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Introduction

This document provides MPLS Operation, Administration, and Maintenance (OAM) configuration examples.

MPLS OAM provides the following fault management tools for LSPs:

- MPLS data plane connectivity verification.
- MPLS data plane and control plane consistency verification.
- Failure detection and locating.

Prerequisites

The configuration examples in this document were created and verified in a lab environment, and all the devices were started with the factory default configuration. When you are working on a live network, make sure you understand the potential impact of every command on your network.

This document assumes that you have basic knowledge of MPLS OAM.

Example: Configuring BFD for an LSP

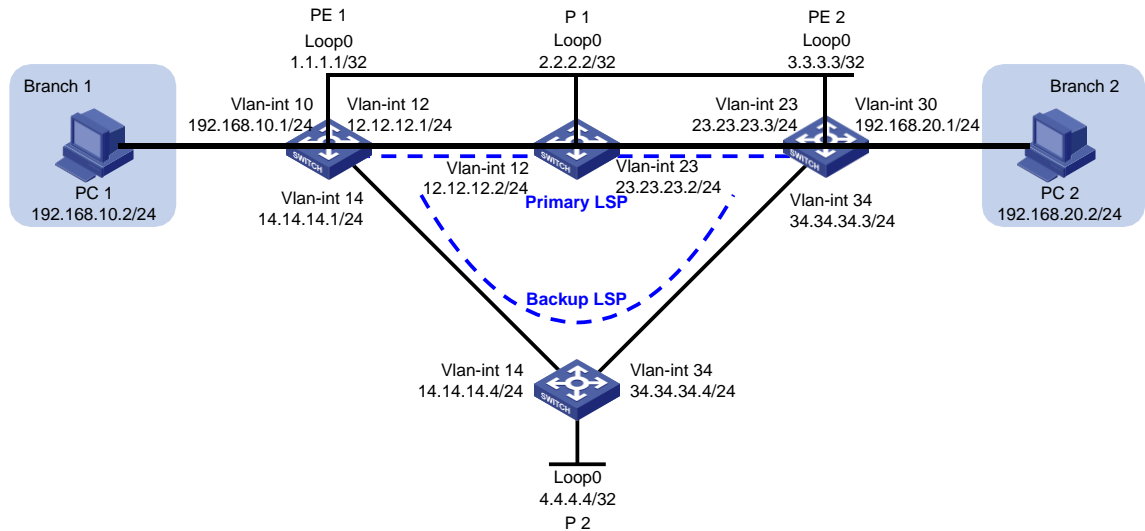
Network configuration

As shown in [Figure 1](#), a company has two branches that are connected to the MPLS backbone. It requires the MPLS backbone to establish LSPs for communication between the branches, and to provide high availability services for uninterrupted business between the branches.

To meet the requirements:

- Establish LSPs by using LDP.
- Configure OSPF FRR on the MPLS backbone so LDP can establish a primary LSP and a backup LSP.
- Configure BFD for the primary LSP. When the primary LSP fails, BFD can quickly detect the failure and notify LDP of the failure, so LDP can immediately switch traffic to the backup LSP.

Figure 1 Network diagram



Applicable hardware and software versions

The following matrix shows the hardware and software versions to which this configuration example is applicable:

Hardware	Software version
SC 5525 switch series	Release 65xx, Release 6615Pxx, Release 6628Pxx
SC 5520 switch series	Release 65xx, Release 6615Pxx, Release 6628Pxx

Restrictions and guidelines

Before configuration, disable the spanning tree feature globally or map each VLAN to an MSTI.

Procedures

1. Configure IP addresses for interfaces:

On PE 1, configure IP addresses and masks for interfaces, including the loopback interface, as shown in [Figure 1](#).

```
<PE1> system-view
[PE1] vlan 10
[PE1-vlan10] port gigabitethernet 1/0/3
[PE1-vlan10] quit
[PE1] interface vlan-interface 10
[PE1-Vlan-interface10] ip address 192.168.10.1 24
[PE1] vlan 12
[PE1-vlan12] port gigabitethernet 1/0/1
[PE1-vlan12] quit
[PE1] interface vlan-interface 12
[PE1-Vlan-interface12] ip address 12.12.12.1 24
[PE1-Vlan-interface12] quit
[PE1] vlan 14
[PE1-vlan14] port gigabitethernet 1/0/2
[PE1-vlan14] quit
[PE1] interface vlan-interface 14
[PE1-Vlan-interface14] ip address 14.14.14.1 24
[PE1-Vlan-interface14] quit
[PE1] interface loopback 0
[PE1-LoopBack0] ip address 1.1.1.1 32
[PE1-LoopBack0] quit
```

Configure other devices in the same way that PE 1 is configured. (Details not shown.)

2. Configure OSPF to ensure IP connectivity within the MPLS backbone, and enable OSPF FRR:

Configure PE 1.

```
[PE1] ospf
[PE1-ospf-1] area 0
[PE1-ospf-1-area-0.0.0.0] network 1.1.1.1 0.0.0.0
[PE1-ospf-1-area-0.0.0.0] network 12.12.12.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] network 14.14.14.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] network 192.168.10.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] quit
[PE1-ospf-1] fast-reroute lfa
[PE1-ospf-1] quit
```

Configure P 1.

```
[P1] ospf
[P1-ospf-1] area 0
[P1-ospf-1-area-0.0.0.0] network 2.2.2.2 0.0.0.0
[P1-ospf-1-area-0.0.0.0] network 12.12.12.0 0.0.0.255
```

```
[P1-ospf-1-area-0.0.0.0] network 23.23.23.0 0.0.0.255
[P1-ospf-1-area-0.0.0.0] quit
[P1-ospf-1] quit
```

Configure PE 2.

```
[PE2] ospf
[PE2-ospf-1] area 0
[PE2-ospf-1-area-0.0.0.0] network 3.3.3.3 0.0.0.0
[PE2-ospf-1-area-0.0.0.0] network 23.23.23.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] network 34.34.34.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] network 192.168.20.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] quit
[PE2-ospf-1] fast-reroute lfa
[PE2-ospf-1] quit
```

Configure P 2.

```
[P2] ospf
[P2-ospf-1] area 0
[P2-ospf-1-area-0.0.0.0] network 4.4.4.4 0.0.0.0
[P2-ospf-1-area-0.0.0.0] network 14.14.14.0 0.0.0.255
[P2-ospf-1-area-0.0.0.0] network 34.34.34.0 0.0.0.255
[P2-ospf-1-area-0.0.0.0] quit
[P2-ospf-1] quit
```

On P 2, set the OSPF cost to 10 for VLAN-interface 14 and VLAN-interface 34. This setting ensures that the backup LSP has a larger OSPF cost than the primary LSP.

```
[P2] interface vlan-interface 14
[P2-Vlan-interface14] ospf cost 10
[P2-Vlan-interface14] quit
[P2] interface vlan-interface 34
[P2-Vlan-interface34] ospf cost 10
[P2-Vlan-interface34] quit
```

3. Configure basic MPLS and MPLS LDP:

Configure PE 1.

```
[PE1] mpls lsr-id 1.1.1.1
[PE1] mpls ldp
[PE1-ldp] quit
[PE1] interface vlan-interface 12
[PE1-Vlan-interface12] mpls enable
[PE1-Vlan-interface12] mpls ldp enable
[PE1-Vlan-interface12] quit
[PE1] interface vlan-interface 14
[PE1-Vlan-interface14] mpls enable
[PE1-Vlan-interface14] mpls ldp enable
[PE1-Vlan-interface14] quit
```

Configure P 1.

```
[P1] mpls lsr-id 2.2.2.2
[P1] mpls ldp
[P1-ldp] quit
[P1] interface vlan-interface 12
[P1-Vlan-interface12] mpls enable
```

```
[P1-Vlan-interface12] mpls ldp enable
[P1-Vlan-interface12] quit
[P1] interface vlan-interface 23
[P1-Vlan-interface23] mpls enable
[P1-Vlan-interface23] mpls ldp enable
[P1-Vlan-interface23] quit
```

Configure PE 2.

```
[PE2] mpls lsr-id 3.3.3.3
[PE2] mpls ldp
[PE2-ldp] quit
[PE2] interface vlan-interface 23
[PE2-Vlan-interface23] mpls enable
[PE2-Vlan-interface23] mpls ldp enable
[PE2-Vlan-interface23] quit
[PE2] interface vlan-interface 34
[PE2-Vlan-interface34] mpls enable
[PE2-Vlan-interface34] mpls ldp enable
[PE2-Vlan-interface34] quit
```

Configure P 2.

```
[P2] mpls lsr-id 4.4.4.4
[P2] mpls ldp
[P2-ldp] quit
[P2] interface vlan-interface 14
[P2-Vlan-interface14] mpls enable
[P2-Vlan-interface14] mpls ldp enable
[P2-Vlan-interface14] quit
[P2] interface vlan-interface 34
[P2-Vlan-interface34] mpls enable
[P2-Vlan-interface34] mpls ldp enable
[P2-Vlan-interface34] quit
```

Verify that LDP sessions in **Operational** state have been established on each device. The following shows the output on PE 1.

```
[PE1] display mpls ldp peer
```

Total number of peers: 2

Peer	LDP ID	State	Role	GR	MD5	KA Sent/Rcvd
2.2.2.2:0		Operational	Passive	Off	Off	55/55
4.4.4.4:0		Operational	Passive	Off	Off	6/6

4. Configure LSP generation policies to establish LSPs to destinations 192.168.10.0/24, 192.168.20.0/24, 1.1.1.1/32, and 3.3.3.3/32:

On PE 1, create IP prefix list PE1, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[PE1] ip prefix-list PE1 index 10 permit 192.168.10.0 24
[PE1] ip prefix-list PE1 index 20 permit 192.168.20.0 24
[PE1] ip prefix-list PE1 index 30 permit 1.1.1.1 32
[PE1] ip prefix-list PE1 index 40 permit 3.3.3.3 32
[PE1] mpls ldp
[PE1-ldp] lsp-trigger prefix-list PE1
[PE1-ldp] quit
```

On P 1, create IP prefix list P1, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[P1] ip prefix-list P1 index 10 permit 192.168.10.0 24
[P1] ip prefix-list P1 index 20 permit 192.168.20.0 24
[P1] ip prefix-list P1 index 30 permit 1.1.1.1 32
[P1] ip prefix-list P1 index 40 permit 3.3.3.3 32
[P1] mpls ldp
[P1-ldp] lsp-trigger prefix-list P1
[P1-ldp] quit
```

On PE 2, create IP prefix list PE2, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[PE2] ip prefix-list PE2 index 10 permit 192.168.10.0 24
[PE2] ip prefix-list PE2 index 20 permit 192.168.20.0 24
[PE2] ip prefix-list PE2 index 30 permit 1.1.1.1 32
[PE2] ip prefix-list PE2 index 40 permit 3.3.3.3 32
[PE2] mpls ldp
[PE2-ldp] lsp-trigger prefix-list PE2
[PE2-ldp] quit
```

On P 2, create IP prefix list P2, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[P2] ip prefix-list P2 index 10 permit 192.168.10.0 24
[P2] ip prefix-list P2 index 20 permit 192.168.20.0 24
[P2] ip prefix-list P2 index 30 permit 1.1.1.1 32
[P2] ip prefix-list P2 index 40 permit 3.3.3.3 32
[P2] mpls ldp
[P2-ldp] lsp-trigger prefix-list P2
[P2-ldp] quit
```

Verify that LSPs to destination 192.168.20.0/24 have been established on PE 1. The primary LSP uses VLAN-interface 12 as the outgoing interface and the backup LSP uses VLAN-interface 14 as the outgoing interface.

```
[PE1]display mpls ldp lsp
```

Status Flags: * - stale, L - liberal, B - backup

Statistics:

FECs: 4	Ingress LSPs: 4	Transit LSPs: 4	Egress LSPs: 2
---------	-----------------	-----------------	----------------

FEC	In/Out Label	Nexthop	OutInterface
1.1.1.1/32	3/-		
	-/1151 (L)		
	-/1279 (L)		
3.3.3.3/32	-/1150	12.12.12.2	Vlan12
	1150/1150	12.12.12.2	Vlan12
	-/1150 (B)	12.12.12.2	Vlan14
	1150/1150 (B)	12.12.12.2	Vlan14
192.168.10.0/24	1141/-		
	-/1141 (L)		
	-/1141 (L)		
192.168.20.0/24	-/1133	12.12.12.2	Vlan12
	1133/1133	12.12.12.2	Vlan12
	-/1133 (B)	14.14.14.4	Vlan14

5. Enable BFD for MPLS and use BFD to verify LSP connectivity:

Configure PE 1.

```
[PE1] mpls bfd enable
[PE1] mpls bfd 3.3.3.3 32
```

Configure PE 2.

```
[PE2] mpls bfd enable
[PE2] mpls bfd 1.1.1.1 32
```

Verifying the configuration

1. Display BFD information for LSPs on PE 1 and PE 2. The following shows the output on PE 1.

```
[PE1] display mpls bfd
Total number of sessions: 2, 2 up, 0 down, 0 init

FEC Type: LSP
FEC Info:
  Destination: 1.1.1.1
  Mask Length: 32
NHLFE ID: -
Local Discr: 1026                      Remote Discr: 514
Source IP: 1.1.1.1                    Destination IP: 3.3.3.3
Session State: Up                     Session Role: Active
Template Name: -

FEC Type: LSP
FEC Info:
  Destination: 3.3.3.3
  Mask Length: 32
NHLFE ID: 1028
Local Discr: 1025                      Remote Discr: -
Source IP: 1.1.1.1                    Destination IP: 127.0.0.1
Session State: Up                     Session Role: Passive
Template Name: -
```

2. Execute the **tracert mpls ipv4** command on PE 1. The output shows that the primary LSP is in use.

NOTE:

Before you use the **tracert** feature, enable sending ICMP time exceeded messages on intermediate devices, and enable sending ICMP destination unreachable messages on the destination device.

```
[PE1] tracert mpls -a 192.168.10.1 ipv4 192.168.20.0 24
MPLS trace route FEC 192.168.20.0/24
```

TTL	Replier	Time	Type	Downstream
0			Ingress	12.12.12.2/[1148]
1	12.12.12.2	2 ms	Transit	23.23.23.3/[1148]
2	23.23.23.3	2 ms	Egress	

3. Verify that the ping operation from PE 1 to PE 2 will not fail after VLAN-interface 23 on P 1 is shut down during the ping operation:

Ping PE 2 from PE 1.

```
[PE1] ping -c 100000 -a 192.168.10.1 192.168.20.1
Ping 192.168.20.1 (192.168.20.1) from 192.168.10.1: 56 data bytes, press CTRL_C
to break
56 bytes from 192.168.20.1: icmp_seq=0 ttl=254 time=2.576 ms
56 bytes from 192.168.20.1: icmp_seq=1 ttl=254 time=1.996 ms
...
```

Shut down VLAN-interface 23 on P 1.

```
[P1] interface vlan-interface 23
[P1-Vlan-interface23] shutdown
```

View the **ping** command output. The output shows that the communication was interrupted, and then immediately resumed.

```
[PE1] ping -c 100000 -a 192.168.10.1 192.168.20.1
Ping 192.168.20.1 (192.168.20.1) from 192.168.10.1: 56 data bytes, press CTRL_C
to break
56 bytes from 192.168.20.1: icmp_seq=0 ttl=254 time=2.576 ms
56 bytes from 192.168.20.1: icmp_seq=1 ttl=254 time=1.996 ms
...
56 bytes from 192.168.20.1: icmp_seq=7 ttl=254 time=2.214 ms
Request time out
56 bytes from 192.168.20.1: icmp_seq=9 ttl=254 time=2.659 ms
56 bytes from 192.168.20.1: icmp_seq=10 ttl=254 time=5.049 ms
56 bytes from 192.168.20.1: icmp_seq=11 ttl=254 time=2.098 ms
56 bytes from 192.168.20.1: icmp_seq=12 ttl=254 time=2.225 ms
56 bytes from 192.168.20.1: icmp_seq=13 ttl=254 time=2.187 ms

--- Ping statistics for 192.168.20.1 ---
14 packet(s) transmitted, 13 packet(s) received, 7.1% packet loss
round-trip min/avg/max/std-dev = 1.990/2.455/5.049/0.772 ms
```

4. Execute the **tracert mpls ipv4** command on PE 1. The output shows that the backup LSP is in use.

```
[PE1] tracert mpls -a 192.168.10.1 ipv4 192.168.20.0 24
MPLS trace route FEC 192.168.20.0/24
```

TTL	Replier	Time	Type	Downstream
0			Ingress	14.14.14.4/[1276]
1	14.14.14.4	2 ms	Transit	34.34.34.3/[1148]
2	34.34.34.3	2 ms	Egress	

Configuration files

- PE 1:

```
#
ospf 1
 fast-reroute lfa
 area 0.0.0.0
 network 1.1.1.1 0.0.0.0
```

```

network 12.12.12.0 0.0.0.255
network 14.14.14.0 0.0.0.255
network 192.168.10.0 0.0.0.255
#
mpls lsr-id 1.1.1.1
#
vlan 10
#
vlan 12
#
vlan 14
#
mpls ldp
lsp-trigger prefix-list PE1
#
mpls bfd enable
#
interface LoopBack0
ip address 1.1.1.1 255.255.255.255
#
interface Vlan-interface10
ip address 192.168.10.1 255.255.255.0
#
interface Vlan-interface12
ip address 12.12.12.1 255.255.255.0
mpls enable
mpls ldp enable
#
interface Vlan-interface14
ip address 14.14.14.1 255.255.255.0
mpls enable
mpls ldp enable
#
interface GigabitEthernet1/0/1
port link-mode bridge
port access vlan 12
#
interface GigabitEthernet1/0/2
port link-mode bridge
port access vlan 14
#
interface GigabitEthernet1/0/3
port link-mode bridge
port access vlan 10
#
ip prefix-list PE1 index 10 permit 192.168.10.0 24
ip prefix-list PE1 index 20 permit 192.168.20.0 24
ip prefix-list PE1 index 30 permit 1.1.1.1 32

```

```

    ip prefix-list PE1 index 40 permit 3.3.3.3 32
#
    mpls bfd 3.3.3.3 32
#
• PE 2:
#
ospf 1
    fast-reroute lfa
    area 0.0.0.0
        network 3.3.3.3 0.0.0.0
        network 23.23.23.0 0.0.0.255
        network 34.34.34.0 0.0.0.255
        network 192.168.20.0 0.0.0.255
#
vlan 23
#
vlan 30
#
vlan 34
#
    mpls lsr-id 3.3.3.3
#
mpls ldp
    lsp-trigger prefix-list PE2
#
    mpls bfd enable
#
interface LoopBack0
    ip address 3.3.3.3 255.255.255.255
#
interface Vlan-interface23
    ip address 23.23.23.3 255.255.255.0
    mpls enable
    mpls ldp enable
#
interface Vlan-interface30
    ip address 192.168.20.1 255.255.255.0
#
interface Vlan-interface34
    ip address 34.34.34.3 255.255.255.0
    mpls enable
    mpls ldp enable
#
interface GigabitEthernet1/0/1
    port link-mode bridge
    port access vlan 34
#
interface GigabitEthernet1/0/2

```

```

port link-mode bridge
port access vlan 23
#
interface GigabitEthernet1/0/3
port link-mode bridge
port access vlan 30
#
ip prefix-list PE2 index 10 permit 192.168.10.0 24
ip prefix-list PE2 index 20 permit 192.168.20.0 24
ip prefix-list PE2 index 30 permit 1.1.1.1 32
ip prefix-list PE2 index 40 permit 3.3.3.3 32
#
mpls bfd 1.1.1.1 32
#
• P1:
#
ospf 1
area 0.0.0.0
network 2.2.2.2 0.0.0.0
network 12.12.12.0 0.0.0.255
network 23.23.23.0 0.0.0.255
#
mpls lsr-id 2.2.2.2
#
vlan 12
#
vlan 23
#
mpls ldp
lsp-trigger prefix-list P1
#
interface LoopBack0
ip address 2.2.2.2 255.255.255.255
#
interface Vlan-interface12
ip address 12.12.12.2 255.255.255.0
mpls enable
mpls ldp enable
#
interface Vlan-interface23
ip address 23.23.23.2 255.255.255.0
mpls enable
mpls ldp enable
#
interface GigabitEthernet1/0/1
port link-mode bridge
port access vlan 12
#

```

```

interface GigabitEthernet1/0/2
  port link-mode bridge
  port access vlan 23
#
  ip prefix-list P1 index 10 permit 192.168.10.0 24
  ip prefix-list P1 index 20 permit 192.168.20.0 24
  ip prefix-list P1 index 30 permit 1.1.1.1 32
  ip prefix-list P1 index 40 permit 3.3.3.3 32
#

```

- **P2:**

```

#
ospf 1
  area 0.0.0.0
    network 4.4.4.4 0.0.0.0
    network 14.14.14.0 0.0.0.255
    network 34.34.34.0 0.0.0.255
#
  mpls lsr-id 4.4.4.4
#
vlan 14
#
vlan 34
#
mpls ldp
  lsp-trigger prefix-list P2
#
interface LoopBack0
  ip address 4.4.4.4 255.255.255.255
#
interface Vlan-interface14
  ip address 14.14.14.4 255.255.255.0
  ospf cost 10
  mpls enable
  mpls ldp enable
#
interface Vlan-interface34
  ip address 34.34.34.4 255.255.255.0
  ospf cost 10
  mpls enable
  mpls ldp enable
#
interface GigabitEthernet1/0/1
  port link-mode bridge
  port access vlan 34
#
interface GigabitEthernet1/0/2
  port link-mode bridge
  port access vlan 14

```

```
#
ip prefix-list P2 index 10 permit 192.168.10.0 24
ip prefix-list P2 index 20 permit 192.168.20.0 24
ip prefix-list P2 index 30 permit 1.1.1.1 32
ip prefix-list P2 index 40 permit 3.3.3.3 32
#
```

Example: Configuring SBFD for an LSP

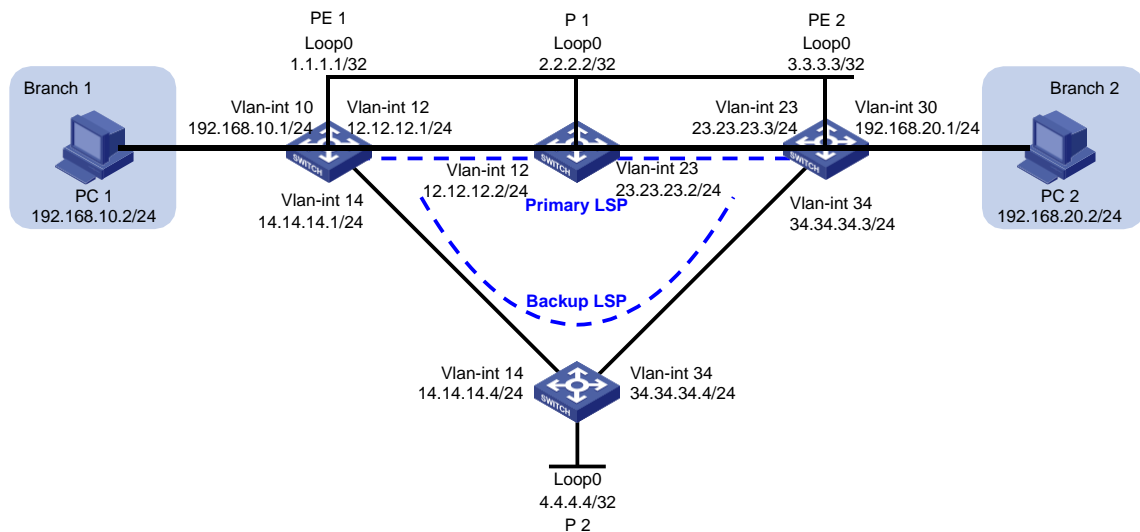
Network configuration

As shown in [Figure 2](#), a company has two branches that are connected to the MPLS backbone. It requires the MPLS backbone to establish LSPs for communication between the branches, and to provide high availability services for uninterrupted business between the branches.

To meet the requirements:

- Establish LSPs by using LDP.
- Configure OSPF FRR on the MPLS backbone so LDP can establish a primary LSP and a backup LSP.
- Configure SBFD for the primary LSP. When the primary LSP fails, SBFD can quickly detect the failure and notify LDP of the failure, so LDP can immediately switch traffic to the backup LSP.

Figure 2 Network diagram



Applicable hardware and software versions

The following matrix shows the hardware and software versions to which this configuration example is applicable:

Hardware	Software version
SC 5525 switch series	Release 65xx, Release 6615Pxx, Release 6628Pxx
SC 5520 switch series	Release 65xx, Release 6615Pxx, Release 6628Pxx

Restrictions and guidelines

Before configuration, disable the spanning tree feature globally or map each VLAN to an MSTI.

Procedures

1. Configure IP addresses for interfaces:

On PE 1, configure IP addresses and masks for interfaces, including the loopback interface, as shown in [Figure 2](#).

```
<PE1> system-view
[PE1] vlan 10
[PE1-vlan10] port gigabitethernet 1/0/3
[PE1-vlan10] quit
[PE1] interface vlan-interface 10
[PE1-Vlan-interface10] ip address 192.168.10.1 24
[PE1] vlan 12
[PE1-vlan12] port gigabitethernet 1/0/1
[PE1-vlan12] quit
[PE1] interface vlan-interface 12
[PE1-Vlan-interface12] ip address 12.12.12.1 24
[PE1-Vlan-interface12] quit
[PE1] vlan 14
[PE1-vlan14] port gigabitethernet 1/0/2
[PE1-vlan14] quit
[PE1] interface vlan-interface 14
[PE1-Vlan-interface14] ip address 14.14.14.1 24
[PE1-Vlan-interface14] quit
```

```
[PE1] interface loopback 0
[PE1-LoopBack0] ip address 1.1.1.1 32
[PE1-LoopBack0] quit
```

2. Configure OSPF to ensure IP connectivity within the MPLS backbone, and enable OSPF FRR:

Configure PE 1.

```
[PE1] ospf
[PE1-ospf-1] area 0
[PE1-ospf-1-area-0.0.0.0] network 1.1.1.1 0.0.0.0
[PE1-ospf-1-area-0.0.0.0] network 12.12.12.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] network 14.14.14.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] network 192.168.10.0 0.0.0.255
[PE1-ospf-1-area-0.0.0.0] quit
[PE1-ospf-1] fast-reroute lfa
[PE1-ospf-1] quit
```

Configure P 1.

```
[P1] ospf
[P1-ospf-1] area 0
[P1-ospf-1-area-0.0.0.0] network 2.2.2.2 0.0.0.0
[P1-ospf-1-area-0.0.0.0] network 12.12.12.0 0.0.0.255
[P1-ospf-1-area-0.0.0.0] network 23.23.23.0 0.0.0.255
[P1-ospf-1-area-0.0.0.0] quit
[P1-ospf-1] quit
```

Configure PE 2.

```
[PE2] ospf
[PE2-ospf-1] area 0
[PE2-ospf-1-area-0.0.0.0] network 3.3.3.3 0.0.0.0
[PE2-ospf-1-area-0.0.0.0] network 23.23.23.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] network 34.34.34.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] network 192.168.20.0 0.0.0.255
[PE2-ospf-1-area-0.0.0.0] quit
[PE2-ospf-1] fast-reroute lfa
[PE2-ospf-1] quit
```

Configure P 2.

```
[P2] ospf
[P2-ospf-1] area 0
[P2-ospf-1-area-0.0.0.0] network 4.4.4.4 0.0.0.0
[P2-ospf-1-area-0.0.0.0] network 14.14.14.0 0.0.0.255
[P2-ospf-1-area-0.0.0.0] network 34.34.34.0 0.0.0.255
[P2-ospf-1-area-0.0.0.0] quit
[P2-ospf-1] quit
```

On P 2, set the OSPF cost to 10 for VLAN-interface 14 and VLAN-interface 34. This setting ensures that the backup LSP has a larger OSPF cost than the primary LSP.

```
[P2] interface vlan-interface 14
[P2-Vlan-interface14] ospf cost 10
[P2-Vlan-interface14] quit
[P2] interface vlan-interface 34
[P2-Vlan-interface34] ospf cost 10
[P2-Vlan-interface34] quit
```


3. Configure basic MPLS and MPLS LDP:

Configure PE 1.

```
[PE1] mpls lsr-id 1.1.1.1
[PE1] mpls ldp
[PE1-ldp] quit
[PE1] interface vlan-interface 12
[PE1-Vlan-interface12] mpls enable
[PE1-Vlan-interface12] mpls ldp enable
[PE1-Vlan-interface12] quit
[PE1] interface vlan-interface 14
[PE1-Vlan-interface14] mpls enable
[PE1-Vlan-interface14] mpls ldp enable
[PE1-Vlan-interface14] quit
```

Configure P 1.

```
[P1] mpls lsr-id 2.2.2.2
[P1] mpls ldp
[P1-ldp] quit
[P1] interface vlan-interface 12
[P1-Vlan-interface12] mpls enable
[P1-Vlan-interface12] mpls ldp enable
[P1-Vlan-interface12] quit
[P1] interface vlan-interface 23
[P1-Vlan-interface23] mpls enable
[P1-Vlan-interface23] mpls ldp enable
[P1-Vlan-interface23] quit
```

Configure PE 2.

```
[PE2] mpls lsr-id 3.3.3.3
[PE2] mpls ldp
[PE2-ldp] quit
[PE2] interface vlan-interface 23
[PE2-Vlan-interface23] mpls enable
[PE2-Vlan-interface23] mpls ldp enable
[PE2-Vlan-interface23] quit
[PE2] interface vlan-interface 34
[PE2-Vlan-interface34] mpls enable
[PE2-Vlan-interface34] mpls ldp enable
[PE2-Vlan-interface34] quit
```

Configure P 2.

```
[P2] mpls lsr-id 4.4.4.4
[P2] mpls ldp
[P2-ldp] quit
[P2] interface vlan-interface 14
[P2-Vlan-interface14] mpls enable
[P2-Vlan-interface14] mpls ldp enable
[P2-Vlan-interface14] quit
[P2] interface vlan-interface 34
[P2-Vlan-interface34] mpls enable
[P2-Vlan-interface34] mpls ldp enable
```

```
[P2-Vlan-interface34] quit
```

Verify that LDP sessions in **Operational** state have been established on each device. The following shows the output on PE 1.

```
[PE1] display mpls ldp peer
```

Total number of peers: 2

Peer LDP ID	State	Role	GR	MD5	KA Sent/Rcvd
2.2.2.2:0	Operational	Passive	Off	Off	55/55
4.4.4.4:0	Operational	Passive	Off	Off	6/6

4. Configure LSP generation policies to establish LSPs to destinations 192.168.10.0/24, 192.168.20.0/24, 1.1.1.1/32, and 3.3.3.3/32:

On PE 1, create IP prefix list PE1, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[PE1] ip prefix-list PE1 index 10 permit 192.168.10.0 24
[PE1] ip prefix-list PE1 index 20 permit 192.168.20.0 24
[PE1] ip prefix-list PE1 index 30 permit 1.1.1.1 32
[PE1] ip prefix-list PE1 index 40 permit 3.3.3.3 32
[PE1] mpls ldp
[PE1-ldp] lsp-trigger prefix-list PE1
[PE1-ldp] quit
```

On P 1, create IP prefix list P1, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[P1] ip prefix-list P1 index 10 permit 192.168.10.0 24
[P1] ip prefix-list P1 index 20 permit 192.168.20.0 24
[P1] ip prefix-list P1 index 30 permit 1.1.1.1 32
[P1] ip prefix-list P1 index 40 permit 3.3.3.3 32
[P1] mpls ldp
[P1-ldp] lsp-trigger prefix-list P1
[P1-ldp] quit
```

On PE 2, create IP prefix list PE2, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[PE2] ip prefix-list PE2 index 10 permit 192.168.10.0 24
[PE2] ip prefix-list PE2 index 20 permit 192.168.20.0 24
[PE2] ip prefix-list PE2 index 30 permit 1.1.1.1 32
[PE2] ip prefix-list PE2 index 40 permit 3.3.3.3 32
[PE2] mpls ldp
[PE2-ldp] lsp-trigger prefix-list PE2
[PE2-ldp] quit
```

On P 2, create IP prefix list P2, and configure LDP to use only the routes permitted by the prefix list to establish LSPs.

```
[P2] ip prefix-list P2 index 10 permit 192.168.10.0 24
[P2] ip prefix-list P2 index 20 permit 192.168.20.0 24
[P2] ip prefix-list P2 index 30 permit 1.1.1.1 32
[P2] ip prefix-list P2 index 40 permit 3.3.3.3 32
[P2] mpls ldp
[P2-ldp] lsp-trigger prefix-list P2
[P2-ldp] quit
```

Verify that LSPs to destination 192.168.20.0/24 have been established on PE 1. The primary LSP uses VLAN-interface 12 as the outgoing interface and the backup LSP uses VLAN-interface 14 as the outgoing interface.

```
[PE1]display mpls ldp lsp
Status Flags: * - stale, L - liberal, B - backup
Statistics:
    FECs: 4          Ingress LSPs: 4          Transit LSPs: 4          Egress LSPs: 2
```

FEC	In/Out Label	Nexthop	OutInterface
1.1.1.1/32	3/-		
	-/1151 (L)		
	-/1279 (L)		
3.3.3.3/32	-/1150	12.12.12.2	Vlan12
	1150/1150	12.12.12.2	Vlan12
	-/1150 (B)	12.12.12.2	Vlan14
	1150/1150 (B)	12.12.12.2	Vlan14
192.168.10.0/24	1141/-		
	-/1141 (L)		
	-/1141 (L)		
192.168.20.0/24	-/1133	12.12.12.2	Vlan12
	1133/1133	12.12.12.2	Vlan12
	-/1133 (B)	14.14.14.4	Vlan14
	1133/1133 (B)	14.14.14.4	Vlan14

5. Enable BFD for MPLS and use SBFd to verify LSP connectivity:

Configure PE 1.

```
[PE1] mpls bfd enable
[PE1] sbfd local-discriminator 3000000
[PE1] mpls sbfd 3.3.3.3 32 remote 2000000
```

Configure PE 2.

```
[PE2] mpls bfd enable
[PE2] sbfd local-discriminator 2000000
[PE2] mpls sbfd 1.1.1.1 32 remote 3000000
```

Verifying the configuration

1. Display SBFd information for LSPs on PE 1 and PE 2. The following shows the output on PE 1.

```
[PE1] display mpls sbfd
Total number of sessions: 1, 1 up, 0 down, 0 init

FEC Type: LSP
FEC Info:
    Destination: 3.3.3.3
    Mask Length: 32
NHLFE ID: 2
Local Discr: 513                      Remote Discr: 2000000
Source IP: 1.1.1.1                    Destination IP: 127.0.0.1
Session State: Up
Template Name: -
```

2. Execute the `tracert mpls ipv4` command on PE 1. The output shows that the primary LSP is in use.

NOTE:

Before you use the `tracert` feature, enable sending ICMP time exceeded messages on intermediate devices, and enable sending ICMP destination unreachable messages on the destination device.

```
[PE1] tracert mpls -a 192.168.10.1 ipv4 192.168.20.0 24
```

```
MPLS trace route FEC 192.168.20.0/24
```

TTL	Replier	Time	Type	Downstream
0			Ingress	12.12.12.2/[1148]
1	12.12.12.2	2 ms	Transit	23.23.23.3/[1148]
2	23.23.23.3	2 ms	Egress	

3. Verify that the ping operation from PE 1 to PE 2 will not fail after VLAN-interface 23 on P 1 is shut down during the ping operation:

Ping PE 2 from PE 1.

```
[PE1] ping -c 100000 -a 192.168.10.1 192.168.20.1
```

```
Ping 192.168.20.1 (192.168.20.1) from 192.168.10.1: 56 data bytes, press CTRL_C to break
```

```
56 bytes from 192.168.20.1: icmp_seq=0 ttl=254 time=2.576 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=1 ttl=254 time=1.996 ms
```

```
...
```

Shut down VLAN-interface 23 on P 1.

```
[P1] interface vlan-interface 23
```

```
[P1-Vlan-interface23] shutdown
```

View the `ping` command output. The output shows that the communication was interrupted, and then immediately resumed.

```
[PE1] ping -c 100000 -a 192.168.10.1 192.168.20.1
```

```
Ping 192.168.20.1 (192.168.20.1) from 192.168.10.1: 56 data bytes, press CTRL_C to break
```

```
56 bytes from 192.168.20.1: icmp_seq=0 ttl=254 time=2.576 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=1 ttl=254 time=1.996 ms
```

```
...
```

```
56 bytes from 192.168.20.1: icmp_seq=7 ttl=254 time=2.214 ms
```

```
Request time out
```

```
56 bytes from 192.168.20.1: icmp_seq=9 ttl=254 time=2.659 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=10 ttl=254 time=5.049 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=11 ttl=254 time=2.098 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=12 ttl=254 time=2.225 ms
```

```
56 bytes from 192.168.20.1: icmp_seq=13 ttl=254 time=2.187 ms
```

```
--- Ping statistics for 192.168.20.1 ---
```

```
14 packet(s) transmitted, 13 packet(s) received, 7.1% packet loss
```

```
round-trip min/avg/max/std-dev = 1.990/2.455/5.049/0.772 ms
```

4. Execute the `tracert mpls ipv4` command on PE 1. The output shows that the backup LSP is in use.

```
[PE1] tracert mpls -a 192.168.10.1 ipv4 192.168.20.0 24
```

```
MPLS trace route FEC 192.168.20.0/24
```

TTL	Replier	Time	Type	Downstream
0			Ingress	14.14.14.4/[1276]
1	14.14.14.4	2 ms	Transit	34.34.34.3/[1148]

Configuration files

- PE 1:

```
#
ospf 1
 fast-reroute lfa
 area 0.0.0.0
  network 1.1.1.1 0.0.0.0
  network 12.12.12.0 0.0.0.255
  network 14.14.14.0 0.0.0.255
  network 192.168.10.0 0.0.0.255
#
mpls lsr-id 1.1.1.1
#
vlan 10
#
vlan 12
#
vlan 14
#
mpls ldp
 lsp-trigger prefix-list PE1
#
mpls bfd enable
#
interface LoopBack0
 ip address 1.1.1.1 255.255.255.255
#
interface Vlan-interface10
 ip address 192.168.10.1 255.255.255.0
#
interface Vlan-interface12
 ip address 12.12.12.1 255.255.255.0
 mpls enable
 mpls ldp enable
#
interface Vlan-interface14
 ip address 14.14.14.1 255.255.255.0
 mpls enable
 mpls ldp enable
#
interface GigabitEthernet1/0/1
 port link-mode bridge
 port access vlan 12
#
interface GigabitEthernet1/0/2
```

```

port link-mode bridge
port access vlan 14
#
interface GigabitEthernet1/0/3
port link-mode bridge
port access vlan 10
#
ip prefix-list PE1 index 10 permit 192.168.10.0 24
ip prefix-list PE1 index 20 permit 192.168.20.0 24
ip prefix-list PE1 index 30 permit 1.1.1.1 32
ip prefix-list PE1 index 40 permit 3.3.3.3 32
#
mpls sbfd 3.3.3.3 32 remote 2000000
#

```

- **PE 2:**

```

#
ospf 1
fast-reroute lfa
area 0.0.0.0
network 3.3.3.3 0.0.0.0
network 23.23.23.0 0.0.0.255
network 34.34.34.0 0.0.0.255
network 192.168.20.0 0.0.0.255
#
vlan 23
#
vlan 30
#
vlan 34
#
sbfd local-discriminator 2000000
#
mpls lsr-id 3.3.3.3
#
mpls ldp
lsp-trigger prefix-list PE2
#
mpls bfd enable
#
interface LoopBack0
ip address 3.3.3.3 255.255.255.255
#
interface Vlan-interface23
ip address 23.23.23.3 255.255.255.0
mpls enable
mpls ldp enable
#
interface Vlan-interface30

```

```

ip address 192.168.20.1 255.255.255.0
#
interface Vlan-interface34
ip address 34.34.34.3 255.255.255.0
mpls enable
mpls ldp enable
#
interface GigabitEthernet1/0/1
port link-mode bridge
port access vlan 34
#
interface GigabitEthernet1/0/2
port link-mode bridge
port access vlan 23
#
interface GigabitEthernet1/0/3
port link-mode bridge
port access vlan 30
#
ip prefix-list PE2 index 10 permit 192.168.10.0 24
ip prefix-list PE2 index 20 permit 192.168.20.0 24
ip prefix-list PE2 index 30 permit 1.1.1.1 32
ip prefix-list PE2 index 40 permit 3.3.3.3 32
#
mpls bfd 1.1.1.1 32
#

```

- **P1:**

```

#
ospf 1
area 0.0.0.0
network 2.2.2.2 0.0.0.0
network 12.12.12.0 0.0.0.255
network 23.23.23.0 0.0.0.255
#
mpls lsr-id 2.2.2.2
#
vlan 12
#
vlan 23
#
mpls ldp
lsp-trigger prefix-list P1
#
interface LoopBack0
ip address 2.2.2.2 255.255.255.255
#
interface Vlan-interface12
ip address 12.12.12.2 255.255.255.0

```

```

mpls enable
mpls ldp enable
#
interface Vlan-interface23
ip address 23.23.23.2 255.255.255.0
mpls enable
mpls ldp enable
#
interface GigabitEthernet1/0/1
port link-mode bridge
port access vlan 12
#
interface GigabitEthernet1/0/2
port link-mode bridge
port access vlan 23
#
ip prefix-list P1 index 10 permit 192.168.10.0 24
ip prefix-list P1 index 20 permit 192.168.20.0 24
ip prefix-list P1 index 30 permit 1.1.1.1 32
ip prefix-list P1 index 40 permit 3.3.3.3 32
#

```

- **P2:**

```

#
ospf 1
area 0.0.0.0
network 4.4.4.4 0.0.0.0
network 14.14.14.0 0.0.0.255
network 34.34.34.0 0.0.0.255
#
mpls lsr-id 4.4.4.4
#
vlan 14
#
vlan 34
#
mpls ldp
lsp-trigger prefix-list P2
#
interface LoopBack0
ip address 4.4.4.4 255.255.255.255
#
interface Vlan-interface14
ip address 14.14.14.4 255.255.255.0
ospf cost 10
mpls enable
mpls ldp enable
#
interface Vlan-interface34

```



```
ip address 34.34.34.4 255.255.255.0
ospf cost 10
mpls enable
mpls ldp enable
#
interface GigabitEthernet1/0/1
port link-mode bridge
port access vlan 34
#
interface GigabitEthernet1/0/2
port link-mode bridge
port access vlan 14
#
ip prefix-list P2 index 10 permit 192.168.10.0 24
ip prefix-list P2 index 20 permit 192.168.20.0 24
ip prefix-list P2 index 30 permit 1.1.1.1 32
ip prefix-list P2 index 40 permit 3.3.3.3 32
#
```