

implemented by enterprises themselves to provide clear partition between units or services.

- (c) MPLS L3VPNs allow an enterprise to simplify their WAN routing. Customer Edge (CE) routers need only peer with one or more Provider Edge (PE) routers rather than with all the other CE routers in the VPN.
- (d) MPLS L3VPNs allow any-to-any connectivity for enterprise customer sites, and can be configured to support quality-of-service (QoS) for real-time and business applications.
- (e) MPLS traffic engineering (associated technology) allows service providers to optimally utilize network bandwidth, and support tight service-level agreements (SLA) with fast failover (fast reroute) and guaranteed bandwidth.

4. Disadvantages of MPLS L3VPNs

Disadvantages of MPLS L3VPNs include the following [1]:

- (a) MPLS L3VPNs natively support IP traffic transport only. If customers want to support other protocols such as IPX, Generic Routing Encapsulation (GRE) tunnels must be configured between CE routers.
- (b) Some service providers do not support native IP multicast traffic transport between sites in MPLS L3VPNs. If a service provider does not offer native IP multicast transport, multicast traffic must be tunneled between customer sites by configuring GRE tunnels between CE routers.
- (c) In MPLS L3VPN, the customer does not have complete control of their WAN IP routing. CE routers at the customer VPN sites do not establish direct routing adjacencies, but must instead peer with PE routers.
- (d) MPLS L3VPNs are trusted VPNs, and although they offer similar traffic segregation and security to that offered by Frame Relay and ATM, they do not natively (by default) offer the strong authentication and encryption of secure VPNs such as IPsec. If authentication and encryption are required, however, it is possible to protect VPN traffic in transit between PE routers using either IPsec or end-to-end between CE devices.

5. Implementation of MPLS L3VPN using GNS3

The configuration of MPLS Layer 3 VPNs (L3VPNs) consists of three elements:

- (a) The configuration of CE Routers
- (b) The configuration of PE Routers
- (c) The configuration of P Routers

The configuration of PE Routers:

A number of steps are associated with the configuration of PE routers:

- (a) Configure a loopback interface for use as the PE Router's BGP router ID/LDP router ID.
- (b) Configure the LDP.
- (c) Enable MPLS on interfaces connected to other PE or P routers.

(d) Configure the backbone network IGP.

(e) Configure MP-BGP for VPN-IPv4 route exchange with other PE routers or route reflectors.

(f) Configure the customer VRFs.

(g) Configure the customer VRF interfaces.

(h) Configure the customer VRF routing protocols or static routes.

(i) Redistribute the CE-PR routing protocol or static VRF routes into MPLS-BGP.

The Configuration of P Routers:

The configuration of P routers consists of a subset of the configuration of PE routers:

(a) Configure a loopback interface for use as the P Router's LDP router ID.

(b) Configure the LDP.

(c) Enable MPLS on interfaces connected to PE or other P routers.

(d) Configure the backbone network IGP.

Implementation of MPLS L3VPN Using GNS3

Requirements

Before starting the implementation of MPLS L3VPN using, the routers must achieve the minimum hardware and software requirement to support MPLS L3VPN.

- (a) GNS3 Simulator to run and implement MPLS L3 VPN
- (b) 4GB RAM, in minimum, installed in the PC/laptop running GNS3
- (c) Cisco IOS Image to support MPLS features

Topology and Address Scheme

Using GNS3, a testbed consisting of 7200 and 3600 Series Cisco Routers was built to test the MPLS L3VPN.

I used "c7200-adventerprisek9-mz.152-4.S2.bin" IOS image which is compatible with Cisco 7200 Series Cisco Routers. In other words, the IOS for 7200 Series routers is c7200-adventerprisek9-mz.152-4.S2.bin.

I used "c3660-jsx-mz.123-4.T.bin" IOS image for 3600 Series CISCO Routers.

The MPLS L3VPN network to be implemented is designed and simulated by GNS3 is given as:

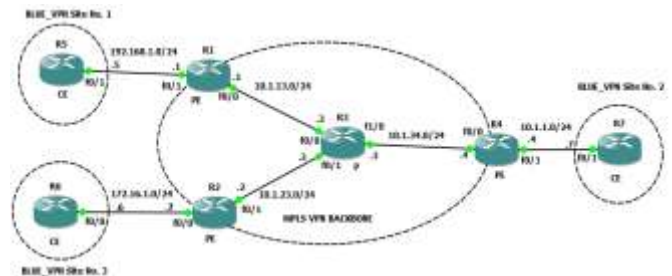


Figure 1: MPLS L3VPN Topology (Full-Mesh Topology) implemented using GNS3

There are four 7200 series Cisco Routers used, three act as PE routers which perform the MPLS L3VPN service, one P router.

There are three 3600 series acting as a CE routers connected directly with PE routers via Fast Ethernet ports. These CE routers are the part of same VPN (L3VPN) named

BLUE_VPN. All devices interfaces are Fast Ethernet set to “auto” duplex and “auto” speed.

The Open Shortest Path First (OSPF) routing protocol was used as the Interior Gateway Protocol (IGP). MP-BGP was used to carry VPNv4 routes as well as exchange VPNv4 labels. The static routing is used in between PE-CE connectivity.

Table 1: Address table

PE/P/CE	ROUTER	INTERFACE	IP ADDRESS	SUBNET
PE	R1	F0/0	10.1.13.1	255.255.255.0
		F0/1	192.168.1.1	255.255.255.0
	R2	F0/0	172.16.1.2	255.255.255.0
		F0/1	10.1.23.2	255.255.255.0
	R4	F0/0	10.1.34.4	255.255.255.0
		F0/1	10.1.1.4	255.255.255.0
P	R3	F0/0	10.1.13.3	255.255.255.0
		F0/1	10.1.23.3	255.255.255.0
		F1/0	10.1.34.3	255.255.255.0
CE	R5	F0/1	192.168.1.5	255.255.255.0
	R6	F0/0	1722.1.1.6	255.255.255.0
	R7	F0/1	10.1.1.7	255.255.255.0

Configuration of MPLS Routers

The configuration of MPLS L3VPN comes under following sections:

Configuration of PE Routers

(a) Configure a loopback interface for use as the PE router's BGP router ID (and update source)/LDP ID.

```
R1#config t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#int lo0
R1(config-if)#ip add 1.1.1.1 255.255.255.255
R2#config t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#int lo0
R2(config-if)#ip add 2.2.2.2 255.255.255.255
R4#config t
Enter configuration commands, one per line. End with CNTL/Z.
R4(config)#int lo0
R4(config-if)#ip add 4.4.4.4 255.255.255.255
```

(b) Configure LDP.

```
R1(config)#mpls label protocol ldp
R1(config)#mpls ldp router-id loopback 0
R2(config)#mpls label protocol ldp
R2(config)#mpls ldp router-id loopback 0
R4(config)#mpls label protocol ldp
R4(config)#mpls ldp router-id loopback 0
```

(c) Enable MPLS on interfaces connected to other PE or P routers

```
R1(config)#int FastEthernet0/0
R1(config-if)#mpls ip
R2(config)#int FastEthernet0/1
R2(config-if)#mpls ip
R4(config)#int FastEthernet0/0
R4(config-if)#mpls ip
```

(d) Configure the Backbone network IGP

```
router ospf 1
router-id 1.1.1.1
network 1.1.1.1 0.0.0.0 area 0
network 10.1.13.0 0.0.0.255 area 0

router ospf 1
router-id 2.2.2.2
network 2.2.2.2 0.0.0.0 area 0
network 10.1.23.0 0.0.0.255 area 0

router ospf 1
router-id 4.4.4.4
network 4.4.4.4 0.0.0.0 area 0
network 10.1.34.0 0.0.0.255 area 0
```

(e) Configure MP-BGP for VPNv4 Route Exchange with other PE Routers or Route Reflectors

```
router bgp 100
bgp log-neighbor-changes
neighbor 2.2.2.2 remote-as 100
neighbor 2.2.2.2 update-source Loopback0
neighbor 4.4.4.4 remote-as 100
neighbor 4.4.4.4 update-source Loopback0
!
address-family ipv4
network 1.1.1.1 mask 255.255.255.255
neighbor 2.2.2.2 activate
neighbor 2.2.2.2 send-community both
neighbor 4.4.4.4 activate
neighbor 4.4.4.4 send-community both
exit-address-family
!
address-family vpnv4
neighbor 2.2.2.2 activate
neighbor 2.2.2.2 send-community both
neighbor 4.4.4.4 activate
neighbor 4.4.4.4 send-community both
exit-address-family

router bgp 100
bgp log-neighbor-changes
neighbor 1.1.1.1 remote-as 100
neighbor 1.1.1.1 update-source Loopback0
neighbor 4.4.4.4 remote-as 100
neighbor 4.4.4.4 update-source Loopback0
!
address-family ipv4
neighbor 1.1.1.1 activate
neighbor 1.1.1.1 send-community both
neighbor 4.4.4.4 activate
neighbor 4.4.4.4 send-community both
exit-address-family
!
address-family vpnv4
neighbor 1.1.1.1 activate
neighbor 1.1.1.1 send-community both
neighbor 4.4.4.4 activate
neighbor 4.4.4.4 send-community both
```

exit-address-family

```
router bgp 100
  bgp log-neighbor-changes
  neighbor 1.1.1.1 remote-as 100
  neighbor 1.1.1.1 update-source Loopback0
  neighbor 2.2.2.2 remote-as 100
  neighbor 2.2.2.2 update-source Loopback0
  !
  address-family ipv4
  network 4.4.4.4 mask 255.255.255.255
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  exit-address-family
  !
  address-family vpnv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  exit-address-family
```

(f) Configure the Customer VRFs and associated routing in BGP

```
ip vrf BLUE_VPN
  rd 100:12
  route-target export 100:12
  route-target import 100:12
```

```
address-family ipv4 vrf BLUE_VPN
  redistribute connected
  redistribute static
  exit-address-family
```

(g) Configuring the Customer VRF Interfaces

On R1:

```
interface FastEthernet0/1
  ip vrf forwarding BLUE_VPN
  ip address 192.168.1.1 255.255.255.0
  speed auto
  duplex auto
```

On R2:

```
interface FastEthernet0/0
  ip vrf forwarding BLUE_VPN
  ip address 172.16.1.2 255.255.255.0
  speed auto
  duplex auto
```

On R4:

```
interface FastEthernet0/1
  ip vrf forwarding BLUE_VPN
  ip address 10.1.1.4 255.255.255.0
  speed auto
  duplex auto
```

5.2.3.2 Configuration of P Routers

i. Configure a loopback interface for use as the P router's LDP Router ID

```
R3#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R3(config)#int lo0
  R3(config-if)#ip add 3.3.3.3 255.255.255.255
```

ii. Configure LDP

```
R3(config)#mpls label protocol ldp
R3(config)#mpls ldp router-id loopback 0
```

iii.Enable MPLS on interfaces connected to PE or P Routers

```
R3#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R3(config)#int fastEthernet 0/0
  R3(config-if)#mpls ip
  R3(config)#int fastEthernet 0/1
  R3(config-if)#mpls ip
  R3(config)#int fastEthernet 1/0
  R3(config-if)#mpls ip
```

iv.Configure the backbone network IGP

```
router ospf 1
  router-id 3.3.3.3
  network 3.3.3.3 0.0.0.0 area 0
  network 10.1.13.0 0.0.0.255 area 0
  network 10.1.23.0 0.0.0.255 area 0
  network 10.1.34.0 0.0.0.255 area 0
```

Configuration of CE Routers

a) Configure the interface connected to PE router

```
R5#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R5(config)#int f0/1
  R5(config-if)#no shut
  R5(config-if)#ip add 192.168.1.5 255.255.255.0
```

```
R5#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R6(config)#int f0/0
  R6(config-if)#no shut
  R6(config-if)#ip add 172.16.1.6 255.255.255.0
```

```
R5#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R5(config)#int f0/1
  R5(config-if)#no shut
  R5(config-if)#ip add 10.1.1.7 255.255.255.0
```

b) Configuring the default routing towards PE router connected to it.

```
R5#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R5(config)#ip route 0.0.0.0 0.0.0.0 192.168.1.1
```

```
R6#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R6(config)#ip route 0.0.0.0 0.0.0.0 172.16.1.2
```

```
R7#config t
  Enter configuration commands, one per line. End with CNTL/Z.
  R7(config)#ip route 0.0.0.0 0.0.0.0 10.1.1.4
```

The connectivity of CE Router R5 to other CE routers, R6 and R7 is given as:

```

Dynamips> R1 Console port
R1#tr 172.16.1.4
Type escape sequence to abort.
Tracing the route to 172.16.1.4
  0 172.168.1.1 124 msec 100 msec 64 msec
  1 10.1.13.3 [MPLS: Labels 17/21 Exp 0] 114 msec 120 msec 121 msec
  2 172.16.1.2 120 msec 156 msec 140 msec
  3 172.16.1.8 124 msec * 94 msec
R1#tr 10.1.1.7
Type escape sequence to abort.
Tracing the route to 10.1.1.7
  0 172.168.1.1 116 msec 112 msec 140 msec
  1 10.1.13.3 [MPLS: Labels 18/23 Exp 0] 112 msec 105 msec 96 msec
  2 10.1.1.4 172 msec 160 msec 126 msec
  3 10.1.1.7 184 msec * 180 msec
R1#ping 172.16.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.4, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/100/164 ms
R1#ping 10.1.1.7
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.7, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 108/156/164 ms
R1#

```

MPLS L3VPN network. This reduces the human efforts to create MP-BGP session.

References

[1] Mark Lewis, "Comparing, Designing and Deploying VPNs", Cisco Press.

Alternatively,

```

Dynamips> R1 Console port
R1#tr 192.168.1.5
Type escape sequence to abort.
Tracing the route to 192.168.1.5
  0 10.1.1.4 32 msec 124 msec 94 msec
  1 10.1.14.3 [MPLS: Labels 16/22 Exp 0] 164 msec 76 msec 44 msec
  2 192.168.1.1 136 msec 140 msec 140 msec
  3 192.168.1.5 176 msec * 216 msec
R1#ping 172.16.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.4, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 24/104/176 ms
R1#tr 172.16.1.6
Type escape sequence to abort.
Tracing the route to 172.16.1.6
  0 10.1.1.4 108 msec 80 msec 96 msec
  1 10.1.14.3 [MPLS: Labels 17/21 Exp 0] 80 msec 48 msec 8 msec
  2 172.16.1.2 92 msec 112 msec 140 msec
  3 172.16.1.6 112 msec * 168 msec
R1#ping 192.168.1.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.5, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 120/136/176 ms
R1#

```

```

Dynamips> R1 Console port
R1#tr 192.168.1.5
Type escape sequence to abort.
Tracing the route to 192.168.1.5
  0 172.16.1.2 116 msec 92 msec 92 msec
  1 10.1.23.3 [MPLS: Labels 16/22 Exp 0] 100 msec 128 msec 96 msec
  2 192.168.1.1 132 msec 152 msec 84 msec
  3 192.168.1.5 100 msec * 32 msec
R1#tr 10.1.1.7
Type escape sequence to abort.
Tracing the route to 10.1.1.7
  0 172.16.1.2 120 msec 90 msec 64 msec
  1 10.1.23.3 [MPLS: Labels 18/23 Exp 0] 108 msec 168 msec 132 msec
  2 10.1.1.4 232 msec 112 msec 180 msec
  3 10.1.1.7 156 msec * 156 msec
R1#ping 192.168.1.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.5, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 124/146/192 ms
R1#ping 10.1.1.7
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.7, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 108/126/156 ms
R1#

```

6. Conclusion

The main goal of this paper was to implement the MPLS L3VPN using GNS3. I implemented MPLS L3VPN Full-Mesh Topology. In this topology, I had to create all possible MP-BGP to other PE routers. If the number of PE routers increases, the MP-BGP session to all PE routers also increases. Creating/Configuring more MP-BGP proves to be more hectic and time consuming, if PE routers increase in number. To decrease the MP-BGP session between all PE routers, we should implement the RR (Route Reflector) in the