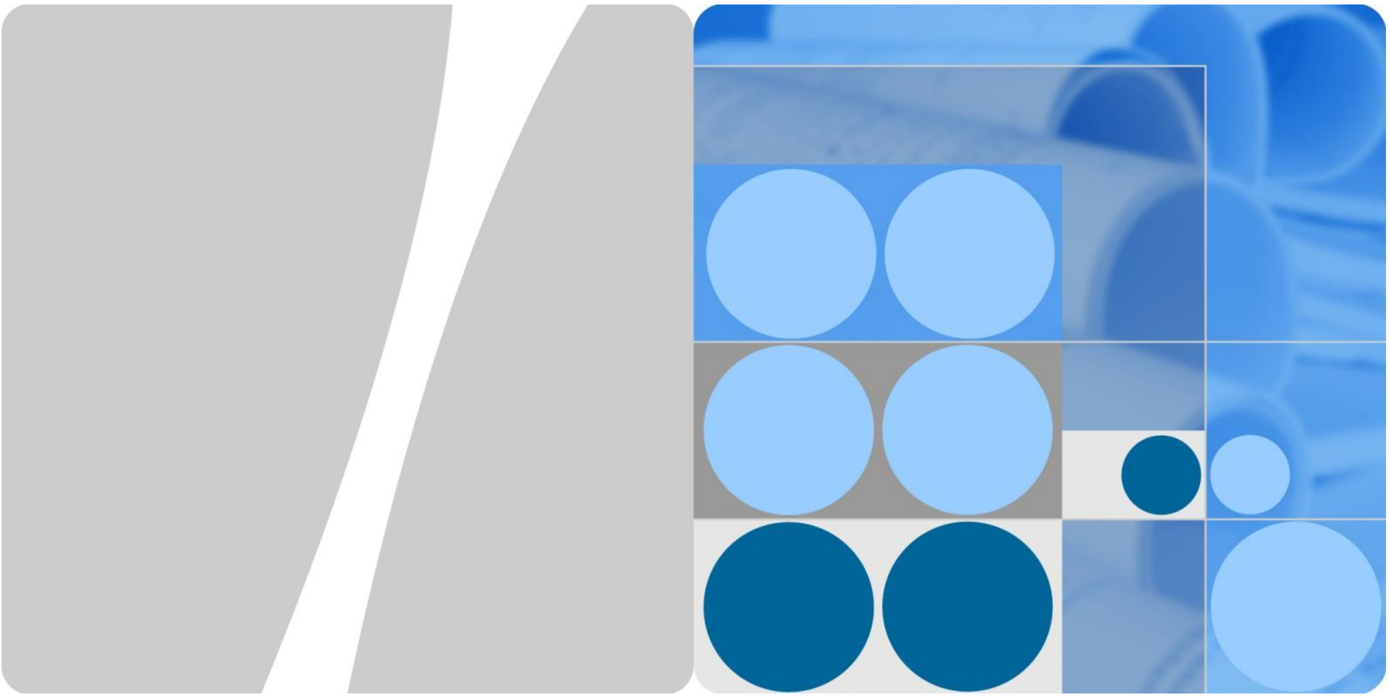

MPLS L2VPN (VLL) Technology White Paper

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Huawei Technologies Co., Ltd.

Address: Huawei Industrial Base
Bantian, Longgang
Shenzhen 518129
People's Republic of China

Website: http://enterprise.huawei.com

About This Document

Keywords:

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Abstract:

Multi-Protocol Label Switching (MPLS) technologies make it easy to provide VPN services based on IP technologies. MPLS VPNs are highly scalable and easy-to-manage. There are two MPLS-based VPN services: L3 MPLS VPN and L2 MPLS VPN. MPLS L2VPN has two modes: Virtual Private LAN Service (VPLS) and Virtual Leased Line (VLL). VLL applies to point-to-point networking scenarios, while VPLS supports point-to-multipoint and multipoint-to-multipoint networking. From users' point of view, the whole MPLS network is a Layer 2 switched network, through which Layer 2 connections can be established between sites. This document describes VLL.

Acronyms:

Acronym	Full spelling
MPLS	Multi-Protocol Label Switching
VLL	Virtual Leased Line

Contents

1 Overview

As the world economy develops, increasing enterprises have to span greater distances to provide quality services to an extensive clientele base. The employees of these enterprises also have to travel more frequently. As a result, enterprises seek out services that enable them to interconnect their branches, so that their employees can easily access enterprise networks from anywhere.

Originally, service providers filled this need by providing leased lines, but leased lines have significant disadvantages. For example, leased lines are not applicable when there are a large number of branches or when the number of branches grows quickly. Furthermore, this method is expensive and a network based on leased lines is difficult to manage.

Then, Asynchronous Transfer Mode (ATM) and Frame Relay (FR) emerged, and service providers turned to them to provide virtual circuits. With these new methods, enterprises could establish their own Layer 3 networks for IP or IPX traffic based on the virtual circuits. However, the virtual links are point-to-point Layer 2 links, which make networks difficult to configure and maintain, especially when a new site is deployed.

Later, after IP networks had become present almost everywhere in the world, service providers began to focus on how to provide enterprises with low-cost private network services using the existing IP networks.

The Multi-protocol Label Switching (MPLS) VPN technology, which is easy to configure and allows service providers to change bandwidth settings easily, address this demand. This technology uses a short but fixed-length label to encapsulate network layer packets, and integrates IP's connectionless control and ATM's connection-oriented packet forwarding. Apart from IP routing and control protocols, MPLS also supports policy-based routing, meeting requirements of emerging applications. MPLS was initially developed to improve forwarding speeds of routers. Due to its intrinsic advantages, it is not limited to this application. For example, MPLS has been widely applied to traffic engineering, VPN services, and other areas. As a result, it has gradually become an important standard for large-scale IP networks.

Traditional VPN technologies use L2 tunneling protocols (such as L2TP, L2F and PPTP) or the L3 tunneling technologies (IPSec and GRE). These technologies were quite successful and widely applied. However, as the use of VPNs expanded, their drawbacks, such as its expansion and management limitations, have become more obvious. In addition, quality of service (QoS) and security are tough problems for the traditional VPN technologies.

The MPLS technology can easily implement IP-based VPN services and satisfy the requirements for VPN expandability and manageability. MPLS VPNs allow for implementation of value-added services. A single access point can be configured with multiple VPNs, each representing a different service, so that the network can transmit different services

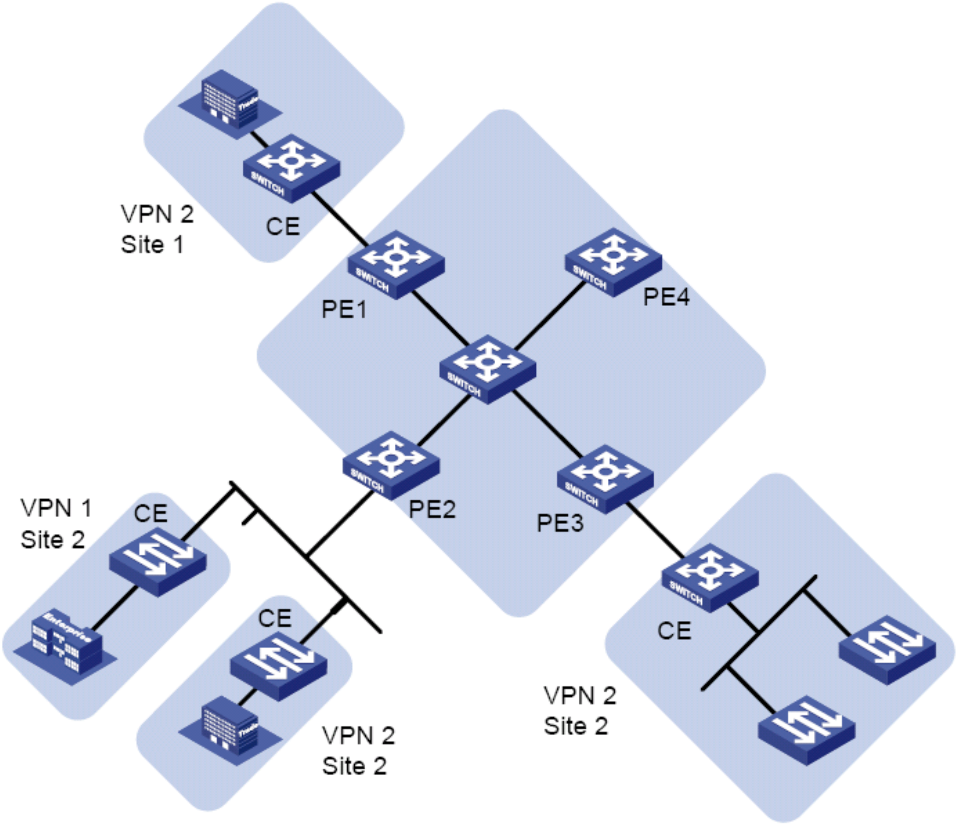
There are two types of MPLS-based VPN services: MPLS L3VPN and MPLS L2VPN. The L2 MPLS VPN service comprises VPLS and VLL, where VLL applies to point-to-point networking and VPLS applies to point-to-point and multipoint-to-multipoint VPN scenarios. From the user’s point of view, the entire MPLS network is an L2 switching network through which L2 connections can be set up between different sites.

This document focuses on the L2 MPLS VPN in VLL mode.

2 Basic Model

2.1 MPLS L2VPN Model

Figure 2-1 MPLS L2VPN model



The service provider has four provider edges (PEs) to provide VPN services for two customers. VPN2 has two sites located in different places, while VPN1 consists of three sites located in different places. As shown in Figure 2-1, the basic L2 MPLS VPN model comprises three major components: customer edge (CE), PE, and provider (P). The carrier manages the PEs, and customers manage the CEs.

2.2 Advantages of the MPLS L2VPN

- **Higher expandability**

  MPLS VPN is much easier to expand than the traditional ATM or FR network. MPLS VPNs can multiplex multiple virtual circuits in the same LSP. A PE only maintains information about one LSP for the virtual circuits; therefore, the system capacity is easy to expand.

- **Clear management responsibility**

  The MPLS L2VPN carrier only provides L2 connectivity, whereas L3 connectivity is provided by customers. Therefore, route flapping caused by incorrect configuration on a user network does not affect stability of the carrier's network.

- **Higher security and confidentiality**

  MPLS VPN can provide security and confidentiality equivalent to that of the ATM or FR VPN network. Since users maintain their own routing information, the carrier does not need to worry about address overlapping among the users or whether the routing information of a user will be disclosed to private networks of other users. This alleviates the management load of the carrier while enhancing security of user information.

- **Support for multiple network protocols**

  As the carrier only provides L2 connectivity, customers can use any L3 protocol, such as IP, IPv6, IPX and SNA.

- **Smooth upgrade from traditional L2VPN**

  MPLS L2VPN is transparent to users. When the carrier upgrades the traditional L2VPN networks, such as ATM and FR networks, to the MPLS L2VPN networks, the customers do not need to make any configuration. The upgrade has almost no impact on the customers except that data may be lost for a short time during the transition.

3 Features

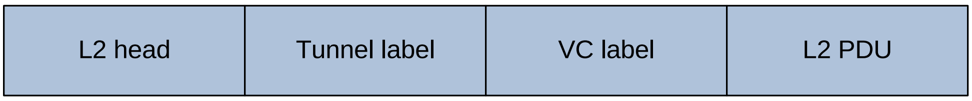
3.1 Terminologies

- Virtual Leased Line (VLL): A point-to-point L2VPN service provided on the MPLS network. Virtual Private LAN Service (VPLS): A point-to-multipoint and multipoint-to-multipoint L2 VPN service provided on the MPLS network.
- Custom Edge (CE): User edge device directly connected to the service provider. The CE can be a router or a switch. It cannot detect VPNs by itself.
- Provider Edge (PE): Carrier device directly connected to the CE. All the processing on the VPN is conducted on the PE of the MPLS network. The PE must support MPLS VPN.
- Provider (P): Backbone device on the carrier's MPLS network. The P is not directly connected to the CE. The P must support MPLS.
- Penultimate Hop Popping (PHP): To pop up a layer of label to simplify label search in MPLS and IP switching.
- Circuit Cross Connect (CCC): An L2 MPLS VPN implementation mode.
- Label Switched Path (LSP): A data forwarding path established through signaling or static configuration on the MPLS network.
- Label Distribution Protocol (LDP): One of the core protocols of MPLS. It classifies packets, attaches labels to different types of packets, and establishes the label switching path.

3.2 Frame Format

Figure 3-1 shows the VLL frame format.

Figure 3-1 VLL frame format



L2 head	Tunnel label	VC label	L2 PDU

- Tunnel label (outer label): An MPLS label that forwards packets from a PE to another PE.

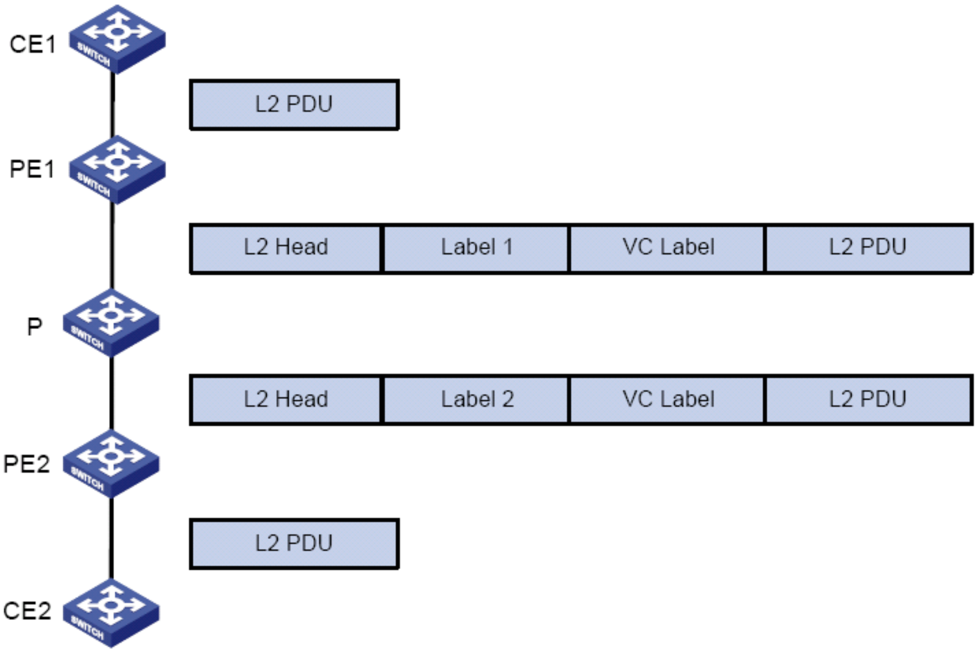
- VC label (inner label): A label that identifies the PE-CE link. In CCC mode, the L2 MPLS VPN does not have such a label.
- MPLS L2VPN supports the following link layer encapsulation modes: Ethernet and VLAN. Nodes in the same VPN must use the same encapsulation mode.

3.3 Packet Forwarding Process

MPLS L2VPN uses a label stack to transparently transmit user packets on an MPLS network. Tunnels are established between PEs through static configuration or signaling protocols. A PE adds the VC label and the tunnel label to the packet sent by the CE and then sends the packet to a remote PE through an MPLS tunnel. After receiving the packet, the remote PE strips the tunnel label and forwards the packet to the corresponding CE based on the VC label. The PHP operation is not taken into account for the encapsulation format among PEs. When the PHP operation is taken into account, packets received by the packet egress PE only has an (inner) VC label.

Figure 3-2 shows the changes of the label stack in the packet during the packet forwarding process on the MPLS network.

Figure 3-2 Label stack processing of the MPLS L2VPN (VLL)



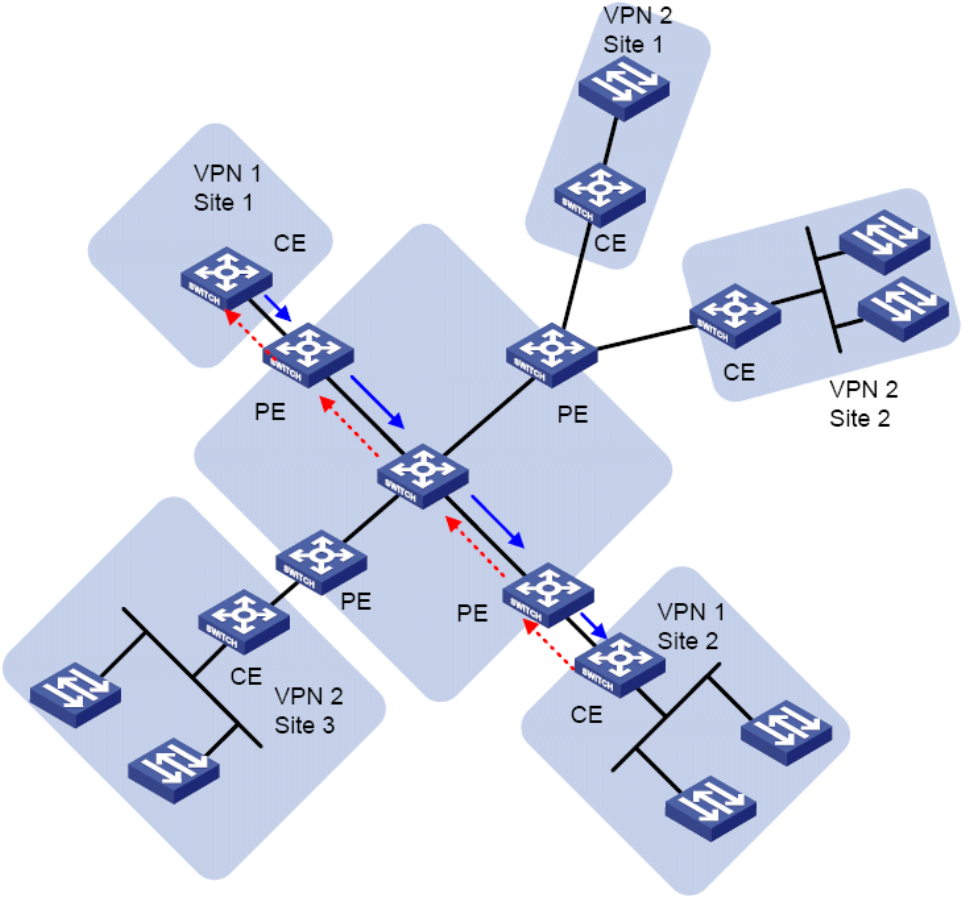
4 Implementation of the MPLS L2VPN (VLL)

4.1 CCC Mode

Circuit Cross Connect (CCC) is the mode in which VLL is implemented through static LSPs. Unlike common MPLS L2VPN, CCC uses one layer of label (tunnel label) to transmit user data. Therefore, each LSP is exclusively used by a virtual circuit. A transparent connection can be configured between a PE and CE. Packets of the source CE can be sent to the destination CE.

CCC falls into local CCC and remote CCC. In local CCC mode, two CEs are connected to the same PE, and the PE is equivalent to an L2 switch. In remote CCC mode, two CEs are connected to different PEs and use the exclusive static LSP between the PEs as a tunnel. This mode does not need any signaling protocol to transfer L2 VPN information. The PEs use the label corresponding to the LSP to forward packets.

Figure 4-1 L2VPN in CCC mode



As shown in Figure 4-1, Site1 and Site2 of VPN2 are interconnected are interconnected through a local CCC connection, and the PE connected to them is equivalent to an L2 switch. Site1 and Site2 can exchange data of link-layer protocols, such as VLAN, Ethernet, RF, ATM AAL5, PPP and HDLC, without needing an LSP tunnel.

Site1 and Site2 of VPN1 are interconnected through remote CCC connections (red dotted line and blue solid line). Two static LSPs need to be configured. The red dotted line from PE1 to PE3 indicates the LSP from Site2 to Site1, while the blue solid line from PE3 to PE1 indicates the LSP from Site1 to Site2. The two LSPs compose a bidirectional virtual circuit, providing customers with L2VPN connections.

The advantage of this mode is that no label signaling is needed to transmit L2 VPN information and only the MPLS forwarding capability should be supported. In addition, it can provide QoS guarantee because the LSPs are exclusively used.

4.2 Martini Mode

Martini mode is defined in the draft-martini-l2circuit-trans-mpls and uses LDP as the signaling for transmitting VC information.

In Martini mode, a remote LDP session is established between PEs. The PE allocates a VC label to each link and forwards the VC label to the remote PE through the LSP established by LDP. In this way, a virtual circuit (VC) is established on the LSP.

Compared with the CCC mode, Martini mode cannot provide the local switching function, but a single LSP can be shared by multiple VCs on the service provider's network.

As shown in Figure 4-2, LSP1 and LSP2 are shared by the VCs between Site1 and Site2 of VPN1, and the VCs between Site1 and Site2 of VPN2. On the ingress PE, the inner layer of the data packet will be tagged with the VC label and then the outer label (stack) of the LSP before the data packet enters the LSP. Upon arriving at the egress PE, the outer label (stack) of the data packet is stripped off. The egress PE can tell from the VC label which VC the packet came from. The egress PE then forwards the data packet to the correct CE.

Figure 4-2 L2VPN in Martini mode

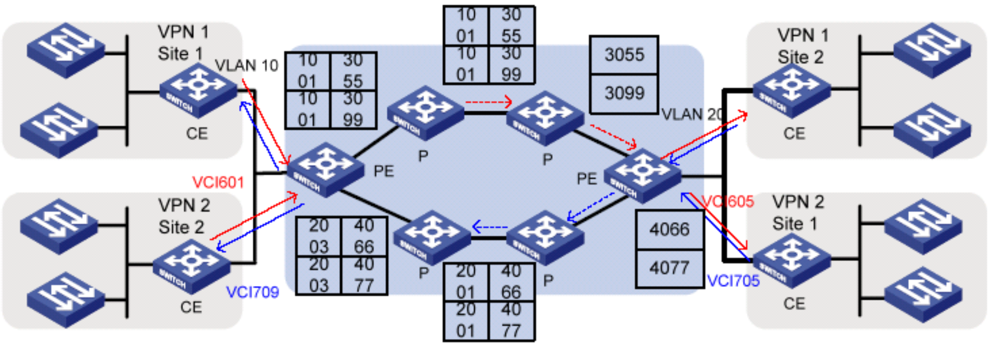


Figure 4-2 shows the following transmission flow:

1. When receiving a packet of VLAN 10 from Site1 of VPN1, PE0 adds VC label 3055 to the packet and outer label 1001 of LSP1. Then PE0 sends the packet through LSP1.
2. When receiving an ATM cell (with VCI 601) from Site2 of VPN2, PE0 adds VC label 3099 and outer label 1001 of LSP1. Then PE0 sends the packet through LSP1.
3. Before the packets reach PE1, in label 1003 of LSP1 pops up by PHP.
4. When PE1 establishes the VCs, it has used LDP to notify PE0 of the VC labels (3055 and 3099). Therefore, PE1 selects the outbound interface connected to Site2 of VPN1 based on the VC label 3055, and selects the outbound interface connected to Site1 of VPN2 based on VC label 3099.

For packets being transmitted in the opposite direction, the same rules apply.

In Martini mode, the PE of the carrier's network only needs to save a little information about the mapping between VC labels and LSPs. Furthermore, since the P does not need to process any L2 VPN information, the network is highly scalable. When a new VC is required, the carrier only needs to configure a unidirectional VC on each of the two PEs without affect network operations.

Martini mode applies when there are only sparse L2 connections (star connections).

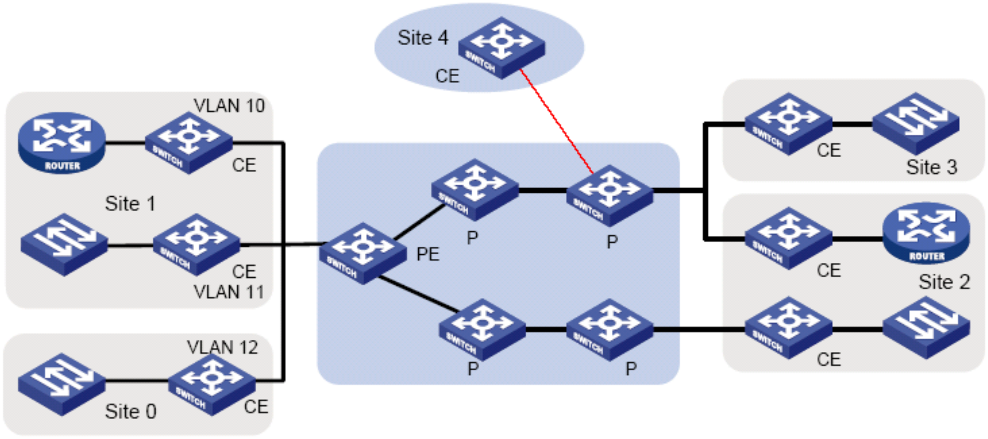
4.3 Kompella Mode

The Kompella mode is defined in draft-kompella-ppvpn-l2vpn. Interior Border Gateway Protocol (IBGP) sessions are established between PEs to detect L2VPN sites and transmit VPN information through extended BGP between PEs.

In label distribution, MPLS L2VPN in Kompella mode uses the label block method. The size of a label block is equal to the CE range (specified by the user), so multiple connections can be allocated labels at one time. This mode allows users to allocate extra labels to VPNs for reserved use and effectively simplifies VPN deployment and expansion. In Kompella mode, VPNs are identified by VPN targets, as a result of which VPN networking is highly flexible. Kompella mode is applicable to a variety of VPN network topologies.

In Kompella mode, VPNs are allocated on the entire service provider network, and CEs are numbered in each VPN. To establish a connection between two CEs, you only need to set the local and remote CE IDs on the PEs and to specify the VC ID allocated to the local CE.

Figure 4-3 L2VPN in Kompella mode



As shown in Figure 4-3, one VPN initially contains four sites (site0-site3) and a total of six CEs (CE0-CE5) are interconnected. To enable these six CEs to communicate with one another, it is necessary to establish a full-mesh topology structure between them. This means establishing a VC from each CE to each of the other five CEs. A local connection can also be established in the same as in CCC mode.

Moreover, you can reserve labels for future use. When new VPN sites need to be added, you only need to configure the PEs connected to the new sites. As shown in Figure 4-3, more than six labels are allocated to each CE on the PE, and the link to CE6 has been specified. When CE6 is added to Site4, you only need to add CE6 on PE2 and specify the links to other CEs.

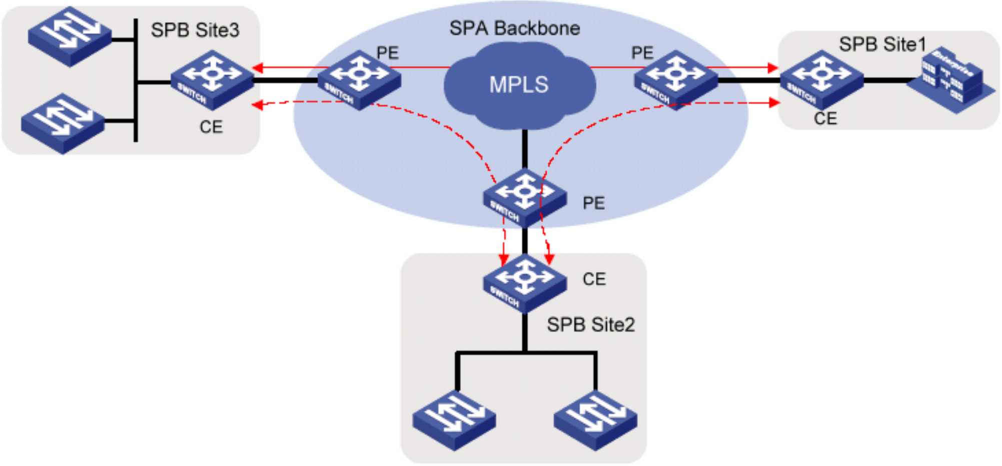
5 VLL Application

The Kompella mode applies to large enterprises with large sites, numerous routes, and simple access mode. These enterprises require site-to-site QoS and have strong network management capabilities. An enterprise that initially used leased lines or traditional VPN can smoothly transition over to MPLS L2VPN services. The carrier can provide L2 links with a strict QoS guarantee for the enterprise.

The Martini mode requires more complex configuration than the Kompella mode and is not suitable for large-scale networks. The Martini mode is flexible and applicable to the intranets of large enterprises or small carriers. This mode is oriented to LAN users and addresses the Ethernet difficulties with long-distance transmission. Many Ethernet switch vendors support this mode.

Figure 5-1 illustrates a typical application scenario. Carrier A has a nationwide backbone network while Carrier B has customer networks in multiple cities. Carrier B may hope to rent the bandwidth of Carrier A to interconnect its own networks in different places. Since Carrier B has sufficient network management and maintenance capabilities, it may adopt the VLL networking to prevent its private network routes from being released to other private networks.

Figure 5-1 Integrated networking diagram


SPB Site3
CE
SPA Backbone
PE
MPLS
PE
SPB Site1
CE
PE
CE
SPB Site2