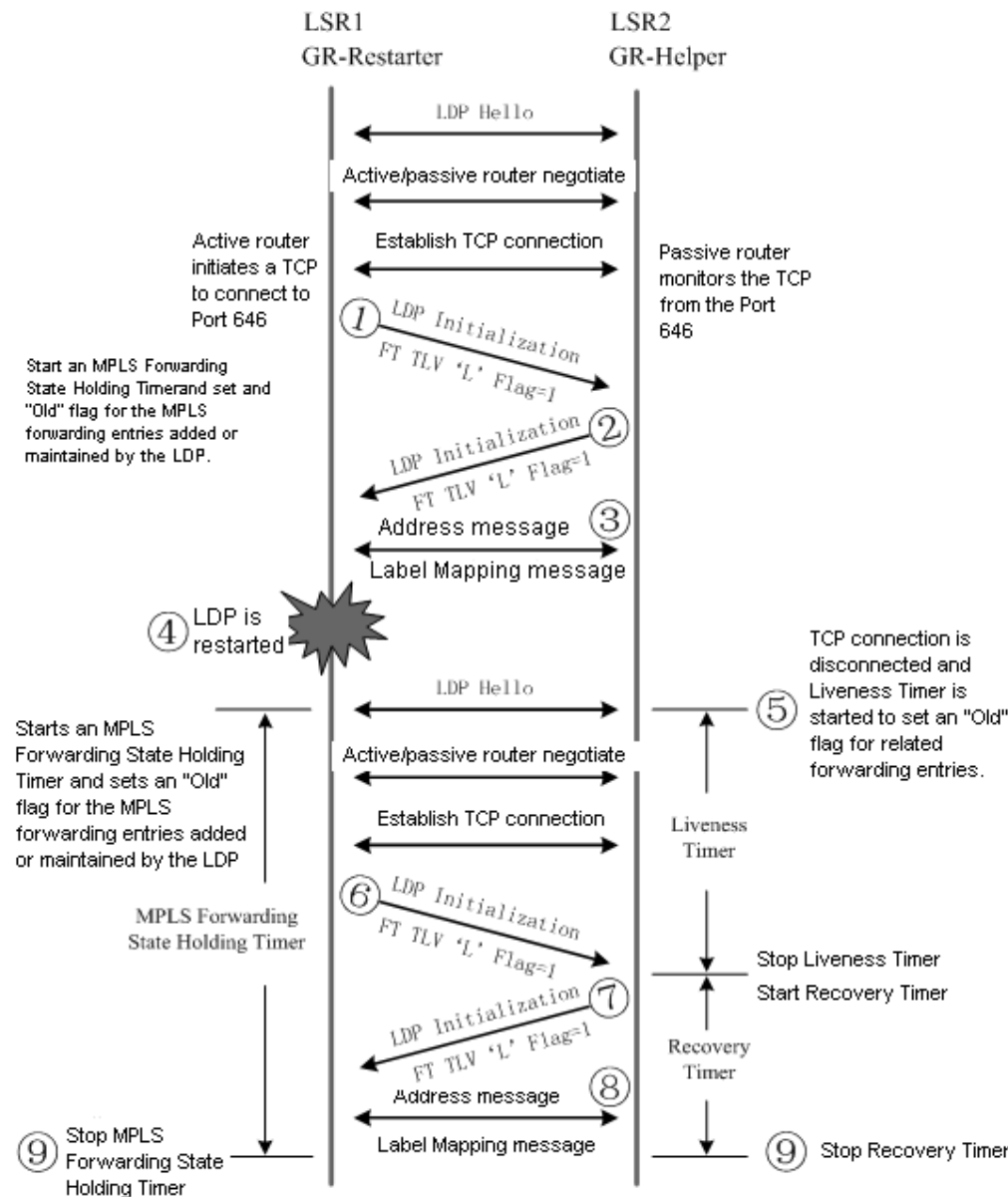
The GR helper is a neighbor of the GR restarter. It must be at least a GR-aware router.

4.1.1.2 Working Principle

The LDP GR function must be enabled on and supported by two routers in order to establish a GR-capable LDP session between them. If not, only a common LDP session can be established. If the initiator supports LDP GR and LDP GR is enabled on it during LDP session establishment, the initiator sends an Initialization message that carries an FT Session TLV.

If the passive router receives an Initialization message that carries an FT Session TLV during session establishment, it may choose to add or not add the FT Session TLV to the Initialization message to be sent to the initiator depending on its LDP GR capability. If the passive router supports LDP GR and LDP GR is enabled on it, the Initialization message will carry the FT Session TLV to establish a GR-capable LDP session. Otherwise, the Initialization message will not carry the FT Session TLV to establish a common GR-incapable LDP session. If the passive router receives an Initialization message that does not carry the FT Session TLV, a common GR-incapable LDP session is established, no matter whether the passive router adds the FT Session TLV to the Initialization message to be sent. Figure 1-1 shows the process of LDP session establishment between two Label Switching Routers (LSRs) with LDP GR capability.

Figure 1-1 LDP GR session establishment process



LSR 1 initiates an Initialization message that carries an optional FT Session TLV, indicating that LSR 1 itself supports LDP GR.

After LSR 2 that supports LDP GR receives the Initialization message that carries the FT Session TLV, it returns an Initialization message that also carries the FT Session TLV to LSR 1. When LSR 1 receives the Initialization message from LSR 2, a GR-capable LDP session is established.

LSR 1 and LSR 2 exchange LDP Address messages and Label Mapping messages with each other.

The LDP on LSR 1 is restarted for a certain reason. LSR 1 keeps all MPLS forwarding entries added or maintained by the LDP, sets an "old" flag for these forwarding entries, and starts an MPLS Forwarding State Holding Timer.

After LSR 2 with LDP GR capability detects that the GR-capable LDP session with LSR 1 is disconnected, LSR 2 keeps the MPLS forwarding entries related to this session and sets an "old" flag for these forwarding entries. At the same time, LSR 2 selects a smaller value of its Liveness Timer and the FT Reconnect Timeout in the received FT Session TLV to start a Liveness Timer, and keeps these "old" forwarding entries before the Liveness Timer is triggered.

To re-establish a session with LSR 2, LSR 1 sets the Recovery Time in the FT Session TLV of the Initialization message to the remaining value of the MPLS Forwarding State Holding Timer.

After receiving the Initialization message that carries the FT Session TLV from LSR 1, LSR 2 detects that Recovery Time is not 0, LSR 2 continues to keep the "old" forwarding entries, stops the Liveness Timer, selects a smaller value of the its Recovery Time and the Recovery Time in the received FT Session TLV to start a Recovery Timer, and keeps these "old" forwarding entries before the Recovery Timer is triggered.

LSR 1 and LSR 2 exchange LDP Address and Label Mapping messages with each other, and keep or remove the "old" flag set for MPLS forwarding entries.

The GR process ends. LSR 1 and LSR 2 delete the MPLS forwarding entries with the "old" flag from themselves respectively.

4.1.1.3 Protocols and Specifications

The protocols or specifications involved are as follows:

- RFC 3036: LDP Specification
- RFC 3037: LDP Applicability
- RFC 3215: LDP State Machine
- RFC 3478: Graceful Restart Mechanism for LDP
- RFC 3479: Fault Tolerance for LDP

4.1.2 Configuring LDP GR

Network Environment

The GR function of the MPLS LDP is configured to maintain the neighborhood and sessions between routers and recover sessions and label information when faults occur on MPLS devices.

Prerequisites

Complete the following tasks before configuring MPLS LDP GR:

- Configure IGP GR.
- Configure MPLS LDP session information.

Data Preparations


Prepare the following data before configuring MPLS LDP GR:

- LDP session re-connection time
- LDP neighbor keep-alive time
- LDP session recovery time

4.1.2.1 Configuring the LDP GR

By default, the LDP GR function is disabled on a device. To enable the LDP GR function on a device, enter privileged user mode and run the following commands:

Command	Function
Qtech#configure terminal	Enters global configuration mode.

Qtech(config)# mpls ip	Enables global MPLS forwarding.
 Caution	
This command is not applicable to forwarding on switch chips.	
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# no switchport	Sets ports to L3 ports (Switch configuration).
Qtech(config-if-type ID)# mpls ip	Enables LDP forwarding on interfaces.
Or:	
Qtech(config-if-type ID)# mpls ip	Enables LDP forwarding on interfaces (Router configuration).
Qtech(config-if-type ID)# ip ref	Enables fast forwarding on interfaces.
Qtech(config-if-type ID)# label-switching	Enables MPLS packet processing on interfaces.
Qtech(config)# mpls router ldp	Enters LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id Loopback ID force	Sets the router ID to a loopback ID (The settings immediately take effect).
Qtech(config-mpls-router)# graceful-restart	Enables LDP GR. By default, LDP GR is disabled.
Qtech(config-mpls-router)# end	Exits LDP configuration mode.
Qtech# show mpls ldp graceful-restart	Displays LDP GR sessions and session parameters.

To disable LDP GR, run the **no graceful-restart** command.



Note

The existing LDP session is not affected when LDP GR is enabled. For example, the LDP session does not restart. The LDP GR takes effect only after the LDP session restarts..

4.1.2.2 Configuring Parameters Related to LDP GR (Optional)

Enter LDP configuration mode and run the following commands:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# mpls router ldp	Enables the LDP and enters LDP configuration mode.
Qtech(config-mpls-router)# graceful-restart timer reconnect seconds	Sets the LDP session re-connection time. By default, the LDP session reconnection time is 300 seconds.
Qtech(config-mpls-router)# graceful-restart timer neighbor-liveness seconds	Sets the LDP neighbor keep-alive time. By default, the LDP neighbor keep-alive time is 120 seconds.
Qtech(config-mpls-router)# graceful-restart timer recovery seconds	Sets the LDP session recovery time. By default, the LDP session recovery time is 120 seconds.
Qtech(config-mpls-router)# end	Exits LDP configuration mode.
Qtech# show mpls ldp graceful-restart	Displays LDP GR sessions and session parameters.

To restore the default settings of parameters related to LDP GR, run the **no graceful-restart timer reconnect**, **no graceful-restart timer neighbor-liveness**, and **no graceful-restart timer recovery** commands.

4.1.2.3 Verification

To display LDP GR configuration and running information, run the following commands.

Command	Function
show mpls ldp graceful-restart	Displays LDP GR sessions and session parameters.

show mpls ldp bindings [all vrf vrf-name] [ip-address/mask label label] [remote local]	Displays the mapping between Forwarding Equivalence Classes (FECs) and labels.
show mpls ldp neighbor [all vrf vrf-name] [ip-address] [detail]	Displays the status of LDP neighbors.

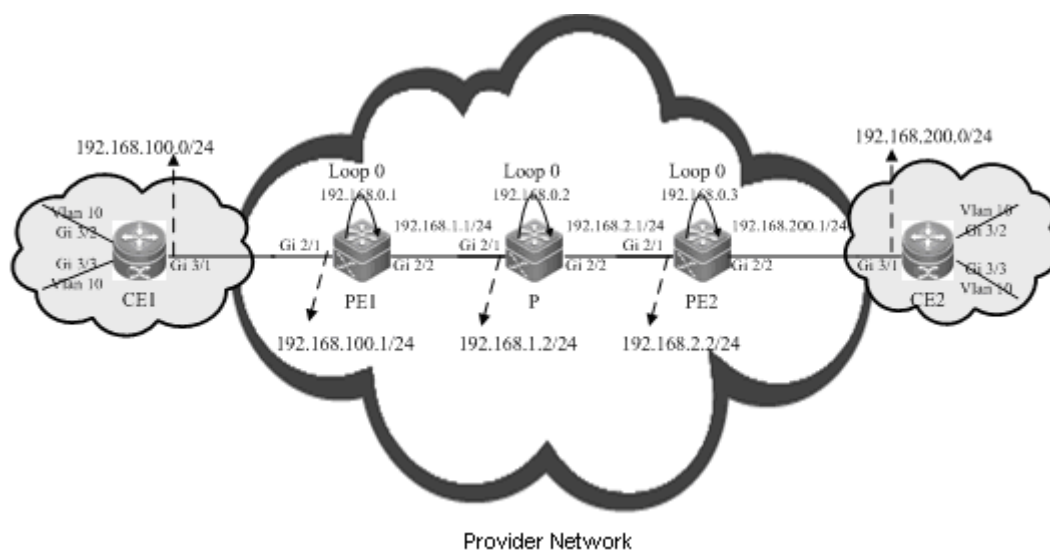
4.1.3 Configuration Examples

Networking Requirements

- An MPLS network consists of Provider Edge (PE) and Provider (P) devices.
- PE and P devices support the LDP and are capable of GR.
- This following describes how to configure LDP GR on PE 1 and a P device. PE 1 is a GR-capable router and the GR restarter. The P device is a GR-aware router and the GR helper.

Networking Topology

Figure 1-2 Networking topology for configuring LDP GR



Configuration Tips

Configure PE 1 and the P device as follows:

- Configure interface IP addresses and the Open Shortest Path First (OSPF) protocol.
- Enable global MPLS packet forwarding on devices, MPLS forwarding, and the LDP on interfaces.
- Configure the LDP to enable the network to forward MPLS traffic.
- Enable the LDP GR protocol.
- Configure parameters related to LDP GR.
- Restart the LDP session for the configurations to take effect.

Configuration Steps

- Configure interface IP addresses and the OSPF protocol.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers, and therefore you do not need to run this command on routers.

```
Qtech(config)#interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)#no switchport
Qtech(config-if-GigabitEthernet 2/1)#ip address 192.168.100.1 255.255.255.0
Qtech(config-if-GigabitEthernet 2/1)#exit
```

The **no switchport** command runs on a switch to switch to Routed Port mode. It is not applicable to routers, and therefore you do not need to run this command on routers.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#no switchport
```

```
Qtech(config-if-GigabitEthernet 2/2)#ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 2/2)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 192.168.0.1 255.255.255.255
Qtech(config-Loopback 0)#exit
Qtech(config)#router ospf 1
Router(config-router)#network 192.168.100.1 255.255.255.0 area 0
Router(config-router)#network 192.168.1.1 255.255.255.0 area 0
Router(config-router)#network 192.168.0.1 255.255.255.255 area 0
Router(config-router)#exit
```

Configure the P device by running the same commands as those on PE 1.

- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#label-switching
Qtech(config-if-GigabitEthernet 2/2)#mpls ip
Qtech(config-if-GigabitEthernet 2/2)#ip ref
Router(config-if-GigabitEthernet 2/2)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)#label-switching
Qtech(config-if-GigabitEthernet 2/1)#mpls ip
Qtech(config-if-GigabitEthernet 2/1)#ip ref
Router(config-if-GigabitEthernet 2/1)#exit
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#label-switching
Qtech(config-if-GigabitEthernet 2/2)#mpls ip
Qtech(config-if-GigabitEthernet 2/2)#ip ref
Router(config-if-GigabitEthernet 2/2)#exit
```

- Configure the LDP to enable the network to forward MPLS traffic.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

- Enable the LDP GR protocol.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

■ Configure parameters related to LDP GR.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

■ Restart the LDP session for the configurations to take effect.

Restart the LDP session on PE 1.

```
Qtech#clear mpls ldp neighbor all
```

Restart the LDP session on the PE device.

```
Qtech#clear mpls ldp neighbor all
```

Verification

Run the following commands to view configurations on PE 1:

View LDP GR information on PE 1.

```
Qtech#show mpls ldp graceful-restart
Default VRF:
LDP Graceful Restart is enabled
Neighbor Liveness Timer: 120 seconds
Max Recovery Time: 120 seconds
Forwarding State Holding Time: 300 seconds
Down Neighbor Database (1 records):
  Peer LDP Ident: 192.168.0.2:0; Local LDP Ident: 192.168.0.1:0
    Status: recovering (86 seconds left)
    Address list contains 3 addresses:
      192.168.1.2   192.168.2.1   192.168.0.2
Graceful Restart-enabled Sessions:
  Peer LDP Ident: 192.168.0.2:0, State: estab
```

View LDP GR neighbor information on PE 1.

```
Qtech#show mpls ldp neighbor
Default VRF:
  Peer LDP Ident: 192.168.0.2:0; Local LDP Ident: 192.168.0.1:0
    TCP connection: 192.168.0.2.15532 - 192.168.0.1.646
    State: OPERATIONAL; Msgs sent/rcv: 23/27; UNSOLICITED
    Up time: 00:04:12
    Graceful Restart enabled; Peer reconnect time (msecs): 0
```

View LDP binding information on PE 1.

```
Router#show mpls ldp bindings
```

```
Default VRF:
  lib entry: 192.168.0.2/32
    local binding: to lsr: 192.168.0.2:0, label: 1024
    remote binding: from lsr: 192.168.0.2:0, label: imp-null stale
  lib entry: 192.168.1.2/24
    local binding: to lsr: 192.168.0.2:0, label: 1025
    remote binding: from lsr: 192.168.0.2:0, label: imp-null stale
  lib entry: 192.168.2.1/24
    local binding: to lsr: 192.168.0.2:0, label: 1026
    remote binding: from lsr: 192.168.0.2:0, label: imp-null stale
```

4.2 L3VPN GR

4.2.1 Overview

L3 VPN GR (VPN GR) implements uninterrupted forwarding of Virtual Private Network (VPN) services. It ensures that the data of VPN services can be normally forwarded when the control plane on a device fails, protecting VPN services on the network.

The following prerequisites must be met for VPN GR:

- Devices support 1+1 management board redundancy.
- Devices support uninterrupted forwarding of routing protocols.
- Devices support the BGP/MPLS GR protocol.
- Devices support the LDP GR protocol.

The objectives of VPN GR are to:

- Minimize routing protocol flapping during master/slave management board switchover.
- Minimize the impact on VPN services.
- Minimize Single-Point Failures (SPFs) on access devices and improve VPN network reliability.
- Minimize the packet loss rate of VPN traffic.



Note

GR must be supported in unicast routing to implement uninterrupted forwarding of routing protocols. In other words, the device must support OSPF GR, IS-IS GR, or BGP GR.

4.2.1.1 Basic Concepts

GR Routers Classified by Capability

GR routers are classified by capability into GR-capable routers, GR-aware routers, and GR-unaware routers.

- GR-Capable Router

A GR-capable router is a router that has GR capability. In general, a GR-capable router is equipped with two management boards which work in 1+1 master/slave mode. The GR-capable router can send an advertisement packet to neighboring routers during master/slave switchover of the management boards, so that neighboring routers keep forwarding entries related to the GR-capable router. After master/slave switchover, routing tables are re-established without causing route flapping or changing the packet forwarding path, guaranteeing uninterrupted data forwarding in the system.

- GR-Aware Router

A GR-aware router is a router that has GR detection capability. It may be not equipped with two management boards but can detect that its neighbors are experiencing GR and can assist its neighbors to complete GR.

- GR-Unaware Router

A GR-unaware router is a router that does not have GR detection capability. It cannot detect that its neighbors are experiencing GR, cannot assist its neighbors to complete GR, and does not have GR capability. Generally, if a router has no awareness capability, it is because the system software does not provide the GR feature or the GR feature is disabled.

GR Routers Classified by Role

GR routers are classified by role during router restart into GR restarters and GR helpers.

- GR Restarter

The GR restarter has GR capability and its restart is triggered by administrators or faults.

- GR Helper

The GR helper is a neighbor of the GR restarter. It must be at least a GR-aware router.

4.2.1.2 Working Principle

Both the control plane and the forwarding plane on a traditional device are implemented by the same processor which simultaneously maintains a routing table and a forwarding table. To improve forwarding performance and reliability of devices, a multi-processor architecture is used on high-end and mid-range devices. The processors of control modules such as the routing protocol module are located on a master management board and data forwarding processors are located on line cards. In this manner, the control plane and the forwarding plane are separated from each other so that data forwarding on line cards is not affected when the control plane is restarted. This technology provides a prerequisite for implementing GR. The GR-capable routers mentioned in this document are such routers where the control plane and the forwarding plane are separated from each other.

The VPN network shown in Figure 1-3 has the following features:

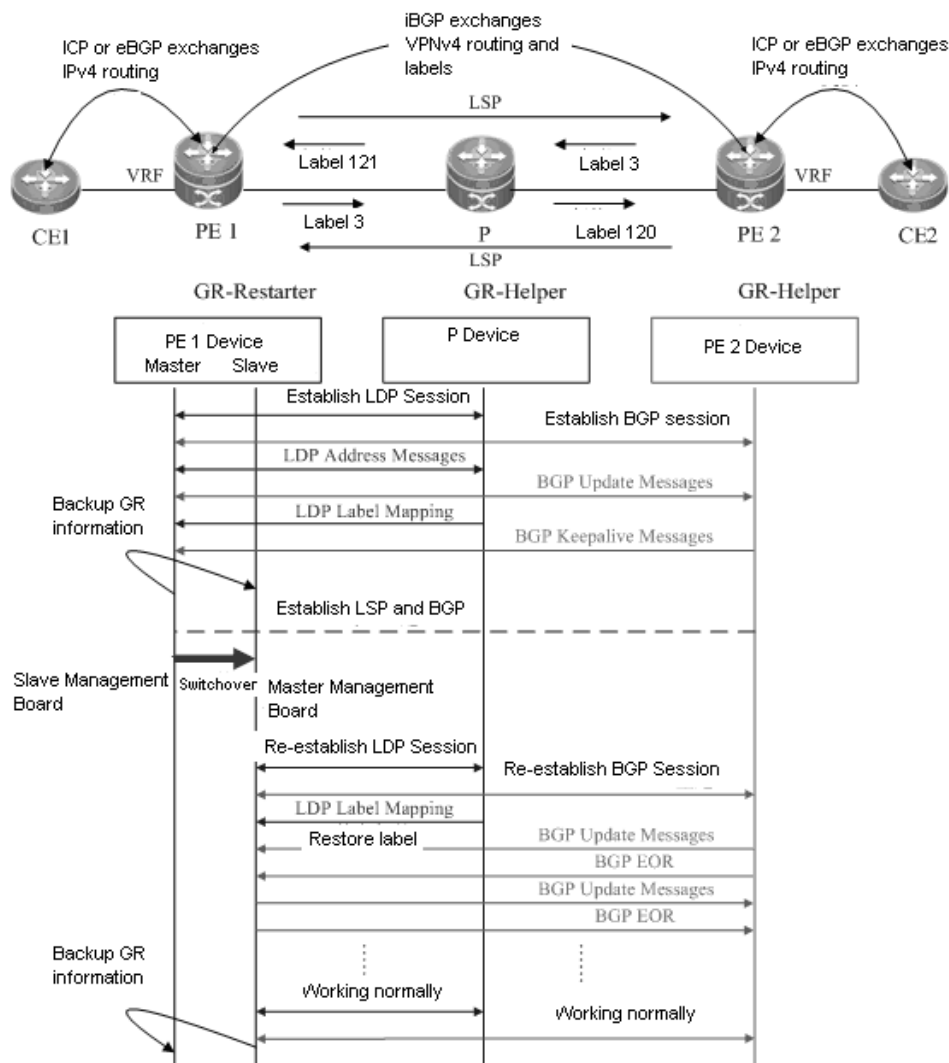
- Customer Edge (CE) devices represent a customer network. The Interior Gateway Protocol (IGP) or Exterior Border Gateway Protocol (eBGP) runs on the CE devices.
- PE and P devices form a provider network. The IGP runs on these devices.
- Public network tunnels and Label Switching Paths (LSPs) are established using the LDP between PE 1, PE 2, and the P device.
- Private network tunnels are established using the Interior Border Gateway Protocol (iBGP) between PE 1 and PE 2.
- The IGP, BGP, and LDP have GR capability.
- PE devices are GR-capable routers, and the P device is a GR-aware router.



Note

For details about IGP GR, BGP GR, and LDP GR, see related sections in *OSPF*, *BGP*, and *LDP GR*.

Figure 1-3 VPN networking topology



The following describes the GR process of the access device PE 1 of a provider network. Master/slave management board switchover occurs on PE 1. PE 1 works as a GR restarter and PE 2 and the P device works as GR helpers.. The process of master/slave management board switchover is as follows:

■ Before master/slave management board switchover

PE 1 performs IGP GR or eBGP GR negotiation with the connected CE device, IGP GR and LDP GR negotiation with the P device, and iBGP GR negotiation with PE 2.

PE 1 sends an Initialization message that carries the optional FT Session TLV to the P device to establish a GR-capable LDP session. After the LDP session is established, they exchange LDP Address messages and Label Mapping messages with each other. In this manner, GR-capable LSPs are established for data forwarding.

PE 1 sends an Open message to PE 2 to establish a GR-capable iBGP session. The Open message carries GR capability parameters <AFI=IPv4, SAFI=Unicast> and <AFI=IPv4, SAFI=VPNv4>.

When the master management board works, the GR information is backed up to the slave management board. In this manner, the GR backup enables the system to access these original data during GR protocol restart and apply the data to the protocol GR process after master/slave management board switchover.

■ During master/slave management board switchover

After the GR information on PE 1 is backed up to the slave management board,, the master/slave management board switchover is performed.

After detecting that the Transfer Control Protocol (TCP) session is down, the P device sets an "old" flag for the respective LSPs and starts a forwarding entry aging timer to continue to forward data before this aging timer expires.

After detecting that the TCP connection is broken, PE 2 immediately marks the route learned from PE 1 as "old" and starts a restart timer for PE 1. If PE 2 does not receive an Open message within the restart timer, it deletes the "old" flag for the route. If PE 2 receives an Open message, it deletes the restart timer. In this period of time, PE 1 and PE 2 continue to forward traffic along the original route.

- After master/slave management board switchover

The slave management board on PE 1 becomes the new master management board, and the original master management board becomes the new slave management board. The new master management board checks the GR information backed up and determines whether forwarding entries before the restart are retained. Then the Command Line Interface (CLI) configuration initialization process and the GR process continue. During IGP GR, BGP GR, and LDP GR, all the devices send notification messages to all IGP, BGP, and LDP neighbors for connection re-establishment.

113) IGP convergence

PE 1 sends an Initialization message that carries the FT Session TLV to the P device, and re-establishes a session upon receiving a response to obtain topology and routing information. PE 1 re-computes the routing table and deletes the "old" routes. The IGP convergence is completed.

114) BGP processing

PE 1 and CE 1 exchange routing information with each other. PE 1 updates its routing table and forwarding entries based on the new routing and forwarding information, substitutes invalid routes. The BGP convergence is completed.

PE 1 and PE 2 start to re-establish a BGP session with each other. PE 1 sends an Open message to PE 2. The Open message carries GR capability parameters. PE 1 receives and processes an Update message from PE 2. These messages carry IP prefix information. PE 1 does not start BGP route preference until receiving an EOR flag from PE2. PE 1 sends an Update message that carries prefix information to PE 2. After sending the Update message, PE 1 sends the EOR flag to PE 2. After receiving the EOR flag, PE 2 starts BGP route preference. The network convergence is completed.

115) LDP processing

PE 1 sends an Initialization message that carries the FT Session TLV to the neighboring P device. A GR-capable LDP session is established after the P device receives the Initialization message. Then PE 1 and the P device exchange LDP Address and Label Mapping messages again with each other, and keep or remove the "old" flag set for MPLS forwarding entries. When the GR process ends, both devices delete their "old" MPLS forwarding entries respectively.



Note

The preceding IGP GR, BGP GR, and LDP GR processes do not follow a strict priority sequence. In terms of route convergence, unicast routes converge first and converged routes are advertised to the LDP.

Before all protocols complete the GR process, only Routing Information Base (RIB) information on the master management board is updated. The Forwarding Information Base (FIB) information on interface boards is not updated.

The FIB information on interface boards is updated only after all protocols complete the GR process.

4.2.1.3 Protocols and Specifications

The protocols or specifications involved are as follows:

- RFC 4724: Graceful Restart Mechanism for BGP
- RFC 4781: Graceful Restart Mechanism for BGP with MPLS

4.2.2 Configuring L3VPN GR

Network Environment

On an MPLS network, L3VPN GR is required for the devices carrying L3VPN services. In this manner, data forwarding is not interrupted during master/slave management board switchover on devices, guaranteeing traffic continuity.



Note The GR capability does not guarantee traffic continuity when master/slave management board switchover also occurs on neighboring devices.

Prerequisites

Complete the following tasks before configuring L3VPN GR:

- Build an L3VPN environment and configure L3VPN.
- Ensure that devices support management board redundancy.
- Ensure that the IGP has GR capability.
- Ensure that the BGP has GR capability.
- Ensure that the LDP has GR capability.



Note For details about L3VPN configuration, see related sections in *BGP/MPLS VPN Configuration*.

Data Preparations

Prepare the following data before configuring L3VPN GR:

- IGP GR parameters
- BGP GR parameters
- LDP GR parameters

4.2.2.1 Configuring IGP GR



Note For details about IGP GR configuration, see related sections in *OSPF*.

4.2.2.2 Configuring BGP GR



Note For details about BGP GR configuration, see related sections in *BGP*.

4.2.2.3 Configuring LDP GR



Note For details about LDP GR configuration, see the "LDP GR" section in this document.

4.2.2.4 Verification

To display L3VPN GR configuration and running information, run the following commands:

Command	Function
<code>show ip vrf [vrf_name]</code>	Displays VRF configuration information.
<code>show ip bgp vpnv4 {all rd route-distinguish vrf vrf_name} [network-address] [summary] [neighbor] [label]</code>	Displays VPN routing information.
<code>show ip bgp summary</code>	Displays the status of all BGP connections.
<code>show ip route vrf vrf_name [A.B.C.D bgp connected isis ospf rip static weight]</code>	Displays VRF routing information.


```
show mpls ldp graceful-restart [all | vrf vrf-name]
```

Displays LDP GR sessions and session parameters.



Note All the preceding commands can be configured in any mode except for user mode.

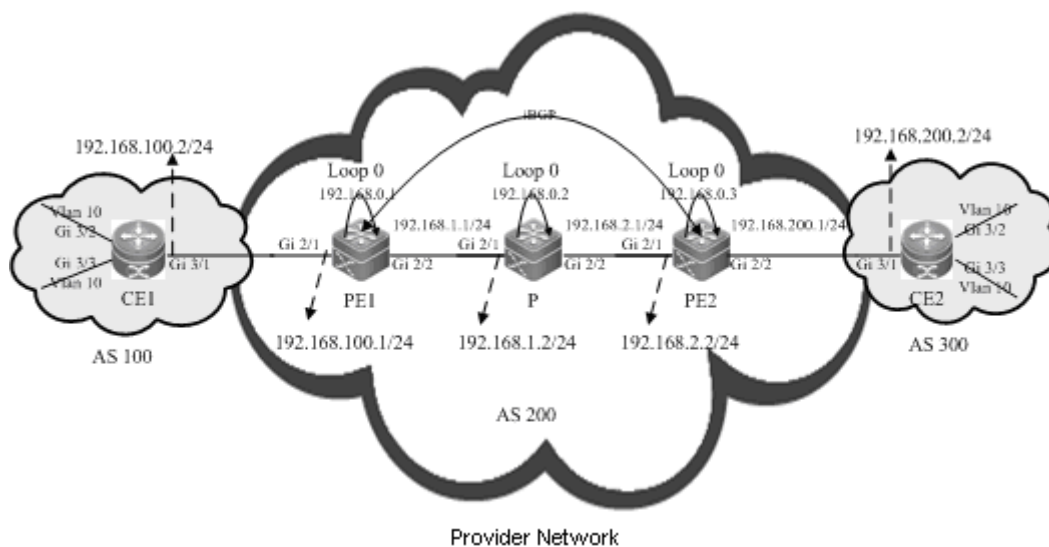
4.2.3 Configuration Examples

Networking Requirements

- CE devices represent a customer network. The IGP or eBGP runs on the CE devices.
- PE and P devices form a provider network. The IGP runs on these devices.
- Public network tunnels and LSPs are established using the LDP between PE 1, PE 2, and the P device.
- Private network tunnels are established using the iBGP between PE 1 and PE 2.
- The IGP, BGP, and LDP have GR capability.
- PE devices are GR-capable routers, and the P device is a GR-aware router.

Networking Topology

Figure 1-4 Networking topology for configuring L3VPN GR



Configuration Tips

Configure PE 1, PE 2, and the P device as follows:

- Configure VRF.
- Configure interface IP addresses and the OSPF protocol.
- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.
- Configure the LDP to enable the network to forward MPLS traffic.
- Enable the LDP GR protocol and configure parameters related to LDP GR.
- Configure L3VPN.
- Enable the BGP GR protocol.
- Restart the LDP session for the configurations to take effect.

Configuration Steps

- Configure VRF.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

Define VRF.

```
Qtech(config)#ip vrf 10
Qtech(config-vrf)#rd 1:100
Qtech(config-vrf)#route-target both 1:100
Qtech(config-vrf)#exit
```

Configure the P device. VRF configuration is not required on the P device.

Configure PE 2 by running the same commands as those on PE 1.

■ Configure interface IP addresses and the OSPF protocol.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)#no switchport
Qtech(config-if-GigabitEthernet 2/1)#ip vrf forwarding 10
Qtech(config-if-GigabitEthernet 2/1)#ip address 192.168.100.1 255.255.255.0
Qtech(config-if-GigabitEthernet 2/1)#exit
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#no switchport
Qtech(config-if-GigabitEthernet 2/2)#ip address 192.168.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 2/2)#exit
```

Configure the loopback interface **loopback 0**.

```
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 192.168.0.1 255.255.255.255
Qtech(config-Loopback 0)#exit
```

Activate the OSPF protocol and enter OSPF mode.

```
Qtech(config)#router ospf 10
Qtech(config-router)#network 192.168.0.1 255.255.255.255 area 0
Qtech(config-router)#network 192.168.1.0 255.255.255.0 area 0
Qtech(config-router)#end
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)#no switchport
Qtech(config-if-GigabitEthernet 2/1)#ip address 192.168.1.2 255.255.255.0
Qtech(config-if-GigabitEthernet 2/1)#exit
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#no switchport
Qtech(config-if-GigabitEthernet 2/2)#ip address 192.168.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 2/2)#exit
```

Configure the loopback interface **loopback 0**.

```
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 192.168.0.2 255.255.255.255
Qtech(config-Loopback 0)#exit
```

Activate the OSPF protocol and enter OSPF mode.

```
Qtech(config)#router ospf 10
Qtech(config-router)#network 192.168.1.0 255.255.255.0 area 0
Qtech(config-router)#network 192.168.2.0 255.255.255.0 area 0
Qtech(config-router)#network 192.168.0.2 255.255.255.255 area 0
```

```
Qtech(config-router)#end
```

Configure PE 2 by running the same commands as those on PE 1.

- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#label-switching
Qtech(config-if-GigabitEthernet 2/2)#mpls ip
Qtech(config-if-GigabitEthernet 2/2)#ip ref
Router(config-if-GigabitEthernet 2/2)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is used on routers to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/1
Qtech(config-if-GigabitEthernet 2/1)#label-switching
Qtech(config-if-GigabitEthernet 2/1)#mpls ip
Qtech(config-if-GigabitEthernet 2/1)#ip ref
Router(config-if-GigabitEthernet 2/1)#exit
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not run this command on switches.

```
Qtech(config)#interface gigabitEthernet 2/2
Qtech(config-if-GigabitEthernet 2/2)#label-switching
Qtech(config-if-GigabitEthernet 2/2)#mpls ip
Qtech(config-if-GigabitEthernet 2/2)#ip ref
Router(config-if-GigabitEthernet 2/2)#exit
```

Configure PE 2 by running the same commands as those on PE 1.

- Configure the LDP to enable the network to forward MPLS traffic.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure PE 2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Enable the LDP GR protocol, and configure parameters related to LDP GR.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

Configure PE 2 by running the same commands as those on PE 1.

- Configure L3VPN.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

Configure the eBGP peer CE.

```
Qtech(config)#router bgp 200
Qtech(config-router)#address-family ipv4 vrf 10
Qtech(config-router-af)#neighbor 192.168.100.2 remote-as 100
Qtech(config-router-af)#neighbor 192.168.100.2 update-source GigabitEthernet 2/1
Qtech(config-router-af)#neighbor 192.168.200.2 activate
Qtech(config-router-af)#exit-address-family
Qtech(config-router)#exit
```

Configure the iBGP peer PE 2.

```
Qtech(config-router)#address-family ipv4
Qtech(config-router-af)#neighbor 192.168.0.3 remote-as 200
Qtech(config-router-af)#neighbor 192.168.0.3 update-source loopback 0
Qtech(config-router-af)#neighbor 192.168.0.3 activate
Qtech(config-router-af)#exit-address-family
Qtech(config-router)#address-family vpnv4 unicast
Qtech(config-router-af)#neighbor 192.168.0.3 activate
Qtech(config-router-af)#exit-address-family
Qtech(config-router)#exit
```

Configure the P device. L3VPN configuration is not required on the P device.

Configure PE 2 by running the same commands as those on PE 1.

- Enable the BGP GR protocol.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

Enable the BGP and enter BPG configuration mode.

```
Qtech(config)#router bgp 200
```

Enable BGP GR.

```
Qtech(config-router)#bgp graceful-restart
```

Configure the P device. BGP GR does not need to be enabled on the P device.

Configure PE 2 by running the same commands as those on PE 1.

Restart the LDP session for the configurations to take effect.

Restart the LDP session on PE 1.

```
Qtech#clear mpls ldp neighbor all
```

Restart the LDP session on the PE device.

```
Qtech#clear mpls ldp neighbor all
```

Restart the LDP session on PE 1.

```
Qtech#clear mpls ldp neighbor all
```

Verification

Run the following commands to view configurations on PE 1:

View LDP GR information on PE 1.

```
Qtech#show mpls ldp graceful-restart
Default VRF:
  LDP Graceful Restart is enabled
  Neighbor Liveness Timer: 120 seconds
  Max Recovery Time: 120 seconds
  Forwarding State Holding Time: 300 seconds
  Down Neighbor Database (1 records):
    Peer LDP Ident: 192.168.0.2:0; Local LDP Ident: 192.168.0.1:0
      Status: recovering (86 seconds left)
      Address list contains 3 addresses:
        192.168.0.2    192.168.1.2    192.168.2.1
  Graceful Restart-enabled Sessions:
    Peer LDP Ident: 192.168.0.2:0, State: estab
```

View BGP GR information on PE 1.

```
Qtech#show bgp vpnv4 unicast all neighbor
BGP neighbor is 192.168.0.3, remote AS 200, internal link
BGP version 4, remote router ID 192.168.0.3
BGP state = Established, up for 02:49:47
Last read 00:00:47, hold time is 180, keepalive interval is 60 seconds
Neighbor capabilities:
Route refresh: advertised and received(new)
Address family VPNv4 Unicast: advertised and received
Graceful Restart Capability: advertised and received
Remote Restart timer is 120 seconds
Address families preserved by peer:
VPNv4 Unicast
```

4.3 L2VPN GR



Note

L2VPN GR described in this section indicates GR for Virtual Pseudo Wire Service (VPWS) and Virtual Private LAN Service (VPLS).

4.3.1 Overview

For VPWS and VPLS services, public network tunnels are established based on basic MPLS network services. In addition, the extended LDP is used to distribute VC labels for the establishment of virtual lines. Therefore, extended LDP GR must be implemented to ensure uninterrupted forwarding of VPWS and VPLS services. Extended LDP GR is implemented based on the same working principles as basic LDP GR, except that the MPLS forwarding entries to be backed up are different. Therefore, extended LDP GR and basic LDP GR can be uniformly implemented.



Note

For details about LDP GR and configuration methods, see the "LDP GR" section in this document. The working principles of VPWS GR are described in the following text. That of VPLS GR is not described in this document.

VPWS GR implements uninterrupted forwarding of VPWS services. It ensures that the data of VPWS services can be forwarded when the control plane on a device fails, protecting VPWS services on the network. The following prerequisites must be met for VPWS GR:

- Devices support 1+1 management board redundancy.
- Devices support uninterrupted forwarding of routing protocols.
- Devices support the LDP GR protocol.

The objectives of VPWS GR are to:

- Minimize routing protocol flapping during master/slave management board switchover.
- Minimize the impact on VPWS services.
- Minimize SPFs on access devices and improve VPWS network reliability.
- Minimize the packet loss rate of VPWS traffic.



Note

GR must be supported in unicast routing to implement uninterrupted forwarding of routing protocols. In other words, the device must support OSPF GR, IS-IS GR, or BGP GR.

4.3.1.1 Basic Concepts

GR Routers Classified by Capability

GR routers are classified by capability into GR-capable routers, GR-aware routers, and GR-unaware routers.

- GR-Capable Router

A GR-capable router is a router that has GR capability. In general, a GR-capable router is equipped with two management boards which work in 1+1 master/slave mode. The GR-capable router can send an advertisement packet to neighboring routers during master/slave switchover of the management boards, so that neighboring routers keep forwarding entries related to the GR-capable router. After master/slave switchover, routing tables are re-established without causing route flapping or changing the packet forwarding path, guaranteeing uninterrupted data forwarding in the system.

- GR-Aware Router

A GR-aware router is a router that has GR detection capability. It may be not equipped with two management boards but can detect that its neighbors are experiencing GR and can assist its neighbors to complete GR.

- GR-Unaware Router

A GR-unaware router is a router that does not have GR detection capability. It cannot detect that its neighbors are experiencing GR, cannot assist its neighbors to complete GR, and does not have GR capability. Generally, if a router has no awareness capability, it is because the system software does not provide the GR feature or the GR feature is disabled.

GR Routers Classified by Role

GR routers are classified by role during router restart into GR restarters and GR helpers.

- GR Restarter

The GR restarter has GR capability and its restart is triggered by administrators or faults.

- GR Helper

The GR helper is a neighbor of the GR restarter. It must be at least a GR-aware router.

4.3.1.2 Working Principle

Both the control plane and the forwarding plane on a traditional device are implemented by the same processor which simultaneously maintains a routing table and a forwarding table. To improve forwarding performance and reliability of devices, a multi-processor architecture is used on high-end and mid-range devices. The processors of control modules such as the routing protocol module are located on a master management board and data forwarding processors are located on line cards. In this manner, the control plane and the forwarding plane are separated from each other so that data forwarding on line cards is not affected when the control plane is restarted. This technology provides a prerequisite for implementing GR. The GR-capable routers mentioned in this document are such routers where the control plane and the forwarding plane are separated from each other.

The VPWS network shown in Figure 1-5 has the following features:

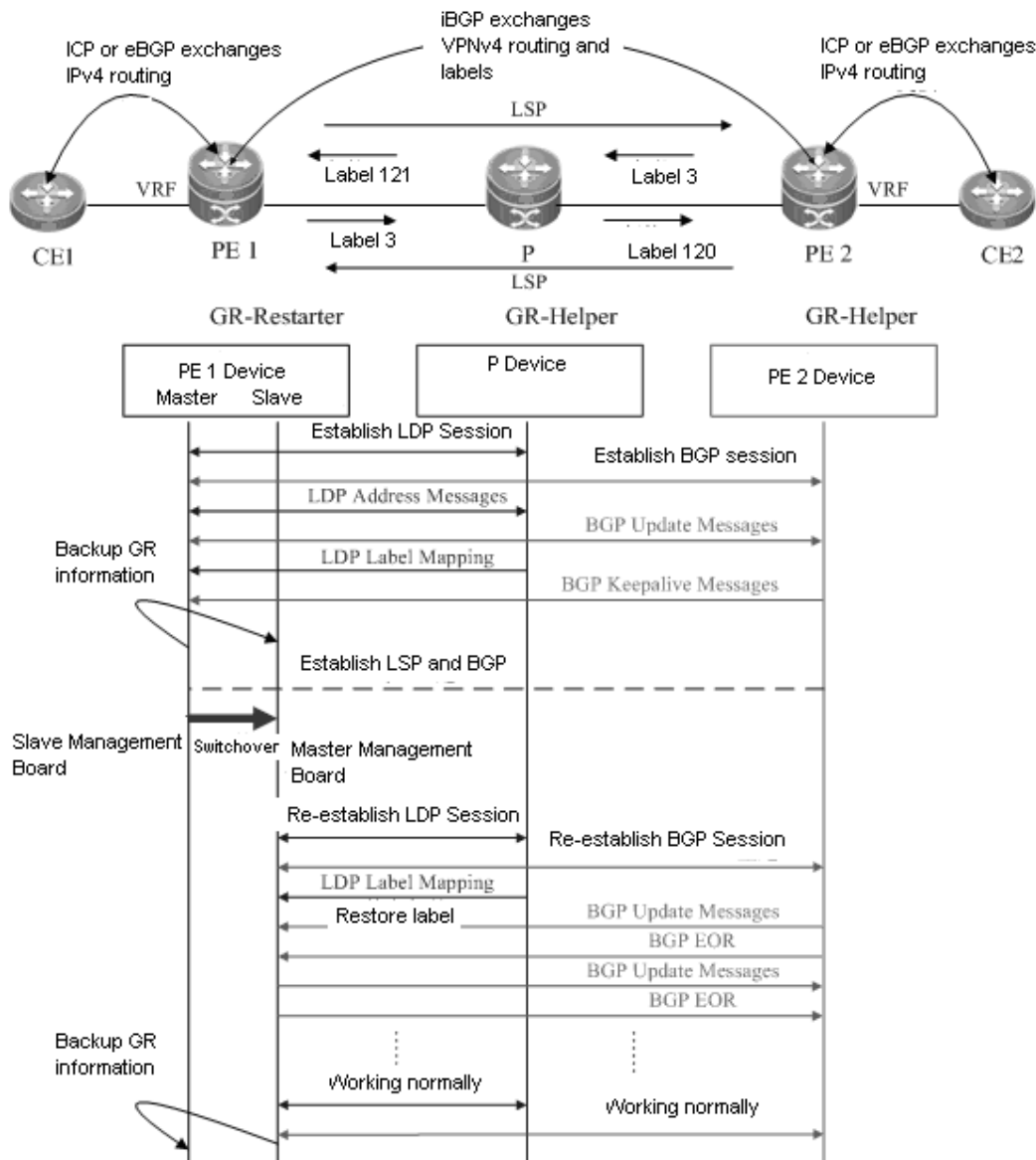
- CE devices represent a customer network. The IGP runs on the CE devices.
- PE and P devices form a provider network. The IGP and LDP run on these devices.

- Public network tunnels and LSPs are established using the LDP between PE 1, PE 2, and the P device.
- Private network tunnels are established using the LDP between PE 1 and PE 2.
- The IGP and LDP have GR capability.
- PE devices are GR-capable routers, and the P device is a GR-aware router.



Note For details about IGP GR and LDP GR, see related sections in *OSPF* and *LDP GR*.

Figure 1-5 VPWS networking topology



The following describes the GR process of the access device PE 1 of a provider network. Master/slave management board switchover occurs on PE 1. PE 1 works as a GR restarter, whereas PE 2 and the P device work as GR helpers. When master/slave management board switchover occurs on PE 1, a certain procedure applies. The procedure consists of the following three phases:

Before Master/Slave Management Board Switchover

PE 1 performs LDP GR and IGP GR negotiation with the P device, IGP GR negotiation with the connected CE device, and extended LDP GR negotiation with PE 2. PE 1 sends an Initialization message that carries the optional FT Session TLV to the P device and PE 2 to establish a GR-capable LDP session.

After the LDP session is established, they exchange LDP Address and Label Mapping messages with each other. In this manner, GR-capable LSPs are established for data forwarding.

When the master management board works normally, it must back up GR information to the slave management board to support GR.

During Master/Slave Management Board Switchover

GR information on PE 1 has been backed up to the slave management board. The major task of PE 1 in this phase is to perform master/slave management board switchover.

The P device and PE 2 detect that the TCP session is down, and therefore set an "old" flag for the respective LSPs. They also start a forwarding entry aging timer and continue to forward data before this aging timer expires. The working process on CEs is similar, except that it is an IGP GR process.

After Master/Slave Management Board Switchover

The slave management board on PE 1 becomes the new master management board, and the original master management board becomes the new slave management board. The new master management board starts to check the GR information previously backed up and determines whether forwarding entries before the restart are retained. Then the CLI configuration initialization process and the GR process continue. During LDP GR and IGP GR, all the devices send notification messages to all IGP and LDP neighbors for connection re-establishment.

- IGP convergence
- PE 1 sends an Initialization message that carries the FT Session TLV to the P device, and re-establishes a session upon receiving a response to obtain topology and routing information. Then PE 1 re-computes the routing table, deletes the "old" routes, and therefore completes IGP convergence.
- LDP processing
- PE 1 sends an Initialization message that carries the FT Session TLV to the neighboring P device and PE 2. A GR-capable LDP session is established after the P device and PE 2 receive the Initialization message. Then the devices exchange LDP Address and Label Mapping messages again with each other, and keep or remove the "old" flag set for MPLS forwarding entries. When the GR process ends, the P device, PE 1, and PE 2 delete the "old" MPLS forwarding entries from themselves respectively.



Note

The preceding IGP GR and LDP GR processes do not follow a strict priority sequence. In terms of route convergence, IGP routes converge first and converged routes are advertised to the LDP.

Before all protocols complete the GR process, only RIB information on the master management board is updated. The FIB information on interface boards do not be updated.

The FIB information on interface boards is updated only after all protocols complete the GR process.

4.3.1.3 Protocols and Specifications

The following protocols or specifications involved are as follows:

- RFC 3036: LDP Specification
- RFC 3037: LDP Applicability
- RFC 3215: LDP State Machine
- RFC 3478: Graceful Restart Mechanism for LDP
- RFC 3479: Fault Tolerance for LDP

4.3.2 Configuring VPWS GR

Network Environment

VPWS GR is required for VPWS applications on service bearing devices on an MPLS network. In this manner, data forwarding is not interrupted during master/slave management board switchover on devices, guaranteeing traffic continuity.



Note The GR capability does not guarantee traffic continuity when master/slave management board switchover also occurs on neighboring devices.

Prerequisites

Complete the following tasks before configuring VPWS GR:

- Build a VPWS environment and configure VPWS.
- Ensure that the IGP has GR capability.
- Ensure that the LDP has GR capability.



Note For details about VPWS configuration, see the "Configuring VPWS" section in *MPLS*.

Data Preparations

Prepare the following data before configuring VPWS GR:

- IGP GR parameters
- LDP GR parameters

4.3.2.1 Configuring IGP GR



Note For details about IGP GR configuration, see related sections in *OSPF*.

4.3.2.2 Configuring LDP GR



Note For details about LDP GR configuration, see the "LDP GR" section in this document.

4.3.2.3 Verification

To display VPWS GR configuration and running information, run the following commands:

Command	Function
<code>show mpls ldp graceful-restart [all vrf vrf-name]</code>	Displays LDP GR sessions and session parameters.
<code>show mpls ldp vc [all vpws hub spoke] [vc-id]</code>	Displays LDP Pseudo Wire (PW) information.



Note All the preceding commands can be configured in any mode except for the user mode.

4.3.3 Configuration Examples

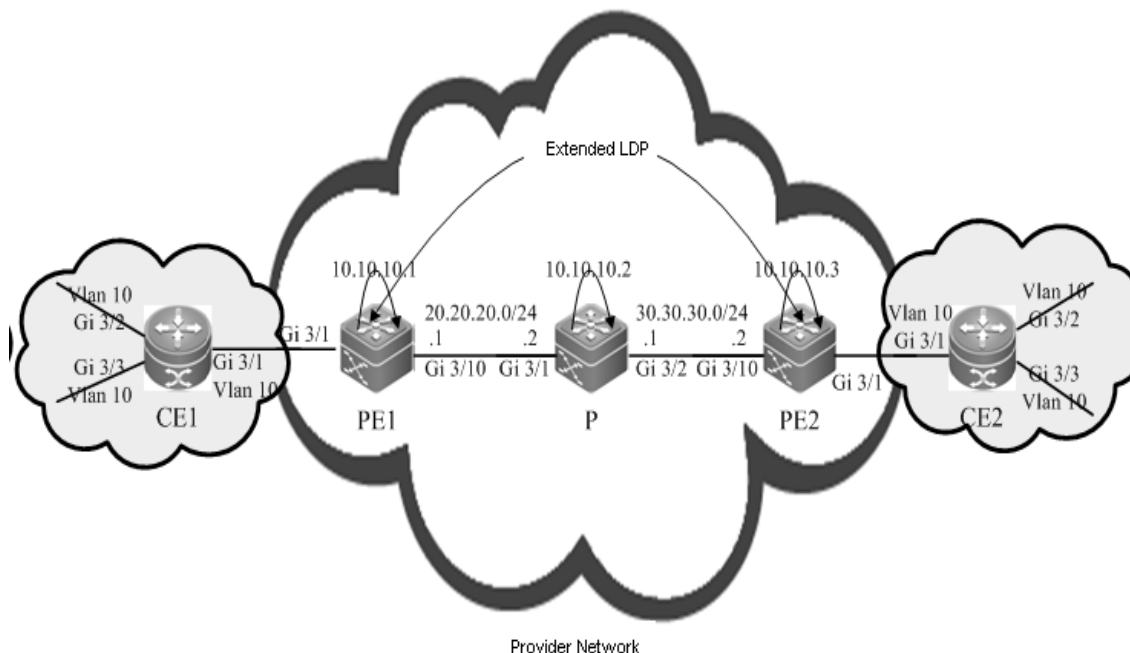
Networking Requirements

- Interconnection ports between PE and CE devices work in access mode, so that each CE device is connected to the respective PE device through an access link. The respective PE device establishes PW services for the Virtual Local Area Network (VLAN) to which the access port belongs. Since the Ethernet mode is applied, frames transmitted on the PW between PE 1 and PE 2 do not carry the VLAN 10 tag.
- CE, PE, and P devices support the LDP and are capable of GR.
- PE and P devices support the LDP and are capable of GR.

- PE and P devices form a provider network.
- PE devices are GR-capable routers, and the P device is a GR-aware router.

Networking Topology

Figure 1-6 Networking topology for configuring L2VPN GR



Configuration Tips

Configure PE 1, PE 2, and the P device as follows:

- Configure interface IP addresses and the OSPF protocol.
- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.
- Configure the LDP to enable the network to forward MPLS traffic.
- Configure VPWS.
- Enable the LDP GR protocol, and configure parameters related to LDP GR.
- Restart the LDP session for the configurations to take effect.

Configuration Steps

- Configure interface IP addresses and the OSPF protocol.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to the Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 3/10
Qtech(config-if-GigabitEthernet 3/10)#no switchport
Qtech(config-if-GigabitEthernet 3/10)#ip address 20.20.20.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/10)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.1 255.255.255.255
Qtech(config-Loopback 0)#exit
```

Activate the OSPF protocol and enter OSPF mode.

```
Qtech(config)#router ospf 10
Qtech(config-router)#network 20.20.20.0 255.255.255.0 area 0
Qtech(config-router)#network 10.10.10.1 255.255.255.255 area 0
Qtech(config-router)#end
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)#no switchport
Qtech(config-if-GigabitEthernet 3/1)#ip address 20.20.20.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/1)#exit
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)#no switchport
Qtech(config-if-GigabitEthernet 3/2)#ip address 30.30.30.1 255.255.255.0
Qtech(config-if-GigabitEthernet 3/2)#exit
```

Configure the loopback interface **loopback 0**.

```
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.1 255.255.255.255
Qtech(config-Loopback 0)#exit
```

Activate the OSPF protocol and enter OSPF mode.

```
Qtech(config)#router ospf 10
Qtech(config-router)#network 20.20.20.0 255.255.255.0 area 0
Qtech(config-router)#network 30.30.30.0 255.255.255.0 area 0
Qtech(config-router)#network 10.10.10.2 255.255.255.255 area 0
Qtech(config-router)#end
```

Configure PE 2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers and therefore you do not need to run the command on routers.

```
Qtech(config)#interface gigabitEthernet 3/10
Qtech(config-if-GigabitEthernet 3/10)#no switchport
Qtech(config-if-GigabitEthernet 3/10)#ip address 30.30.30.2 255.255.255.0
Qtech(config-if-GigabitEthernet 3/10)#exit
```

Configure the loopback interface **loopback 0**.

```
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.3 255.255.255.255
Qtech(config-Loopback 0)#exit
```

Activate the OSPF protocol and enter OSPF mode.

```
Qtech(config)#router ospf 10
Qtech(config-router)#network 30.30.30.0 255.255.255.0 area 0
Qtech(config-router)#network 10.10.10.3 255.255.255.255 area 0
Qtech(config-router)#end
```

■ Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run the command on switches.

```
Qtech(config)#interface gigabitEthernet 3/10
Qtech(config-if-GigabitEthernet 3/10)#label-switching
Qtech(config-if-GigabitEthernet 3/10)#mpls ip
Qtech(config-if-GigabitEthernet 3/10)#ip ref
Router(config-if-GigabitEthernet 3/10)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

```
Qtech(config)#mpls ip
```

The **ip ref** command is used on a router to enable MPLS fast forwarding on the router. You do not need to run the command on switches.

```
Qtech(config)#interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)#label-switching
Qtech(config-if-GigabitEthernet 3/1)#mpls ip
Qtech(config-if-GigabitEthernet 3/1)#ip ref
Router(config-if-GigabitEthernet 3/1)#exit
```

The **ip ref** command is run a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 3/2
Qtech(config-if-GigabitEthernet 3/2)#label-switching
Qtech(config-if-GigabitEthernet 3/2)#mpls ip
Qtech(config-if-GigabitEthernet 3/2)#ip ref
Router(config-if-GigabitEthernet 3/2)#exit
```

Configure PE 2 by running the same commands as those on PE 1.

- Configure the LDP to enable the network to forward MPLS traffic.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure a remote LDP neighbor.

```
Qtech(config-mpls-router)#neighbor 10.10.10.3
Qtech(config-mpls-router)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure PE 2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure a remote LDP neighbor.

```
Qtech(config-mpls-router)#neighbor 10.10.10.1
Qtech(config-mpls-router)#exit
```

- Configure VPWS.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

Switch configurations

Configure access ports between PE 1 and CE 1.

```
Qtech(config)#interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)#switchport mode access
Qtech(config-if-GigabitEthernet 3/1)#switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/1)#exit
```

Configure PW services for VLAN 10 on PE 1.

```
Qtech(config)#interface vlan 10
Qtech(config-if-VLAN 10)#xconnect 10.10.10.3 2 encapsulation mpls ethernet
Qtech(config-if-VLAN 10)#exit
```

Router configurations

Configure PW services for the GE interface 3/1 on PE 1.

```
Qtech(config)#interface gigabitEthernet 3/1
```

```
Qtech(config-if-GigabitEthernet 3/1)#ip ref
Qtech(config-if-GigabitEthernet 3/1)#xconnect 10.10.10.3 2 encapsulation mpls
ethernet
Qtech(config-if-GigabitEthernet 3/1)#exit
```

Configure PE 2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

Switch configurations

Configure access ports between PE 2 and CE 2.

```
Qtech(config)#interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)#switchport mode access
Qtech(config-if-GigabitEthernet 3/1)#switchport access vlan 10
Qtech(config-if-GigabitEthernet 3/1)#exit
```

Configure PW services for VLAN 10 on PE 2.

```
Qtech(config-if-VLAN 10)#interface vlan 10
Qtech(config-if-VLAN 10)#xconnect 10.10.10.1 2 encapsulation mpls ethernet
Qtech(config-if-VLAN 10)#exit
```

Router configurations

Configure PW services for the GE interface 3/1 on PE 2.

```
Qtech(config)#interface gigabitEthernet 3/1
Qtech(config-if-GigabitEthernet 3/1)#ip ref
Qtech(config-if-GigabitEthernet 3/1)#xconnect 10.10.10.1 2 encapsulation mpls
ethernet
Qtech(config-if-GigabitEthernet 3/1)#exit
```

- Enable the LDP GR protocol, and configure parameters related to LDP GR.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

Configure the P device.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#graceful-restart
```

Set the LDP reconnection time to 300 seconds, LDP neighbor keep-alive time to 120 seconds, and LDP recovery time to 120 seconds.

```
Qtech(config-mpls-router)#graceful-restart timer reconnect 300
Qtech(config-mpls-router)#graceful-restart timer neighbor-liveness 120
Qtech(config-mpls-router)#graceful-restart timer recovery 120
Qtech(config-mpls-router)#exit
```

Configure PE 2 by running the same commands as those on PE 1.

- Restart the LDP session for the configurations to take effect.

Restart the LDP session on PE 1.

```
Qtech#clear mpls ldp neighbor all
```

Restart the LDP session on the PE device.

```
Qtech#clear mpls ldp neighbor all
```

Restart the LDP session on PE 1.

```
Qtech#clear mpls ldp neighbor all
```

Verification

Run the following commands to view configurations on PE 1:

View LDP GR information on PE 1.

```
Qtech#show mpls ldp graceful-restart
Default VRF:
  LDP Graceful Restart is enabled
  Neighbor Liveness Timer: 120 seconds
  Max Recovery Time: 120 seconds
  Forwarding State Holding Time: 300 seconds
  Down Neighbor Database (1 records):
    Peer LDP Ident: 10.10.10.2:0; Local LDP Ident: 10.10.10.1:0
      Status: recovering (86 seconds left)
      Address list contains 3 addresses:
        10.10.10.2    20.20.20.2    30.30.30.1
  Graceful Restart-enabled Sessions:
Peer LDP Ident: 10.10.10.2:0, State: estab
```

5 CONFIGURING MPLS BFD



Note The routers or router icons involved in this chapter represent common routers or L3 switches where routing protocols are running.

5.1 Overview



Note MPLS Bidirectional Forwarding Detection (BFD) is implemented in accordance with *BFD For MPLS LSPs* as defined by IETF. As a component of BFD applications, MPLS BFD describes a method for detecting MPLS LSPs. For details about BFD, see related sections in *BFD*.

In general, the following methods are used to detect LSP faults on an MPLS network:

- MPLS OAM mechanism. It can effectively detect, confirm, and locate internal defects or faults on an MPLS network. Currently, the standardization for MPLS OAM is still under way and various OAM mechanisms are in a starting-off phase in terms of practical network applications. Therefore, not all devices on a network can support the OAM.
- Hello packet mechanism of the MPLS signaling protocol. It takes a long time for the mechanism to detect a fault. In general, the detection time is a matter of seconds. Therefore, plenty of traffic is lost if the hello mechanism is applied.

MPLS BFD can resolve all the preceding problems. It has the following features:

- MPLS BFD supports interworking and provides a unified detection mechanism for the entire network.
- MPLS BFD provides fast detection. It makes possible lightly-loaded fast detection to quicken the start of a backup forwarding path and therefore improves MPLS network reliability.
- MPLS BFD can detect MPLS LSP faults on the data plane. BFD uses a fixed packet format which facilitates hardware implementation and firewall transversal.

5.1.1 EFD Session Establishment

BFD uses a local discriminator My Discriminator and a remote discriminator Your Discriminator to differentiate BFD sessions between a pair of systems. The discriminators can be configured in either manual or auto mode.

- Manual configuration: The local discriminator and the remote discriminator are manually configured for BFD. In this manner, the LSP Ping Echo packet to be sent before BFD session establishment does not need to carry any discriminator to perform negotiation and learn the remote discriminator. Instead, a BFD session is directly established.
- Auto configuration: The LSP Ping Echo packet to be sent before BFD session establishment carries a discriminator to perform negotiation and learn the remote discriminator before a BFD session is established.

At the initial stage of BFD session establishment, the roles of devices at both ends are classified into initiators and passive LSRs. Whether the ingress/egress LSR is an initiator or a passive LSR depends on specific applications, but at least one of them must be the initiator. Therefore, the following two scenarios may exist at the initial stage:

Both Are Initiators

If both the ingress LSR and the egress LSR are initiators, LSPs are unidirectional. Therefore, this scenario can be further divided into the following two cases:

- BFD is applied to detect both LSPs from the ingress LSR to the egress LSR and from the egress LSR to the ingress LSR

The ingress LSR sends an LSP Ping echo request that carries a local discriminator to the egress LSR. When the egress LSR receives the echo request, it obtains a remote discriminator from the echo request, so that the egress LSR owns both a local discriminator generated by itself and a remote discriminator. Then the egress LSR sends a BFD control packet to the ingress LSR. When the ingress LSR receives the BFD control packet, it obtains a remote discriminator from the received BFD control packet. Therefore, the ingress LSR also owns a local discriminator

generated by itself and a remote discriminator, and then sends a BFD control packet to the egress LSR. Till now, both LSRs proceed to the initial stage of BFD session establishment.

You must noted that the egress LSR may return or not return an echo reply upon receipt of the echo request. If the egress LSR returns an echo reply, the echo reply must carry a local discriminator generated by the egress LSR itself. In this manner, the ingress LSR can obtain a remote discriminator from either the BFD control packet or the echo reply.



Note The working process on the egress LSR is similar to that on the ingress LSR.

- BFD is applied to detect the LSP from the ingress LSR to the egress LSR, and detect IP addresses (in a multi-hop situation) from the egress LSR to the ingress LSR

In this case, discriminators are manually configured on the ingress LSR and the egress LSR to establish a BFD session. In other words, the BFD session is established without experiencing automatic discriminator negotiation but the session establishment process directly starts after discriminators are manually configured on the two LSRs.

One Is the Initiator and the Other Is a Passive LSR

The initiator sends an LSP Ping echo request that carries a local discriminator to the passive LSR. When the passive LSR receives the echo request, it obtains a remote discriminator from the echo request, so that it owns both a local discriminator generated by itself and a remote discriminator. Then the passive LSR sends a BFD control packet to the initiator. When the initiator receives the BFD control packet, it obtains a remote discriminator from the received BFD control packet. Therefore, the initiator also owns a local discriminator generated by itself and a remote discriminator, and then sends a BFD control packet to the passive LSR. Till now, both LSRs proceed to the initial stage of BFD session establishment.

You must noted that the passive LSR may return or not return an echo reply upon receipt of the echo request. If the passive LSR returns an echo reply, the echo reply must carry a local discriminator generated by the passive LSR itself. In this manner, the initiator can obtain a remote discriminator from either the BFD control packet or the echo reply.

The passive LSR does not send any BFD control packet to the initiator unless it has received the echo request from the initiator.

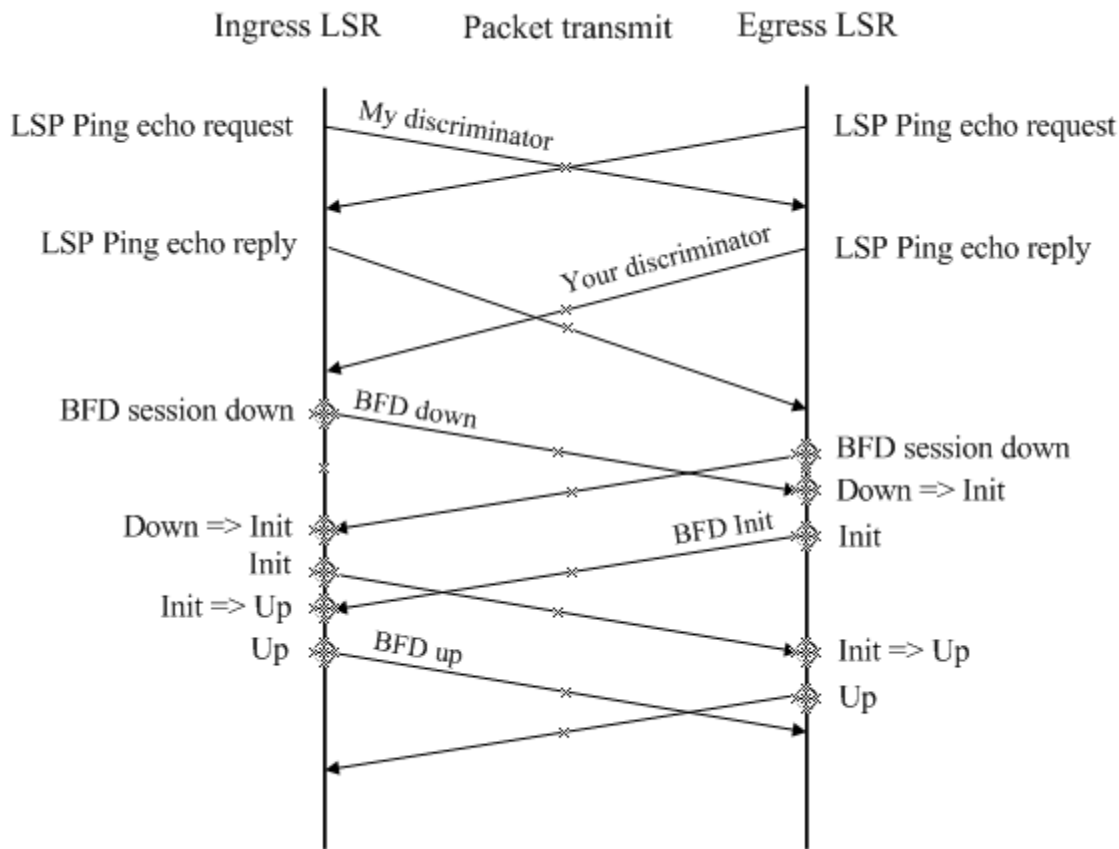


Note Currently, only the first case is supported for BFD+LSP. That is, both LSRs must be initiators.

Example

This section describes the BFD session establishment process when both LSRs are initiators and BFD is applied to detect both LSPs from the ingress LSR to the egress LSR and from the egress LSR to the ingress LSR.

Figure 2-1 BFD session establishment process



- Before the ingress LSR and the egress LSR start BFD, they must learn the remote discriminator from each other and ensure that the LSPs are up. As shown in Figure 2-1, the ingress LSR sends an LSP Ping echo request that carries a local discriminator to the egress LSR. Upon receipt of the echo request, the egress LSR returns an echo reply that carries the local discriminator generated by the egress LSR itself to the ingress LSR. This is the same for the egress LSR. You must note that an LSR needs to learn the remote discriminator from the LSP Ping echo request if discriminators are not manually specified on both LSRs. If both the local discriminator and the remote discriminator are specified on both LSRs, this step does not apply during BFD session establishment but the next step directly continues. For details about discriminator configuration, see the "BFD+LSP" section in this document.
- The ingress LSR and the egress LSR start the BFD mechanism. The initial BFD status is Down on both LSRs. Each LSR sends a BFD packet that carries the Down status.
- Upon receipt of the BFD packet that carries the Down status, the egress LSR transits its local BFD status to "Init" and sends a BFD packet that carries the Init status.
- The egress LSR no longer processes any received BFD packet that carries the Down status after its local BFD status changes to the Init state.
- The same BFD status transition process applies on the ingress LSR.
- When receiving a BFD packet that carries the Init status, the egress LSR changes its local BFD status to the Up status.
- The same BFD status transition process applies on the ingress LSR.
- The status of the local BFD session status is Up, indicating that a BFD session has been successfully established.

5.1.2 BFD Modes

Before two LSRs exchange BFD control packets, a BFD session must be established on the condition that the control plane and the data plane take the same path. The following two modes exist for BFD session operations:

- Asynchronous mode
- Inquiry mode

In addition to the two operation modes, an echo function is defined for BFD. The echo function can be applied to both the asynchronous mode and the inquiry mode.

**Note**

Currently, only the asynchronous mode is supported for BFD+LSP. The inquiry mode and the echo function are not supported in the BFD+LSP scenario.

5.1.3 BFD+LSP

A BFD session is identified by a local discriminator My Discriminator and a remote discriminator Your Discriminator. The following two configuration modes can be applied to BFD+LSP based on the way by which the local discriminator and the remote discriminator are specified:

- Manual configuration
 - In manual configuration mode, the local discriminator and remote discriminator are manually configured for BFD, so that the LSP Ping Echo packet to be sent before BFD session establishment does not need to carry any discriminator to perform negotiation and learn the remote discriminator. Instead, a BFD session is directly established.
- Auto configuration
 - In automatic configuration mode, the LSP Ping Echo packet to be sent before BFD session establishment carries a discriminator to perform negotiation and learn the remote discriminator before a BFD session is established.

Currently, BFD+LSP is classified into BFD for static LSPs and BFD for LDP LSPs based on LSP type.

BFD for Static LSPs

BFD for static LSPs can be configured in manual or automatic mode. Since LSPs are unidirectional links but BFD is a bidirectional mechanism, reverse link detection can be performed based on one of the following detection methods when BFD is used to detect static LSPs:

- IP address mode for reverse link detection
- Static LSP mode for reverse link detection

BFD for LDP LSPs

BFD for static LSPs can be configured in manual or automatic mode. Since LSPs are unidirectional links but BFD is a bidirectional mechanism, reverse link detection can be performed based on one of the following detection methods when BFD is used to detect LDP LSPs:

- IP address mode for reverse link detection
- LDP LSP mode for reverse link detection

LDP LSPs bear basic VPN/PW public network services, so BFD for LDP LSPs is a mechanism for detecting faults of basic VPN/PW public network services. It provides fast detection for MPLS-based applications, such as VPN FRR and PW FRR, to protect services and guarantee MPLS network reliability.

5.1.4 Default Settings

Feature	Default
BFD session establishment mode	Active mode. Both LSRs must be initiators during BFD+LSP applications.
BFD mode	Asynchronous mode. Currently, only the asynchronous mode is supported for BFD+LSP. The inquiry mode and the echo function are not supported in the BFD+LSP scenario.
BFD session parameters	No default values are available. The BFD session parameters must be configured.
BFD authentication mode	Disabled. BFD authentication is not supported.

5.1.5 Protocols and Specifications

The following protocols or specifications involved are as follows:

- draft-ietf-bfd-base-09: Bidirectional Forwarding Detection
- draft-ietf-bfd-generic-05: Generic Application of BFD
- draft-ietf-bfd-mib-06: Bidirectional Forwarding Detection Management Information Base

- draft-ietf-bfd-v4v6-1hop-09: BFD for IPv4 and IPv6 (Single Hop)
- draft-ietf-bfd-multihop-07: BFD for IPv4 and IPv6 (Multihop)
- draft-ietf-bfd-mpls-07: BFD For MPLS LSPs

5.2 Configuring MPLS BFD

5.2.1 Configuring BFD for Static LSPs

Network Environment

BFD can be used to detect the continuity of static LSPs. When BFD is used for static LSPs, a static LSP that is down is not selected as the forwarding path of a private network route.

Prerequisites

Complete the following tasks before configuring BFD for static LSPs:

- Enable MPLS.
- Configure static LSPs.

Data Preparations

Prepare the following data before configuring BFD for static LSPs:

- My Discriminator and Your Discriminator of the BFD session
- Selection of the reverse link detection method
- BFD session parameters: BFD control packet sending interval, BFD control packet receiving interval, and the detection multiplier of BFD control packets

5.2.1.1 Configuring BFD on the Ingress LSR

By default, BFD for static LSPs is disabled on a device. To enable BFD for static LSPs on a device, enter privileged user mode to run the following commands:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters the interface configuration mode.
Qtech(config-if-type ID)# bfd interval <i>milliseconds</i> <i>min_rx milliseconds</i> <i>multiplier multiplier-value</i>	Sets BFD session parameters.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# bfd bind static-lsp peer-ip <i>ip-address source-ip ip-address</i> [local-discriminator <i>discr-value</i>] [remote-discriminator <i>discr-value</i>] [process-state]	Sets BFD for static LSPs along with BFD session status handling. If manual configuration is applied on the ingress LSR, manual configuration must also be applied on the egress LSR. In other words, the configuration modes on both LSRs must be symmetrical.

To disable BFD for static LSPs, run the **no bfd bind static-lsp peer-ip ip-address** command.



Caution

Only static LSPs established by host route triggering are supported in BFD for static LSPs. The *process-state* parameter must be specified for applications using BFD for fault detection, for example, when BFD is combined with LSP. If discriminators are manually configured, the local and remote discriminators configured on the ingress LSR must match with those configured on the egress LSR.

5.2.1.2 Configuring BFD on the Egress LSR

By default, BFD for static LSPs is disabled on a device. To enable BFD for static LSPs on a device, enter privileged user mode to run the following commands:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.

Qtech(config-if-type ID)# bfd interval <i>milliseconds</i> <i>min_rx milliseconds</i> multiplier <i>multiplier-value</i>	Sets BFD session parameters.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# bfd bind static-lsp peer-ip <i>ip-address</i> source-ip <i>ip-address</i> [local-discriminator <i>discr-value</i> remote-discriminator <i>discr-value</i>] [process-state]	Sets BFD for static LSPs without BFD session status handling. If manual configuration is applied on the ingress LSR, manual configuration must also be applied on the egress LSR. In other words, the configuration modes on both LSRs must be symmetrical.
Or:	
bfd bind backward-lsp-with-ip peer-ip <i>ip-address</i> [vrf <i>vrf-name</i>] interface <i>interface-type interface-number</i> [source-ip <i>ip-address</i>] { local-discriminator <i>discr-value</i> remote-discriminator <i>discr-value</i> }	Sets the IP address mode for reverse link detection in BFD for LSPs. If the IP mode is applied for LSP reverse link detection during configuration, a local discriminator and a remote discriminator must be manually specified for the forward LSP.
Qtech(config)# exit	Exits global configuration mode.

To disable BFD for static LSPs, run the **no bfd bind static-lsp peer-ip** *ip-address* or **no bfd bind backward-lsp-with-ip peer-ip** *ip-address* [**vrf** *vrf-name*] command.



Caution

Only static LSPs established by host route triggering are supported in BFD for static LSPs. The IP detection mode can be applied on the reverse link during BFD for LSPs. If discriminators are manually configured, the local and remote discriminators configured on the egress LSR must match with those configured on the ingress LSR.

5.2.1.3 Verification

To display configuration and running information about BFD for static LSPs, run the following commands:

Command	Function
show bfd neighbors [vrf <i>vrf-name</i>] [ipv4 <i>ip-address</i> [details] client { static-lsp backward-lsp-with-ip } [ipv4 <i>ip-address</i> [details] [details]]]	Displays BFD session information.

5.2.2 Configuring BFD for LDP LSPs

Network Environment

BFD can be used to detect the continuity of LDP LSPs. When BFD is used with LDP LSPs, an LDP LSP that is Down is not selected as the forwarding path of a private network route.

Prerequisites

Complete the following tasks before configuring BFD for LDP LSPs:

- Enable MPLS.
- Enable LDP.

Data Preparations

Prepare the following data before configuring BFD for LDP LSPs:

- My Discriminator and Your Discriminator of the BFD session
- Selection of the reverse link detection method
- BFD session parameters: BFD control packet sending interval, BFD control packet receiving interval, and the detection multiplier of BFD control packets

5.2.2.1 Configuring BFD on the Ingress LSR

By default, BFD for LDP LSPs is disabled on a device. To enable BFD for LDP LSPs on a device, enter privileged user mode to run the following commands:

Command	Function
Qtech# configure terminal	Enters the global configuration mode

Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# bfd interval <i>milliseconds</i> <i>min_rx milliseconds</i> multiplier <i>multiplier-value</i>	Sets BFD session parameters.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# mpls router ldp	Enters LDP configuration mode.
Qtech(config-mpls-router)# bfd bind ldp-lsp peer-ip <i>ip-address</i> nexthop <i>ip-address</i> [interface <i>interface-type interface-number</i>] source-ip <i>ip-address</i> [local-discriminator <i>discr-value</i> remote-discriminator <i>discr-value</i>] [process-state]	Sets BFD for LDP LSPs along with BFD session status handling. If manual configuration is applied on the ingress LSR, manual configuration must also be applied on the egress LSR. In other words, the configuration modes on both LSRs must be symmetrical.

To disable BFD for LDP LSPs, run the **no bfd bind ldp-lsp peer-ip ip-address** command.



Caution

Only LDP LSP established by host route triggering is supported in BFD for LDP LSPs. One LSP can be bound to only one BFD session. BFD binding can be performed only on the ingress LSR of the LDP LSP. The *process-state* parameter must be specified for applications using BFD for fault detection, for example, when BFD is combined with LSP. If discriminators are manually configured, the local and remote discriminators configured on the ingress LSR must match with those configured on the egress LSR.

5.2.2.2 Configuring BFD on the Egress LSR

By default, BFD for LDP LSPs is disabled on a device. To enable BFD for LDP LSPs on a device, enter the privileged user mode to run the following commands:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# bfd interval <i>milliseconds</i> <i>min_rx milliseconds</i> multiplier <i>multiplier-value</i>	Sets BFD session parameters.
Qtech(config-if-type ID)# exit	Exits interface configuration mode.
Qtech(config)# bfd bind backward-lsp-with-ip peer-ip <i>ip-address</i> [vrf <i>vrf-name</i>] interface <i>interface-type interface-number</i> [source-ip <i>ip-address</i>] local-discriminator <i>discr-value</i> remote-discriminator <i>discr-value</i>	Sets the IP address mode for reverse link detection in BFD for LSPs. If the IP mode is applied for LSP reverse link detection during configuration, a local discriminator and a remote discriminator must be manually specified for the forward LSP.
Or:	
Qtech(config)# mpls router ldp	Enters LDP configuration mode.
Qtech(config-mpls-router)# bfd bind ldp-lsp peer-ip <i>ip-address</i> nexthop <i>ip-address</i> [interface <i>interface-type interface-number</i>] source-ip <i>ip-address</i> [local-discriminator <i>discr-value</i> remote-discriminator <i>discr-value</i>] [process-state]	Sets BFD for LDP LSPs without BFD session status handling. If manual configuration is applied on the ingress LSR, manual configuration must also be applied on the egress LSR. In other words, the configuration modes on both LSRs must be symmetrical.
Qtech(config-bfd-router)# exit	Exits the LDP configuration mode.

To disable BFD for LDP LSPs, run the **no bfd bind backward-lsp-with-ip peer-ip ip-address [vrf vrf-name]** or **no bfd bind ldp-lsp peer-ip ip-address** command.



Caution

The IP detection mode can be applied on the reverse link during BFD for LSPs. Or BFD can be configured to detect the other LSP.

1. Only LDP LSPs established by host route triggering are supported in BFD for LDP LSPs.
2. One LSP can be bound to only one BFD session.
3. BFD binding can be performed only on the ingress LSR of the LDP LSP.

If discriminators are manually configured, the local and remote discriminators configured on the egress LSR must match with those configured on the ingress LSR.

5.2.2.3 Verification

To display configuration and running information about BFD for LDP LSPs, run the following commands:

Command	Function
<code>show bfd neighbors [vrf vrf-name] [ipv4 ip-address [details] client {ldp-lsp backward-lsp-with-ip} [ipv4 ip-address [details] [details]]</code>	Displays BFD session information.

5.3 Configuration Examples

5.3.1 Configuring BFD for Static LSPs

Networking Requirements

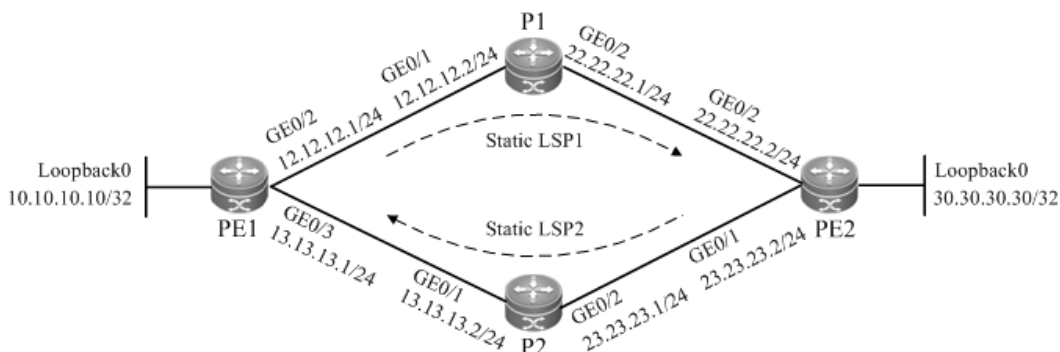
BFD can be configured to detect the continuity of static LSPs. Two links exist between PE 1 and PE 2, as shown in Figure 2-2.

- PE 1, PE 2, P1, and P2 form an MPLS network.
- A static LSP (LSP 1) exists and spans PE 1, P1 and PE 2 in turn. BFD is configured to detect this static LSP.
- A static LSP (LSP 2) exists and spans PE 2, P2 and PE 1 in turn. BFD is configured to detect this static LSP and notify faults if any to PE 1. This static LSP is used on the reverse link.

If LSP 1 fails, PE 1 can quickly receive a fault notification and handle the fault by deleting respective static MPLS routes.

Networking Topology

Figure 2-2 Networking topology for configuring BFD for static LSPs



Configuration Tips

Configure all devices as follows:

- Configure interface IP addresses and the OSPF protocol on devices.
- Enable global MPLS forwarding on all devices, and MPLS packet forwarding on interfaces.
- Configure static MPLS routes on the devices to enable the network to forward MPLS traffic.
- Configure BFD on PE 1 to detect static LSP 1.
- Configure BFD on PE 2 to detect static LSP 2, which is used as the LSP on the reverse link.

Configuration Steps

Configure interface IP addresses and the OSPF protocol on devices.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#no switchport
Qtech(config-if-GigabitEthernet 0/2)#ip address 12.12.12.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/2)#exit
```

```
Qtech(config)#interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)#no switchport
Qtech(config-if-GigabitEthernet 0/3)#ip address 13.13.13.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/3)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.10 255.255.255.255
Qtech(config-Loopback 0)#exit
Qtech(config)#router ospf 1
Router(config-router)#network 12.12.12.1 255.255.255.0 area 0
Router(config-router)#network 13.13.13.1 255.255.255.0 area 0
Router(config-router)#network 10.10.10.10 255.255.255.255 area 0
Router(config-router)#exit
```

Configure the other devices by running the same commands as those on PE 1.

Enable global MPLS forwarding on all devices, and MPLS packet forwarding on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#label-switching
Qtech(config-if-GigabitEthernet 0/2)#mpls ip
Router(config-if-GigabitEthernet 0/2)#exit
Qtech(config)#interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)#label-switching
Qtech(config-if-GigabitEthernet 0/3)#mpls ip
Router(config-if-GigabitEthernet 0/3)#exit
```

Configure the other devices by running the same commands as those on PE 1.

Configure static MPLS routes on the devices to enable the network to forward MPLS traffic.

Configure static LSP 1: PE1->P1->PE2.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls static ftn 30.30.30.30/32 out-label 16 nexthop gigabitEthernet 0/2
12.12.12.2
```

Configure P1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls static ilm in-label 16 forward-action swap-label 3 nexthop
gigabitEthernet 0/2 22.22.22.2 fec 30.30.30.30/32
```

Run the **ping mpls ipv4 30.30.30.30** command on PE 1 after the preceding configurations are complete. Ensure that the ping operation is successful.

Configure static LSP 2: PE2->P2->PE1.

Configure PE 2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls static ftn 10.10.10.10/32 out-label 16 nexthop gigabitEthernet 0/1
23.23.23.1
```

Configure P2.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls static ilm in-label 16 forward-action swap-label 3 nexthop
gigabitEthernet 0/1 13.13.13.1 fec 10.10.10.10/32
```

Run the **ping mpls ipv4 10.10.10.10** command on PE 2 after the preceding configurations are complete. Ensure that the ping operation is successful.

Configure BFD on PE 1 to detect LSP 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/2)#exit
Qtech(config)#bfd bind static-lsp peer-ip 30.30.30.30 source-ip 10.10.10.10 local-
discriminator 1 remote-discriminator 2 process-state
Qtech(config)#exit
```

Configure BFD on PE 2 to detect LSP 2, which is used as the LSP on the reverse link.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/1)#exit
Qtech(config)#bfd bind static-lsp peer-ip 10.10.10.10 source-ip 30.30.30.30 local-
discriminator 2 remote-discriminator 1
Qtech(config)#exit
```

Verification

View BFD session establishment information.

View BFD session establishment information on PE 1.

```
Qtech# show bfd neighbors details
OurAddr          NeighAddr          LD/RD RH          Holdown(mult)          State Int
10.10.10.10      30.30.30.30      1/2          1          532 (3 )          Up
          Ge2/1
Local Diag: 0, Demand mode: 0, Poll bit: 0
MinTxInt: 200000, MinRxInt: 200000, Multiplier: 3
Received MinRxInt: 50000, Received Multiplier: 3
Holdown (hits): 600(22), Hello (hits): 200(84453)
Rx Count: 49824, Rx Interval (ms) min/max/avg: 208/440/332
Tx Count: 84488, Tx Interval (ms) min/max/avg: 152/248/196
Registered protocols: static-lsp
Uptime: 02:18:49
Last packet: Version: 1          - Diagnostic: 0
I Hear You bit: 1          - Demand bit: 0
Poll bit: 0          - Final bit: 0
Multiplier: 3          - Length: 24
My Discr.: 2          - Your Discr.: 1
Min tx interval: 50000          - Min rx interval: 50000
Min Echo interval: 0
```

View BFD session establishment information on PE 2.

```
Qtech# show bfd neighbors details
OurAddr          NeighAddr          LD/RD RH          Holdown(mult)          State Int
30.30.30.30      10.10.10.10      1/2          1          532 (3 )          Up
          Ge2/1
Local Diag: 0, Demand mode: 0, Poll bit: 0
MinTxInt: 200000, MinRxInt: 200000, Multiplier: 3
Received MinRxInt: 50000, Received Multiplier: 3
Holdown (hits): 600(22), Hello (hits): 200(84453)
Rx Count: 49824, Rx Interval (ms) min/max/avg: 208/440/332
Tx Count: 84488, Tx Interval (ms) min/max/avg: 152/248/196
Registered protocols: static-lsp
Uptime: 02:18:49
Last packet: Version: 1          - Diagnostic: 0
I Hear You bit: 1          - Demand bit: 0
Poll bit: 0          - Final bit: 0
Multiplier: 3          - Length: 24
My Discr.: 2          - Your Discr.: 1
Min tx interval: 50000          - Min rx interval: 50000
Min Echo interval: 0
```


5.3.2 Configuring BFD for LDP LSPs

Networking Requirements

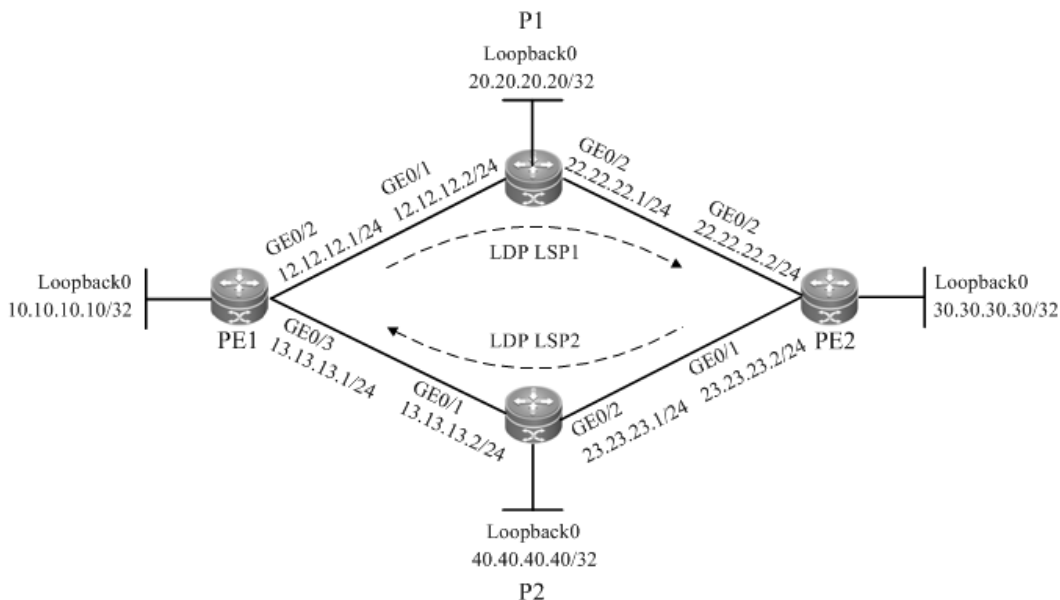
BFD can be configured to detect the continuity of LDP LSPs. Two links exist between PE 1 and PE 2, as shown in Figure 2-3.

- PE 1, PE 2, P1, and P2 form an MPLS network.
- Costs are configured for the interfaces on PE 1 and PE 2, so that two LSPs can be established between PE 1 and PE 2, as shown in Figure 2-3.
- An LDP LSP (LDP LSP 1) exists and spans PE 1, P1 and PE 2 in turn. BFD is configured to detect this LDP LSP.
- An LDP LSP (LDP LSP 2) exists and spans PE 2, P2 and PE 1 in turn. BFD is configured to detect this LDP LSP and notify faults if any to PE 1. This LDP LSP is used on the reverse link.

If LDP LSP 1 fails, PE 1 can quickly receive a fault notification and handle the fault by deleting respective MPLS routes.

Networking Topology

Figure 2-3 Networking topology for configuring BFD for LDP LSPs



Configuration Tips

Configure all devices as follows:

- Configure interface IP addresses and the OSPF protocol on devices.
- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.
- Configure the LDP to enable the network to forward MPLS traffic.
- Configure BFD on PE 1 to detect LDP LSP 1.
- Configure BFD on PE 2 to detect LDP LSP 2, which is used as the LSP on the reverse link.

Configuration Steps

Configure interface IP addresses and the OSPF protocol on devices.

Configure PE 1.

```
Qtech#configure terminal
```

```
Enter configuration commands, one per line. End with CNTL/Z.
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers, and therefore you do not need to run this command on routers.

```
Qtech(config)#interface gigabitEthernet 0/2
```

```
Qtech(config-if-GigabitEthernet 0/2)#no switchport
```

```
Qtech(config-if-GigabitEthernet 0/2)#ip address 12.12.12.1 255.255.255.0
```

```
Qtech(config-if-GigabitEthernet 0/2)#exit
```

The **no switchport** command is used on a switch to switch to Routed Port mode. It is not applicable to routers, and therefore you do not need to run this command on routers.

```
Qtech(config)#interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)#no switchport
Qtech(config-if-GigabitEthernet 0/3)#ip address 13.13.13.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/3)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.10 255.255.255.255
Qtech(config-Loopback 0)#exit
Qtech(config)#router ospf 1
Router(config-router)#network 12.12.12.1 255.255.255.0 area 0
Router(config-router)#network 13.13.13.1 255.255.255.0 area 0
Router(config-router)#network 10.10.10.10 255.255.255.255 area 0
Router(config-router)#exit
```

Configure the other devices by running the same commands as those on PE 1.

Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is run a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches..

```
Qtech(config)#interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)#label-switching
Qtech(config-if-GigabitEthernet 0/3)#mpls ip
Qtech(config-if-GigabitEthernet 0/3)#ip ref
Router(config-if-GigabitEthernet 0/3)#exit
```

The **ip ref** command is run a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 0/3
Qtech(config-if-GigabitEthernet 0/3)#label-switching
Qtech(config-if-GigabitEthernet 0/3)#mpls ip
Qtech(config-if-GigabitEthernet 0/3)#ip ref
Router(config-if-GigabitEthernet 0/3)#exit
```

Configure P1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
```

The **ip ref** command is run a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches.

```
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#label-switching
Qtech(config-if-GigabitEthernet 0/1)#mpls ip
Qtech(config-if-GigabitEthernet 0/1)#ip ref
Router(config-if-GigabitEthernet 0/1)#exit
```

The **ip ref** command is run a router to enable MPLS fast forwarding on the router. You do not need to run this command on switches..

```
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#label-switching
Qtech(config-if-GigabitEthernet 0/2)#mpls ip
Qtech(config-if-GigabitEthernet 0/2)#ip ref
Router(config-if-GigabitEthernet 0/2)#exit
```

Configure the other devices by running the same commands as those on PE 1.

Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE1

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

```
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure PE1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure the other devices by running the same commands as those on PE 1.

Configure BFD on PE 1 to detect LDP LSP 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/2)#exit
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#bfd bind ldp-lsp peer-ip 30.30.30.30 nexthop 12.12.12.2
interface gigabitEthernet 0/2 source-ip 10.10.10.10 local-discriminator 1 remote-
discriminator 2 process-state
Qtech(config-mpls-router)#exit
```

Configure BFD on PE 2 to detect LDP LSP 2, which is used as the LSP on the reverse link.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/1)#exit
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#bfd bind ldp-lsp peer-ip 10.10.10.10 nexthop 23.23.23.1
interface gigabitEthernet 0/1 source-ip 30.30.30.30 local-discriminator 2 remote-
discriminator 1
Qtech(config-mpls-router)#exit
```

Verification

View BFD session establishment information.

View BFD session establishment information on PE 1.

```
Qtech# show bfd neighbors details
OurAddr           NeighAddr           LD/RD RH           Holdown(mult)       State Int
10.10.10.10       30.30.30.30         1/2                1                   532 (3 )           Up
    Ge2/1
Local Diag: 0, Demand mode: 0, Poll bit: 0
MinTxInt: 200000, MinRxInt: 200000, Multiplier: 3
Received MinRxInt: 50000, Received Multiplier: 3
Holdown (hits): 600(22), Hello (hits): 200(84453)
Rx Count: 49824, Rx Interval (ms) min/max/avg: 208/440/332
Tx Count: 84488, Tx Interval (ms) min/max/avg: 152/248/196
Registered protocols: ldp-lsp
Uptime: 02:18:49
Last packet: Version: 1                               - Diagnostic: 0
I Hear You bit: 1                                     - Demand bit: 0
Poll bit: 0                                           - Final bit: 0
Multiplier: 3                                         - Length: 24
My Discr.: 2                                           - Your Discr.: 1
Min tx interval: 50000                                 - Min rx interval: 50000
Min Echo interval: 0
```

View BFD session establishment information on PE 2.

```
Qtech# show bfd neighbors details
OurAddr           NeighAddr           LD/RD RH           Holdown(mult)       State Int
30.30.30.30       10.10.10.10         1/2                1                   532 (3 )           Up
    Ge2/1
Local Diag: 0, Demand mode: 0, Poll bit: 0
MinTxInt: 200000, MinRxInt: 200000, Multiplier: 3
Received MinRxInt: 50000, Received Multiplier: 3
```

```
Holdown (hits): 600(22), Hello (hits): 200(84453)
Rx Count: 49824, Rx Interval (ms) min/max/avg: 208/440/332
Tx Count: 84488, Tx Interval (ms) min/max/avg: 152/248/196
Registered protocols: ldp-lsp
Uptime: 02:18:49
Last packet: Version: 1 - Diagnostic: 0
I Hear You bit: 1 - Demand bit: 0
Poll bit: 0 - Final bit: 0
Multiplier: 3 - Length: 24
My Discr.: 2 - Your Discr.: 1
Min tx interval: 50000 - Min rx interval: 50000
Min Echo interval: 0
```

6 CONFIGURING LDP FRR



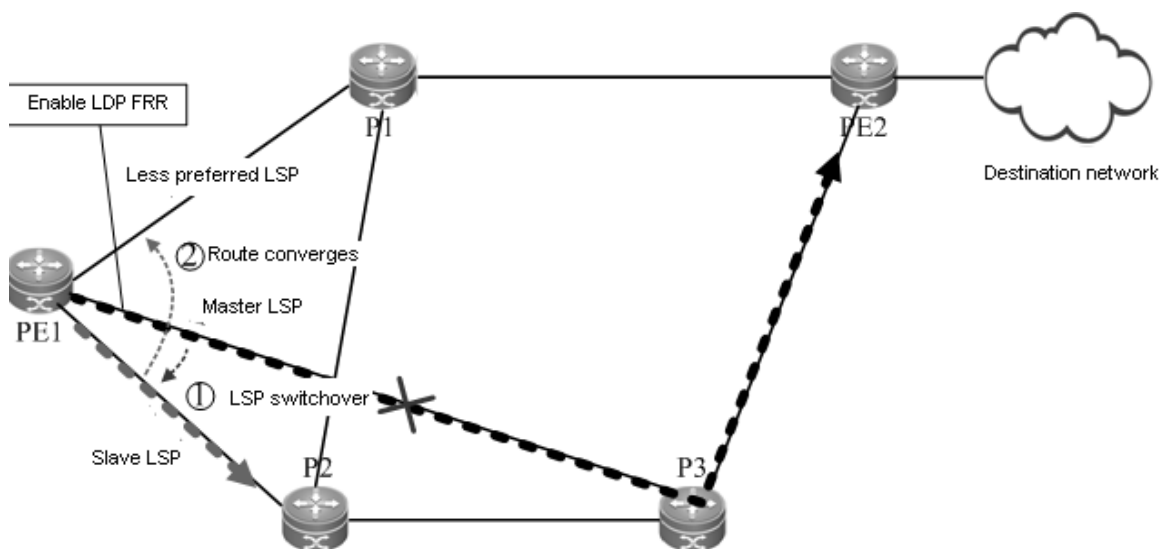
Note

The routers or router icons involved in this chapter represent common routers or L3 switches where routing protocols are running.

6.1 Overview

LDP Fast Rerouting (FRR) ensures that traffic can switch over from a master LSP to a backup LSP within a very short time when the master LSP fails and that traffic switches back to a new LSP from the backup LSP during route convergence. In this manner, traffic is not interrupted in the short time before network convergence, improving MPLS network reliability and protecting key services on the MPLS network.

Figure 3-1 Working principles of LDP FRR



LDP FRR is an extension of the LDP. The LDP works in free label retention mode. LDP FRR backs up retained labels (i.e. LSPs). When a link fails, the system can quickly detect the failure of the master LSP using a fast link failure detection technology such as BFD. While the LDP regenerates a new LSP, traffic on the master LSP switches back to the backup LSP to implement uninterrupted traffic forwarding. After the new LSP is generated, traffic is forwarded on the new LSP.

As shown in Figure 3-1, LDP FRR involves three types of LSPs: master LSP, less preferred LSP, and backup LSP. The master LSP is the optimal LSP along which traffic is forwarded when the network is stable and routes are converged. The less preferred LSP is one that has a cost value larger than the cost value of the master LSP. When the master LSP fails, routes converge on the less preferred LSP. The backup LSP is a backup LSP with a specified next hop. The three LSPs have different cost values.

In the LDP FRR solution, the next hop of the backup LSP interface is specified on the master LSP interface and BFD is configured on the master link to quickly detect faults of the master link. If the master link fails suddenly and a long time is required for routes to converge on the less preferred LSP, the quick link fault detection mechanism detects that the master link fails and therefore immediately switches traffic from the master LSP to the backup LSP, so that traffic is not discarded. In this manner, traffic to the destination network is forwarded by the backup LSP before routes converge on the less preferred LSP.

In the following several seconds, the master link fault is detected by the routing protocol and rerouting is performed through information exchange between routers. Finally, a notification message is sent to the LDP. The LDP regenerates a less preferred LSP based on the new next hop carried in the notification, and changes the path of the traffic to the destination network to the less preferred LSP, so that traffic smoothly switches over to the less preferred LSP from the backup LSP. If the less preferred LSP is just the backup LSP, traffic does not need to switch back to

the less preferred LSP from the backup LSP. Even so, traffic still experiences the backup LSP phase and the less preferred LSP phase after route convergence, except that traffic just passes the same link in the two phases.

6.2 Configuring LDP FRR

Network Environment

When the LDP cannot effectively protect traffic on an MPLS network, LDP FRR can be configured on ports to protect the traffic and avoid traffic loss.

Prerequisites

Complete the following tasks before configuring LDP FRR:

- Enable MPLS.
- Configure MPLS LDP.


Data Preparations

Prepare the following data before configuring LDP FRR:

- Interface of the backup LSP, which is also the master interface
- Next-hop IP address of the backup LSP
- Name of the access control list (ACL)
- Priority of the backup LSP
- Length of the LDP FRR protection timer (optional)
- BRD single-hop detection parameters (optional)

6.2.1.1 Configuring the LDP FRR

By default, LDP FRR is disabled on a device. To enable the LDP FRR function on a device, enter the privileged user mode to run the following commands:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# mpls ip	Enables MPLS forwarding.  Caution This command is not applicable to forwarding on switch chips.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# mpls ip	Enables LDP forwarding on interfaces (router configuration).
Qtech(config-if-type ID)# ip ref	Enables fast forwarding on interfaces.
Qtech(config-if-type ID)# label-switching	Enables MPLS packet processing on interfaces.
Qtech(config-if-type ID)# exit	Exits the interface configuration mode.
Qtech(config)# mpls router ldp	Enters the LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id Loopback ID force	Sets the router ID to a loopback ID (the settings immediately take effect).
Qtech(config-mpls-router)# exit	Exits LDP configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# mpls ldp frr nexthop nexthop-address [interface interface-type interface-number] [acl acl-name] [priority priority]	Enables LDP FRR on interfaces.

To disable LDP FRR, run the **no mpls ldp frr [nexthop nexthop-address] [acl acl-name] [priority priority]** command.



Note Do not enable or disable LDP FRR during LDP GR.

**Caution**

You must specify labels to work in free retention mode during LDP FRR configuration.

6.2.1.2 Configuring the LDP FRR Protection Timer (Optional)

If the master LSP link is recovered within the LDP FRR protection timer, traffic switches over to the master LSP link only after the LDP FRR protection timer expires. To configure the LDP FRR protection timer, enter the interface configuration mode to run the following commands in turn:

Command	Function
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# mpls ip	Enables MPLS forwarding. This command is not applicable to forwarding on switch chips.
Qtech(config)# interface type ID	Enters the interface configuration mode.
Qtech(config-if-type ID)# mpls ip	Enables LDP forwarding on interfaces.
Qtech(config-if-type ID)# ip ref	Enables fast forwarding on interfaces.
Qtech(config-if-type ID)# label-switching	Enables MPLS packet processing on interfaces.
Qtech(config-if-type ID)# exit	Exits the interface configuration mode.
Qtech(config)# mpls router ldp	Enters the LDP configuration mode.
Qtech(config-mpls-router)# ldp router-id Loopback ID force	Sets the router ID to a loopback ID (the settings immediately take effect).
Qtech(config-mpls-router)# exit	Exits the LDP configuration mode.
Qtech(config)# interface type ID	Enters the interface configuration mode.
Qtech(config-if-type ID)# mpls ldp fr nexthop nexthop-address [acl acl-name] [priority priority]	Enables LDP FRR on interfaces.
Qtech(config-if-type ID)# mpls ldp fr timer protect-time {infinity seconds}	Sets the LDP FRR protection timer on interfaces.

To enable the LDP FRR protection timer, run the **no mpls ldp fr timer protect-time** command.

6.2.1.3 Configuring Single-Hop BFD (Optional)

Run the **bfd bind peer-ip** command to configure single-hop BFD. After single-hop BFD is configured, the status of a BFD session is indicated in interface status information. Then LDP FRR detects the interface status and perform switchover. By default, single-hop BFD is disabled on a device. You can run the **no bfd bind peer-ip** command to disable single-hop BFD if necessary.

**Note**

Single-hop BFD is optional during LDP FRR configuration. For details about single-hop BFD configuration, see related sections in *BFD Configuration*.

6.2.1.4 Configuring DLDP (Optional)

Run the **dlldp ip** command to configure the Device Link Detection Protocol (DLDP) function on a device. By default, probes are tried three times every 100 milliseconds. You can run the **no dlldp ip** command to restore the default DLDP settings.

**Note**

For details about DLDP and configuration methods, see related sections in *DLDP*.

6.2.1.5 Verification

After configuring LDP FRR, run the following command to show LSP information:

Command	Function
show mpls rib	Displays MPLS routing information.

6.3 Configuration Examples

Networking Requirements

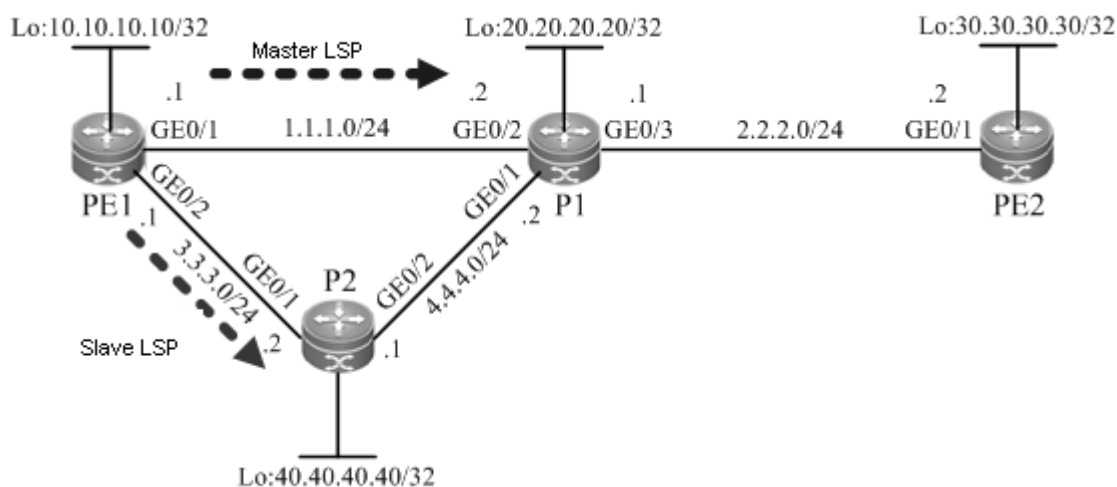
At least two links to the destination network are required when the LDP FRR is configured. Two links exist between PE 1 and PE 2, as shown in Figure 3-2.

- The PE1->P1->PE2 link is the master LSP.
- The PE1->P2->P1->PE2 link is the backup LSP.

LDP FRR can be configured on PE 1 and P1 to protect links between PE 1 and P1 and therefore avoid traffic loss.

Networking Topology

Figure 3-2 Networking topology for configuring LDP FRR



Configuration Tips

Configure all devices as follows:

- Configure interface IP addresses and the OSPF protocol on devices.
- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.
- Configure the LDP to enable the network to forward MPLS traffic.
- Configure LDP FRR.

116) Enable LDP FRR on the interfaces of PE 1 and P1 to generate the backup LSP.

117) Configure the LDP FRR protection timer on the interfaces of PE 1 and P1.

118) Configure single-hop BFD on the interfaces of PE 1 and P1.

Configuration Steps

- Configure interface IP addresses and the OSPF protocol on devices.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#no switchport
Qtech(config-if-GigabitEthernet 0/1)#ip address 1.1.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/1)#exit
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#no switchport
Qtech(config-if-GigabitEthernet 0/2)#ip address 3.3.3.1 255.255.255.0
Qtech(config-if-GigabitEthernet 0/2)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.10 255.255.255.255
Qtech(config-Loopback 0)#exit
Qtech(config)#router ospf 1
Router(config-router)#network 1.1.1.1 255.255.255.0 area 0
Router(config-router)#network 3.3.3.1 255.255.255.0 area 0
```



```
Router(config-router)#network 10.10.10.10 255.255.255.255 area 0
Router(config-router)#exit
```

Configure the other devices by running the same commands as those on PE 1.

- Enable global MPLS forwarding on devices, MPLS packet forwarding, and the LDP on interfaces.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#label-switching
Qtech(config-if-GigabitEthernet 0/1)#mpls ip
Router(config-if-GigabitEthernet 0/1)#exit
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#label-switching
Qtech(config-if-GigabitEthernet 0/2)#mpls ip
Router(config-if-GigabitEthernet 0/2)#exit
```

Configure the other devices by running the same commands as those on PE 1.

- Configure the LDP so that the network can forward MPLS traffic.

Configure PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure the other devices by running the same commands as those on PE 1.

- Configure LDP FRR.

Configure PE 1.

Enable LDP FRR on the interface of PE 1 to generate the backup LSP.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#mpls ldp frr nexthop 3.3.3.2
Qtech(config-if-GigabitEthernet 0/1)#exit
```

Configure the LDP FRR protection timer on the interface of PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#mpls ldp frr timer protect-time 15
Qtech(config-if-GigabitEthernet 0/1)#exit
```

Configure single-hop BFD on the interface of PE 1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/1
Qtech(config-if-GigabitEthernet 0/1)#no bfd echo
Qtech(config-if-GigabitEthernet 0/1)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/1)#bfd bind peer-ip 20.20.20.20 source-ip 1.1.1.1
process-pst
Qtech(config-if-GigabitEthernet 0/1)#exit
```

Configure P1.

Enable LDP FRR on the interface of P1 so as to generate the backup LSP.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#mpls ldp frr nexthop 4.4.4.1
Qtech(config-if-GigabitEthernet 0/2)#exit
```

Configure the LDP FRR protection timer on the interface of P1.

```
Qtech#configure terminal
```

```
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#mpls ldp frr timer protect-time 15
Qtech(config-if-GigabitEthernet 0/2)#exit
```

Configure single-hop BFD on the interface of P1.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 0/2
Qtech(config-if-GigabitEthernet 0/2)#no bfd echo
Qtech(config-if-GigabitEthernet 0/2)#bfd interval 50 min_rx 50 multiplier 3
Qtech(config-if-GigabitEthernet 0/2)#bfd bind peer-ip 1.1.1.1 source-ip 1.1.1.2
process-pst
Qtech(config-if-GigabitEthernet 0/2)#exit
```

Verification

View MPLS routing information.

View MPLS routing information on PE 1.

```
Qtech#show mpls rib
Status codes: m - main entry, b - backup entry, * - active, s - stale.
Default VRF:
LSP Information      Total
STATIC LSP          0
LDP LSP              2
RSVP LSP             0
BGP LSP              0
L3VPN LSP            0
LDP LSP:
```

```
-----
FEC          In/Out Label      In/Out IF      Nexthop
m* 2.2.2.0/24  -/1024          -/Gi0/1        1.1.1.2
b  2.2.2.0/24  -/1025          -/Gi0/2        3.3.3.2
m* 30.30.30.30/32 -/1026         -/Gi0/1        1.1.1.2
b  30.30.30.30/32 -/1031         -/Gi0/2        3.3.3.2
-----
```

7 CONFIGURING LDP IGP SYNCHRONIZATION



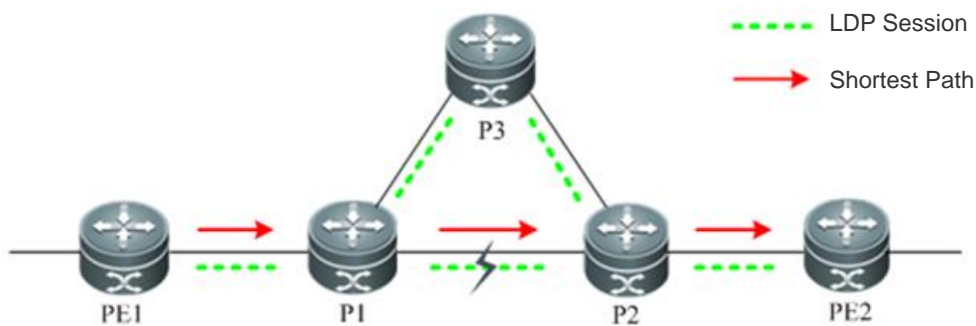
Note The routers and router icons described in this document represent those in common sense.

7.1 Overview

Link Detection Protocol (LDP)-Interior Gateway Protocol (IGP) synchronization is a technology that realizes uniform LDP and IGP convergence by changing the way of route release to avoid Multiple Protocol Label Switching (MPLS) route black holes.

In the MPLS network, LDP establishes Label Switched Paths (LSPs) based on the shortest IP path. As LDP and routing protocols have different convergence conditions and speeds, convergence of LDP LSPs may be inconsistent with that of the shortest IP path.

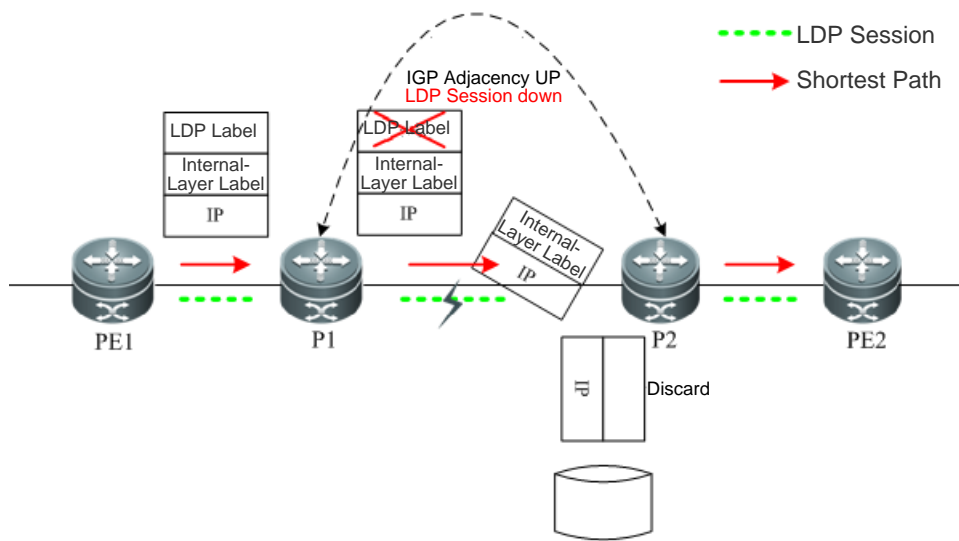
Figure 7-1 MPLS Network Topology



As shown in the figure, the devices are interconnected with each other at the link layer and run routing protocols and LDP. The shortest path from Provider Edge 1 (PE1) to PE2 is PE1-P1-P2-PE2, which covers LDP LSP. Routing protocols will not detect disconnection of the LDP session between P1 and P2 (the P1-P2 link and IGP remain normal) because the network topology is not changed. Although LDP detects the LSP disconnection, LDP cannot trigger route switching to a standby path because it is not a routing protocol. In this case, the shortest path from PE1 to PE2 is still PE1-P1-P2-PE2, but the LSP from PE1 to PE2 is disconnected between P1 and P2.

If MPLS Virtual Private Network (VPN)/6PE traffic is being forwarded through the path, the MPLS traffic will be affected.

Figure 7-2 MPLS VPN/6PE Traffic Being Forwarded through LSP

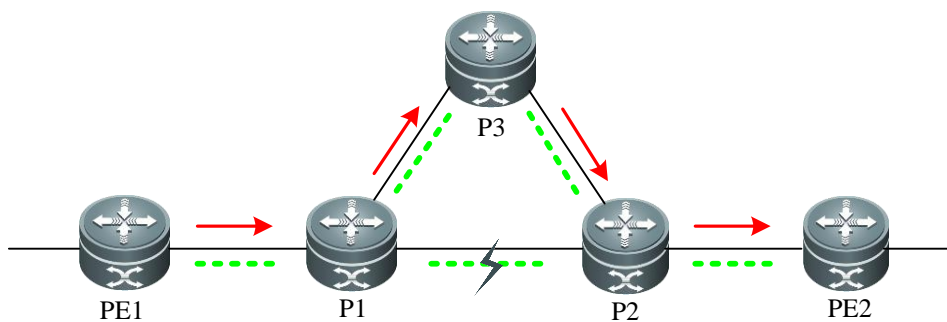


As shown in the figure above, the LSP between PE1 and PE2 is used to forward MPLS VPN/6PE traffic. Label packets are transmitted through the LDP LSP. When the LDP session between P1 and P2 is disconnected, packets have only inbound LDP labels on P1. P1 pops LDP labels upon receipt of the packets, and then forwards the packets with internal-layer labels to P2. However, P2 cannot identify internal-layer labels (because there is no private network route in the IPv4 routing table of the core device P on a public network and internal-layer labels are not assigned by P2), so the packets are discarded between P1 and P2, which results in traffic forwarding black holes.

Therefore, for applications such as MPLS VPN (including L2 VPN and L3 VPN) and 6PE that rely on end-to-end LDP LSPs on an MPLS network, if the convergence of LDP LSPs is inconsistent with that of the shortest IP path, MPLS route black holes will be incurred.

To solve this problem, you can configure LDP IGP synchronization on the core devices.

Figure 7-3 MPLS Network Topology



As shown in the figure, the LSP between PE1 and PE2 is used to forward MPLS VPN/6PE traffic. Label packets are transmitted through the LDP LSP. LDP IGP synchronization is enabled on core devices P1, P2 and P3. When the LDP session between P1 and P2 is disconnected, LDP IGP synchronization triggers IGP and LDP LSP convergence to the standby path P1-P3-P2, and the new path covers IGP and LDP LSP so that MPLS route black holes will not be incurred.



Caution

You must to deploy standby paths for active links in the network topology; otherwise, it makes no sense to configure LDP IGP synchronization.

7.2 Configuring LDP IGP Synchronization

Scenario

LDP IGP synchronization aims at traffic loss caused by failure of the active LSP link on a network with active and standby LSP links. The following describes major application scenarios:

- When the active link is normal but the LDP session between two nodes on the active link fails, LSP traffic is switched to the standby link, while IGP traffic is still forwarded through the active link, which results in LSP traffic loss.
- When the active link fails, both IGP traffic and LSP traffic are switched to the standby link. However, when the fault is removed, as IGP converges faster than LDP, IGP is switched back to the active link before LDP does, which results in LSP traffic loss.

Prerequisites

Before configuring LDP IGP synchronization, you are advised to do the following:

- Enable MPLS.
- Configure MPLS LDP.

Data

Before configuring LDP IGP synchronization, you are advised to do the following:

- Configure IGP instances for LDP IGP synchronization (interfaces on which LDP IGP synchronization will be enabled).
- Configure the LDP IGP synchronization delay (optional).
- Configure the IGP waiting time for LDP synchronization (optional).

7.2.1 Enabling LDP IGP Synchronization

You can enable LDP IGP synchronization for all the interfaces that run Open Shortest Path First (OSPF) in OSPF routing process configuration mode. The following table describes the steps:

Command	Description
Qtech # configure terminal	Enters global configuration mode.
Qtech(config)# router ospf process-id [vrf vrf-name]	Creates an OSPF process and enters OSPF process configuration mode.
Qtech(config-router)# mpls ldp sync	Enables LDP IGP synchronization.

Run the **no mpls ldp sync** command to disable LDP IGP synchronization.

7.2.2 (Optional) Enabling LDP IGP Synchronization in Interface Configuration Mode

You can enable/disable LDP IGP synchronization in interface configuration mode. By default, LDP IGP synchronization is enabled for all interfaces.

Command	Description
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# mpls ldp igp sync	Enables LDP IGP synchronization for an interface.

7.2.3 (Optional) Configuring a Timer for LDP IGP Synchronization Delay

You can configure the LDP IGP synchronization delay in interface configuration mode.

Command	Description
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# mpls ldp igp sync delay 30	Configures the LDP IGP synchronization delay as 30 seconds.

7.2.4 (Optional) Configuring the IGP Waiting Time for LDP Synchronization

You can configure IGP waiting time for LDP synchronization in interface configuration mode.

Command	Description
Qtech# configure terminal	Enters global configuration mode.
Qtech(config)# interface type ID	Enters interface configuration mode.
Qtech(config-if-type ID)# mpls ldp igp sync holddown20	Configures the IGP waiting time for LDP synchronization as 20 seconds.

7.2.5 Displaying Configuration Effect

You can run the following commands to display configurations.

Command	Description
show mpls ldp igp sync [all vrf vrf-name interface interface-name]	Displays configuration of LDP IGP synchronization.
show ip ospf [process-id] mpls ldp interface [interface-name]	Displays configuration of LDP IGP synchronization for an OSPF-enabled interface.

7.3 Configuration Example

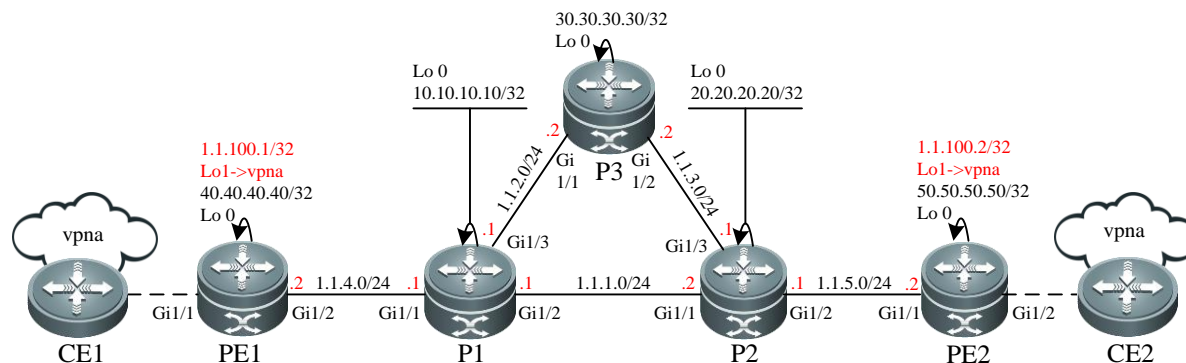
7.3.1 OSPF Network

Networking Requirements

The public network of an Internet Service Provider (ISP) carries VPN traffic. Each device runs OSPF. To improve the network reliability and avoid route black holes caused by inconsistent LDP and OSPF convergence, you can configure LDP IGP synchronization on the core device P.

Network Topology

Figure 7-4 OSPF Network Topology for Configuring LDP IGP Synchronization



Configuration Tips

The following describes Configuration Tips:

- Configure interface IP addresses on each node, configure OSPF and enable LDP.
- Configure VPN route instances and MP-IBGP neighbors and transfer VPN routing information on PEs.
- Enable LDP IGP synchronization on P1, P2 and P3.

Steps

- Configure interface IP addresses on each node, configure OSPF and enable LDP.

Configure PE1.

Configure a loopback interface.

```
Qtech(config)# interface Loopback 0
Qtech(config-if-Loopback 0)# ip address 40.40.40.40 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

```
## Enable MPLS and LDP in global configuration mode.
```

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface Loopback 0force
Qtech(config-mpls-router)# exit
```

```
## Configure interface IP addresses and enable MPLS and LDP for the interfaces.
```

```
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 1.1.4.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

```
## Configure IGP (OSPF).
```

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 1.1.4.0.0.0.255 area 0
Qtech(config-router)# network 40.40.40.40.0.0.0 area 0
Qtech(config-router)# exit
```

```
# Configure P1.
```

```
## Configure a loopback interface.
```

```
Qtech(config)# interface Loopback 0
Qtech(config-if-Loopback 0)# ip address 10.10.10.10 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

```
## Enable MPLS and LDP in global configuration mode.
```

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
Qtech(config-mpls-router)# ldp router-id interface Loopback 0force
Qtech(config-mpls-router)# exit
```

```
## Configure interface IP addresses and enable MPLS and LDP for the interfaces.
```

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 1.1.4.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 1.1.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
Qtech(config)# interface gigabitEthernet 1/3
Qtech(config-if-GigabitEthernet 1/3)# ip address 1.1.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/3)# mpls ip
Qtech(config-if-GigabitEthernet 1/3)# label-switching
Qtech(config-if-GigabitEthernet 1/3)# exit
```

```
## Configure IGP (OSPF).
```

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 1.1.1.0.0.0.255 area 0
Qtech(config-router)# network 1.1.2.0.0.0.255 area 0
Qtech(config-router)# network 1.1.4.0.0.0.255 area 0
Qtech(config-router)# network 10.10.10.100.0.0.0 area 0
Qtech(config-router)# exit
```

```
# Configure P3.
```

```
## Configure a loopback interface.
```

```
Qtech(config)# interface Loopback 0
Qtech(config-if-Loopback 0)# ip address 30.30.30.30 255.255.255.255
Qtech(config-if-Loopback 0)# exit
```

```
## Enable MPLS and LDP in global configuration mode.
```

```
Qtech(config)# mpls ip
Qtech(config)# mpls router ldp
```

```
Qtech(config-mpls-router)# ldp router-id interface Loopback 0 force
Qtech(config-mpls-router)# exit
```

Configure interface IP addresses and enable MPLS and LDP for the interfaces.

```
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip address 1.1.2.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)# mpls ip
Qtech(config-if-GigabitEthernet 1/1)# label-switching
Qtech(config-if-GigabitEthernet 1/1)# exit
Qtech(config)# interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)# ip address 1.1.3.2 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)# mpls ip
Qtech(config-if-GigabitEthernet 1/2)# label-switching
Qtech(config-if-GigabitEthernet 1/2)# exit
```

Configure IGP (OSPF).

```
Qtech(config)# router ospf 1
Qtech(config-router)# network 1.1.2.0 0.0.255 area 0
Qtech(config-router)# network 1.1.3.0 0.0.255 area 0
Qtech(config-router)# network 30.30.30.30 0.0.0 area 0
Qtech(config-router)# exit
```

Configuration of P2/PE2 is the same as that of P1/PE1, respectively.

- Configure VPN routing instances and MP-IBGP neighbors and transfer VPN routing information on PEs.

Configure VPN Routing & Forwarding (VRF): Take PE1 as an example, which is similar to PE2.

```
Qtech(config)# ip vrf vpna
Qtech(config-vrf)# rd 65001:20
Qtech(config-vrf)# route-target both 65001:20
Qtech(config-vrf)# exit
Qtech(config)# interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)# ip vrf forwarding vpna
Qtech(config-if-GigabitEthernet 1/1)# ip address 1.1.100.1 255.255.255.0
```

Configure MP-IBGP neighbors and transfer VPN routing instances: Take PE1 as an example, which is similar to PE2.

```
Qtech(config)# router bgp 65001
Qtech(config-router)# neighbor 50.50.50.50 remote-as 65001
Qtech(config-router)# neighbor 50.50.50.50 update-source Loopback 0
Qtech(config-router)# address-family vpnv4
Qtech(config-router-af)# neighbor 50.50.50.50 activate
Qtech(config-router-af)# neighbor 50.50.50.50 send-community both
Qtech(config-router-af)# exit
Qtech(config-router)# address-family ipv4 vrf vpna
Qtech(config-router-af)# redistribute connected
Qtech(config-router-af)# exit
Qtech(config-router)# exit
```

- Enable LDP IGP synchronization on P1, P2 and P3.

Enable LDP IGP synchronization: Take P1 as an example, which is similar to P2 and P3.

```
Qtech# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)# router ospf 1
Qtech(config-router)# mpls ldp sync
Qtech(config-router)# exit
```

Verification

Display whether LDP IGP synchronization is enabled.

Display whether LDP IGP synchronization is enabled on P1.

```
Qtech# show mpls ldp igp sync
GigabitEthernet 1/1:
  LDP configured; LDP-IGP Synchronization enabled.
  Sync status: sync required; not achieved.
  Sync delay time: 5 seconds
  IGP holddown time: infinite.
```



```
Peer LDP Ident: 40.40.40.40:0
IGP enabled: OSPF 1
GigabitEthernet 1/2:
LDP configured; LDP-IGP Synchronization enabled.
Sync status: sync required; not achieved.
Sync delay time: 5 seconds
IGP holddown time: infinite.
Peer LDP Ident: 20.20.20.20:0
IGP enabled: OSPF 1
GigabitEthernet 1/3:
LDP configured; LDP-IGP Synchronization enabled.
Sync status: sync required; not achieved.
Sync delay time: 5 seconds
IGP holddown time: infinite.
Peer LDP Ident: 30.30.30.30:0
IGP enabled: OSPF 1
```

8 CONFIGURING MPLS ECMP



Note The routers and router icons described in this document represent those in common sense.

8.1 Overview

Establishment of Multiple Protocol Label Switching (MPLS) forwarding entries is driven by IP routing. If a Forward Error Correction (FEC) has multiple equal cost next hops, the MPLS signaling protocol can establish multiple equal cost next hops for the FEC, and the FEC traffic can be forwarded through the equal cost paths. When an MPLS network supports Equal-Cost MultiPath (ECMP), Facsimile Transmission Network (FTN) or Identity Lifecycle Manager (ILM) for the same FEC can be mapped to multiple Next Hop Label Forwarding Entries (NHLFEs), and each next hop matches one NHLFE. The FEC packets can be forwarded through the equal cost paths, thereby achieving load balancing.

The following describes the benefits of load balancing:

- Increases the MPLS network bandwidth without updating hardware.
- Strengthens protection of MPLS network links (end-to-end and point-to-point). Balances traffic to multiple links. When one of these links fails, traffic can be forwarded through other links, which improves reliability.
- Balances MPLS traffic toward the same destination on multiple Label Switched Paths (LSPs) and thereby makes the most of network resources.

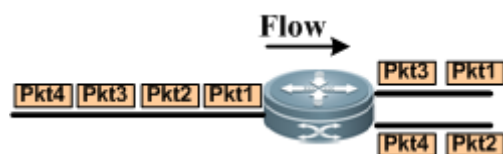
8.1.1 Working Principle

8.1.1.1 Scheduling Algorithms for MPLS Load Balancing

Scheduling algorithms for MPLS load balancing aim to select a next hop for an FEC packet from multiple equal cost paths. There are many algorithms, among which per packet scheduling and per flow scheduling algorithms are frequently used.

8.1.1.2 Per Packet Scheduling

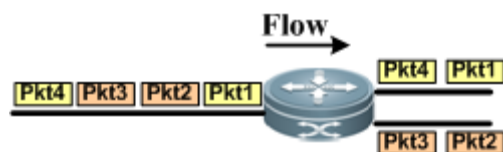
Figure 8-1 Per Packet Scheduling



Per packet scheduling forwards the packets toward the same destination network successively to different equal cost next-hop links to balance the traffic equally. As shown in the following figure, on a Link-State Request (LSR), two equal cost links are destined for the same destination network. There are 4 packets. Packet 1 is transmitted through Link 1, Packet 2 through Link 2, Packet 3 through Link 1, and Packet 4 through Link 2. This is called per packet scheduling.

8.1.1.3 Per Flow Scheduling

Figure 8-2 Per Flow Scheduling



Under per flow scheduling, the router checks certain fields of packets and uses these fields as key words to map the packets of the same type to the same next-hop link through a hash function. As shown in the figure, there are 4

packets destined for the same destination network. Packet 1 and Packet 4 are of the same type; Packet 2 and Packet 3 are of the same type. Packet 1 and Packet 4 are forwarded to Link 1, and Packet 2 and Packet 3 are forwarded to Link 2 by hashing the fields that mark the packet type. This is called per flow scheduling.

Selection of hash key words:

- **MPLS LSP load balancing**
If the MPLS label stack is followed by the IPv4 header, use destination and source IP addresses for hash calculation and select a next hop for packet forwarding. If the MPLS label stack is not followed by the IPv4 header, use the innermost label for hash calculation and select a next hop for packet forwarding; otherwise, hash calculation is not performed and packets are forwarded to the first valid next hop.
- **MPLS L3VPN load balancing**
Use destination and source IP addresses for hash calculation and select a next hop to forward packets.
- **MPLS Virtual Private Wire Service (VPWS) load balancing**
Use Pseudo Wire (PW) labels for hash calculation and select a next hop to forward packets.
- **MPLS Virtual Private LAN Service (VPLS) load balancing**
Use destination and source MAC addresses for hash calculation and select a next hop to forward packets.

8.1.1.4 Protocols and Standards

N/A.

8.1.1.5 Defaults

Feature	Default Settings
Load balancing mode	Per flow scheduling is used.
Establish equal cost LSPs for all public network routes	Equal cost LSPs are established only for host routes.

8.2 Configuring MPLS ECMP

8.2.1 Establishing Equal Cost LSPs for All Equal Cost Routing FECs

Command	Description
Qtech#configure terminal	Enters global configuration mode.
Qtech(config)#mpls router ldp	Enables MPLS forwarding.
Qtech(config-mpls-router)# ldp-ecmp for all-fec	Establishes equal cost LSPs for all equal cost routing FECs.

8.3 Configuring MPLS Load Balancing Mode

Command	Description
Qtech#configure terminal	Enters global configuration mode.
Qtech(config)# mpls load-balance { flow packet }	Configures the MPLS load balancing mode.

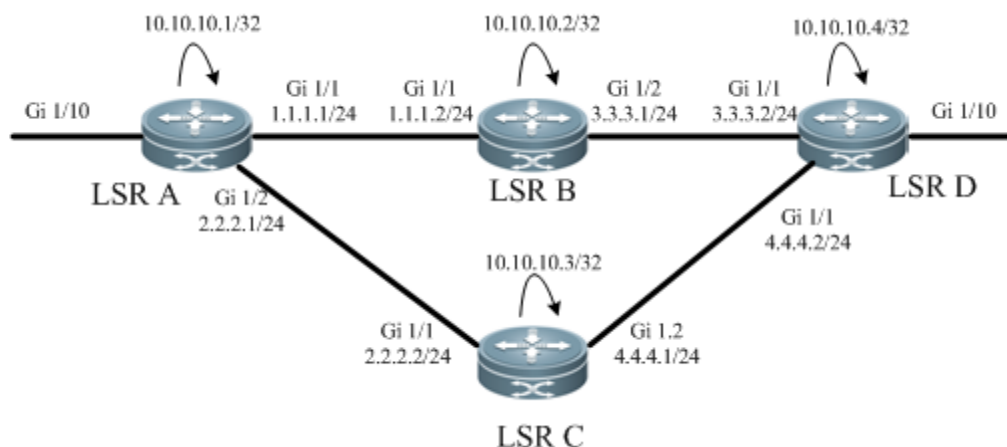
8.4 Configuration Example

Networking Requirements

As shown in the following figure, all nodes support MPLS and run Open Shortest Path First (OSPF) as the Interior Gateway Protocol (IGP) on the MPLS backbone network. Two LSPs from LSR A to LSR D are available for load balancing: LSR A→LSR B→LSR D and LSR A→LSR C→LSR D.

Network Topology

Figure 8-3 Network Topology for MPLS Load Balancing



Configuration Tips

The following describes the Configuration Tips of configuration for each node:

Configure the interface IP address and OSPF protocol.

Configure MPLS and MPLS Link Detection Protocol (LDP) in global and interface configuration modes.

Configure the load balancing policy on the start node.

Steps

Configure the interface IP address and OSPF protocol.

Configure LSR A.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#no switchport
Qtech(config-if-GigabitEthernet 1/1)#ip address 1.1.1.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#no switchport
Qtech(config-if-GigabitEthernet 1/2)#ip address 2.2.2.1 255.255.255.0
Qtech(config-if-GigabitEthernet 1/2)#exit
Qtech(config)#interface loopback 0
Qtech(config-Loopback 0)#ip address 10.10.10.1 255.255.255.255
Qtech(config-Loopback 0)#exit
Qtech(config)#router ospf 1
Qtech(config-router)#network 1.1.1.1 255.255.255.0 area 0
Qtech(config-router)#network 2.2.2.1 255.255.255.0 area 0
Qtech(config-router)#network 10.10.10.1 255.255.255.255 area 0
Qtech(config-router)#exit
```

Configure other nodes. The configurations of other nodes are the same as LSR A.

- On each node, enable global MPLS forwarding, interface-based MPLS label packet forwarding as well as interface-based LDP.

Configure LSR A.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls ip
Qtech(config)#interface gigabitEthernet 1/1
Qtech(config-if-GigabitEthernet 1/1)#label-switching
Qtech(config-if-GigabitEthernet 1/1)#mpls ip
Qtech(config-if-GigabitEthernet 1/1)#exit
Qtech(config)#interface gigabitEthernet 1/2
Qtech(config-if-GigabitEthernet 1/2)#label-switching
```

```
Qtech(config-if-GigabitEthernet 1/2)#mpls ip
Qtech(config-if-GigabitEthernet 1/2)#exit
```

Configure other nodes. The configurations of other nodes are the same as LSR A.

- Configure LDP to enable MPLS traffic forwarding.

Configure LSR A.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp router-id interface loopback 0 force
```

Configure other nodes. The configurations of other nodes are the same as LSR A.

- Configure per packet scheduling and establish equal cost LSPs for all equal cost routes.

Configure LSR A.

```
Qtech#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Qtech(config)#mpls load-balance packet
Qtech(config)#mpls router ldp
Qtech(config-mpls-router)#ldp-ecmp for all-fec
```

Verification

Display MPLS route information on LSR A.

```
Qtech#show mpls rib
Status codes: m - main entry, b - backup entry, * - active, s - stale.
Default VRF:
LSP Information      Total
STATIC LSP           0
LDP LSP              2
RSVP LSP             0
BGP LSP              0
L3VPN LSP            0
LDP LSP:
```

```
-----
FEC          In/Out Label      In/Out IF      Nexthop
* 10.10.10.4/32  -/1024          -/Gi1/1        1.1.1.2
* 10.10.10.4/32  -/2001          -/Gi1/2        2.2.2.2
-----
```

Display the MPLS forwarding table on LSR A.

```
Qtech# show mpls forwarding-table
Label Operation Code:
PH--PUSH label
PP--POP label
SW--SWAP label
SP--SWAP topmost label and push new label
DP--DROP packet
PC--POP label and continue lookup( IP or Label )
PI--POP label and do ip lookup forward
PN--POP label and forward to nexthop
PM--POP label and do MAC lookup forward
PV--POP label and output to VC attach interface
IP--IP lookup forward
Local  Outgoing  OP   FEC          Outgoing      Next Hop
label  label
--    1024      PH  10.10.10.4/32  Gi1/1         1.1.1.2
--    2001      PH  10.10.10.4/32  Gi2/2         2.2.2.2
.....
```