MPLS

Protocol x Labels

Mason and Hoffman – Period 6-8

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Purpose

This lab exists to help us comprehend the concepts and configurations of Multiprotocol Label Switching (MPLS). The goal of this lab would be to associate with certain routers that would be able to ping specifically as corresponding end hosts. We would also need to be able to demonstrate that the switches in our topology are facilitating MPLS through our forwarding tables and the LDP labels within those forwarding tables. The LDP labels should match the packets caught within Wireshark.

Background

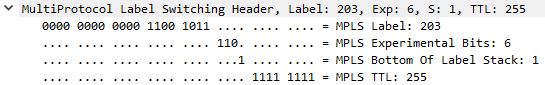
There are multiple nodes used in MPLS topologies with various properties, one being the Label Switch router, or the LSR, which is a router/node that uses the label of packets to perform routing typically in the middle of an MPLS network. The LSR switches the labels on the packets which are then used to redirect those packets. Without using the network addresses directly, the LSR takes the packet label in the header to calculate a next hop on the label-switched path (LSP). Simultaneously, a new corresponding label is determined from a lookup table. The LSR strips the old label from the header and replaces it with the newly determined label promptly before the packet is routed. Another such node is a Label Edge Router (LER/edge LSR) which is placed at the edge of an MPLS topology and serves as a border guard for the network, processing traffic as an entry and exit point. The LER uses the proper routing information to affix the proper label and forwards any label packet that was meant to be forwarded into the MPLS domain. If the packet is destined for outside the domain, the LER removes the label for the IP packet to be forwarded on traditional IP rules. MPLS uses the Label Distribution Protocol (LDP) where MPLS routers exchange label mapping information. Two routes become LDP peers once they are both in an established session for bilateral swapping of information. This exchange allows LDP to build and maintain databases used to forward traffic through MPLS networks. LDP also relies on routing information from an IGP for forwarding label packets. The router forwarding information base (router FIB) simultaneously is purposed for determining a hop-by-hop path through the network. LDP is used for signaling best-effort LSP instead of using constraints and dictated routes like traffic engineered paths for end-to-end LSPs. BGP can be deployed on a network’s edges while the core MPLS routers carry information limited to BGP’s following step (note that MPLs does not scatter BGP, it simply provides end-to-end paths). BGP establishes loop-free routes in distributing information among autonomous systems.

Lab Summary

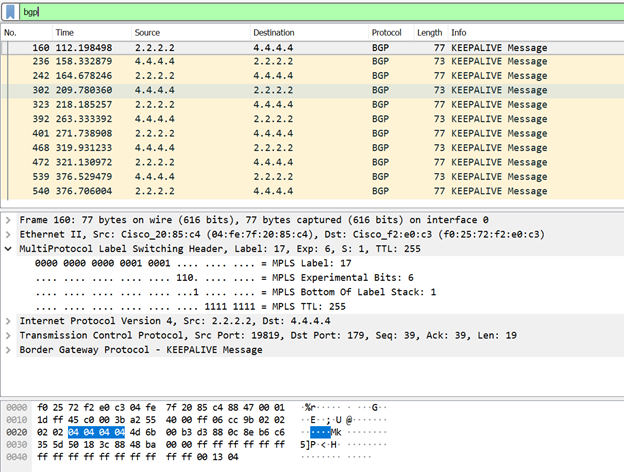
In detail, we configured an IP addressing scheme by clearing interfaces and then by entering ip address commands. A single OSPF area was added atop the bare-bones of the topology. The “Router ospf [process-id]]” commands and “network [ip address] [wildcard mask] area [area number]” commands were implemented to the end of creating a backbone area and initiate OSPF. Skills from previous labs like “Multi-area OSPF” came in handy on this step.

MPLS was implemented by first ensuring Cisco Express Forwarding (CEF) on the router is enabled by using the “Ip cef distributed” command. Subsequently, LDP is required as the protocol backbone for MPLS , and thus is needed to replace TDP (default) through the “Mpls label protocol ldp” command. LDP also has helpful additional configuration details, such as its router ID, which is especially useful for easy identification of the routers running LDP. This can be accomplished through the “Mpls ldp router-id Loopback0 force” command. Finally, MPLS can now be enabled through the “MPLS ip” command, which needs to be enabled in both router configuration mode and within each relevant interface for it to function as desired. With MPLS complete, BGP is the last remaining block of steps. Global BGP parameters were configured on LERs by the “Router bgp [AS number]” command. LERS are induced into advertising networks connected to BGP routers (contained in database) through the “network [ip address] mask [subnet mask]” command for BGP. Because of their essential nature for the tasks of this lab, loopback interfaces are configured to become the update source for MPLS operations within autonomous systems. The “Neighbor [Ip address] remote-as [AS number]” and “Neighbor [Ip address] update-source [Interface ID]” commands were used

The BGP configuration was especially necessary for allowing us to wireshark the packets later.



MPLS needs to be configured on the node and Wireshark would need to search for BGP to make specific captures. By finding “Multiprotocol Label Switching header”, we can prove that MPLS functions and thus are able to reach the goal for this lab.



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Configurations

The following commands are important to the following lab, and used extensively within the topology:

**Router ospf** [process-id]: Creates an OSPF routing process and enters routing configuration mode for this OSPF process, given a process-id/identifier (any positive integer)

**network** [ip address] [wildcard mask] **area** [area number]: Describes the IP addresses on which OSPF runs and the area (unique ID for each area) for the relevant interface

**network** [ip address] **mask** [subnet mask]: Configures the advertisement of networks in BGP

**Ip cef distributed**: Enables distributed Cisco Express Forwarding operation to line cards where express forwarding is performed  
**Mpls label protocol ldp**: Configures the use of LDP on all interfaces (LDP default) (If global, can be overridden on specific interface configurations)

**Mpls label range** [minimum label] [maximum label]: Specifies the range of labels for use with MPLS static label assignments

**Mpls ldp session protection**: Enables MPLS LDP session protection (protects all LDP session if entered with keyword)

**Mpls ldp router-id Loopback0 force**: Specifies the preferred interface for determining the LDP router ID (as IP address of an interface). “force” causes the router-id to take effect more quickly

**Mpls ip**: Implemented by default, configures MPLS hop-by-hop forwarding globally (needs to be entered both in router configuration and in each interface)

**Router bgp** [AS number]: Configures a BGP routing process associated with a specified number

**Redistribute bgp** [AS number] **subnets**: Redistributes bgp routes into OSPF processes (propagates routes learned with one protocol into another routing protocol)

**Bgp log-neighbor-changes**: Allows for the enabling/disabling of logging messages generated when the status of a BGP neighbor changes (resets, up, or down)

**Neighbor** [Ip address] **remote-as** [AS number]: Establishes connection with neighbor

**Neighbor** [Ip address] **update-source** [Interface ID]: .Configures an interface for use in establishing BGP peer connections with an internal BGP session (same autonomous system).

**Neighbor** [Ip address] **default-orig**: Originates a default route for the specified neighbor

**Monitor session** [session number] **source interface** [interface|interface range,interface range] [both (if more than 1)]: Creates a Ethernet Switched Port Analyzer for analyzer session configuration for analyzing traffic between ports

**Monitor session** [session number] **destination interface** [interface]: Specifies destination interface for specified session

Below is the **router** configuration for the router used within the topology.

RB2#traceroute 1.1.1.1

Type escape sequence to abort.

Tracing the route to 1.1.1.1

VRF info: (vrf in name/id, vrf out name/id)

1 192.168.4.1 0 msec 4 msec 4 msec

2 172.16.20.1 [AS 100] [MPLS: Label 206 Exp 0] 0 msec 4 msec 0 msec

3 172.16.10.1 [AS 100] [MPLS: Label 205 Exp 0] 0 msec 0 msec 0 msec

4 192.168.1.2 [AS 100] 4 msec \* 0 msec

RB2#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is 192.168.4.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.4.1, 00:38:55

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.4.1, 00:32:20

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.4.1, 00:31:49

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.4.1, 00:31:49

4.0.0.0/32 is subnetted, 1 subnets

C 4.4.4.4 is directly connected, Loopback0

B 192.168.1.0/24 [20/0] via 192.168.4.1, 00:38:55

B 192.168.2.0/24 [20/0] via 192.168.4.1, 00:38:55

B 192.168.3.0/24 [20/0] via 192.168.4.1, 00:38:55

192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.4.0/24 is directly connected, GigabitEthernet0/0

L 192.168.4.2/32 is directly connected, GigabitEthernet0/0

RB2#show run

Building configuration...

Current configuration : 1672 bytes

!

! Last configuration change at 17:58:12 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RB2

interface Loopback0

ip address 4.4.4.4 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.4.2 255.255.255.0

duplex auto

speed auto

router bgp 4

bgp log-neighbor-changes

network 4.4.4.4 mask 255.255.255.255

network 192.168.4.0

neighbor 192.168.4.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

RA2#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is 192.168.3.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.3.1, 00:38:00

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.3.1, 00:31:25

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.3.1, 00:30:54

3.0.0.0/32 is subnetted, 1 subnets

C 3.3.3.3 is directly connected, Loopback0

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.3.1, 00:30:54

B 192.168.1.0/24 [20/0] via 192.168.3.1, 00:38:00

B 192.168.2.0/24 [20/0] via 192.168.3.1, 00:38:00

192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.3.0/24 is directly connected, GigabitEthernet0/0

L 192.168.3.2/32 is directly connected, GigabitEthernet0/0

B 192.168.4.0/24 [20/0] via 192.168.3.1, 00:38:00

RA2#show run

Building configuration...

Current configuration : 1755 bytes

Last configuration change at 18:25:24 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RA2

interface Loopback0

ip address 3.3.3.3 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.3.2 255.255.255.0

duplex auto

speed auto

router bgp 3

bgp log-neighbor-changes

network 3.3.3.3 mask 255.255.255.255

network 192.168.3.0

neighbor 192.168.3.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

RB1#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is 192.168.2.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.2.1, 00:37:23

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.2.1, 00:30:15

2.0.0.0/32 is subnetted, 1 subnets

C 2.2.2.2 is directly connected, Loopback0

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.2.1, 00:29:45

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.2.1, 00:29:14

B 192.168.1.0/24 [20/0] via 192.168.2.1, 00:37:23

192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.2.0/24 is directly connected, GigabitEthernet0/0

L 192.168.2.2/32 is directly connected, GigabitEthernet0/0

B 192.168.3.0/24 [20/0] via 192.168.2.1, 00:36:51

B 192.168.4.0/24 [20/0] via 192.168.2.1, 00:36:51

RB1#show run

Building configuration...

Current configuration : 1969 bytes

Last configuration change at 18:24:19 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RB1

interface Loopback0

ip address 2.2.2.2 255.255.255.255

ip broadcast-address 2.2.2.2

interface GigabitEthernet0/0

ip address 192.168.2.2 255.255.255.0

ip broadcast-address 192.168.2.0

duplex auto

speed auto

router bgp 2

bgp log-neighbor-changes

network 2.2.2.2 mask 255.255.255.255

network 192.168.2.0

neighbor 192.168.2.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

RA1#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is 192.168.1.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.1.1, 00:36:29

1.0.0.0/32 is subnetted, 1 subnets

C 1.1.1.1 is directly connected, Loopback0

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.1.1, 00:28:51

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.1.1, 00:28:51

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.1.1, 00:28:20

192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.1.0/24 is directly connected, GigabitEthernet0/0

L 192.168.1.2/32 is directly connected, GigabitEthernet0/0

B 192.168.2.0/24 [20/0] via 192.168.1.1, 00:36:29

B 192.168.3.0/24 [20/0] via 192.168.1.1, 00:35:56

B 192.168.4.0/24 [20/0] via 192.168.1.1, 00:35:56

RA1#show run

Building configuration...

Current configuration : 1754 bytes

Last configuration change at 19:13:58 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RA1

interface Loopback0

ip address 1.1.1.1 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.1.2 255.255.255.0

duplex auto

speed auto

router bgp 1

bgp log-neighbor-changes

network 1.1.1.1 mask 255.255.255.255

network 192.168.1.0

neighbor 192.168.1.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

This is the configuration for the Switches used within the topology:

S3#show mpls ldp bind

lib entry: 1.1.1.1/32, rev 20

local binding: label: 205

remote binding: lsr: 20.20.20.20:0, label: 206

lib entry: 2.2.2.2/32, rev 22

local binding: label: 206

remote binding: lsr: 20.20.20.20:0, label: 207

lib entry: 3.3.3.3/32, rev 24

local binding: label: 207

remote binding: lsr: 20.20.20.20:0, label: 208

lib entry: 4.4.4.4/32, rev 26

local binding: label: 208

remote binding: lsr: 20.20.20.20:0, label: 209

lib entry: 10.10.10.10/32, rev 2

local binding: label: 200

remote binding: lsr: 20.20.20.20:0, label: 200

lib entry: 20.20.20.20/32, rev 4

local binding: label: 201

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 30.30.30.30/32, rev 6

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 203

lib entry: 172.16.10.0/24, rev 8

local binding: label: 202

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 172.16.20.0/24, rev 10

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 192.168.1.0/24, rev 12

local binding: label: 203

remote binding: lsr: 20.20.20.20:0, label: 201

lib entry: 192.168.2.0/24, rev 14

local binding: label: 204

remote binding: lsr: 20.20.20.20:0, label: 202

lib entry: 192.168.3.0/24, rev 18

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 205

lib entry: 192.168.4.0/24, rev 16

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 204

S3#show mpls ldp neigh

Peer LDP Ident: 20.20.20.20:0; Local LDP Ident 30.30.30.30:0

TCP connection: 20.20.20.20.646 - 30.30.30.30.53728

State: Oper; Msgs sent/rcvd: 58/57; Downstream

Up time: 00:35:50

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.20.1

Addresses bound to peer LDP Ident:

20.20.20.20 172.16.10.2 172.16.20.1

S3#show mpls forw

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 200 10.10.10.10/32 0 Gi1/1/1 172.16.20.1

201 Pop Label 20.20.20.20/32 0 Gi1/1/1 172.16.20.1

202 Pop Label 172.16.10.0/24 0 Gi1/1/1 172.16.20.1

203 201 192.168.1.0/24 0 Gi1/1/1 172.16.20.1

204 202 192.168.2.0/24 0 Gi1/1/1 172.16.20.1

205 206 1.1.1.1/32 0 Gi1/1/1 172.16.20.1

206 207 2.2.2.2/32 0 Gi1/1/1 172.16.20.1

207 No Label 3.3.3.3/32 0 Fa1/0/1 192.168.3.2

208 No Label 4.4.4.4/32 610 Fa1/0/2 192.168.4.2

S3#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

O E2 1.1.1.1 [110/1] via 172.16.20.1, 00:27:44, GigabitEthernet1/1/1

2.0.0.0/32 is subnetted, 1 subnets

O E2 2.2.2.2 [110/1] via 172.16.20.1, 00:27:14, GigabitEthernet1/1/1

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.3.2, 00:27:14

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.4.2, 00:27:14

10.0.0.0/32 is subnetted, 1 subnets

O 10.10.10.10 [110/3] via 172.16.20.1, 00:35:32, GigabitEthernet1/1/1

20.0.0.0/32 is subnetted, 1 subnets

O 20.20.20.20 [110/2] via 172.16.20.1, 00:35:32, GigabitEthernet1/1/1

S3#show run

Building configuration...

Current configuration : 2541 bytes

Last configuration change at 00:12:30 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname S3

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 30.30.30.30 255.255.255.255

interface FastEthernet1/0/1

no switchport

ip address 192.168.3.1 255.255.255.0

interface FastEthernet1/0/2

no switchport

ip address 192.168.4.1 255.255.255.0

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.20.2 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

redistribute bgp 100 subnets

network 30.30.30.30 0.0.0.0 area 0

network 172.16.20.0 0.0.0.255 area 0

router bgp 100

bgp log-neighbor-changes

network 192.168.3.0

network 192.168.4.0

neighbor 10.10.10.10 remote-as 100

neighbor 10.10.10.10 update-source Loopback0

neighbor 192.168.3.2 remote-as 3

neighbor 192.168.3.2 default-originate

neighbor 192.168.4.2 remote-as 4

neighbor 192.168.4.2 default-originate

no auto-summary

mpls ldp router-id Loopback0 force

line con 0

line vty 5 15

monitor session 1 source interface Fa1/0/1 - 2

monitor session 1 source interface Gi1/1/1

monitor session 1 destination interface Fa1/0/3

end

S2#show mpls ldp bind

lib entry: 1.1.1.1/32, rev 20

local binding: label: 206

remote binding: lsr: 10.10.10.10:0, label: 205

remote binding: lsr: 30.30.30.30:0, label: 205

lib entry: 2.2.2.2/32, rev 22

local binding: label: 207

remote binding: lsr: 30.30.30.30:0, label: 206

remote binding: lsr: 10.10.10.10:0, label: 206

lib entry: 3.3.3.3/32, rev 24

local binding: label: 208

remote binding: lsr: 30.30.30.30:0, label: 207

remote binding: lsr: 10.10.10.10:0, label: 207

lib entry: 4.4.4.4/32, rev 26

local binding: label: 209

remote binding: lsr: 30.30.30.30:0, label: 208

remote binding: lsr: 10.10.10.10:0, label: 208

lib entry: 10.10.10.10/32, rev 2

local binding: label: 200

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 200

lib entry: 20.20.20.20/32, rev 4

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 200

remote binding: lsr: 30.30.30.30:0, label: 201

lib entry: 30.30.30.30/32, rev 14

local binding: label: 203

remote binding: lsr: 30.30.30.30:0, label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 202

lib entry: 172.16.10.0/24, rev 6

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 202

lib entry: 172.16.20.0/24, rev 8

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 201

remote binding: lsr: 30.30.30.30:0, label: imp-null

lib entry: 192.168.1.0/24, rev 10

local binding: label: 201

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 203

lib entry: 192.168.2.0/24, rev 12

local binding: label: 202

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 204

lib entry: 192.168.3.0/24, rev 18

local binding: label: 205

remote binding: lsr: 10.10.10.10:0, label: 204

remote binding: lsr: 30.30.30.30:0, label: imp-null

lib entry: 192.168.4.0/24, rev 16

local binding: label: 204

remote binding: lsr: 30.30.30.30:0, label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 203

S2#show mpls ldp neigh

Peer LDP Ident: 10.10.10.10:0; Local LDP Ident 20.20.20.20:0

TCP connection: 10.10.10.10.646 - 20.20.20.20.47613

State: Oper; Msgs sent/rcvd: 55/55; Downstream

Up time: 00:34:21

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.10.1

Addresses bound to peer LDP Ident:

10.10.10.10 192.168.1.1 192.168.2.1 172.16.10.1

Peer LDP Ident: 30.30.30.30:0; Local LDP Ident 20.20.20.20:0

TCP connection: 30.30.30.30.53728 - 20.20.20.20.646

State: Oper; Msgs sent/rcvd: 55/56; Downstream

Up time: 00:34:06

LDP discovery sources:

GigabitEthernet1/1/2, Src IP addr: 172.16.20.2

Addresses bound to peer LDP Ident:

30.30.30.30 192.168.4.1 172.16.20.2 192.168.3.1

S2#show mpls forw

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 Pop Label 10.10.10.10/32 5747 Gi1/1/1 172.16.10.1

201 Pop Label 192.168.1.0/24 590 Gi1/1/1 172.16.10.1

202 Pop Label 192.168.2.0/24 590 Gi1/1/1 172.16.10.1

203 Pop Label 30.30.30.30/32 5824 Gi1/1/2 172.16.20.2

204 Pop Label 192.168.4.0/24 590 Gi1/1/2 172.16.20.2

205 Pop Label 192.168.3.0/24 0 Gi1/1/2 172.16.20.2

206 205 1.1.1.1/32 0 Gi1/1/1 172.16.10.1

207 206 2.2.2.2/32 0 Gi1/1/1 172.16.10.1

208 207 3.3.3.3/32 0 Gi1/1/2 172.16.20.2

209 208 4.4.4.4/32 610 Gi1/1/2 172.16.20.2

S2#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

O E2 1.1.1.1 [110/1] via 172.16.10.1, 00:26:01, GigabitEthernet1/1/1

2.0.0.0/32 is subnetted, 1 subnets

O E2 2.2.2.2 [110/1] via 172.16.10.1, 00:25:30, GigabitEthernet1/1/1

3.0.0.0/32 is subnetted, 1 subnets

O E2 3.3.3.3 [110/1] via 172.16.20.2, 00:25:30, GigabitEthernet1/1/2

4.0.0.0/32 is subnetted, 1 subnets

O E2 4.4.4.4 [110/1] via 172.16.20.2, 00:25:30, GigabitEthernet1/1/2

10.0.0.0/32 is subnetted, 1 subnets

O 10.10.10.10 [110/2] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

20.0.0.0/32 is subnetted, 1 subnets

C 20.20.20.20 is directly connected, Loopback0

30.0.0.0/32 is subnetted, 1 subnets

O 30.30.30.30 [110/2] via 172.16.20.2, 00:33:48, GigabitEthernet1/1/2

172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks

C 172.16.10.0/24 is directly connected, GigabitEthernet1/1/1

L 172.16.10.2/32 is directly connected, GigabitEthernet1/1/1

C 172.16.20.0/24 is directly connected, GigabitEthernet1/1/2

L 172.16.20.1/32 is directly connected, GigabitEthernet1/1/2

O E2 192.168.1.0/24 [110/1] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

O E2 192.168.2.0/24 [110/1] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

O E2 192.168.3.0/24 [110/1] via 172.16.20.2, 00:33:33, GigabitEthernet1/1/2

O E2 192.168.4.0/24 [110/1] via 172.16.20.2, 00:33:45, GigabitEthernet1/1/2

S2#show run

Building configuration...

Current configuration : 2280 bytes

Last configuration change at 02:15:04 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname S2

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 20.20.20.20 255.255.255.255

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.10.2 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

interface GigabitEthernet1/1/2

no switchport

ip address 172.16.20.1 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

network 20.20.20.20 0.0.0.0 area 0

network 172.16.10.0 0.0.0.255 area 0

network 172.16.20.0 0.0.0.255 area 0

mpls ldp router-id Loopback0 force

line con 0

line vty 5 15

monitor session 1 source interface Gi1/1/1 - 2

monitor session 1 destination interface Fa1/0/3

end

S1#show mpls ldp bind

lib entry: 1.1.1.1/32, rev 20

local binding: label: 205

remote binding: lsr: 20.20.20.20:0, label: 206

lib entry: 2.2.2.2/32, rev 22

local binding: label: 206

remote binding: lsr: 20.20.20.20:0, label: 207

lib entry: 3.3.3.3/32, rev 24

local binding: label: 207

remote binding: lsr: 20.20.20.20:0, label: 208

lib entry: 4.4.4.4/32, rev 26

local binding: label: 208

remote binding: lsr: 20.20.20.20:0, label: 209

lib entry: 10.10.10.10/32, rev 2

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 200

lib entry: 20.20.20.20/32, rev 10

local binding: label: 200

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 30.30.30.30/32, rev 15

local binding: label: 202

remote binding: lsr: 20.20.20.20:0, label: 203

lib entry: 172.16.10.0/24, rev 4

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 172.16.20.0/24, rev 12

local binding: label: 201

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 192.168.1.0/24, rev 6

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 201

lib entry: 192.168.2.0/24, rev 8

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 202

lib entry: 192.168.3.0/24, rev 18

local binding: label: 204

remote binding: lsr: 20.20.20.20:0, label: 205

lib entry: 192.168.4.0/24, rev 16

local binding: label: 203

remote binding: lsr: 20.20.20.20:0, label: 204

S1#show mpls ldp neigh

Peer LDP Ident: 20.20.20.20:0; Local LDP Ident 10.10.10.10:0

TCP connection: 20.20.20.20.47613 - 10.10.10.10.646

State: Oper; Msgs sent/rcvd: 53/53; Downstream

Up time: 00:32:50

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.10.2

Addresses bound to peer LDP Ident:

20.20.20.20 172.16.10.2 172.16.20.1

S1#show mpls forw

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 Pop Label 20.20.20.20/32 0 Gi1/1/1 172.16.10.2

201 Pop Label 172.16.20.0/24 0 Gi1/1/1 172.16.10.2

202 203 30.30.30.30/32 0 Gi1/1/1 172.16.10.2

203 204 192.168.4.0/24 0 Gi1/1/1 172.16.10.2

204 205 192.168.3.0/24 0 Gi1/1/1 172.16.10.2

205 No Label 1.1.1.1/32 0 Fa1/0/1 192.168.1.2

206 No Label 2.2.2.2/32 0 Fa1/0/2 192.168.2.2

207 208 3.3.3.3/32 0 Gi1/1/1 172.16.10.2

208 209 4.4.4.4/32 0 Gi1/1/1 172.16.10.2

S1#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, 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, U - per-user static route

o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP

+ - replicated route, % - next hop override

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.1.2, 00:24:26

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.2.2, 00:23:55

3.0.0.0/32 is subnetted, 1 subnets

O E2 3.3.3.3 [110/1] via 172.16.10.2, 00:23:55, GigabitEthernet1/1/1

4.0.0.0/32 is subnetted, 1 subnets

O E2 4.4.4.4 [110/1] via 172.16.10.2, 00:23:55, GigabitEthernet1/1/1

10.0.0.0/32 is subnetted, 1 subnets

C 10.10.10.10 is directly connected, Loopback0

20.0.0.0/32 is subnetted, 1 subnets

O 20.20.20.20 [110/2] via 172.16.10.2, 00:32:29, GigabitEthernet1/1/1

30.0.0.0/32 is subnetted, 1 subnets

O 30.30.30.30 [110/3] via 172.16.10.2, 00:32:03, GigabitEthernet1/1/1

172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks

C 172.16.10.0/24 is directly connected, GigabitEthernet1/1/1

L 172.16.10.1/32 is directly connected, GigabitEthernet1/1/1

O 172.16.20.0/24

[110/2] via 172.16.10.2, 00:32:13, GigabitEthernet1/1/1

192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.1.0/24 is directly connected, FastEthernet1/0/1

L 192.168.1.1/32 is directly connected, FastEthernet1/0/1

192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.2.0/24 is directly connected, FastEthernet1/0/2

L 192.168.2.1/32 is directly connected, FastEthernet1/0/2

O E2 192.168.3.0/24 [110/1] via 172.16.10.2, 00:31:58, GigabitEthernet1/1/1

O E2 192.168.4.0/24 [110/1] via 172.16.10.2, 00:32:03, GigabitEthernet1/1/1

S1#show run

Building configuration...

Current configuration : 4775 bytes

Last configuration change at 02:14:49 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug uptime

service timestamps log uptime

no service password-encryption

hostname S1

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 10.10.10.10 255.255.255.255

interface FastEthernet1/0/1

no switchport

ip address 192.168.1.1 255.255.255.0

interface FastEthernet1/0/2

no switchport

ip address 192.168.2.1 255.255.255.0

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.10.1 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

redistribute bgp 100 subnets

network 10.10.10.10 0.0.0.0 area 0

network 172.16.10.0 0.0.0.255 area 0

router bgp 100

bgp log-neighbor-changes

network 192.168.1.0

network 192.168.2.0

neighbor 30.30.30.30 remote-as 100

neighbor 30.30.30.30 update-source Loopback0

neighbor 192.168.1.2 remote-as 1

neighbor 192.168.1.2 default-originate

neighbor 192.168.2.2 remote-as 2

neighbor 192.168.2.2 default-originate

no auto-summary

mpls ldp router-id Loopback0 force

line con 0

line vty 0 4

login

line vty 5 15

login

monitor session 1 source interface Fa1/0/1 - 2

monitor session 1 source interface Gi1/1/1

monitor session 1 destination interface Fa1/0/3

end

Problems

A few problems were encountered during the configuration of this lab. The primary root of our difficulties was that MPLS had multiple different methods of completion, some involving OSPF, others not, others being automatic while others are unsurprising not automatic. As such, everyone in the lab was using a scramble of different configurations with mixes of the necessary commands, and as such we were unable to completely rely on advice from one another. As such, we had to experiment for hours on end using different sources online. One especially irritating issue was in finding the proper command for showing the labels in the protocol analyzer, which simply turned out to be show mpls forwarding-table, which some help from a labmate.

BGP and understanding its uses of remote-as and update sources was especially interesting and time-consuming to research, and as such we spent a substantial proportion of time simply trying to understand it.

MPLS commands were especially easy to find online, however the use of them remained unclear for quite a while. Conceptually, there are a string of label switching, with edge routers and penultimate routers towards the end of the MPLS topology. It took a while to read and understand the purpose of each one in the label-switching process despite their names being quite self-explanatory (like penultimate meaning second to last).

**Mpls label protocol ldp** was easy to find online and implement, and so was **Mpls ldp session protection**. **Mpls ldp router-id Loopback0 force** was found after a little of trial and error, but **Mpls label range** [minimum label] [maximum label]required reading into its numerical numbers to understand how to implement the ranges of labels and how to use the command most effectively.

Conclusion

This lab was a valuable experience in MPLS. We not only learned that MPLS functions as a sort of “layer 2.5” protocol, but also the structure of the chain of devices that represents an MPLS topology (refer to problems above). It was helpful to understand the operation of deciding the shortest path without using long network addresses and with hop-by-hop label configurations as an alternative. As MPLS becomes an increasingly popular routing method among ISPs, it is paramount that we have acquired crucial knowledge in such an industry-relevant protocol.