INSTITUTO SUPERIOR TÉCNICO

TRAFFIC ENGINEERING

METI

Lab Report II and III

Introduction to GNS3 and Test of IP VPNs on MPLS

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1 Introduction

This report is divided in two major sections. Laboratory 2 and 3.

2 Laboratory 2

In the guide we were asked to deploy a simple network with a few routers and two VPCS. The goal of this laboratory is to remember Cisco IOS configurations and commands.

We deployed the network displayed on figure 1.

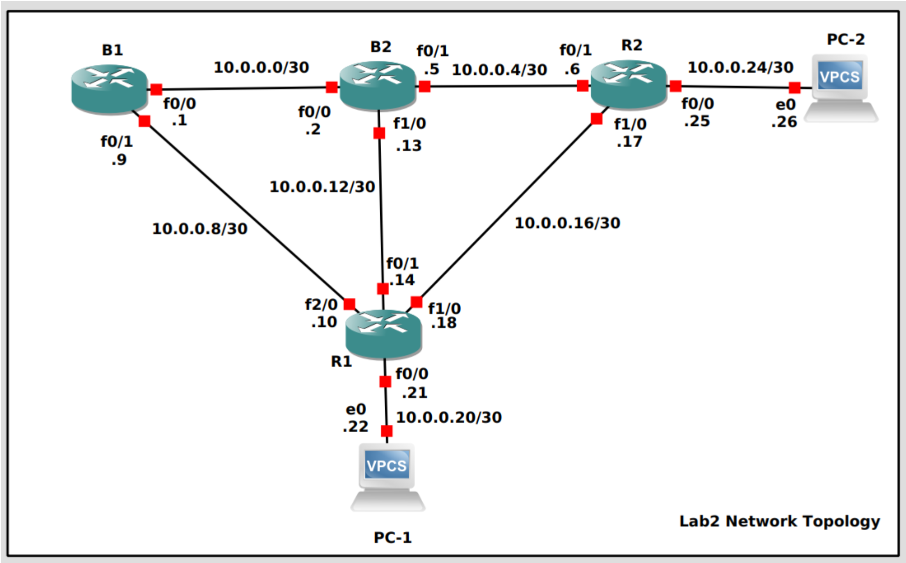
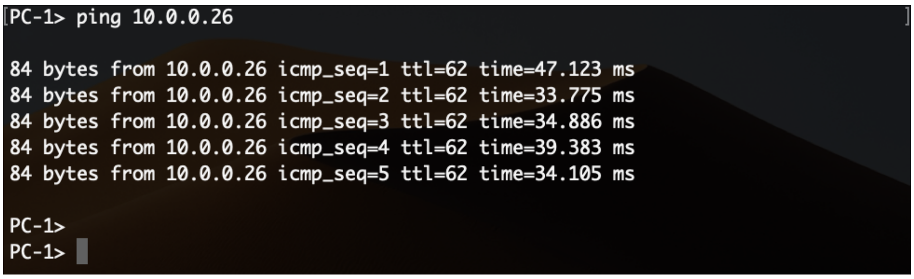


Figure 1: Laboratory 2 - Network Topology

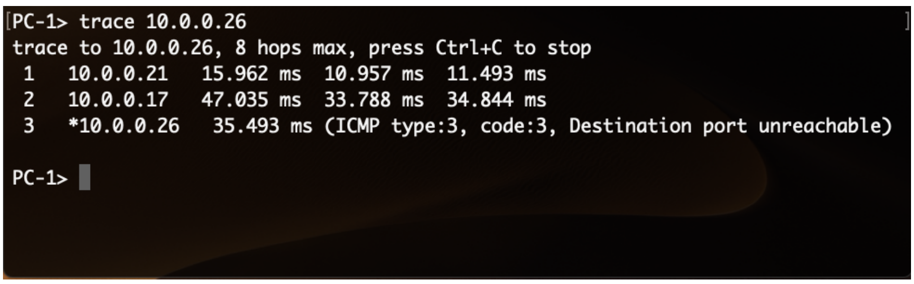
Between routers we have implemented OSPF (Open Shortest Path First) protocol.

To test connectivity between VPCS we pinged and traced the route between VPCS 1 and 2. As shown in figures 2 and 3.



```
PC-1> ping 10.0.0.26

84 bytes from 10.0.0.26 icmp_seq=1 ttl=62 time=47.123 ms
84 bytes from 10.0.0.26 icmp_seq=2 ttl=62 time=33.775 ms
84 bytes from 10.0.0.26 icmp_seq=3 ttl=62 time=34.886 ms
84 bytes from 10.0.0.26 icmp_seq=4 ttl=62 time=39.383 ms
84 bytes from 10.0.0.26 icmp_seq=5 ttl=62 time=34.105 ms

PC-1>
PC-1>
```

Figure 2: Ping between VPCS 1 and 2



```
PC-1> trace 10.0.0.26
trace to 10.0.0.26, 8 hops max, press Ctrl+C to stop
 1   10.0.0.21   15.962 ms  10.957 ms  11.493 ms
 2   10.0.0.17   47.035 ms  33.788 ms  34.844 ms
 3   *10.0.0.26   35.493 ms (ICMP type:3, code:3, Destination port unreachable)

PC-1>
```

Figure 3: Trace between VPCS 1 and 2

As we can see the route taken is PC1->R1->R2->PC2.

To further test our network redundancy we have turned off interface f1/0 of R2 and then interface f1/0 of B2.

The routes taken are first PC1->R1->B2->R2->PC2 and then PC1->R1->B1->B2->R2->PC2 as displayed on figure 4.

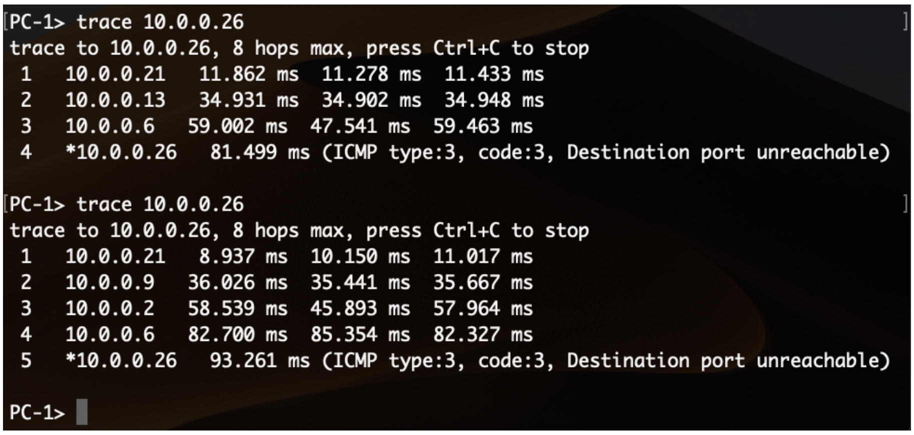


Figure 4: Trace between VPCS 1 and 2 with some interfaces off

With this simple network we were able to remember some fundamentals on Cisco IOS and GNS3 configurations and commands.

3 Laboratory 3

In this lab work we were asked to deploy a network and implement MPLS (Multi Protocol Label Switching) and MPLS IP VPN on top of it. The topology of our network is displayed on figure 5. Our MPLS network is composed by four LERs (Label Edge Routers) and six LSRs (Label Switching Routers).

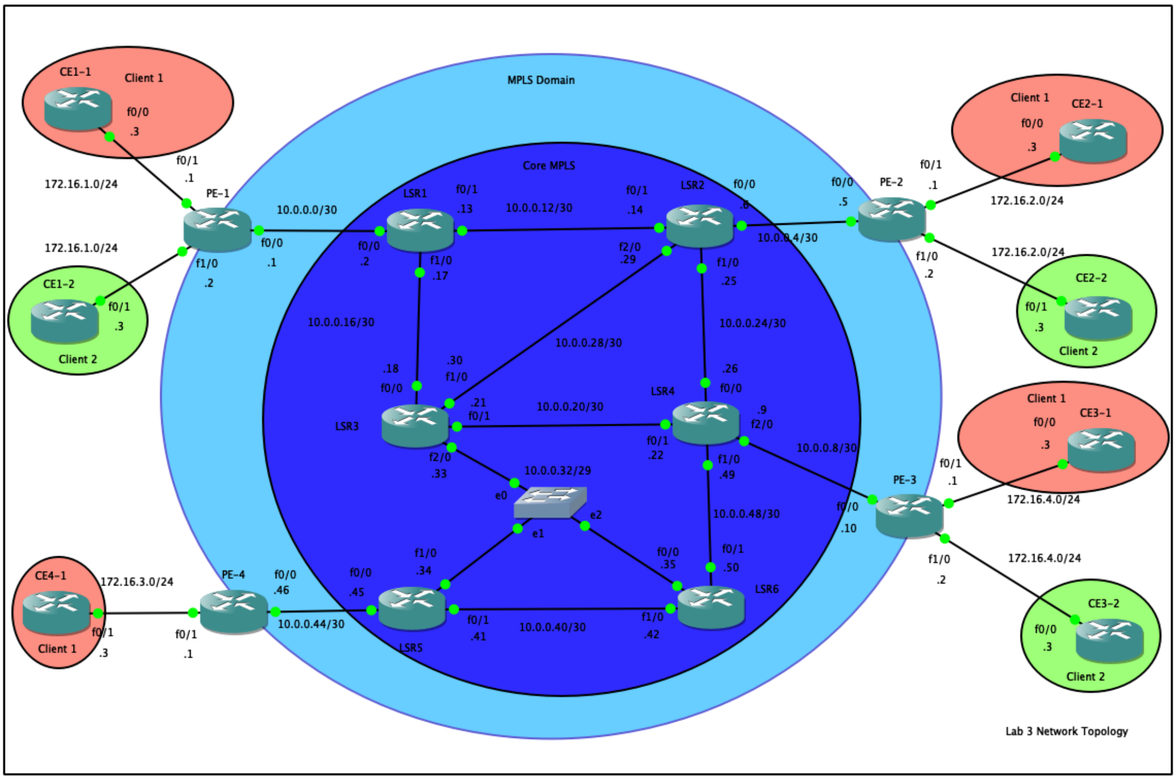


Figure 5: Laboratory 3 - Network Topology

For this work we divided our implementation in 6 main tasks:

1. Deploy network topology and OSPF between routers
2. Implement MPLS protocol between providers
3. Create VRFs (Virtual Route Forwarding) and atribute interfaces
4. Config MP-BGP between each PE (Provider Edge)
5. Config OSPF between PEs and CEs (Costumer Edge)
6. Activate routes redistribution between CE and backbone

3.1 Deploy network topology and OSPF between routers

Similarly to laboratory guide 2, in this guide we started to deploy the routers that will compose our MPLS network, LERs and LSRs (light blue area in figure 5). The protocol between them is OSPF.

3.2 MPLS protocol between providers

After all routers on MPLS domain being able to comunicate with each other (OSPF) we had to enable MPLS at the interfaces inside our light blue area.

MPLS is enabled as shown in figure 6 with command `mpls ip` at the corresponding interfaces.

```
!
!
!
interface FastEthernet0/0
 ip address 10.0.0.2 255.255.255.252
 duplex auto
 speed auto
 mpls ip
!
interface FastEthernet0/1
 ip address 10.0.0.13 255.255.255.252
 duplex auto
 speed auto
 mpls ip
!
interface FastEthernet1/0
 ip address 10.0.0.17 255.255.255.252
 duplex auto
 speed auto
 mpls ip
!
interface FastEthernet2/0
 no ip address
 shutdown
```

Figure 6: MPLS IP activation on interface

At this moment we have successfully deployed and MPLS network.

3.3 Create VRFs and attribute interfaces

Now that we have and MPLS network we want to config MPLS IP VPN on top of it, first we have to define and attribute VRFs. Each route has the syntax: `<ASN>:<customer_number>`.

The commands on the following images were used to define and attribute the VRFs.

```
ip vrf client1
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
ip vrf client2
 rd 100:2
 route-target export 100:2
 route-target import 100:2
```

Figure 7: Define VRF routes

```
!
interface FastEthernet0/1
 ip vrf forwarding client1
 ip address 172.16.1.1 255.255.255.0
 ip ospf 2 area 2
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip vrf forwarding client2
 ip address 172.16.1.2 255.255.255.0
 ip ospf 3 area 2
 duplex auto
 speed auto
!
```

Figure 8: Attribute VRF to each interface

3.4 MP-BGP on each PE

On a MPLS IP VPN, all PE routers must have MP-BGP protocol between them. So they can communicate the VRF routes they know.

The configuration for this is shown on the following image.

```
!
router bgp 100
 no synchronization
 bgp log-neighbor-changes
 neighbor 2.2.2.2 remote-as 100
 neighbor 2.2.2.2 update-source Loopback0
 neighbor 3.3.3.3 remote-as 100
 neighbor 3.3.3.3 update-source Loopback0
 neighbor 4.4.4.4 remote-as 100
 neighbor 4.4.4.4 update-source Loopback0
 no auto-summary
 !
 address-family vpnv4
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  neighbor 3.3.3.3 activate
  neighbor 3.3.3.3 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
 exit-address-family
 !
```

Figure 9: MP-BGP on PE-1

3.5 OSPF between PEs and CEs

PEs and CEs must be able to communicate. For this we use OSPF again, but with a different OSPF process than OSPF in MPLS domain.

Figure 10 displays the configuration of CE1-1.

```
!
interface Loopback0
 ip address 11.11.11.11 255.255.255.255
 ip ospf 2 area 2
!
interface FastEthernet0/0
 ip address 172.16.1.3 255.255.255.0
 ip ospf 2 area 2
 duplex auto
 speed auto
!
```

Figure 10: OSPF on PE-CE

3.6 Routes redistribution between CE and backbone

The configuration is almost finished. We just need to redistribute OSPF in BGP and BGP in OSPF.

This is configured as shown in figures 11 and 12.

```
router ospf 2 vrf client1
 router-id 222.222.222.1
 log-adjacency-changes
 redistribute bgp 100 subnets
!
router ospf 3 vrf client2
 log-adjacency-changes
 redistribute bgp 100 subnets
!
```

Figure 11: Redistribute OSPF in MP-BGP

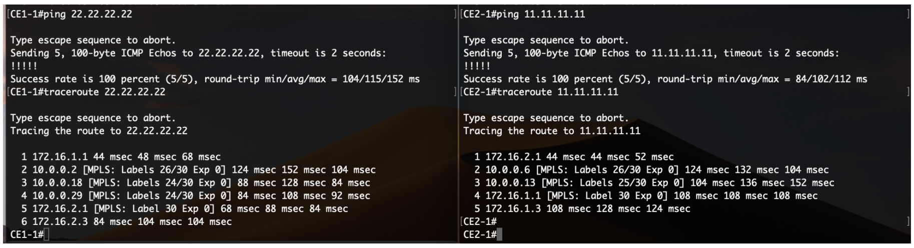
```
!
address-family ipv4 vrf client2
 redistribute ospf 3 vrf client2
 no synchronization
exit-address-family
!
address-family ipv4 vrf client1
 redistribute ospf 2 vrf client1
 no synchronization
exit-address-family
```

Figure 12: Redistribute MP-BGP in OSPF

4 Analysis of deployed network

To check if our network is working as expected, with MPLS IP VPN between customers we made a few pings, traceroutes and wireshark captures.

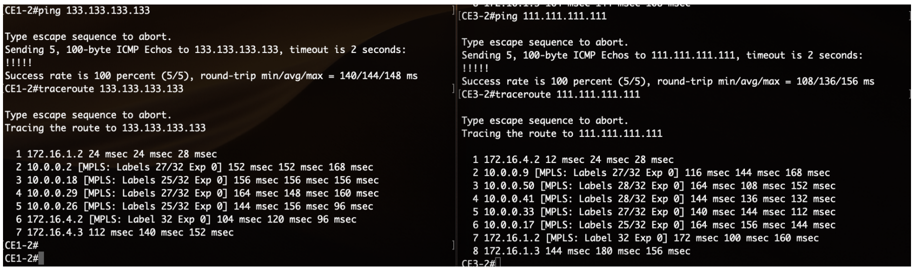
On the following images we can see a ping and traceroute between client1 VPN, CE1-1 <-> CE2-1 and client2 CE1-2 <-> CE3-2.



```
CE1-1#ping 22.22.22.22

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 22.22.22.22, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 104/115/152 ms
CE1-1#traceroute 22.22.22.22

Type escape sequence to abort.
Tracing the route to 22.22.22.22

  1 172.16.1.1 44 msec 48 msec 68 msec
  2 10.0.0.2 [MPLS: Labels 26/30 Exp 0] 124 msec 152 msec 104 msec
  3 10.0.0.18 [MPLS: Labels 24/30 Exp 0] 88 msec 128 msec 84 msec
  4 10.0.0.29 [MPLS: Labels 24/30 Exp 0] 84 msec 108 msec 92 msec
  5 172.16.2.1 [MPLS: Label 30 Exp 0] 68 msec 88 msec 84 msec
  6 172.16.2.3 84 msec 104 msec 104 msec
CE1-1#
```

```
CE2-1#ping 11.11.11.11

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 11.11.11.11, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/102/112 ms
CE2-1#traceroute 11.11.11.11

Type escape sequence to abort.
Tracing the route to 11.11.11.11

  1 172.16.2.1 44 msec 44 msec 52 msec
  2 10.0.0.6 [MPLS: Labels 26/30 Exp 0] 124 msec 132 msec 104 msec
  3 10.0.0.13 [MPLS: Labels 25/30 Exp 0] 104 msec 136 msec 152 msec
  4 172.16.1.1 [MPLS: Label 30 Exp 0] 108 msec 108 msec 108 msec
  5 172.16.1.3 108 msec 128 msec 124 msec
CE2-1#
CE2-1#
```

Figure 13: Ping and traceroute between client1 VPN



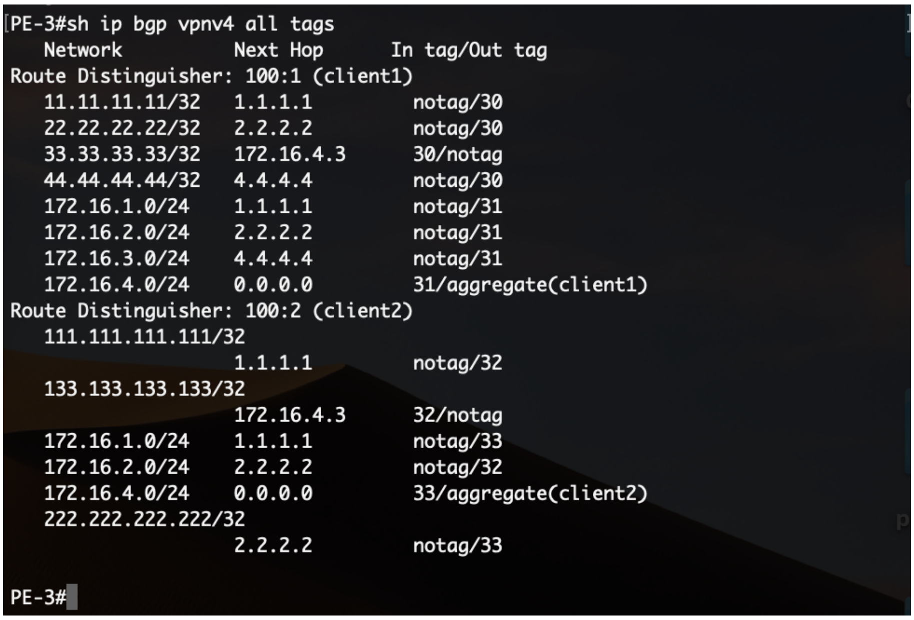
```
CE1-2#ping 133.133.133.133

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 133.133.133.133, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 140/144/148 ms
CE1-2#traceroute 133.133.133.133

Type escape sequence to abort.
Tracing the route to 133.133.133.133

  1 172.16.1.2 24 msec 24 msec 28 msec
  2 10.0.0.2 [MPLS: Labels 27/32 Exp 0] 152 msec 152 msec 168 msec
  3 10.0.0.18 [MPLS: Labels 25/32 Exp 0] 156 msec 156 msec 156 msec
  4 10.0.0.29 [MPLS: Labels 27/32 Exp 0] 164 msec 148 msec 160 msec
  5 10.0.0.26 [MPLS: Labels 25/32 Exp 0] 144 msec 156 msec 96 msec
  6 172.16.4.2 [MPLS: Label 32 Exp 0] 104 msec 120 msec 96 msec
  7 172.16.4.3 112 msec 140 msec 152 msec
CE1-2#
CE1-2#
```

```
CE3-2#ping 111.111.111.111

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 111.111.111.111, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 108/136/156 ms
CE3-2#traceroute 111.111.111.111

Type escape sequence to abort.
Tracing the route to 111.111.111.111

  1 172.16.4.2 12 msec 24 msec 28 msec
  2 10.0.0.9 [MPLS: Labels 27/32 Exp 0] 116 msec 144 msec 168 msec
  3 10.0.0.50 [MPLS: Labels 28/32 Exp 0] 164 msec 108 msec 152 msec
  4 10.0.0.41 [MPLS: Labels 28/32 Exp 0] 144 msec 136 msec 132 msec
  5 10.0.0.33 [MPLS: Labels 27/32 Exp 0] 140 msec 144 msec 112 msec
  6 10.0.0.17 [MPLS: Labels 25/32 Exp 0] 164 msec 156 msec 144 msec
  7 172.16.1.2 [MPLS: Label 32 Exp 0] 172 msec 100 msec 160 msec
  8 172.16.1.3 144 msec 180 msec 156 msec
CE3-2#
```

Figure 14: Ping and traceroute between client2 VPN

As we can see there are two labels on the traceroute, label 27/32 in CE2-1. These labels correspond to VPN (Virtual Private Network) and LDP (Label Distribution Protocol).

We know that the VPN label in this case is label 32 because on an MPLS IP VPN the LDP label is popped first. We can confirm this by looking at the tags table on PE-3 using `show ip bgp vpnv4 all tags`. As shown below.



```
PE-3#sh ip bgp vpnv4 all tags
   Network          Next Hop      In tag/Out tag
Route Distinguisher: 100:1 (client1)
   11.11.11.11/32   1.1.1.1         notag/30
   22.22.22.22/32   2.2.2.2         notag/30
   33.33.33.33/32   172.16.4.3      30/notag
   44.44.44.44/32   4.4.4.4         notag/30
   172.16.1.0/24    1.1.1.1         notag/31
   172.16.2.0/24    2.2.2.2         notag/31
   172.16.3.0/24    4.4.4.4         notag/31
   172.16.4.0/24    0.0.0.0         31/aggregate(client1)
Route Distinguisher: 100:2 (client2)
   111.111.111.111/32
                    1.1.1.1         notag/32
   133.133.133.133/32
                    172.16.4.3      32/notag
   172.16.1.0/24    1.1.1.1         notag/33
   172.16.2.0/24    2.2.2.2         notag/32
   172.16.4.0/24    0.0.0.0         33/aggregate(client2)
   222.222.222.222/32
                    2.2.2.2         notag/33

PE-3#
```

Figure 15: Output of `show ip bgp vpnv4 all tags` in PE-3

In addition to this tests we also made two wireshark captures. One at link PE-1 <-> LSR1 and another at LSR3 <-> PE-3. In the first we can see both VPN and LDP labels and at the last we only have the VPN label. This occurs because of the penultimate hop hopping property of the MPLS.

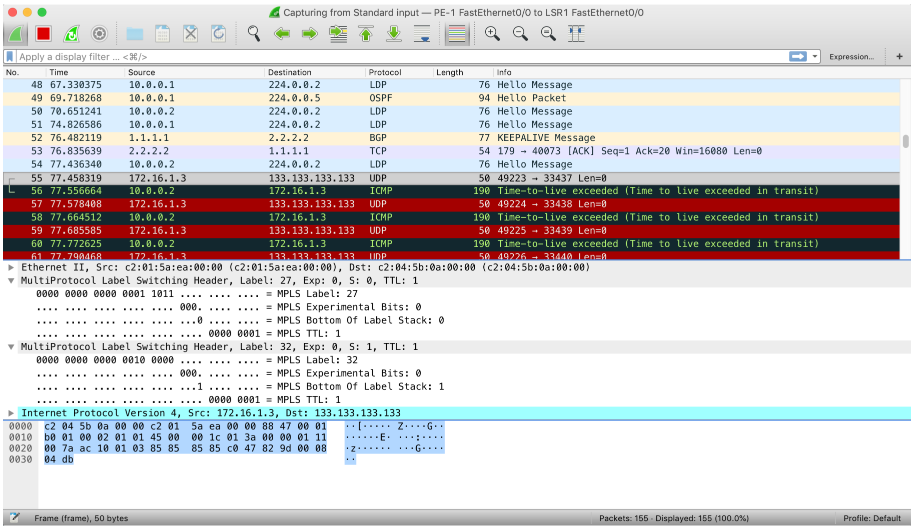


Figure 16: Wireshark capture on PE-1 <-> LSR1 link

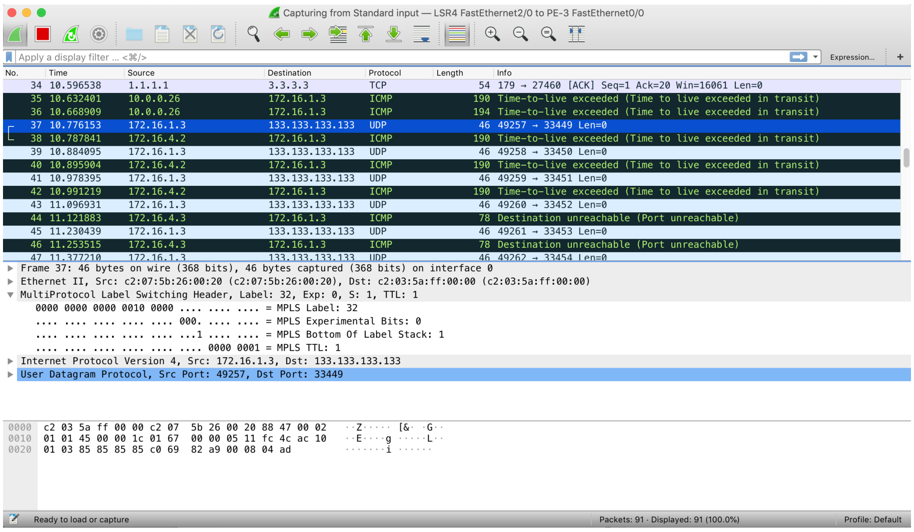


Figure 17: Wireshark capture on LSR3 <-> PE-3 link

5 Conclusions

The goal of these lab works, especially lab 3 were to simulate a real network, implement and understand MPLS and MPLS IP VPN.

We now understand the differences between MPLS IP VPN and the VPNs of the application level which we were used to work with.

We are glad we have implemented technology that is largely used worldwide by operators and we can see the potential of this protocols nowadays for instance to connect two offices of the same bank, separated by hundreds of kilometers or more.

We were able to reach the expected results and implement everything that was requested.

Annex:

A

Annex A - List of devices and IPs

Device	f0/0	f0/1	f1/0	f2/0	lo0
PE-1	10.0.0.1/30	172.16.1.1/24	172.16.1.2/24	unassigned	1.1.1.1
PE-2	10.0.0.5/30	172.16.2.1/24	172.16.2.2/24	unassigned	2.2.2.2
PE-3	10.0.0.10/30	172.16.4.1/24	172.16.4.2/24	unassigned	3.3.3.3
PE-4	10.0.0.46/30	172.16.3.1/24	unassigned	unassigned	4.4.4.4
LSR1	10.0.0.2/30	10.0.0.13/30	10.0.0.17/30	unassigned	unassigned
LSR2	10.0.0.6/30	10.0.0.14/30	10.0.0.25/30	10.0.0.29/30	unassigned
LSR3	10.0.0.18/30	10.0.0.21/30	10.0.0.30/30	10.0.0.33/30	unassigned
LSR4	10.0.0.26/30	10.0.0.22/30	10.0.0.49/30	10.0.0.9/30	unassigned
LSR5	10.0.0.45/30	10.0.0.41/30	10.0.0.34/29	unassigned	unassigned
LSR6	10.0.0.35/30	10.0.0.50/30	10.0.0.42/29	unassigned	unassigned
CE1-1	172.16.1.3/24	unassigned	unassigned	unassigned	11.11.11.11
CE1-2	unassigned	172.16.1.3/24	unassigned	unassigned	111.111.111.111
CE2-1	172.16.2.3/24	unassigned	unassigned	unassigned	22.22.22.22
CE2-2	unassigned	172.16.1.3/24	unassigned	unassigned	222.222.222.222
CE3-1	172.16.4.3/24	unassigned	unassigned	unassigned	33.33.33.33
CE3-2	172.16.1.3/24	unassigned	unassigned	unassigned	133.133.133.133
CE4-1	unassigned	172.16.3.3/24	unassigned	unassigned	44.44.44.44