SAN JOSE STATE UNIVERSITY

SPRING 2017

SAN JOSÉ STATE UNIVERSITY

EE 283 – BROADBAND COMMUNICATION NETWORKING

SIMULATION OF MPLS LABEL DESCRIPTION PROTOCOL USING GNS3

ADDITIONAL- ADVANCED MPLS USING VRF AND BGP AND TRAFFIC ENGINEERING

SUPERVISOR – PROF. NADER MIR

TEAM MEMBERS

SAISHRUTHI SWAMINATHAN – 011430939 (Mo-We 1:30-2:45)

VAIDEHEE BARDE – 011447267 (Mo-We 4:30-5:45)

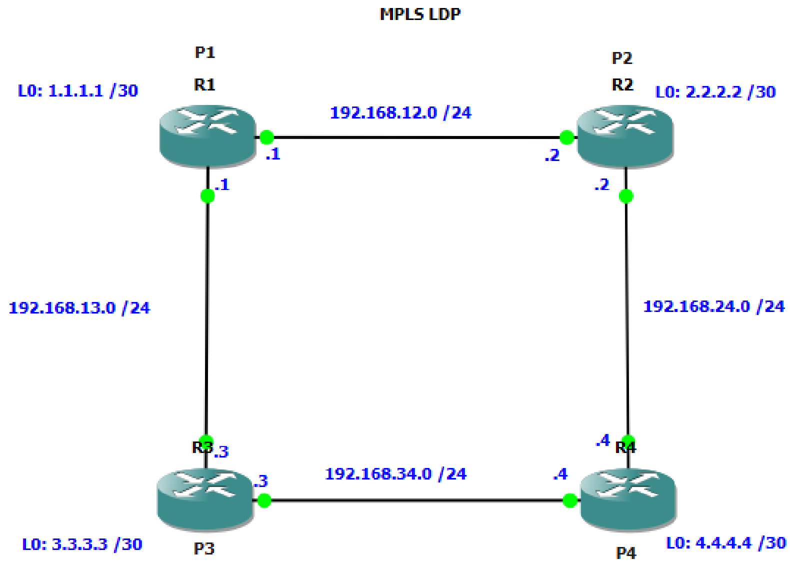
ABSTRACT

The Internet has grown explosively in the past years. In addition to this growth, the advent of sophisticated services requires an effective change. MPLS was proposed as an effect to bring about these changes.

The main goal of this project is to understand the working of an MPLS network. In this project, we try to understand and learn the concept of GNS3 which is a popular computer communication network simulation tool. We understand how to simulate computer networks such as multi-protocol label switching (MPLS) networks. We also try to understand the basics of Cisco IOS using CLI (Command line interface).

Also, we will be implementing advanced MPLS using VRF and BGP in addition to the basic part along with traffic engineering.

NETWORK DIAGRAM



Router used: CISCO 3640

- This topology connects 4 CISCO 3640 routers using fast ethernet links.
- Drag four C3640 routers from browse router pane to the map pane
- Select the link and connect the routers to the desired interfaces.
- Interface f0/0 of R1 is connected to f0/0 of R2

  Interface f1/0 of R1 is connected to f0/0 of R3

  Interface f1/0 of R2 is connected to f0/0 of R4

  Interface f1/0 of R3 is connected to f1/0 of R4

MPLS

- Multi Protocol Label switching is a protocol for speeding up and shaping network traffic flows.
- MPLS protocol – This protocol is used to direct data from one network node to the next network node. The next network node is based on short path labels rather than long network addresses. This avoids complex lookups in a routing table.
- It allows most of the packets to be forwarded at layer 2 which is switching level rather than having to be passed up to layer 3.
- The ingress router labels each packet on entry into the service provider's network.
- Packet forwarding is performed by all the subsequent routing switches based only on those labels—they never look as far as the IP header.
- The label is finally removed by the egress router and the original IP packet is forwarded towards its final destination.

LDP

- In Label Distribution Protocol (LDP), the routers are capable of Multiprotocol Label Switching (MPLS) exchange label mapping information. LDP peers are two routers with an established session to exchange information.
- This information exchange is bidirectional. LDP is used to build and maintain LSP databases. These are used to forward traffic through MPLS networks.

LABEL ASSIGNMENT AND DISTRIBUTION

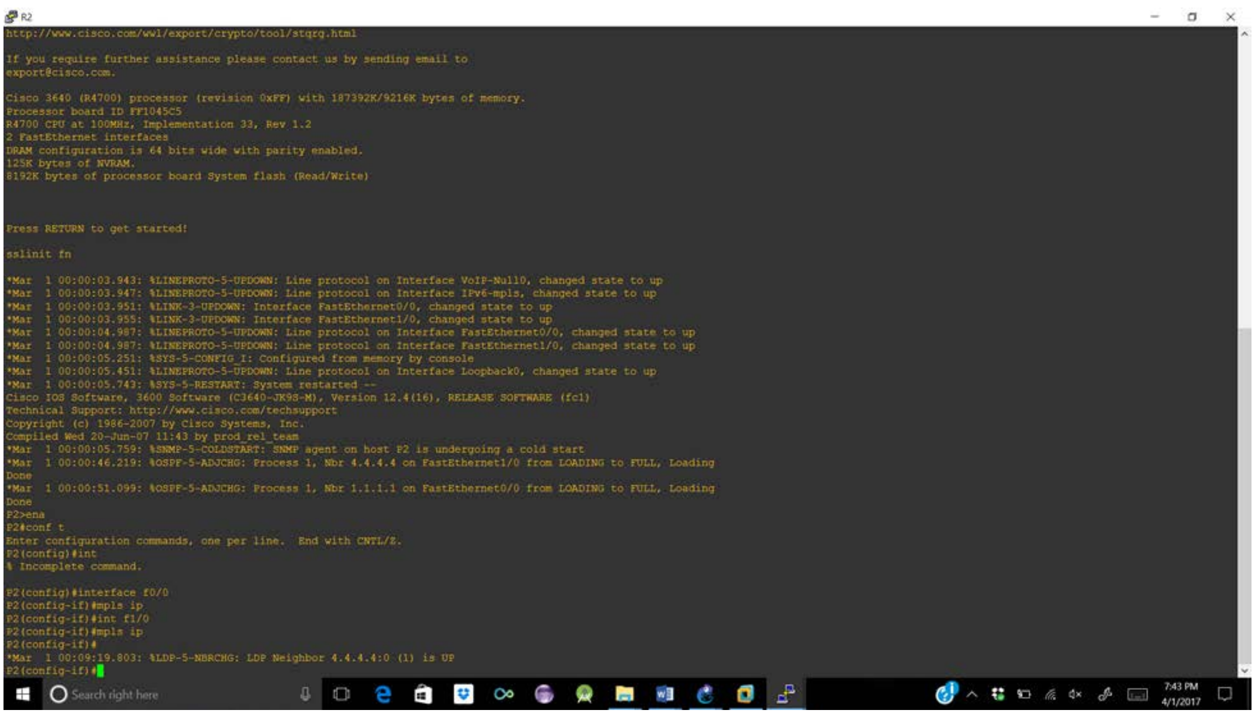
- In the MPLS architecture, the decision to bind a label L to a particular FEC F is made by the LSR which is DOWNSTREAM with respect to that binding.
- The downstream LSR then informs the upstream LSR of the binding. Thus, labels are "downstream-assigned", and label bindings are distributed in the "downstream to upstream" direction.
- If an LSR has been designed so that it can only look up labels that fall into a certain numeric range, then it merely needs to ensure that it only binds labels that are in that range.

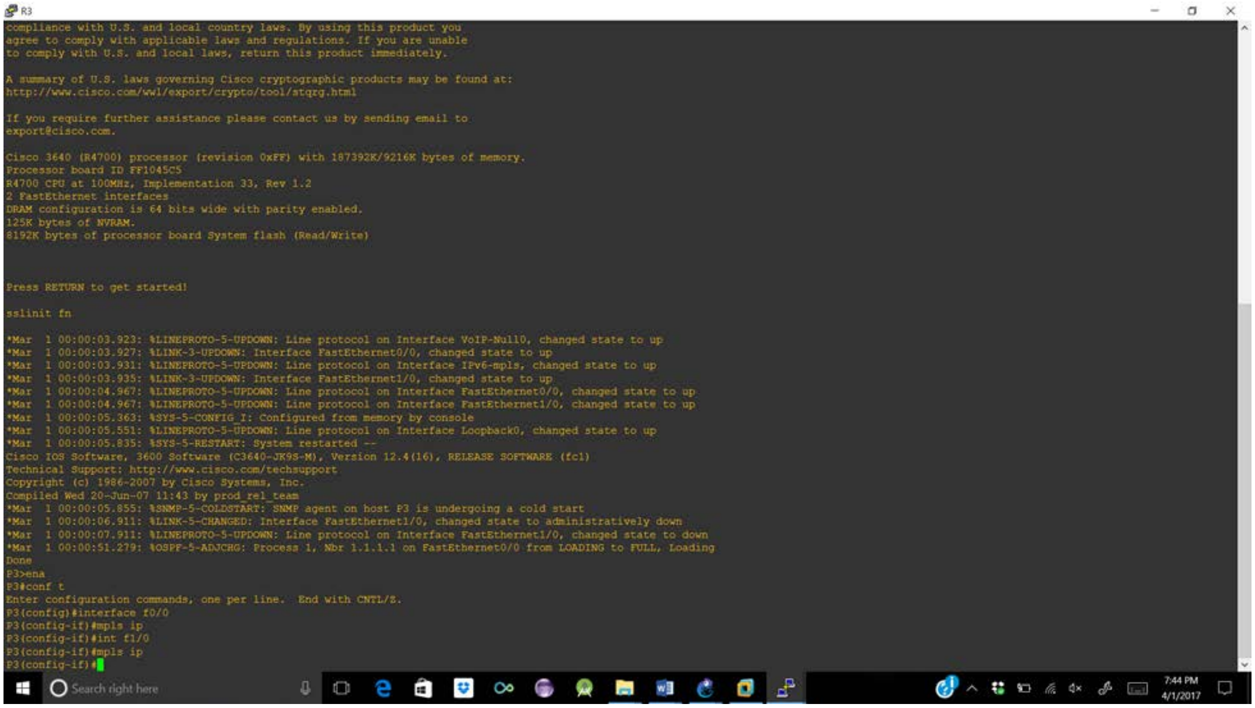
STEP BY STEP EXPLANATION OF THE CODE

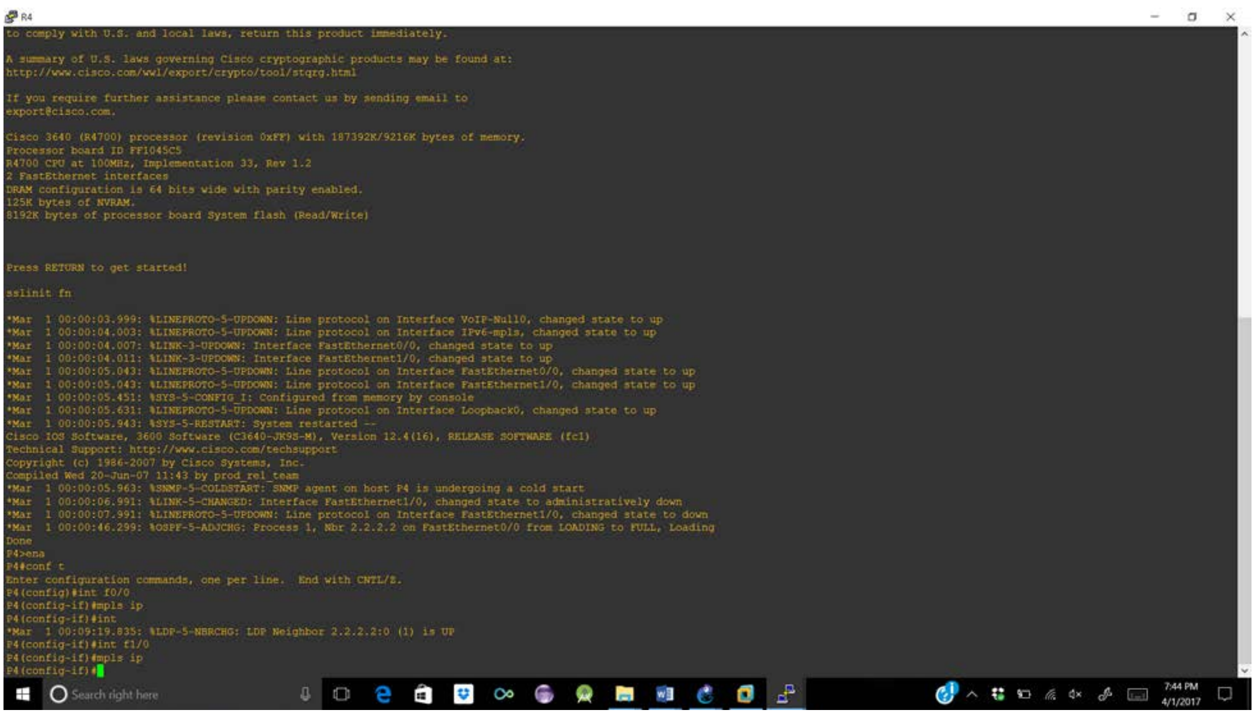
STEP 1: Configure router P2, P3 and P4 to activate MPLS an IETF standard MPLS protocol.

mpls ip – It is used to globally configure MPLS hop-by-hop. Router interfaces are not enabled just by globally enabling MPLS forwarding. You must enable MPLS forwarding on both, the interfaces and the router.

OBSERVATION




R3
compliance with U.S. and local country laws. By using this product you
agree to comply with applicable laws and regulations. If you are unable
to comply with U.S. and local laws, return this product immediately.
A summary of U.S. laws governing Cisco cryptographic products may be found at:
http://www.cisco.com/wwl/export/crypto/tool/stqrg.html
If you require further assistance please contact us by sending email to
export@cisco.com.
Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
Processor board ID FF1045C5
R4700 CPU at 100MHz, Implementation 33, Rev 1.2
2 FastEthernet interfaces
DRAM configuration is 64 bits wide with parity enabled.
125K bytes of NVRAM.
8192K bytes of processor board System flash (Read/Write)
Press RETURN to get started!
sslinit fn
*Mar 1 00:00:03.923: %LINEPROTO-5-UPDOWN: Line protocol on Interface VoIP-Null0, changed state to up
*Mar 1 00:00:03.927: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:03.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:03.935: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.363: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.551: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.835: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.855: %SNMP-5-COLDSTART: SNMP agent on host P3 is undergoing a cold start
*Mar 1 00:00:06.911: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Mar 1 00:00:07.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Mar 1 00:00:51.279: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading
Done
P3>ena
P3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P3(config)#interface f0/0
P3(config-if)#mpls ip
P3(config-if)#int f1/0
P3(config-if)#mpls ip
P3(config-if)#
Search right here
7:44 PM
4/1/2017


R4
to comply with U.S. and local laws, return this product immediately.
A summary of U.S. laws governing Cisco cryptographic products may be found at:
http://www.cisco.com/wwl/export/crypto/tool/stqrg.html
If you require further assistance please contact us by sending email to
export@cisco.com.
Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
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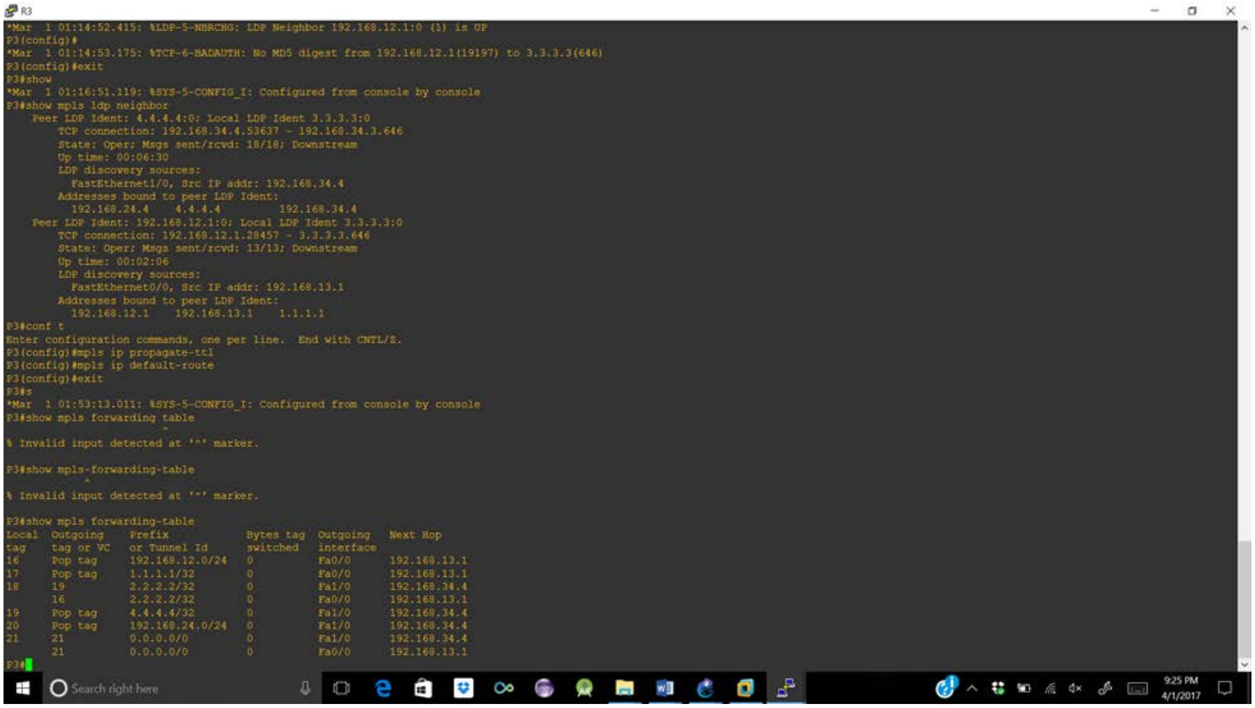
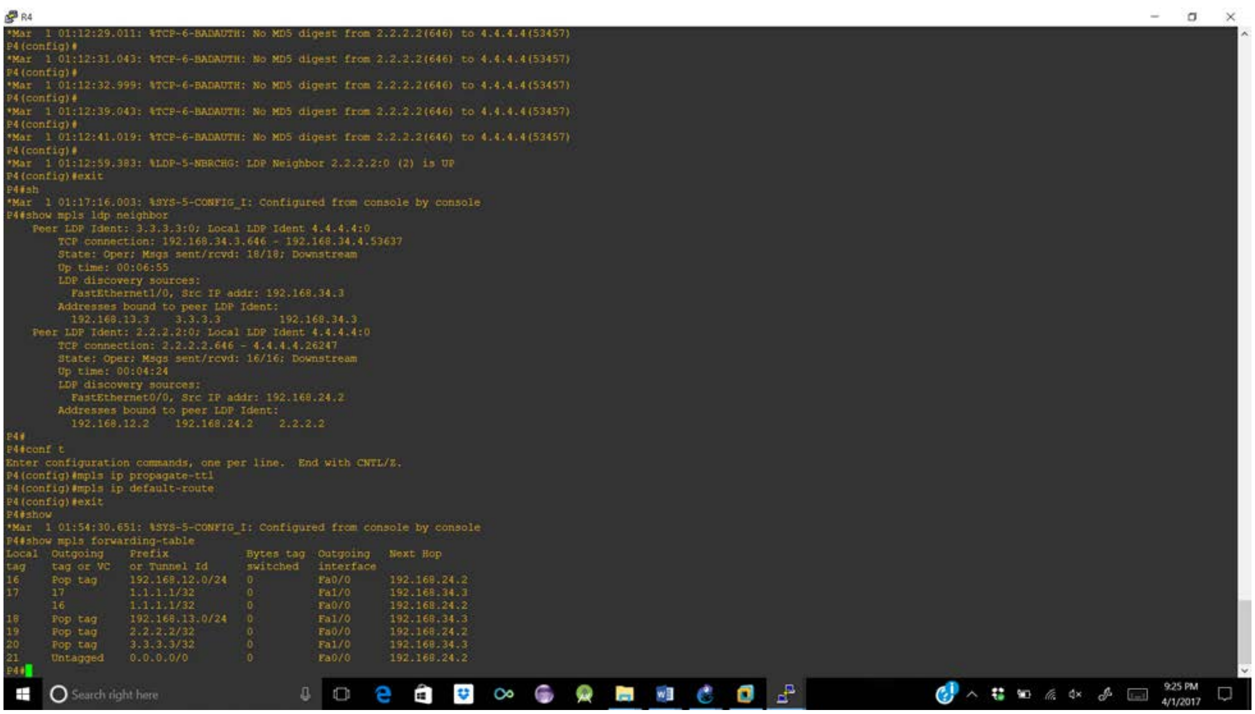
*Mar 1 00:00:04.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:04.007: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.011: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:05.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.451: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.943: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.963: %SNMP-5-COLDSTART: SNMP agent on host P4 is undergoing a cold start
*Mar 1 00:00:06.991: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Mar 1 00:00:07.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Mar 1 00:00:46.299: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading
Done
P4>ena
P4#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P4(config)#int f0/0
P4(config-if)#mpls ip
P4(config-if)#int
*Mar 1 00:09:19.835: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
P4(config-if)#int f1/0
P4(config-if)#mpls ip
P4(config-if)#
Search right here
7:44 PM
4/1/2017




```
*Mar  1 01:14:52.415: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (1) is UP
P3(config)#
*Mar  1 01:14:53.175: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#exit
P3#show
*Mar  1 01:16:51.119: %SYS-5-CONFIG_I: Configured from console by console
P3#show mpls ldp neighbor
    Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.34.4.53637 - 192.168.34.3.646
        State: Oper; Msgs sent/rcvd: 18/18; Downstream
        Up time: 00:06:30
        LDP discovery sources:
          FastEthernet1/0, Src IP addr: 192.168.34.4
        Addresses bound to peer LDP Ident:
          192.168.24.4    4.4.4.4         192.168.34.4
    Peer LDP Ident: 192.168.12.1:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.12.1.28457 - 3.3.3.3.646
        State: Oper; Msgs sent/rcvd: 13/13; Downstream
        Up time: 00:02:06
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.13.1
        Addresses bound to peer LDP Ident:
          192.168.12.1    192.168.13.1    1.1.1.1
P3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
P3(config)#mpls ip propagate-ttl
P3(config)#mpls ip default-route
P3(config)#exit
P3#s
*Mar  1 01:53:13.011: %SYS-5-CONFIG_I: Configured from console by console
P3#show mpls forwarding table
                        ^
% Invalid input detected at '^' marker.

P3#show mpls-forwarding-table
            ^
% Invalid input detected at '^' marker.

P3#show mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     192.168.12.0/24   0          Fa0/0      192.168.13.1
17     Pop tag     1.1.1.1/32        0          Fa0/0      192.168.13.1
18     19          2.2.2.2/32        0          Fa1/0      192.168.34.4
       16          2.2.2.2/32        0          Fa0/0      192.168.13.1
19     Pop tag     4.4.4.4/32        0          Fa1/0      192.168.34.4
20     Pop tag     192.168.24.0/24   0          Fa1/0      192.168.34.4
21     21          0.0.0.0/0         0          Fa1/0      192.168.34.4
       21          0.0.0.0/0         0          Fa0/0      192.168.13.1
P3#
```



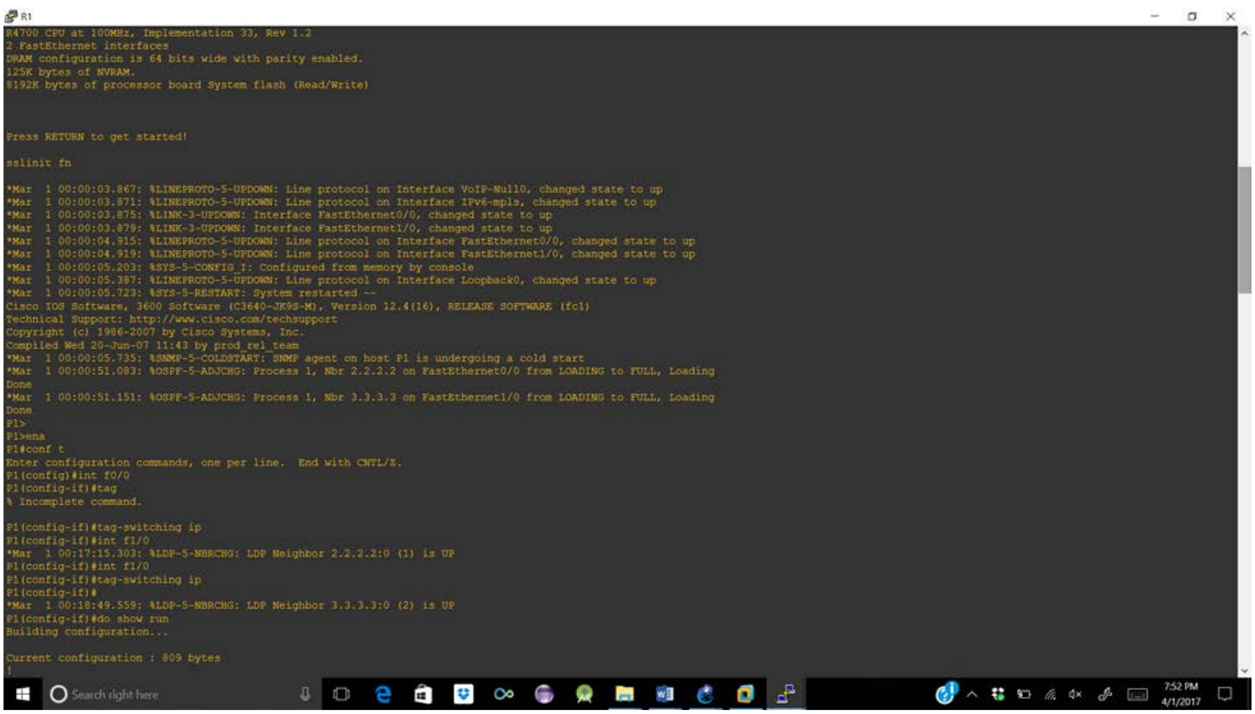

```
*Mar  1 01:12:29.011: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar  1 01:12:31.043: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar  1 01:12:32.999: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar  1 01:12:39.043: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar  1 01:12:41.019: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar  1 01:12:59.383: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (2) is UP
P4(config)#exit
P4#sh
*Mar  1 01:17:16.003: %SYS-5-CONFIG_I: Configured from console by console
P4#show mpls ldp neighbor
    Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 4.4.4.4:0
        TCP connection: 192.168.34.3.646 - 192.168.34.4.53637
        State: Oper; Msgs sent/rcvd: 18/18; Downstream
        Up time: 00:06:55
        LDP discovery sources:
          FastEthernet1/0, Src IP addr: 192.168.34.3
        Addresses bound to peer LDP Ident:
          192.168.13.3    3.3.3.3         192.168.34.3
    Peer LDP Ident: 2.2.2.2:0; Local LDP Ident 4.4.4.4:0
        TCP connection: 2.2.2.2.646 - 4.4.4.4.26247
        State: Oper; Msgs sent/rcvd: 16/16; Downstream
        Up time: 00:04:24
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.24.2
        Addresses bound to peer LDP Ident:
          192.168.12.2    192.168.24.2    2.2.2.2
P4#
P4#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
P4(config)#mpls ip propagate-ttl
P4(config)#mpls ip default-route
P4(config)#exit
P4#show
*Mar  1 01:54:30.651: %SYS-5-CONFIG_I: Configured from console by console
P4#show mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     192.168.12.0/24   0          Fa0/0      192.168.24.2
17     17          1.1.1.1/32        0          Fa1/0      192.168.34.3
       16          1.1.1.1/32        0          Fa0/0      192.168.24.2
18     Pop tag     192.168.13.0/24   0          Fa1/0      192.168.34.3
19     Pop tag     2.2.2.2/32        0          Fa0/0      192.168.24.2
20     Pop tag     3.3.3.3/32        0          Fa1/0      192.168.34.3
21     Untagged    0.0.0.0/0         0          Fa0/0      192.168.24.2
P4#
```

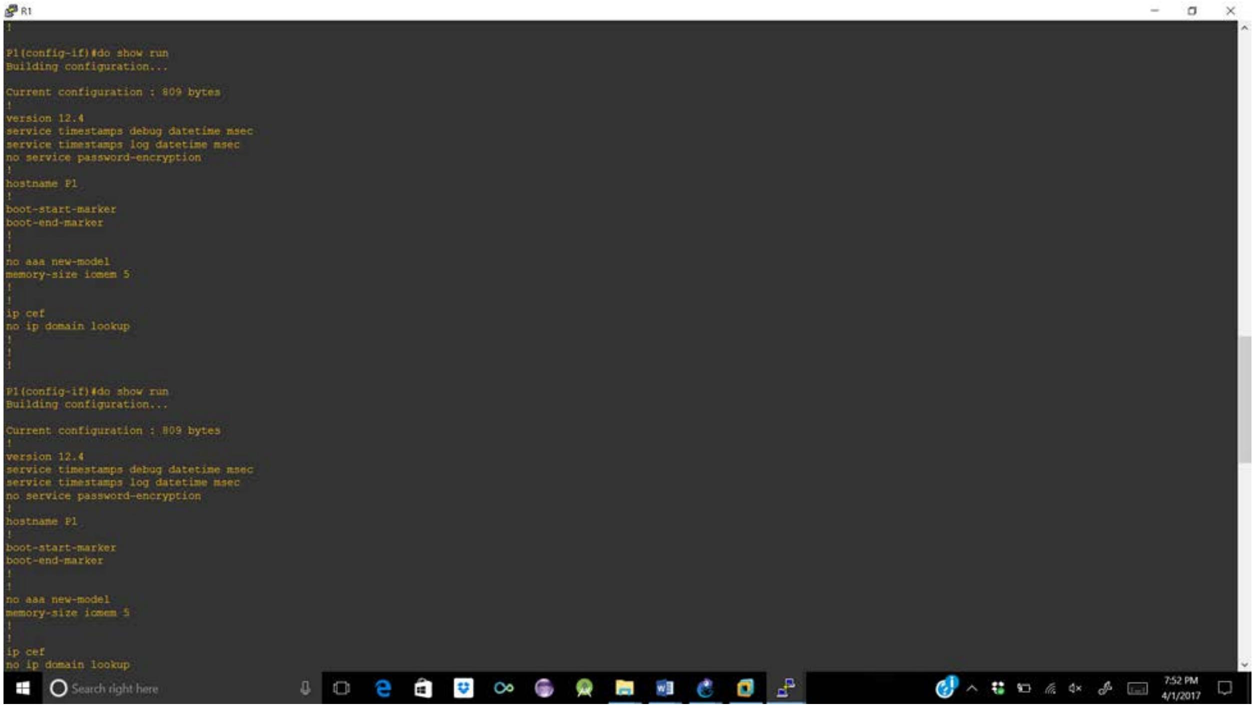
STEP 2: Configure router P1 to enable the same MPLS protocol without using the ‘mpls ip’ command.

Tag switching is a flexible and efficient network communication mechanism. Internet Protocol (IP) traffic is transmitted over a telecommunications network. Different networking routes are supported by tag switching. Tag switching is also known as label switching.

‘do show run’ command shows the current configuration of the router, switch, or firewall. This configuration is the config that is present in the router's memory.

OBSERVATION




R1
P1(config-if)#do show run
Building configuration...
Current configuration : 809 bytes
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
hostname P1
boot-start-marker
boot-end-marker
no aaa new-model
memory-size iomem 5
ip cef
no ip domain lookup
P1(config-if)#do show run
Building configuration...
Current configuration : 809 bytes
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
hostname P1
boot-start-marker
boot-end-marker
no aaa new-model
memory-size iomem 5
ip cef
no ip domain lookup
Search right here
7:52 PM
4/1/2017

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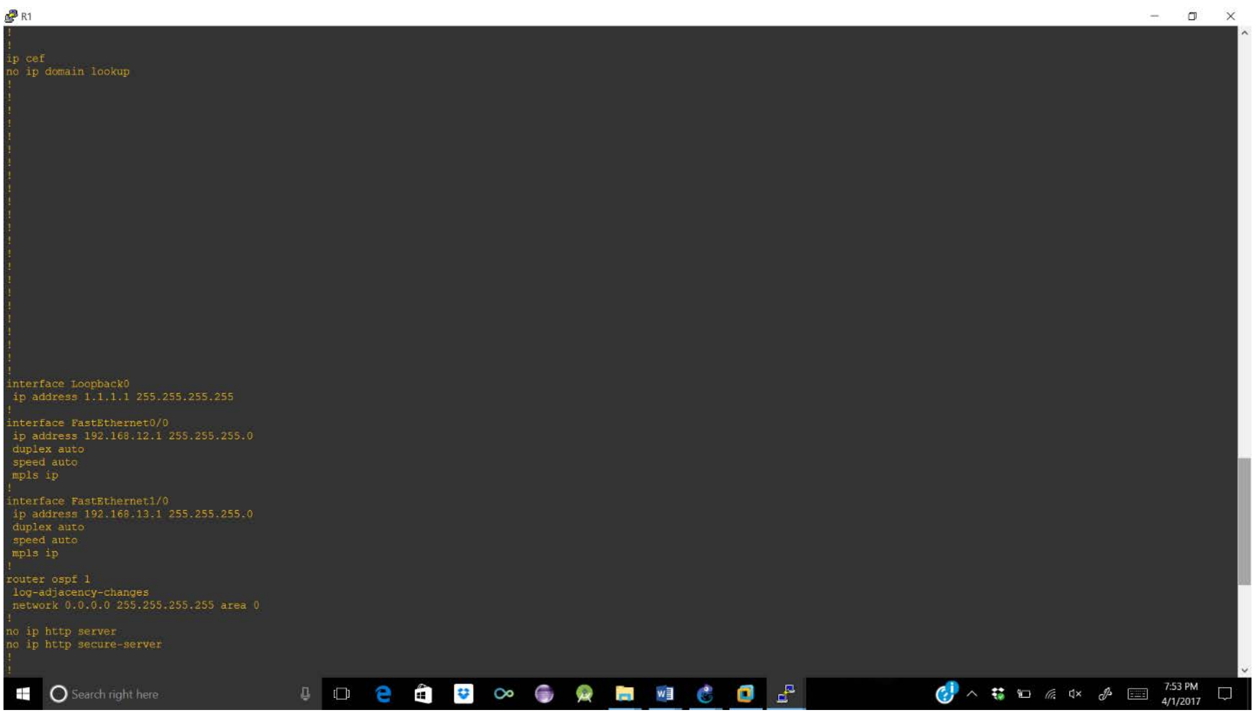
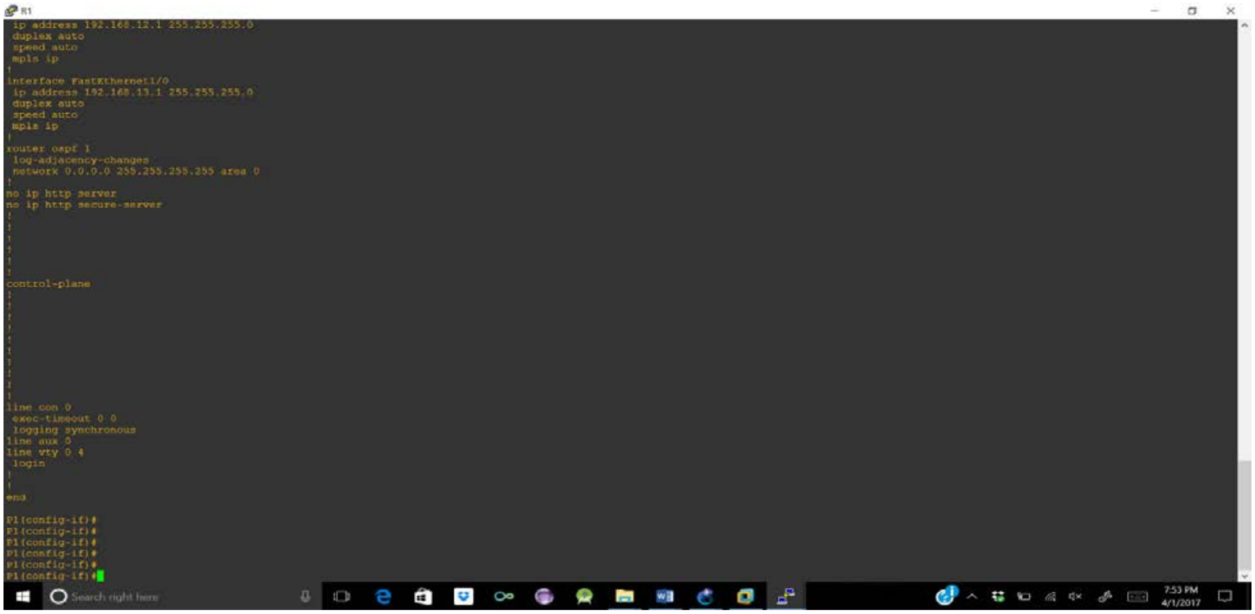
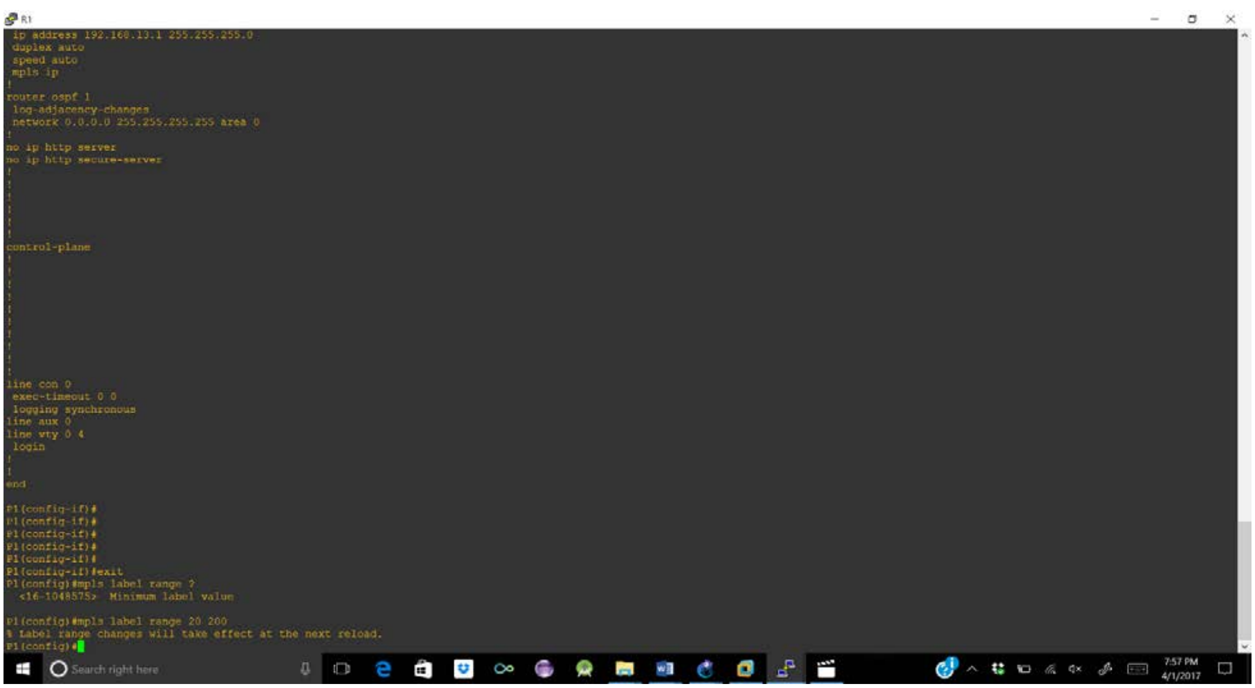

R1
ip cef
no ip domain lookup
interface Loopback0
ip address 1.1.1.1 255.255.255.255
interface FastEthernet0/0
ip address 192.168.12.1 255.255.255.0
duplex auto
speed auto
mpls ip
interface FastEthernet1/0
ip address 192.168.13.1 255.255.255.0
duplex auto
speed auto
mpls ip
router ospf 1
log-adjacency-changes
network 0.0.0.0 255.255.255.255 area 0
no ip http server
no ip http secure-server
Search right here
7:53 PM
4/1/2017

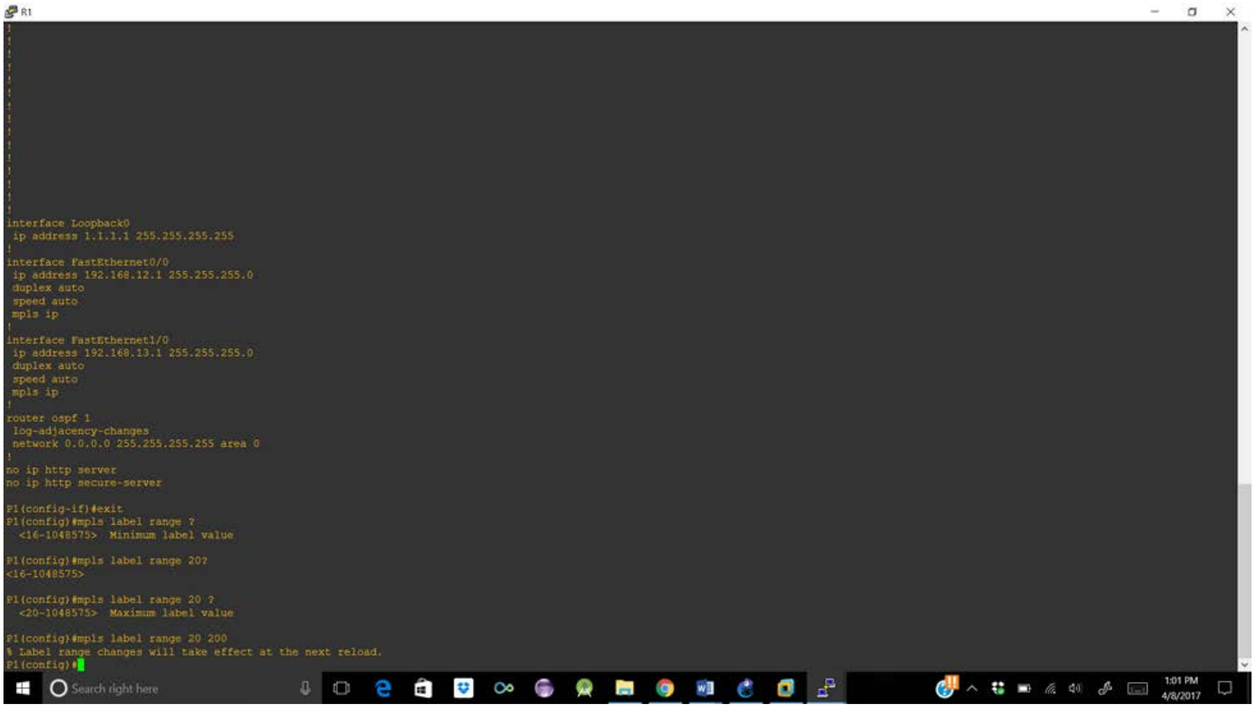


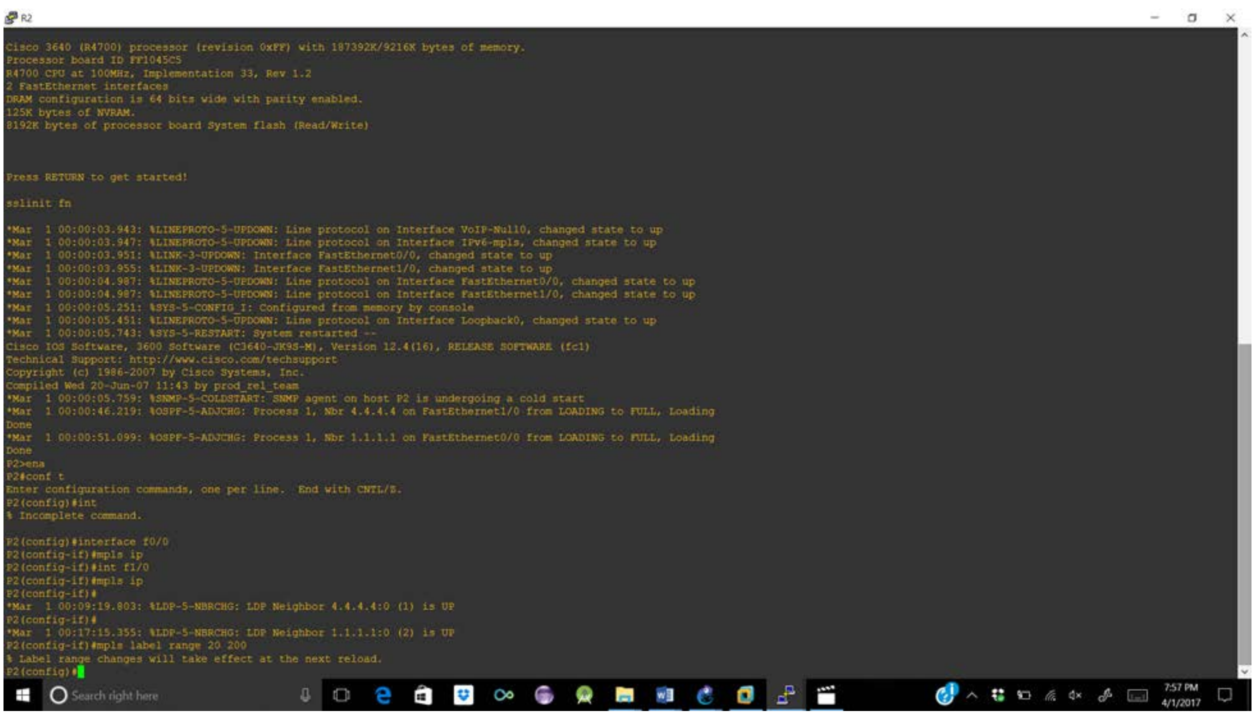
STEP 3: Configure all routers so only label range 20 – 200 will be used.

The default MPLS label range for cisco router 3640 used in the topology is 16-1048575.

Label range – Using the label range command, the header for the label ranges are configured using commands label-range min-value value max-value value. Thus, using these commands, we set a label range.




R1
!
interface Loopback0
ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
ip address 192.168.12.1 255.255.255.0
duplex auto
speed auto
mpls ip
!
interface FastEthernet1/0
ip address 192.168.13.1 255.255.255.0
duplex auto
speed auto
mpls ip
!
router ospf 1
log-adjacency-changes
network 0.0.0.0 255.255.255.255 area 0
!
no ip http server
no ip http secure-server
P1(config-if)#exit
P1(config)#mpls label range ?
<16-1048575> Minimum label value
P1(config)#mpls label range 20?
<16-1048575>
P1(config)#mpls label range 20 ?
<20-1048575> Maximum label value
P1(config)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P1(config)#
Search right here
1:01 PM
4/8/2017


R2
Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
Processor board ID FF1045C5
R4700 CPU at 100MHz, Implementation 33, Rev 1.2
2 FastEthernet interfaces
DRAM configuration is 64 bits wide with parity enabled.
125K bytes of NVRAM.
8192K bytes of processor board System flash (Read/Write)
Press RETURN to get started!
sslinit fn
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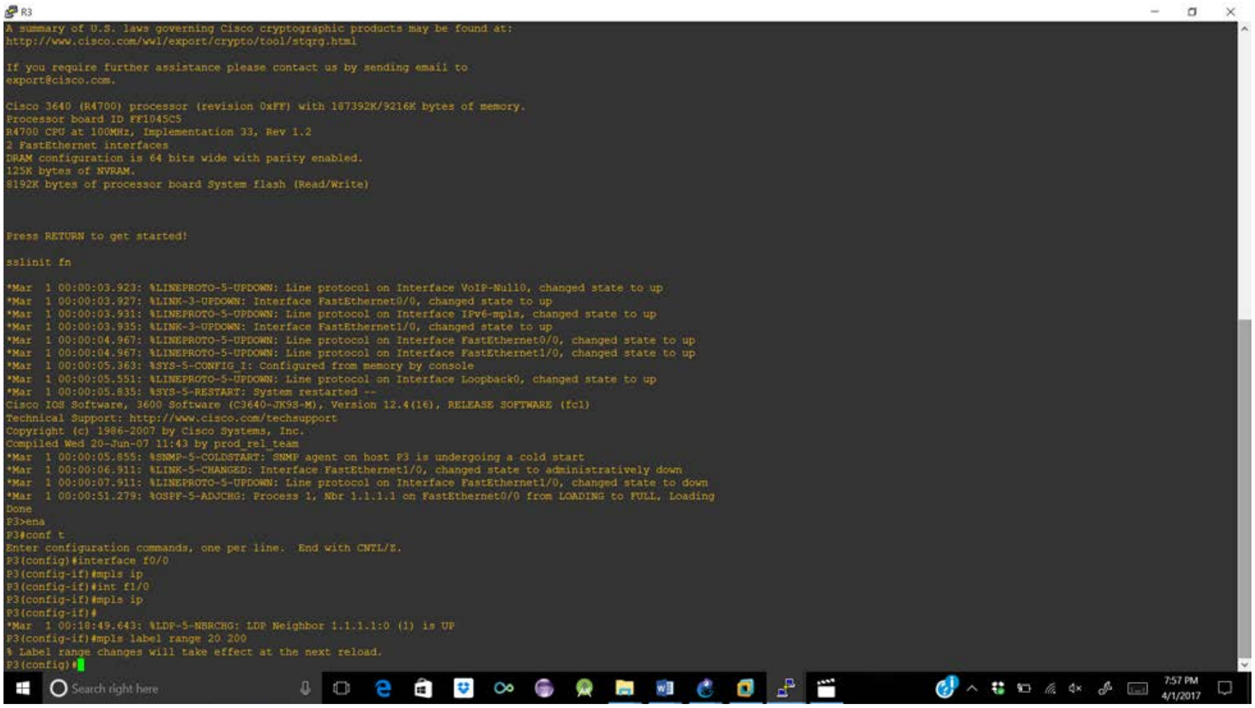
*Mar 1 00:00:03.947: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:03.951: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:03.955: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:04.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.251: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.451: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.743: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.759: %SNMP-5-COLDSTART: SNMP agent on host P2 is undergoing a cold start
*Mar 1 00:00:46.219: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on FastEthernet1/0 from LOADING to FULL, Loading Done
*Mar 1 00:00:51.099: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
P2>ena
P2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P2(config)#int
% Incomplete command.
P2(config)#interface f0/0
P2(config-if)#mpls ip
P2(config-if)#int f1/0
P2(config-if)#mpls ip
P2(config-if)#
*Mar 1 00:09:19.803: %LDP-5-NBRCHG: LDP Neighbor 4.4.4.4:0 (1) is UP
P2(config-if)#
*Mar 1 00:17:15.355: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (2) is UP
P2(config-if)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P2(config)#
Search right here
7:57 PM
4/1/2017


R3
A summary of U.S. laws governing Cisco cryptographic products may be found at:
http://www.cisco.com/wwl/export/crypto/tool/stqrg.html

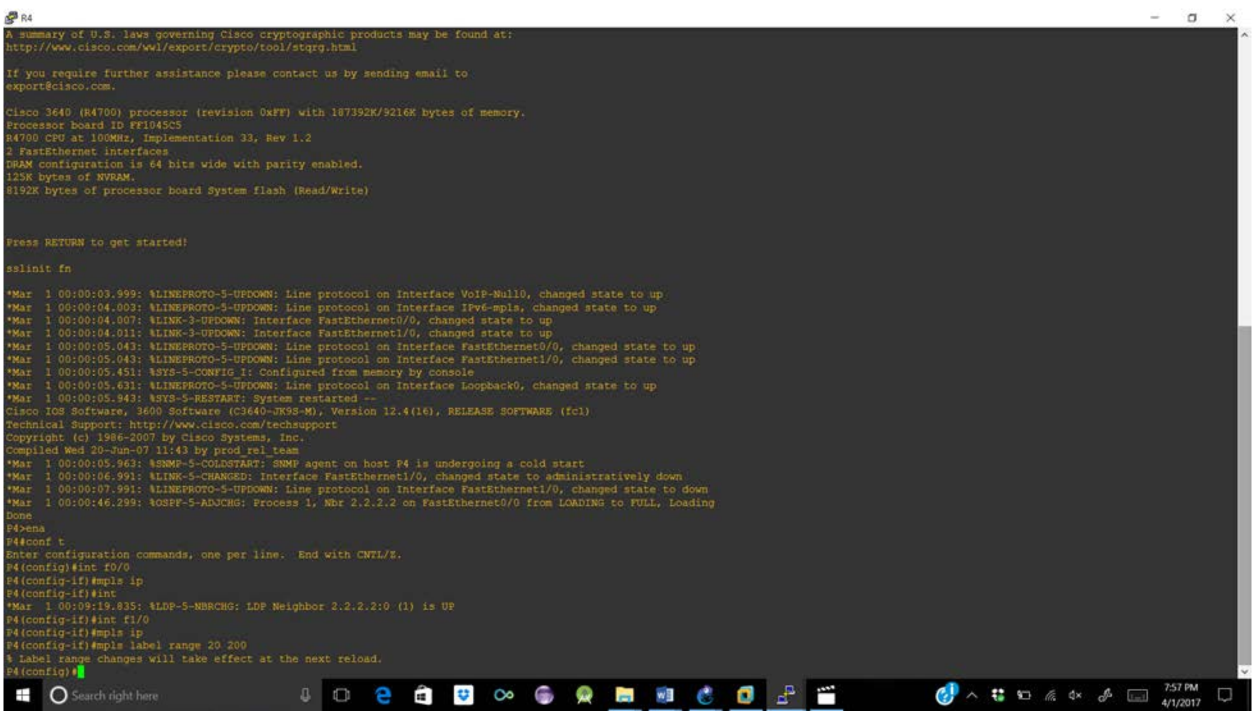
If you require further assistance please contact us by sending email to
export@cisco.com.

Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
Processor board ID FF1045C5
R4700 CPU at 100MHz, Implementation 33, Rev 1.2
2 FastEthernet interfaces
DRAM configuration is 64 bits wide with parity enabled.
125K bytes of NVRAM.
8192K bytes of processor board System flash (Read/Write)

Press RETURN to get started!

sslinit fn

*Mar 1 00:00:03.923: %LINEPROTO-5-UPDOWN: Line protocol on Interface VoIP-Null0, changed state to up
*Mar 1 00:00:03.927: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:03.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:03.935: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.363: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.551: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.835: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.855: %SNMP-5-COLDSTART: SNMP agent on host P3 is undergoing a cold start
*Mar 1 00:00:06.911: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Mar 1 00:00:07.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Mar 1 00:00:51.279: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading
Done
P3>ena
P3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P3(config)#interface f0/0
P3(config-if)#mpls ip
P3(config-if)#int f1/0
P3(config-if)#mpls ip
P3(config-if)#
*Mar 1 00:18:49.643: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
P3(config-if)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P3(config)#
Search right here
7:57 PM
4/1/2017


R4
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http://www.cisco.com/wwl/export/crypto/tool/stqrg.html

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Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
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R4700 CPU at 100MHz, Implementation 33, Rev 1.2
2 FastEthernet interfaces
DRAM configuration is 64 bits wide with parity enabled.
125K bytes of NVRAM.
8192K bytes of processor board System flash (Read/Write)

Press RETURN to get started!

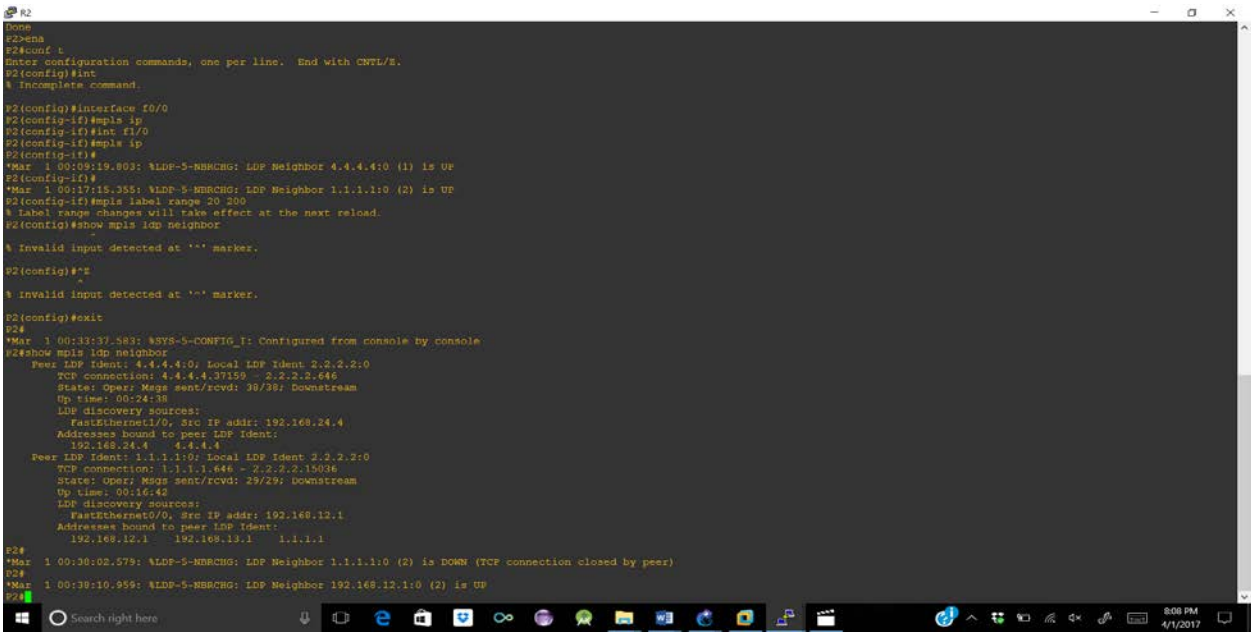
sslinit fn

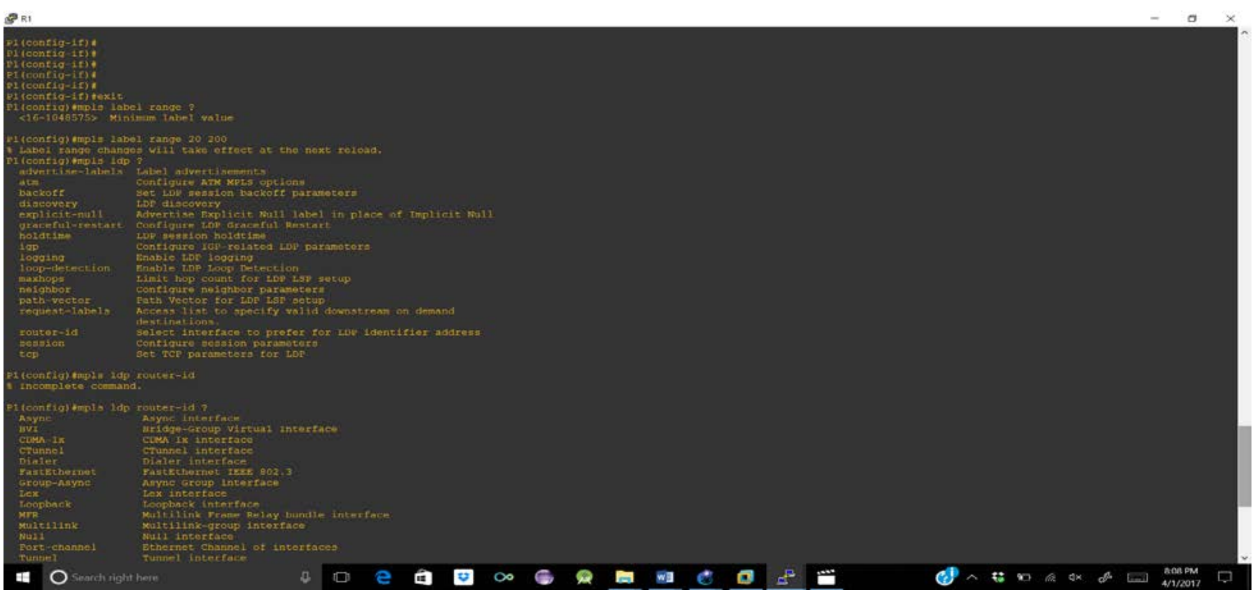
*Mar 1 00:00:03.999: %LINEPROTO-5-UPDOWN: Line protocol on Interface VoIP-Null0, changed state to up
*Mar 1 00:00:04.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:04.007: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.011: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:05.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.451: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.943: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.963: %SNMP-5-COLDSTART: SNMP agent on host P4 is undergoing a cold start
*Mar 1 00:00:06.991: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Mar 1 00:00:07.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Mar 1 00:00:46.299: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading
Done
P4>ena
P4#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P4(config)#int f0/0
P4(config-if)#mpls ip
P4(config-if)#int
*Mar 1 00:09:19.835: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
P4(config-if)#int f1/0
P4(config-if)#mpls ip
P4(config-if)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P4(config)#
Search right here
7:57 PM
4/1/2017

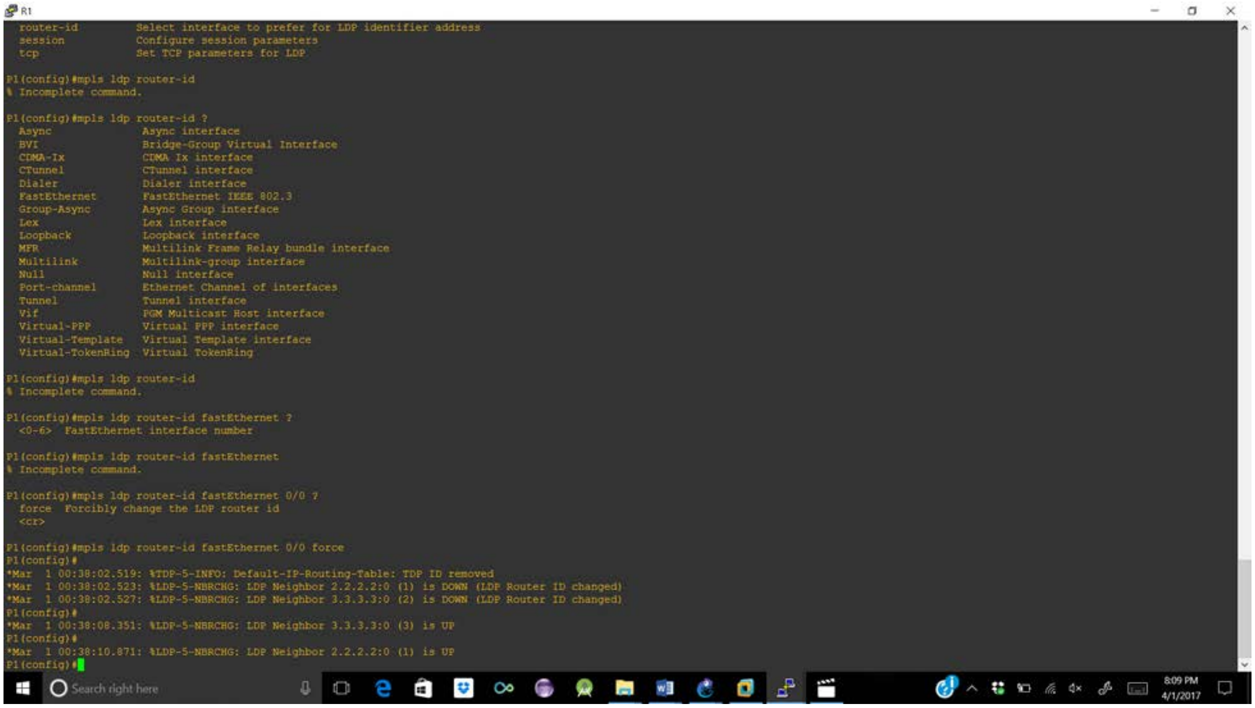
STEP 4: Configure router P1 to use the IP address on the F0/0 interface as the MPLS Router-ID

‘show mpls ldp neighbor’ command is the command that configures Label Distribution Protocol (LDP) in a Multiprotocol Label Switching (MPLS) network. It also provides the means for label switching routers (LSRs) to request, distribute, and release label prefix binding information to peer routers in a network. This command displays the status of LDP sessions.

‘mpls ldp router-id fastEthernet 0/0 force’ command







STEP 5: Configure all routers to send the MPLS Hello every 2 seconds, the holdtime should be 10 seconds.

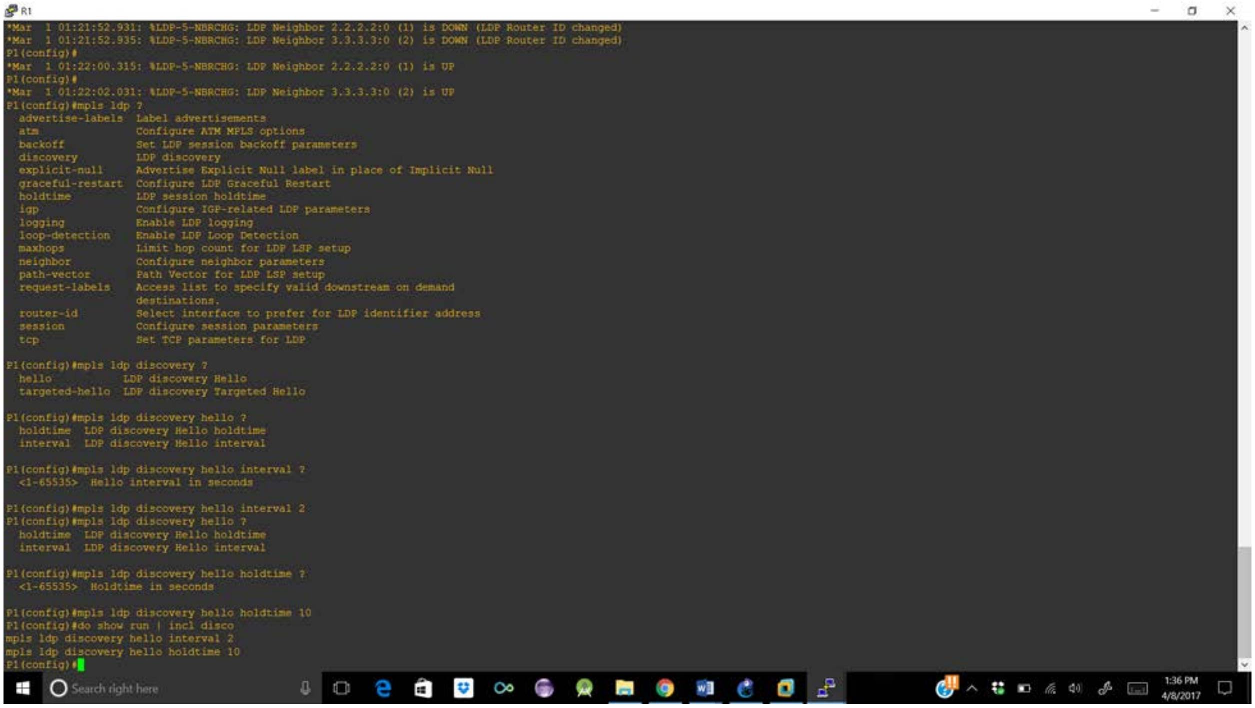
mpls ldp discovery hello message verifies that the interface is up and is sending hello messages.r

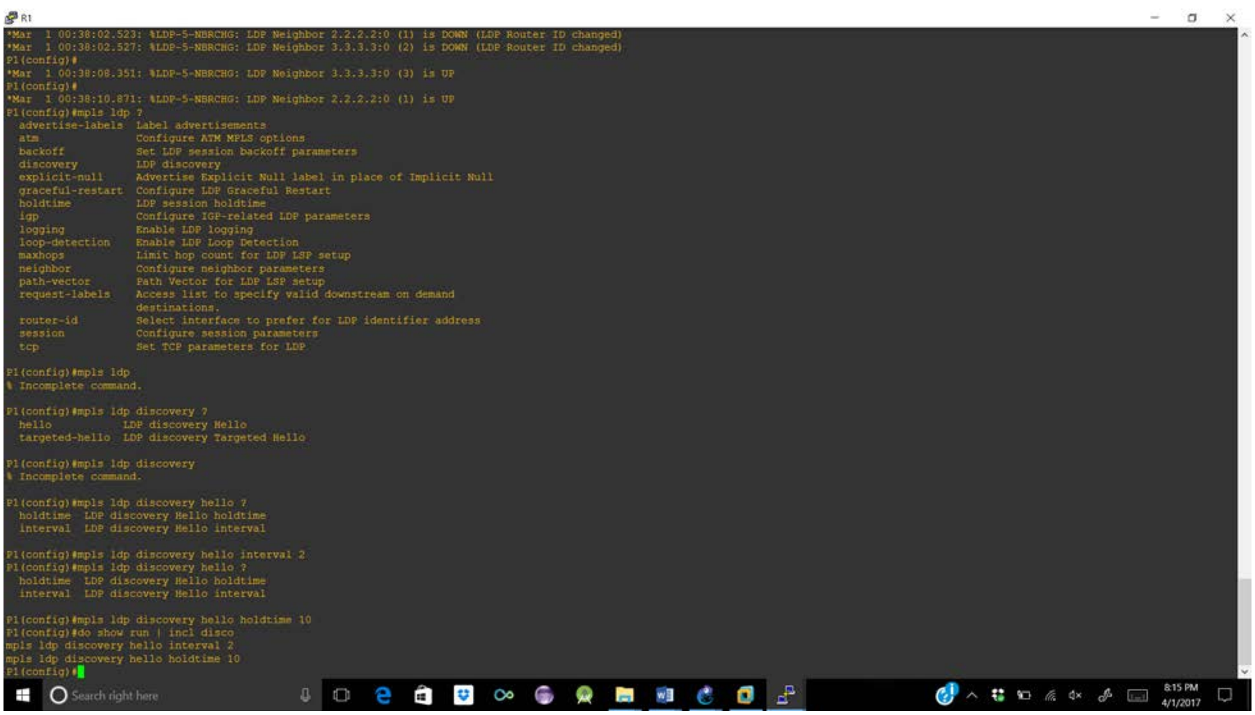
The range for mpls ldp hello interval is <1-65535> in seconds.

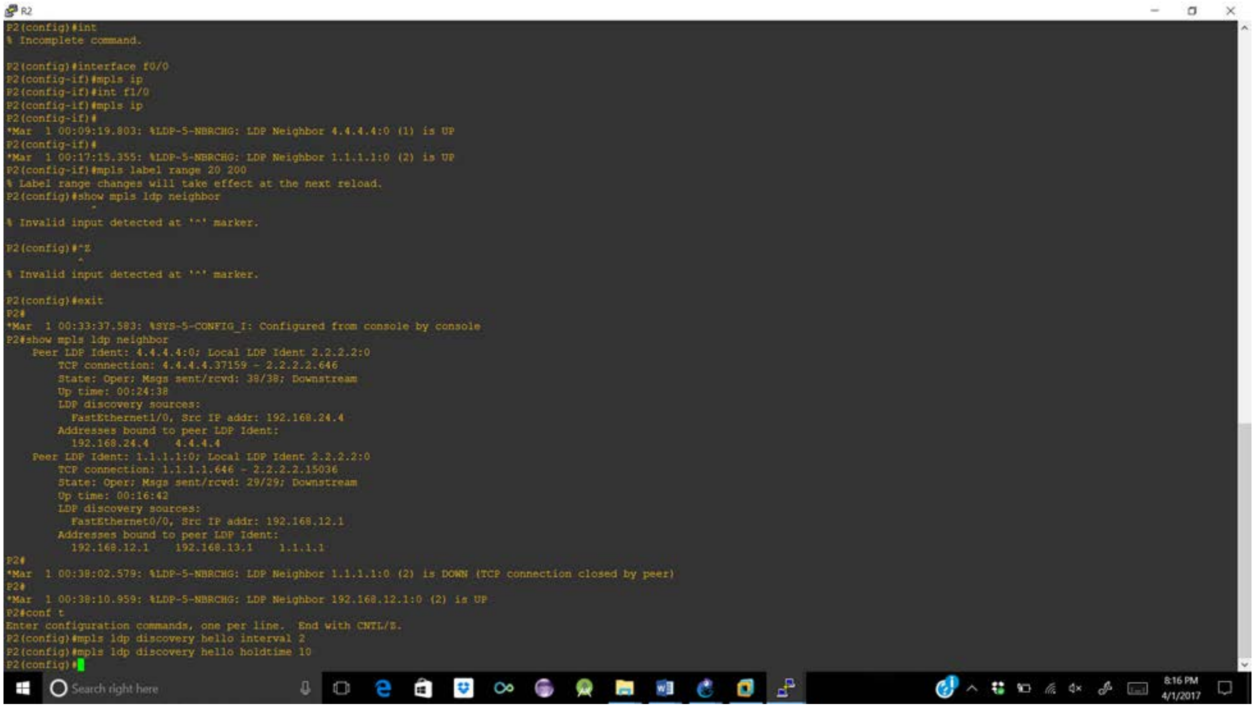
We assign a hello interval of 2 seconds.

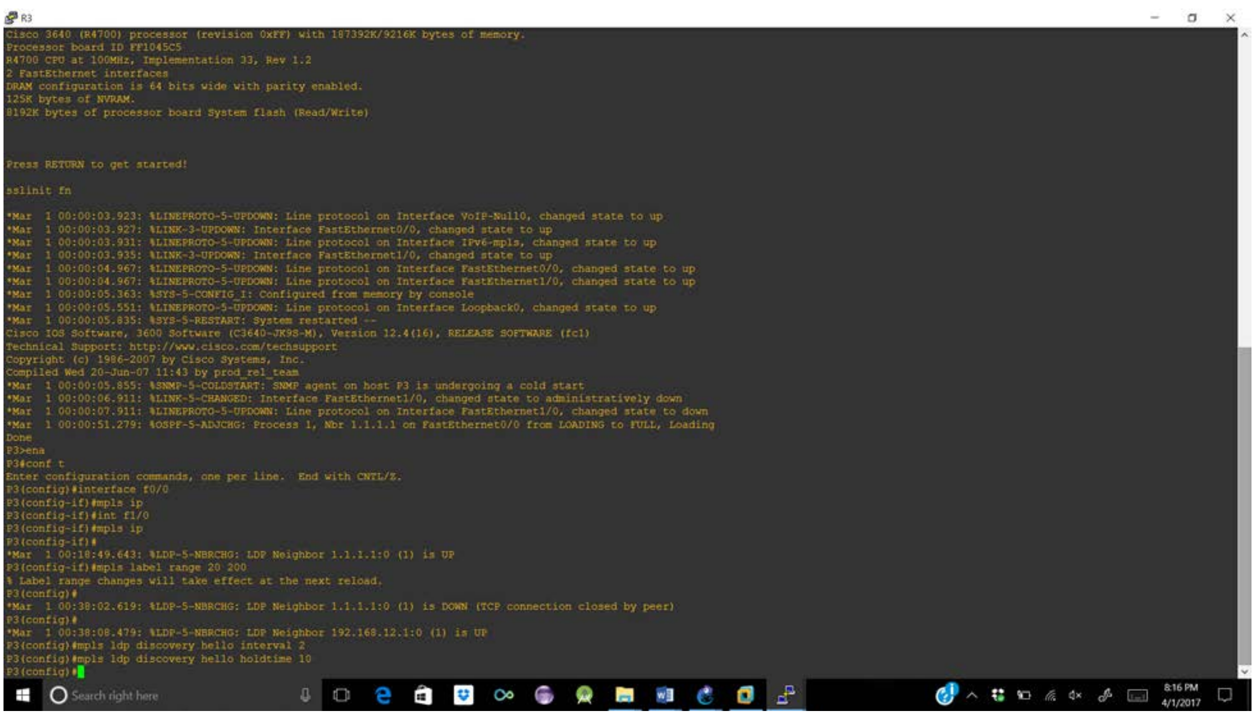
The range for mpls ldp hello holdtime is <1-65535> in seconds.

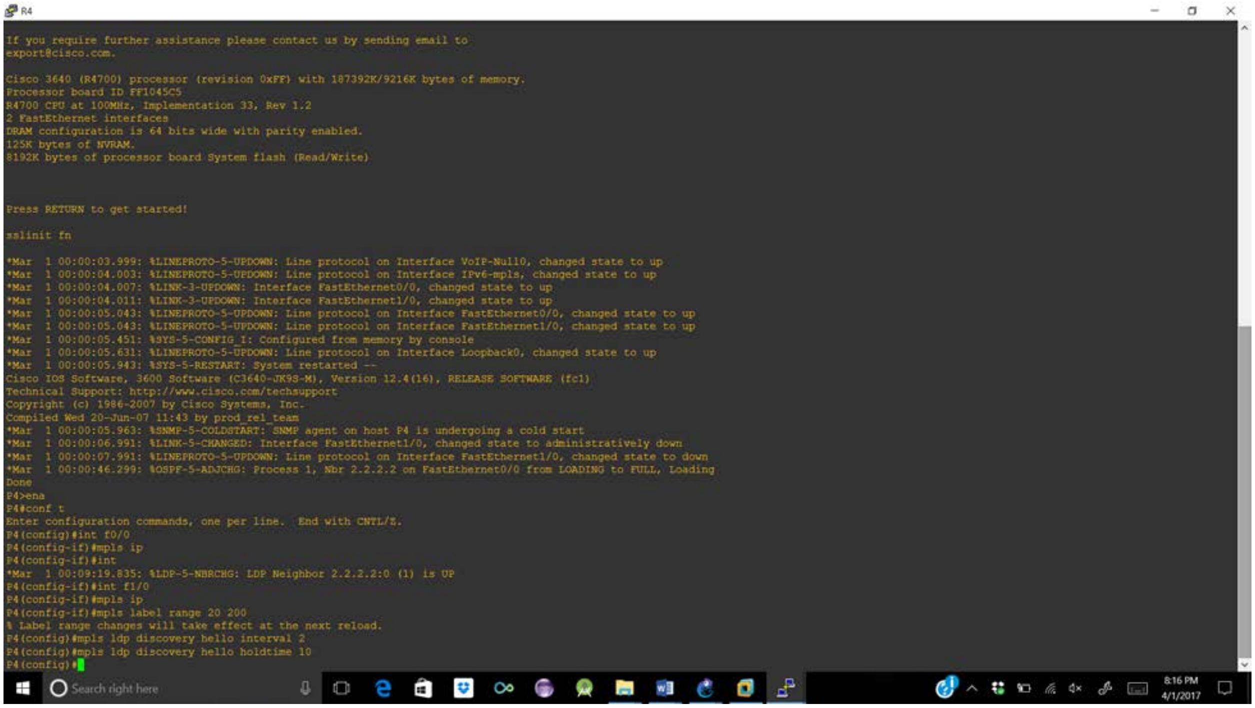
We assign a holdtime of 10 seconds.


R1
*Mar 1 01:21:52.931: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is DOWN (LDP Router ID changed)
*Mar 1 01:21:52.935: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is DOWN (LDP Router ID changed)
P1(config)#
*Mar 1 01:22:00.315: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
P1(config)#
*Mar 1 01:22:02.031: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is UP
P1(config)#mpls ldp ?
advertise-labels Label advertisements
atm Configure ATM MPLS options
backoff Set LDP session backoff parameters
discovery LDP discovery
explicit-null Advertise Explicit Null label in place of Implicit Null
graceful-restart Configure LDP Graceful Restart
holdtime LDP session holdtime
igp Configure IGP-related LDP parameters
logging Enable LDP logging
loop-detection Enable LDP Loop Detection
maxhops Limit hop count for LDP LSP setup
neighbor Configure neighbor parameters
path-vector Path Vector for LDP LSP setup
request-labels Access list to specify valid downstream on demand
destinations.
router-id Select interface to prefer for LDP identifier address
session Configure session parameters
tcp Set TCP parameters for LDP
P1(config)#mpls ldp discovery ?
hello LDP discovery Hello
targeted-hello LDP discovery Targeted Hello
P1(config)#mpls ldp discovery hello ?
holdtime LDP discovery Hello holdtime
interval LDP discovery Hello interval
P1(config)#mpls ldp discovery hello interval ?
<1-65535> Hello interval in seconds
P1(config)#mpls ldp discovery hello interval 2
P1(config)#mpls ldp discovery hello ?
holdtime LDP discovery Hello holdtime
interval LDP discovery Hello interval
P1(config)#mpls ldp discovery hello holdtime ?
<1-65535> Holdtime in seconds
P1(config)#mpls ldp discovery hello holdtime 10
P1(config)#do show run | incl disco
mpls ldp discovery hello interval 2
mpls ldp discovery hello holdtime 10
P1(config)#
Search right here
1:36 PM
4/8/2017


R1
*Mar 1 00:38:02.523: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is DOWN (LDP Router ID changed)
*Mar 1 00:38:02.527: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is DOWN (LDP Router ID changed)
P1(config)#
*Mar 1 00:38:08.351: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (3) is UP
P1(config)#
*Mar 1 00:38:10.871: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
P1(config)#mpls ldp ?
advertise-labels Label advertisements
atm Configure ATM MPLS options
backoff Set LDP session backoff parameters
discovery LDP discovery
explicit-null Advertise Explicit Null label in place of Implicit Null
graceful-restart Configure LDP Graceful Restart
holdtime LDP session holdtime
igp Configure IGP-related LDP parameters
logging Enable LDP logging
loop-detection Enable LDP Loop Detection
maxhops Limit hop count for LDP LSP setup
neighbor Configure neighbor parameters
path-vector Path Vector for LDP LSP setup
request-labels Access list to specify valid downstream on demand
destinations.
router-id Select interface to prefer for LDP identifier address
session Configure session parameters
tcp Set TCP parameters for LDP
P1(config)#mpls ldp
% Incomplete command.
P1(config)#mpls ldp discovery ?
hello LDP discovery Hello
targeted-hello LDP discovery Targeted Hello
P1(config)#mpls ldp discovery
% Incomplete command.
P1(config)#mpls ldp discovery hello ?
holdtime LDP discovery Hello holdtime
interval LDP discovery Hello interval
P1(config)#mpls ldp discovery hello interval 2
P1(config)#mpls ldp discovery hello ?
holdtime LDP discovery Hello holdtime
interval LDP discovery Hello interval
P1(config)#mpls ldp discovery hello holdtime 10
P1(config)#do show run | incl disco
mpls ldp discovery hello interval 2
mpls ldp discovery hello holdtime 10
P1(config)#
Search right here
8:15 PM
4/1/2017


R2
P2(config)#int
% Incomplete command.
P2(config)#interface f0/0
P2(config-if)#mpls ip
P2(config-if)#int f1/0
P2(config-if)#mpls ip
P2(config-if)#
*Mar 1 00:09:19.803: %LDP-5-NBRCHG: LDP Neighbor 4.4.4.4:0 (1) is UP
P2(config-if)#
*Mar 1 00:17:15.355: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (2) is UP
P2(config-if)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P2(config)#show mpls ldp neighbor
% Invalid input detected at '^' marker.
P2(config)#^Z
% Invalid input detected at '^' marker.
P2(config)#exit
P2#
*Mar 1 00:33:37.583: %SYS-5-CONFIG_I: Configured from console by console
P2#show mpls ldp neighbor
Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 2.2.2.2:0
TCP connection: 4.4.4.4.37159 - 2.2.2.2.646
State: Oper; Msgs sent/rcvd: 38/38; Downstream
Up time: 00:24:38
LDP discovery sources:
FastEthernet1/0, Src IP addr: 192.168.24.4
Addresses bound to peer LDP Ident:
192.168.24.4 4.4.4.4
Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
TCP connection: 1.1.1.1.646 - 2.2.2.2.15036
State: Oper; Msgs sent/rcvd: 29/29; Downstream
Up time: 00:16:42
LDP discovery sources:
FastEthernet0/0, Src IP addr: 192.168.12.1
Addresses bound to peer LDP Ident:
192.168.12.1 192.168.13.1 1.1.1.1
P2#
*Mar 1 00:38:02.579: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (2) is DOWN (TCP connection closed by peer)
P2#
*Mar 1 00:38:10.959: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (2) is UP
P2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P2(config)#mpls ldp discovery hello interval 2
P2(config)#mpls ldp discovery hello holdtime 10
P2(config)#
Search right here
8:16 PM
4/1/2017

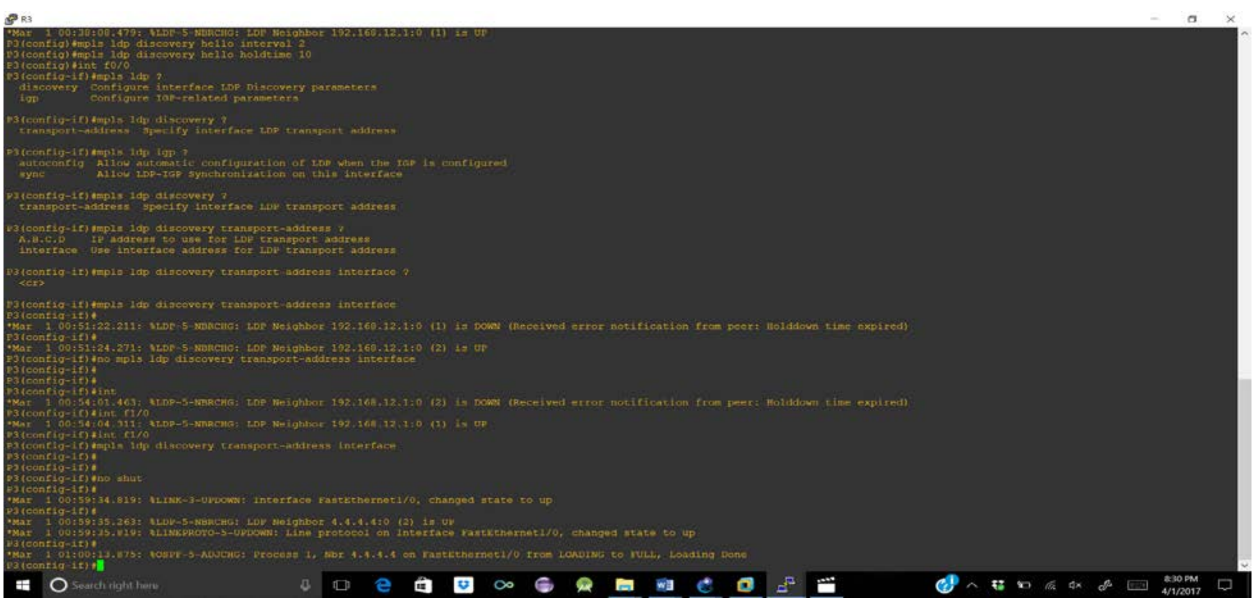

R3
Cisco 3640 (R4700) processor (revision 0xFF) with 187392K/9216K bytes of memory.
Processor board ID FF1045C5
R4700 CPU at 100MHz, Implementation 33, Rev 1.2
2 FastEthernet interfaces
DRAM configuration is 64 bits wide with parity enabled.
125K bytes of NVRAM.
8192K bytes of processor board System flash (Read/Write)
Press RETURN to get started!
sslinit fn
*Mar 1 00:00:03.923: %LINEPROTO-5-UPDOWN: Line protocol on Interface VoIP-Null0, changed state to up
*Mar 1 00:00:03.927: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:03.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface IPv6-mpls, changed state to up
*Mar 1 00:00:03.935: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:04.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Mar 1 00:00:05.363: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:05.551: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 1 00:00:05.835: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3600 Software (C3640-JK9S-M), Version 12.4(16), RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 20-Jun-07 11:43 by prod_rel_team
*Mar 1 00:00:05.855: %SNMP-5-COLDSTART: SNMP agent on host P3 is undergoing a cold start
*Mar 1 00:00:06.911: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Mar 1 00:00:07.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Mar 1 00:00:51.279: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading
Done
P3>ena
P3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
P3(config)#interface f0/0
P3(config-if)#mpls ip
P3(config-if)#int f1/0
P3(config-if)#mpls ip
P3(config-if)#
*Mar 1 00:18:49.643: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
P3(config-if)#mpls label range 20 200
% Label range changes will take effect at the next reload.
P3(config)#
*Mar 1 00:38:02.619: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is DOWN (TCP connection closed by peer)
P3(config)#
*Mar 1 00:38:08.479: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (1) is UP
P3(config)#mpls ldp discovery hello interval 2
P3(config)#mpls ldp discovery hello holdtime 10
P3(config)#
Search right here
8:16 PM
4/1/2017

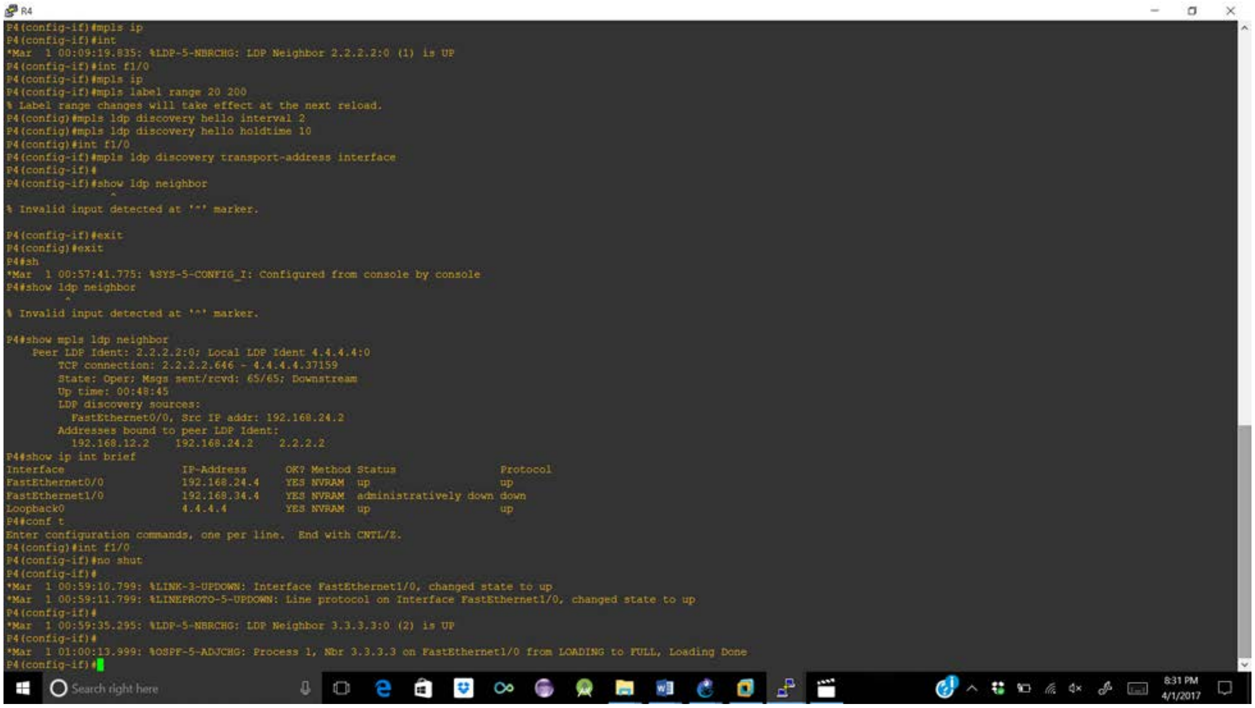


STEP 6: Configure router P3 and P4 to establish the LDP connection between their fastethernet interfaces.

'show mpls ldp neighbor' command displays the status of LDP sessions.

'show ip int brief' command displays the description of the interface briefly.

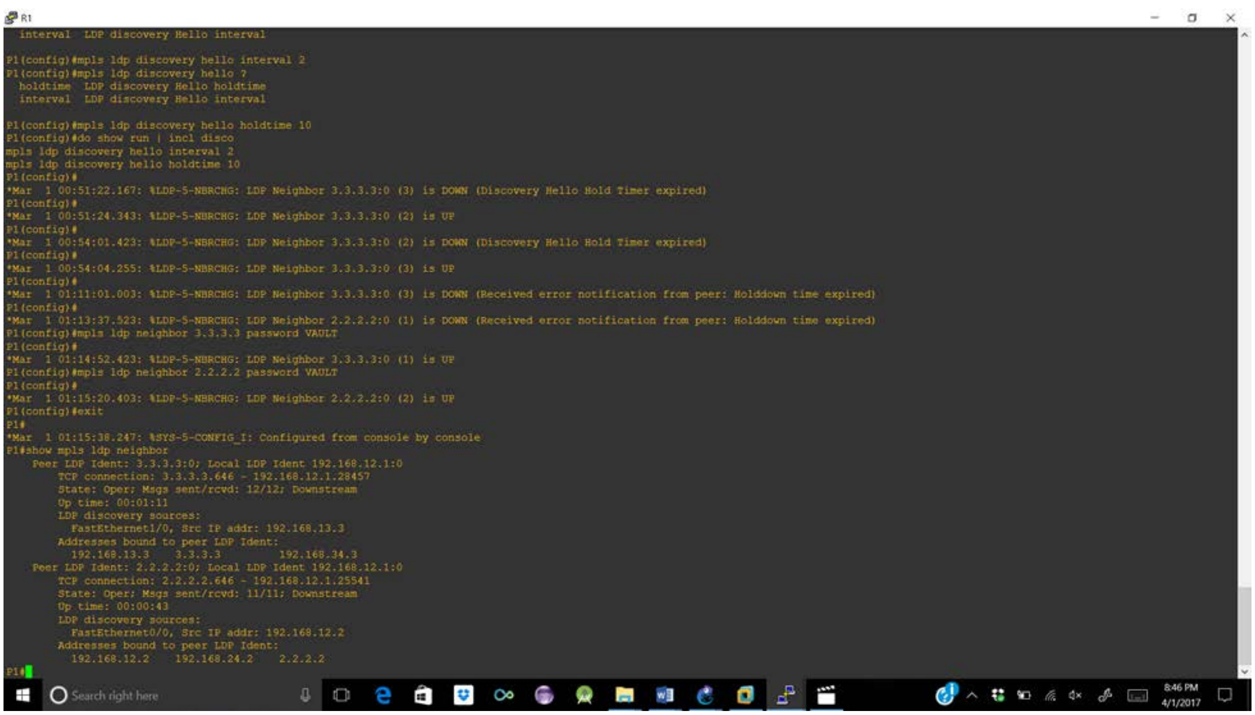


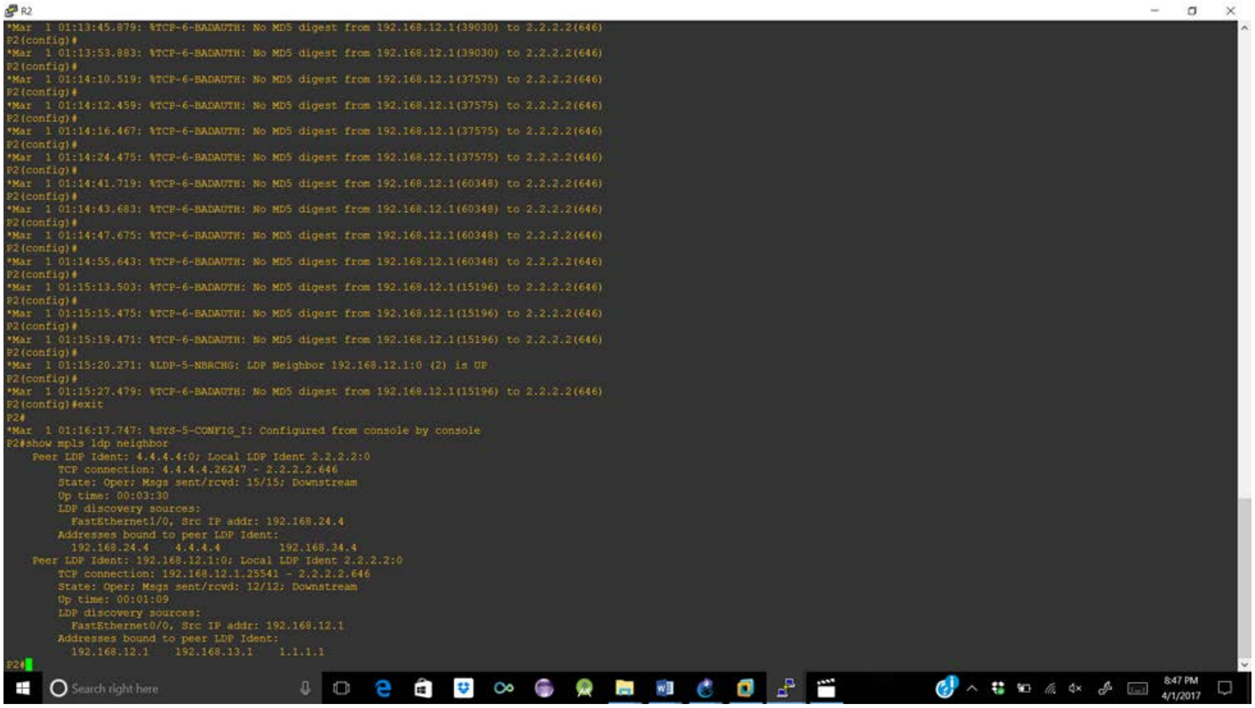


STEP 7: Configure all routers to use MPLS MD5 authentication, the password should be "VAULT".

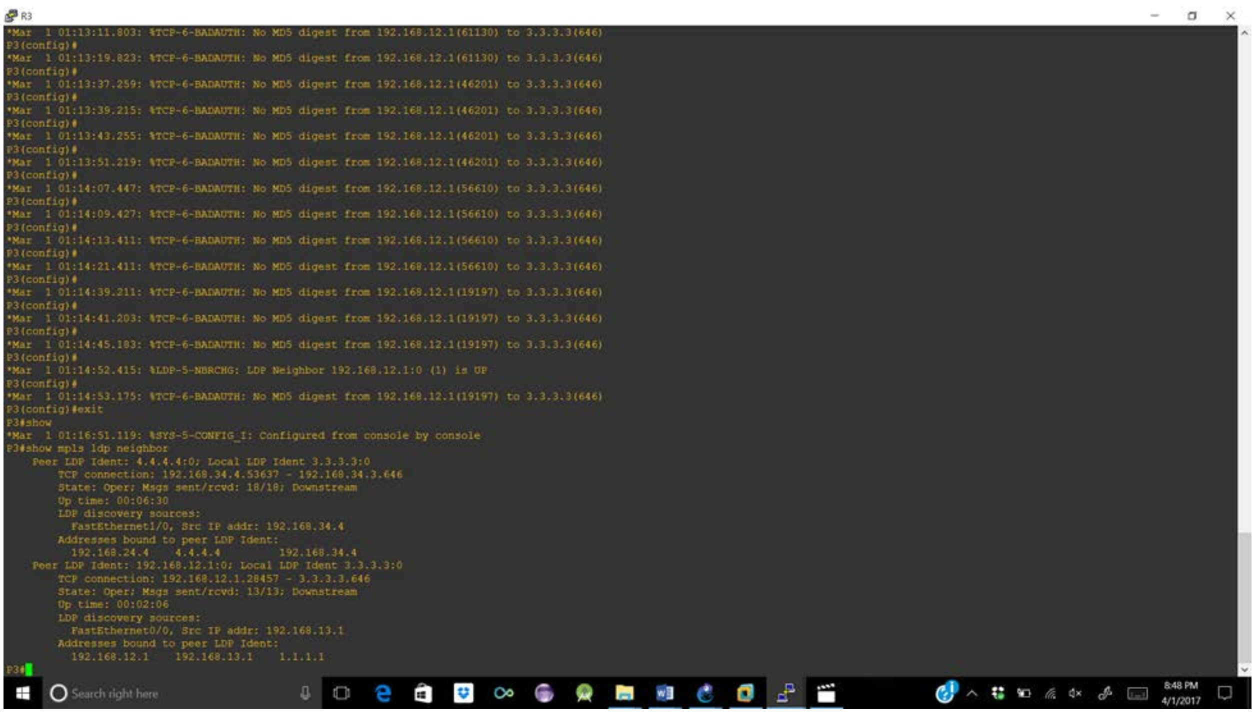
'show mpls ldp neighbor' command displays the status of LDP sessions.

The following screenshots show the execution after typing the show mpls ldp neighbor command.

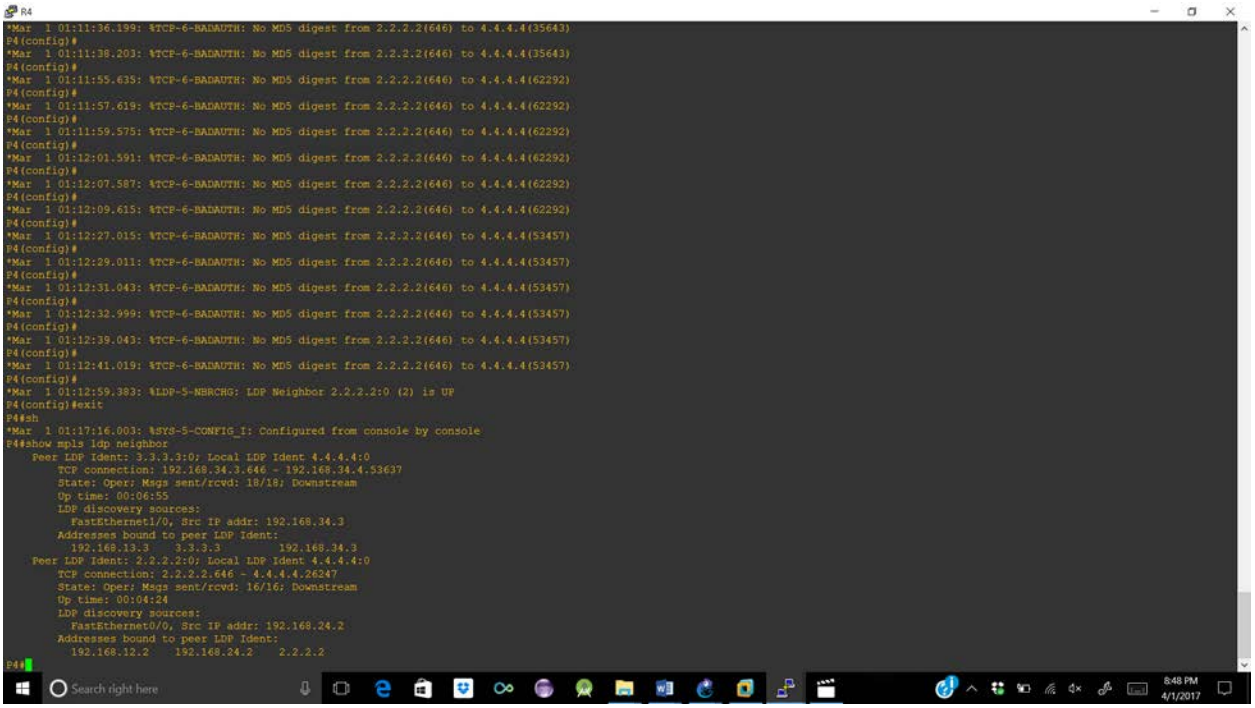




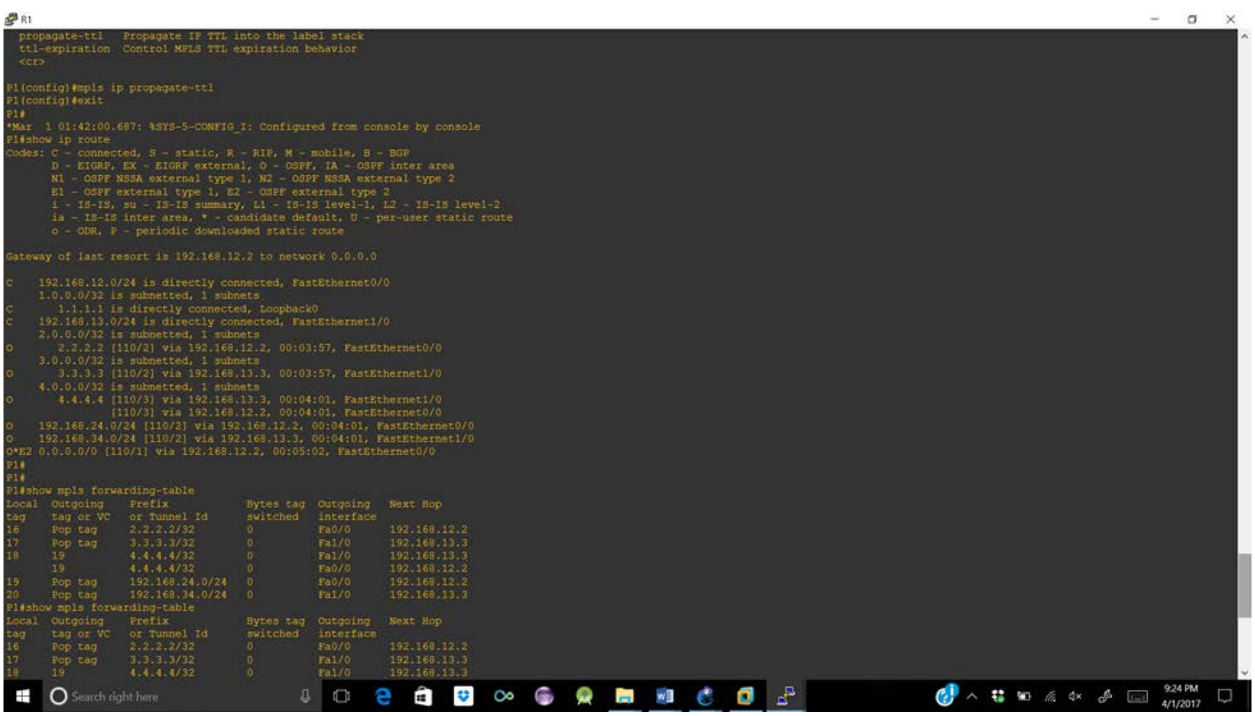
```
*Mar  1 01:13:45.879: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(39030) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:13:53.883: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(39030) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:10.519: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(37575) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:12.459: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(37575) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:16.467: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(37575) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:24.475: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(37575) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:41.719: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(60348) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:43.683: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(60348) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:47.675: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(60348) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:14:55.643: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(60348) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:15:13.503: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(15196) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:15:15.475: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(15196) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:15:19.471: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(15196) to 2.2.2.2(646)
P2(config)#
*Mar  1 01:15:20.271: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (2) is UP
P2(config)#
*Mar  1 01:15:27.479: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(15196) to 2.2.2.2(646)
P2(config)#exit
P2#
*Mar  1 01:16:17.747: %SYS-5-CONFIG_I: Configured from console by console
P2#show mpls ldp neighbor
    Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 4.4.4.4.26247 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 15/15; Downstream
        Up time: 00:03:30
        LDP discovery sources:
          FastEthernet1/0, Src IP addr: 192.168.24.4
        Addresses bound to peer LDP Ident:
          192.168.24.4    4.4.4.4         192.168.34.4
    Peer LDP Ident: 192.168.12.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 192.168.12.1.25541 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:01:09
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.12.1
        Addresses bound to peer LDP Ident:
          192.168.12.1    192.168.13.1    1.1.1.1
P2#
```



```
*Mar  1 01:13:11.803: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(61130) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:19.823: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(61130) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:37.259: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:39.215: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:43.255: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:51.219: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:07.447: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:09.427: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:13.411: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:21.411: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:39.211: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:41.203: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:45.183: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:52.415: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (1) is UP
P3(config)#
*Mar  1 01:14:53.175: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#exit
P3#show
*Mar  1 01:16:51.119: %SYS-5-CONFIG_I: Configured from console by console
P3#show mpls ldp neighbor
    Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.34.4.53637 - 192.168.34.3.646
        State: Oper; Msgs sent/rcvd: 18/18; Downstream
        Up time: 00:06:30
        LDP discovery sources:
          FastEthernet1/0, Src IP addr: 192.168.34.4
        Addresses bound to peer LDP Ident:
          192.168.24.4    4.4.4.4         192.168.34.4
    Peer LDP Ident: 192.168.12.1:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.12.1.28457 - 3.3.3.3.646
        State: Oper; Msgs sent/rcvd: 13/13; Downstream
        Up time: 00:02:06
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.13.1
        Addresses bound to peer LDP Ident:
          192.168.12.1    192.168.13.1    1.1.1.1
P3#
```



STEP 8: The TTL from IP packets should be copied into the label on all routers.

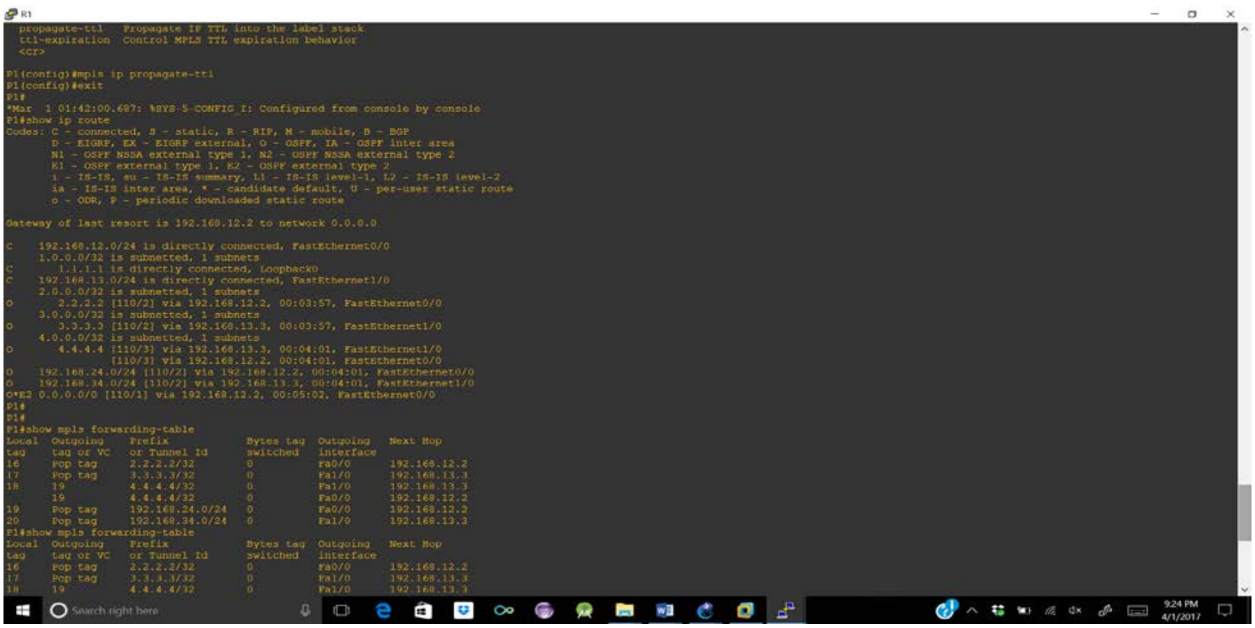


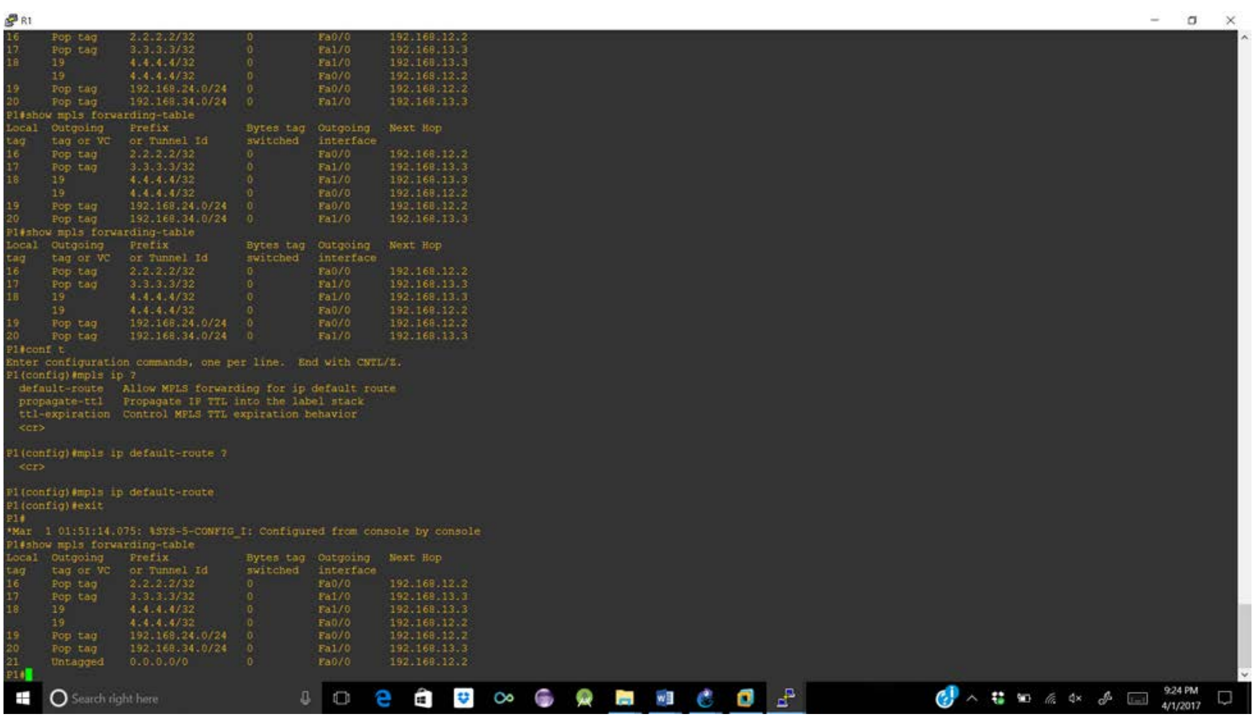
STEP 9: Advertise a default route on router P2 & Make sure that there is also a label advertised for the default route.

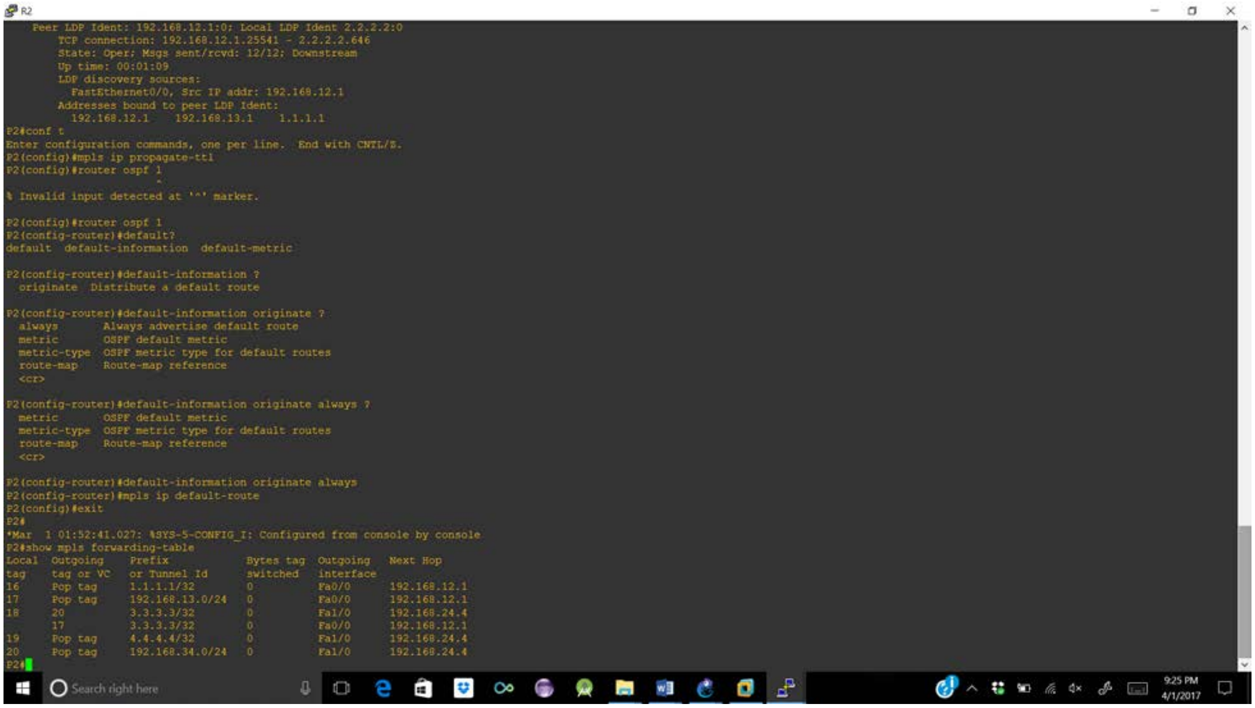
'show ip route' command shows the router's routing table. This includes the list of all the routers the network can reach. It also includes their metrics and how to get there.

'mpls ip default route' associates a label to a default route.

'show mpls forwarding-table' displays the mpls forwarding table of the router.

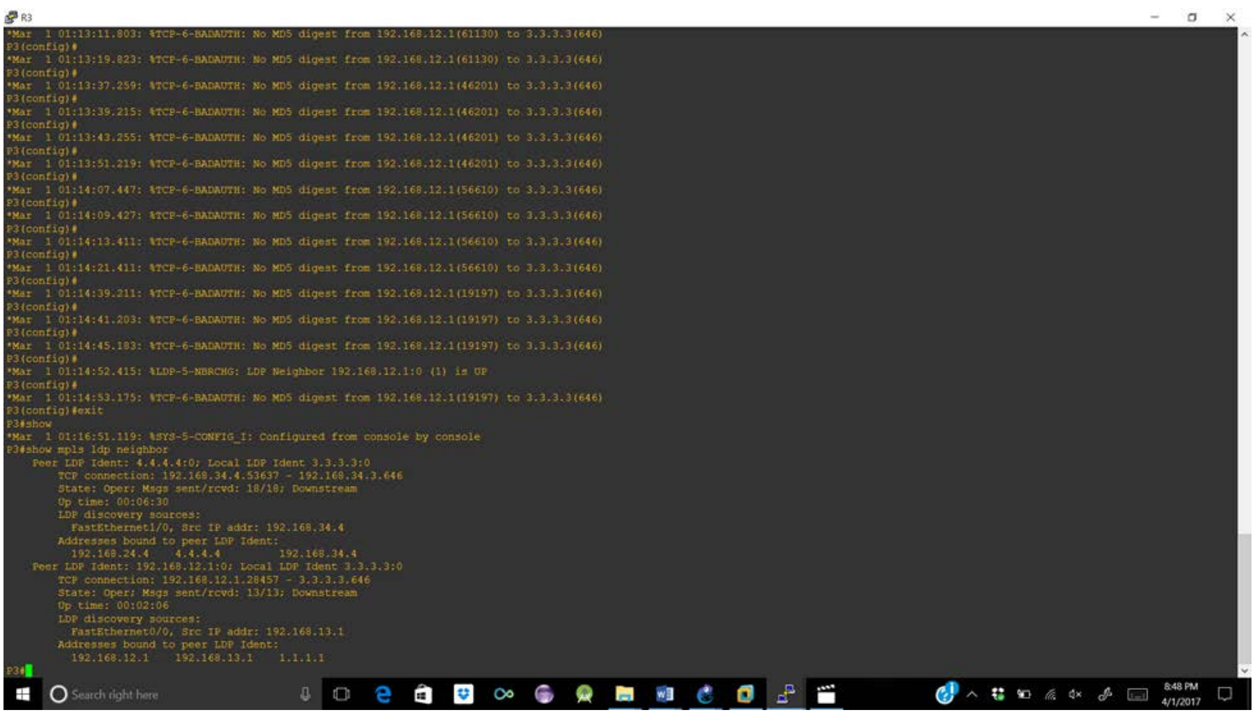






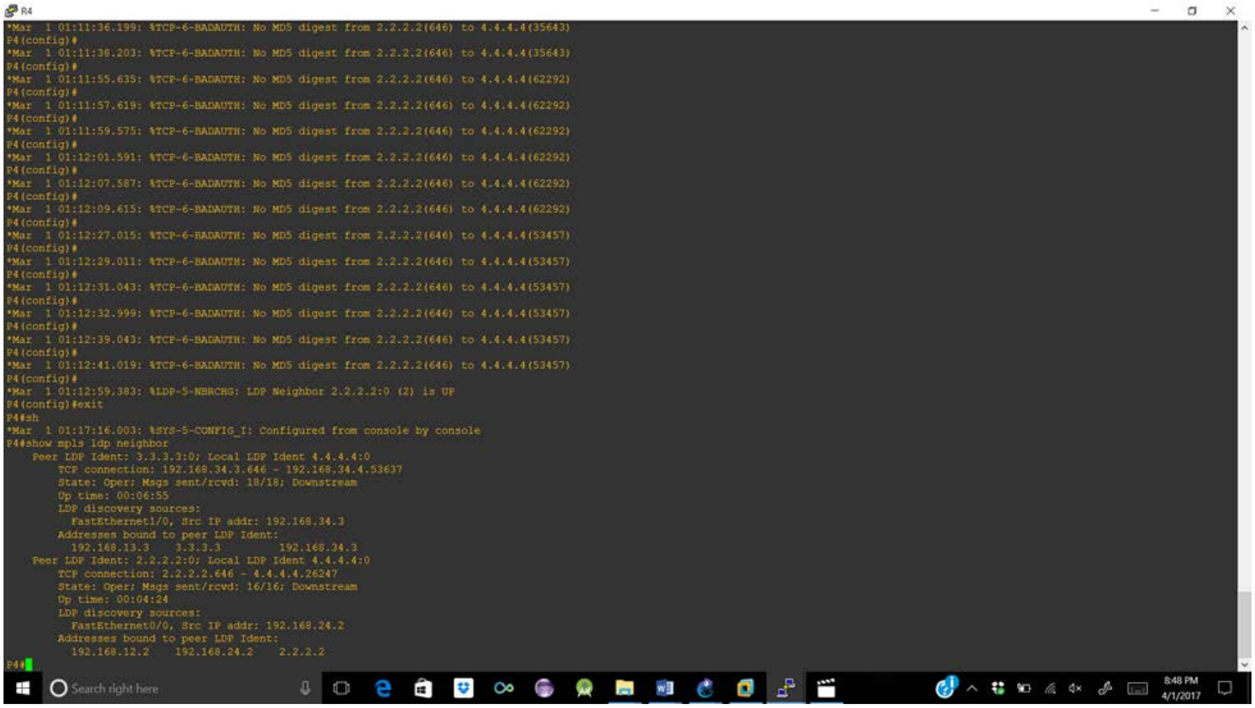
R2

```
    Peer LDP Ident: 192.168.12.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 192.168.12.1.25541 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:01:09
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.12.1
        Addresses bound to peer LDP Ident:
          192.168.12.1    192.168.13.1    1.1.1.1
P2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
P2(config)#mpls ip propagate-ttl
P2(config)#router ospf 1
                        ^
% Invalid input detected at '^' marker.

P2(config)#router ospf 1
P2(config-router)#default?
default  default-information  default-metric

P2(config-router)#default-information ?
  originate  Distribute a default route

P2(config-router)#default-information originate ?
  always       Always advertise default route
  metric       OSPF default metric
  metric-type  OSPF metric type for default routes
  route-map    Route-map reference
  <cr>

P2(config-router)#default-information originate always ?
  metric       OSPF default metric
  metric-type  OSPF metric type for default routes
  route-map    Route-map reference
  <cr>

P2(config-router)#default-information originate always
P2(config-router)#mpls ip default-route
P2(config)#exit
P2#
*Mar  1 01:52:41.027: %SYS-5-CONFIG_I: Configured from console by console
P2#show mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     1.1.1.1/32        0          Fa0/0      192.168.12.1
17     Pop tag     192.168.13.0/24   0          Fa0/0      192.168.12.1
18     20          3.3.3.3/32        0          Fa1/0      192.168.24.4
       17          3.3.3.3/32        0          Fa0/0      192.168.12.1
19     Pop tag     4.4.4.4/32        0          Fa1/0      192.168.24.4
20     Pop tag     192.168.34.0/24   0          Fa1/0      192.168.24.4
P2#
```



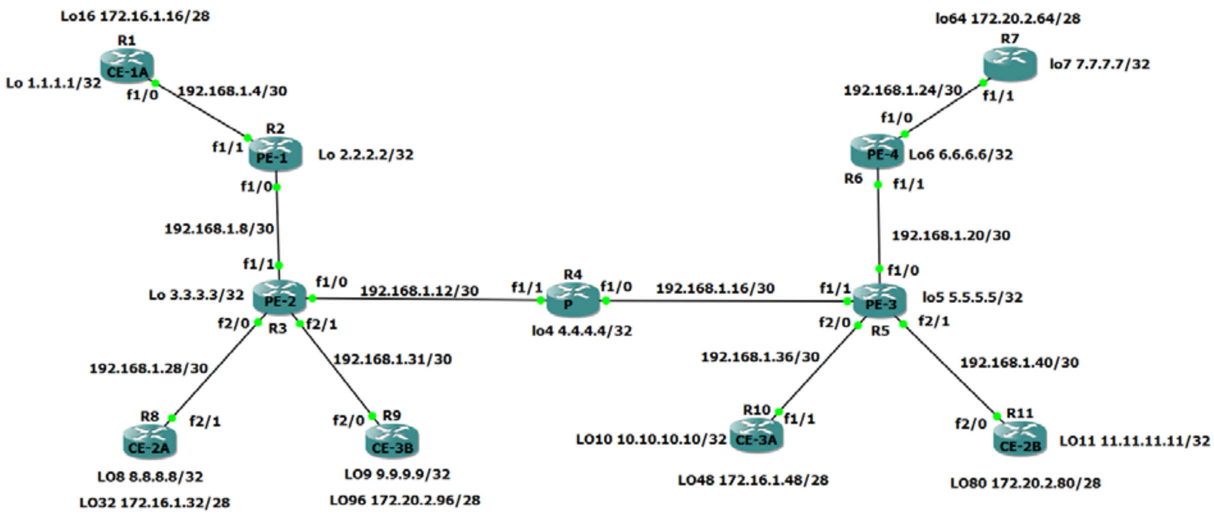
R3

```
*Mar  1 01:13:11.803: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(61130) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:19.823: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(61130) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:37.259: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:39.215: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:43.255: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:13:51.219: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(46201) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:07.447: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:09.427: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:13.411: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:21.411: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(56610) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:39.211: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:41.203: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:45.183: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#
*Mar  1 01:14:52.415: %LDP-5-NBRCHG: LDP Neighbor 192.168.12.1:0 (1) is UP
P3(config)#
*Mar  1 01:14:53.175: %TCP-6-BADAUTH: No MD5 digest from 192.168.12.1(19197) to 3.3.3.3(646)
P3(config)#exit
P3#show
*Mar  1 01:16:51.119: %SYS-5-CONFIG_I: Configured from console by console
P3#show mpls ldp neighbor
    Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.34.4.53637 - 192.168.34.3.646
        State: Oper; Msgs sent/rcvd: 18/18; Downstream
        Up time: 00:06:30
        LDP discovery sources:
          FastEthernet1/0, Src IP addr: 192.168.34.4
        Addresses bound to peer LDP Ident:
          192.168.24.4    4.4.4.4         192.168.34.4
    Peer LDP Ident: 192.168.12.1:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 192.168.12.1.28457 - 3.3.3.3.646
        State: Oper; Msgs sent/rcvd: 13/13; Downstream
        Up time: 00:02:06
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 192.168.13.1
        Addresses bound to peer LDP Ident:
          192.168.12.1    192.168.13.1    1.1.1.1
P3#
```


R4
*Mar 1 01:11:36.199: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(35643)
P4(config)#
*Mar 1 01:11:38.203: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(35643)
P4(config)#
*Mar 1 01:11:55.635: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:11:57.619: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:11:59.575: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:12:01.591: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:12:07.587: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:12:09.615: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(62292)
P4(config)#
*Mar 1 01:12:27.015: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:29.011: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:31.043: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:32.999: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:39.043: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:41.019: %TCP-6-BADAUTH: No MD5 digest from 2.2.2.2(646) to 4.4.4.4(53457)
P4(config)#
*Mar 1 01:12:59.383: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (2) is UP
P4(config)#exit
P4#sh
*Mar 1 01:17:16.003: %SYS-5-CONFIG_I: Configured from console by console
P4#show mpls ldp neighbor
Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 4.4.4.4:0
TCP connection: 192.168.34.3.646 - 192.168.34.4.53637
State: Oper; Msgs sent/rcvd: 18/18; Downstream
Up time: 00:06:55
LDP discovery sources:
FastEthernet1/0, Src IP addr: 192.168.34.3
Addresses bound to peer LDP Ident:
192.168.13.3 3.3.3.3 192.168.34.3
Peer LDP Ident: 2.2.2.2:0; Local LDP Ident 4.4.4.4:0
TCP connection: 2.2.2.2.646 - 4.4.4.4.26247
State: Oper; Msgs sent/rcvd: 16/16; Downstream
Up time: 00:04:24
LDP discovery sources:
FastEthernet0/0, Src IP addr: 192.168.24.2
Addresses bound to peer LDP Ident:
192.168.12.2 192.168.24.2 2.2.2.2
P4#
Search right here
8:48 PM
4/1/2017

ADVANCED MPLS LAB

The network topology of advanced MPLS lab is as follows,



- The first step in this is to establish connectivity in the network. The routing protocol used here is IS-IS (Intermediate System-to-Intermediate System).
- It is a link-state protocol, flexible, fast converging, support larger internetworks and less susceptible to routing loops.
- It runs Dijkstra shortest path first (SPF) algorithm to create database of network's topology. The best route is determined from that topology.
- The packets carrying information about the network topology are called link-state protocol data units. It includes IP routes, checksums and other additional information
- It runs SPF algorithm on the information available in the link-state database to get the shortest path for reaching the destination.
- This protocol runs over data-link layer. It does not require IP address to exchange information
- Its addresses are called as network entity titles. They are 8 to 12 bytes long.
- For example, 49.0100.0040.0400.4004.00

- It consists of three parts:
  1. Area identifier: First three bytes are area ID. 49 is the address family identifier of the authority.

     0100: IS-IS area number
  2. System identifier: The next six bytes identifies the node on the network. IP address filled with all leading zeros an d decimal points are repositioned.

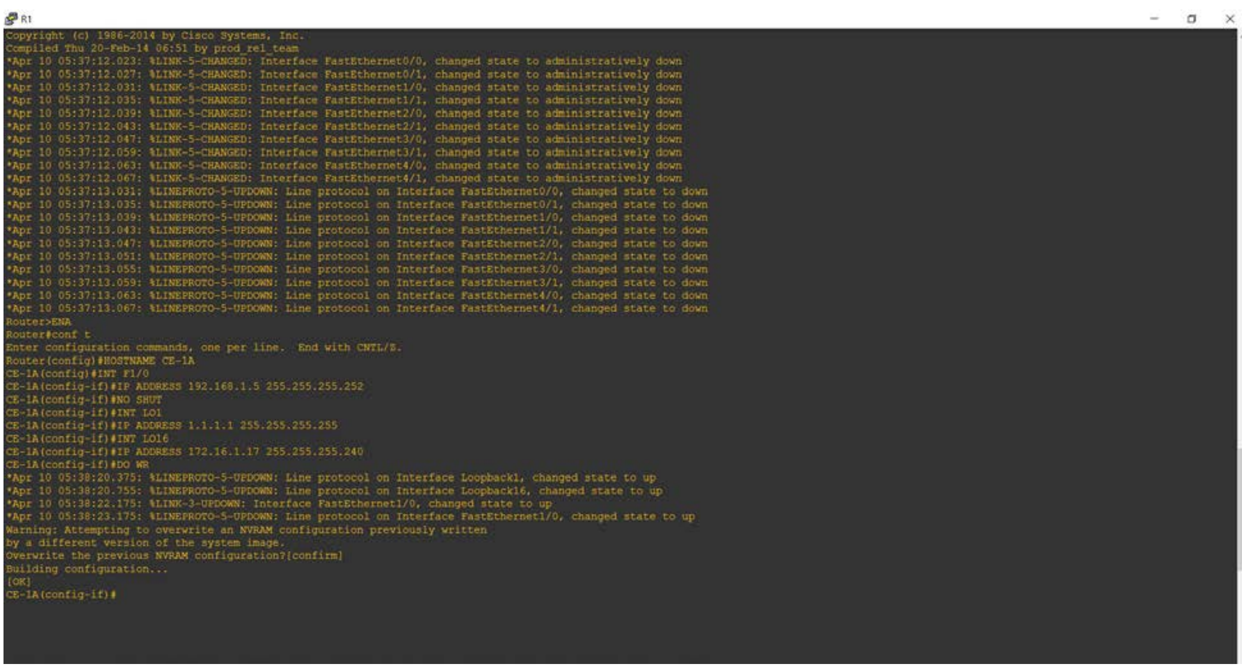
     0040.0400.4004.
  3. NET selector: The final two bytes are the NET selector. ‘00’ indicates this system

Type of routers in the network,

- P- Router: Provider router which are within the cloud
- PE Router: They are provider edge router. They will be facing the customers
- CE Router: They are customer edge routers. They will be facing PE Router. Customer edge router do not participate in MPLS process. They pop out MPLS label and send IP straight forward.

ROUTER CONFIGURATION:

R1:



```
R1
Copyright (c) 1986-2014 by Cisco Systems, Inc.
Compiled Thu 20-Feb-14 06:51 by prod_rel_team
*Apr 10 05:37:12.023: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state to administratively down
*Apr 10 05:37:12.027: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state to administratively down
*Apr 10 05:37:12.031: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Apr 10 05:37:12.035: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:12.039: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:12.043: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:12.047: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:12.059: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:12.063: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:12.067: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:13.031: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to down
*Apr 10 05:37:13.035: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:13.039: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:13.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:13.047: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:13.051: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:13.055: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:13.059: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:13.063: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:13.067: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ENA
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-1A
CE-1A(config)#INT F1/0
CE-1A(config-if)#IP ADDRESS 192.168.1.5 255.255.255.252
CE-1A(config-if)#NO SHUT
CE-1A(config-if)#INT LO1
CE-1A(config-if)#IP ADDRESS 1.1.1.1 255.255.255.255
CE-1A(config-if)#INT LO16
CE-1A(config-if)#IP ADDRESS 172.16.1.17 255.255.255.240
CE-1A(config-if)#DO WR
*Apr 10 05:38:20.375: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
*Apr 10 05:38:20.755: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback16, changed state to up
*Apr 10 05:38:22.175: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:38:23.175: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
CE-1A(config-if)#
```

R2:

```
R2
*Apr 10 05:37:12.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:12.595: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:12.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:12.603: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:12.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:12.611: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:12.615: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:12.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:12.623: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ena
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME PE-1
PE-1(config)#INT F1/1
PE-1(config-if)#IP ADDRESS 192.168.1.6 255.255.255.252
PE-1(config-if)#NO SHUT
PE-1(config-if)#INT F1/0
PE-1(config-if)#IP ADDRESS 192.168.1.9 255.255.255.252
PE-1(config-if)#IP ROUTER ISIS
PE-1(config-if)#NO SHUT
PE-1(config-if)#INT L02
PE-1(config-if)#IP ADDRESS 2.2.2.2 255.255.255.255
PE-1(config-if)#IP ROUTER ISIS
PE-1(config-if)#EXIT
PE-1(config)#ROUTER ISIS
*Apr 10 05:38:53.547: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
*Apr 10 05:38:54.855: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:38:55.355: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:38:55.855: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
*Apr 10 05:38:56.355: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
PE-1(config-router)#NET 49.0100.0020.0200.2002.00
PE-1(config-router)#IS-TYPE LEVEL-1-2
PE-1(config-router)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
PE-1(config-router)#EXIT
PE-1(config)#EXIT
```

R3:

```
R3
*Apr 10 05:37:04.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:04.623: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:04.627: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:04.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:04.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:04.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ena
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME PE-2
PE-2(config)#INT F1/1
PE-2(config-if)#IP ADDRESS 192.168.1.10 255.255.255.252
PE-2(config-if)#NO SHUT
PE-2(config-if)#IP ROUTER ISIS
PE-2(config-if)#INT F1/0
PE-2(config-if)#IP ADDRESS 192.168.1.13 255.255.255.252
PE-2(config-if)#IP ROUTER ISIS
PE-2(config-if)#NO SHUT
PE-2(config-if)#INT L03
PE-2(config-if)#IP ADDRESS 3.3.3.3 255.255.255.255
PE-2(config-if)#IP ROUTER ISIS
PE-2(config-if)#EXIT
PE-2(config)#ROUTER ISIS
PE-2(config-router)#NET 49.0100.0030.0300.3003.00
PE-2(config-router)#IS-TYPE LEVEL-1-2
PE-2(config-router)#INT F2/0
PE-2(config-if)#IP ADDRESS 192.168.1.29 255.255.255.252
PE-2(config-if)#NO SHUT
PE-2(config-if)#INT F2/1
PE-2(config-if)#IP ADDRESS 192.168.1.33 255.25
*Apr 10 05:40:19.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed state to up5.255.252
PE-2(config-if)#NO SHUT
PE-2(config-if)#DO WR
*Apr 10 05:40:20.283: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:40:20.847: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:40:21.283: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
*Apr 10 05:40:21.847: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Apr 10 05:40:21.911: %LINK-3-UPDOWN: Interface FastEthernet2/0, changed state to up
*Apr 10 05:40:22.231: %LINK-3-UPDOWN: Interface FastEthernet2/1, changed state to up
*Apr 10 05:40:22.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to up
*Apr 10 05:40:23.231: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
```

R4:

```
R4
Press RETURN to get started.




Router>
Router>
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME P1
P1(config)#INT F1/1
P1(config-if)#IP ADDRESS 192.168.1.14 255.255.255.252
P1(config-if)#NO SHUT
P1(config-if)#IP ROUTER ISIS
P1(config-if)#INT F1/0
P1(config-if)#IP ADDRESS 192.168.1.17 255.255.255.252
P1(config-if)#IP ROUTER ISIS
P1(config-if)#NO SHUT
P1(config-if)#INT L04
P1(config-if)#IP ADDRESS 4.4.4.4 255.255.255.255
P1(config-if)#IP ROUTER ISIS
P1(config-if)#EXIT
P1(config)#ROUTER ISIS
P1(config-router)#NET 49.0100.0040.0400.4004.00
P1(config-router)#IS-TYPE LEVEL-1-2
P1(config-router)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
*Apr 10 05:41:21.299: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback4, changed state to up
*Apr 10 05:41:22.511: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:41:23.103: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:41:23.511: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
*Apr 10 05:41:24.103: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
Building configuration...
[OK]
P1(config-router)#
```

R5:

```
R5
*Apr 10 05:37:03.675: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:03.679: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:03.683: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:03.687: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME PE-3
PE-3(config)#INT F1/1
PE-3(config-if)#IP ADDRESS 192.168.1.18 255.255.255.252
PE-3(config-if)#NO SHUT
PE-3(config-if)#IP ROUTER ISIS
PE-3(config-if)#INT F1/0
PE-3(config-if)#IP ADDRESS 192.168.1.21 255.255.255.252
PE-3(config-if)#IP ROUTER ISIS
PE-3(config-if)#NO SHUT
PE-3(config-if)#INT L05
PE-3(config-if)#IP ADDRESS 5.5.5.5 255.255.255.255
PE-3(config-if)#IP ROUTER ISIS
PE-3(config-if)#EXIT
PE-3(config)#ROUTER ISIS
PE-3(config-router)#NET 49.0100.0050.0500.5005.00
PE-3(config-router)#IS-TYPE LEVEL-1-2
PE-3(config-router)#INT F2/0
PE-3(config-if)#IP ADDRESS 192.168.1.37 255.255.255.252
PE-3(config-if)#NO SHUT
PE-3(config-if)#INT F2/1
PE-3(config-if)#IP ADDRESS 192.168.1.41 255.255.255.252
PE-3(config-if)#NO SHUT
PE-3(config-if)#DO WR
*Apr 10 05:42:03.323: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback5, changed state to up
*Apr 10 05:42:04.551: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:42:05.127: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:42:05.551: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
*Apr 10 05:42:06.127: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Apr 10 05:42:06.203: %LINK-3-UPDOWN: Interface FastEthernet2/0, changed state to up
*Apr 10 05:42:06.571: %LINK-3-UPDOWN: Interface FastEthernet2/1, changed state to up
*Apr 10 05:42:07.203: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to up
*Apr 10 05:42:07.571: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
PE-3(config-if)#
```

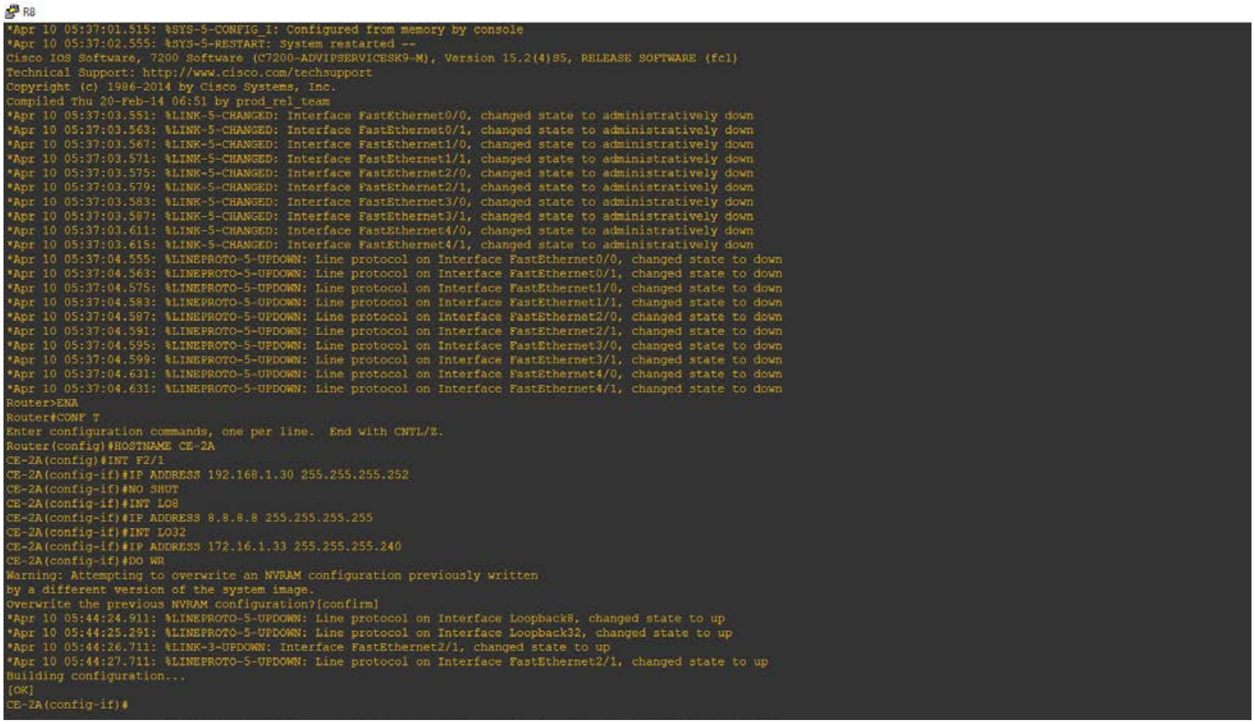
R6:

```
*Apr 10 05:37:10.663: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:10.667: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:10.671: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:10.675: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:10.679: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:10.683: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:10.687: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:11.651: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to down
*Apr 10 05:37:11.655: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:11.659: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:11.663: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:11.667: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:11.671: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:11.675: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:11.679: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:11.683: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:11.687: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ENA
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME PE-4
PE-4(config)#INT F1/0
PE-4(config-if)#IP ADDRESS 192.168.1.25 255.255.255.252
PE-4(config-if)#NO SHUT
PE-4(config-if)#INT F1/1
PE-4(config-if)#IP ADDRESS 192.168.1.22 255.255.255.252
PE-4(config-if)#NO SHUT
PE-4(config-if)#IP ROUTER ISIS
PE-4(config-if)#INT LO6
PE-4(config-if)#IP ADDRESS 6.6.6.6 255.255.255.255
PE-4(config-if)#IP ROUTER ISIS
PE-4(config-if)#ROUTER ISIS
PE-4(config-router)#NET 49.0100.0060.0600.6006.00
PE-4(config-router)#IS-TYPE LEVEL-1-2
PE-4(config-router)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
*Apr 10 05:42:59.783: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback6, changed state to up
*Apr 10 05:43:01.083: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:43:01.387: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:43:02.083: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Apr 10 05:43:02.387: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
Building configuration...
[OK]
PE-4(config-router)#
```

R7:

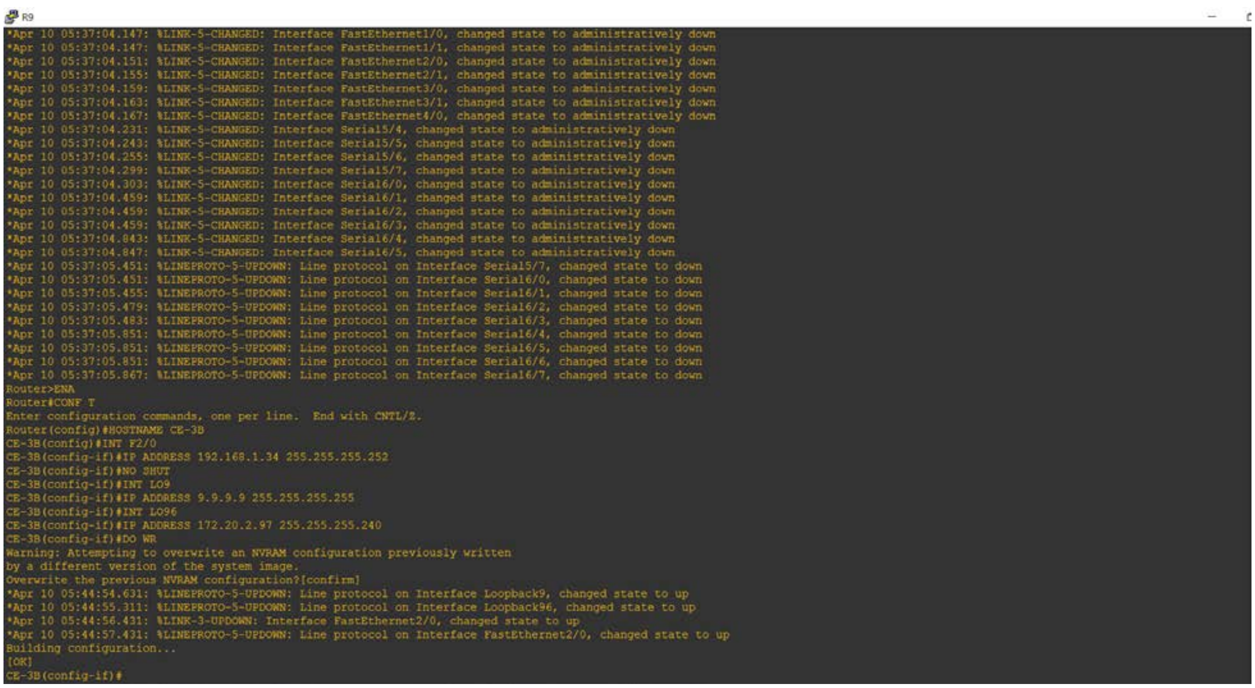
```
*Apr 10 05:37:10.371: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:10.375: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:10.375: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:10.379: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:10.383: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:10.387: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:11.131: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 7200 Software (C7200-ADVIPSERVICESK9-M), Version 15.2(4)S5, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2014 by Cisco Systems, Inc.
Compiled Thu 20-Feb-14 06:51 by prod_rel_team
*Apr 10 05:37:11.463: %LINK-5-CHANGED: Interface Serial6/3, changed state to administratively down
*Apr 10 05:37:11.467: %LINK-5-CHANGED: Interface Serial6/4, changed state to administratively down
*Apr 10 05:37:11.471: %LINK-5-CHANGED: Interface Serial6/5, changed state to administratively down
*Apr 10 05:37:11.475: %LINK-5-CHANGED: Interface Serial6/6, changed state to administratively down
*Apr 10 05:37:11.479: %LINK-5-CHANGED: Interface Serial6/7, changed state to administratively down
*Apr 10 05:37:11.483: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to down
*Apr 10 05:37:11.487: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:11.499: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:11.503: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:12.467: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/3, changed state to down
*Apr 10 05:37:12.467: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/4, changed state to down
*Apr 10 05:37:12.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5, changed state to down
*Apr 10 05:37:12.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6, changed state to down
*Apr 10 05:37:12.479: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-1B
CE-1B(config)#INT F1/1
CE-1B(config-if)#IP ADDRESS 192.168.1.26 255.255.255.252
CE-1B(config-if)#NO SHUT
CE-1B(config-if)#INT LO1
CE-1B(config-if)#IP ADDRESS 7.7.7.7 255.255.255.255
CE-1B(config-if)#INT LO16
CE-1B(config-if)#IP ADDRESS 172.20.2.65 255.255.255.240
CE-1B(config-if)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
*Apr 10 05:43:56.603: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
*Apr 10 05:43:56.979: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback16, changed state to up
*Apr 10 05:43:58.395: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:43:59.395: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
Building configuration...
[OK]
CE-1B(config-if)#
```

R8:



```
*Apr 10 05:37:01.515: %SYS-5-CONFIG_I: Configured from memory by console
*Apr 10 05:37:02.555: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 7200 Software (C7200-ADVIPSERVICESK9-M), Version 15.2(4)S5, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2014 by Cisco Systems, Inc.
Compiled Thu 20-Feb-14 06:51 by prod_rel_team
*Apr 10 05:37:03.551: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state to administratively down
*Apr 10 05:37:03.563: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state to administratively down
*Apr 10 05:37:03.567: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Apr 10 05:37:03.571: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:03.575: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:03.579: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:03.583: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:03.587: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:03.611: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:03.615: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:04.555: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to down
*Apr 10 05:37:04.563: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:04.575: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:04.583: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:04.587: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:04.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:04.595: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:04.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:04.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:04.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-2A
CE-2A(config)#INT F2/1
CE-2A(config-if)#IP ADDRESS 192.168.1.30 255.255.255.252
CE-2A(config-if)#NO SHUT
CE-2A(config-if)#INT LO8
CE-2A(config-if)#IP ADDRESS 8.8.8.8 255.255.255.255
CE-2A(config-if)#INT LO32
CE-2A(config-if)#IP ADDRESS 172.16.1.33 255.255.255.240
CE-2A(config-if)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
*Apr 10 05:44:24.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback8, changed state to up
*Apr 10 05:44:25.291: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback32, changed state to up
*Apr 10 05:44:26.711: %LINK-3-UPDOWN: Interface FastEthernet2/1, changed state to up
*Apr 10 05:44:27.711: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to up
Building configuration...
[OK]
CE-2A(config-if)#
```

R9:



```
*Apr 10 05:37:04.147: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Apr 10 05:37:04.147: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:04.151: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:04.155: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:04.159: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:04.163: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:04.167: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:04.231: %LINK-5-CHANGED: Interface Serial5/4, changed state to administratively down
*Apr 10 05:37:04.243: %LINK-5-CHANGED: Interface Serial5/5, changed state to administratively down
*Apr 10 05:37:04.255: %LINK-5-CHANGED: Interface Serial5/6, changed state to administratively down
*Apr 10 05:37:04.299: %LINK-5-CHANGED: Interface Serial5/7, changed state to administratively down
*Apr 10 05:37:04.303: %LINK-5-CHANGED: Interface Serial6/0, changed state to administratively down
*Apr 10 05:37:04.459: %LINK-5-CHANGED: Interface Serial6/1, changed state to administratively down
*Apr 10 05:37:04.459: %LINK-5-CHANGED: Interface Serial6/2, changed state to administratively down
*Apr 10 05:37:04.459: %LINK-5-CHANGED: Interface Serial6/3, changed state to administratively down
*Apr 10 05:37:04.843: %LINK-5-CHANGED: Interface Serial6/4, changed state to administratively down
*Apr 10 05:37:04.847: %LINK-5-CHANGED: Interface Serial6/5, changed state to administratively down
*Apr 10 05:37:05.451: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial5/7, changed state to down
*Apr 10 05:37:05.451: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/0, changed state to down
*Apr 10 05:37:05.455: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/1, changed state to down
*Apr 10 05:37:05.479: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/2, changed state to down
*Apr 10 05:37:05.483: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/3, changed state to down
*Apr 10 05:37:05.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/4, changed state to down
*Apr 10 05:37:05.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5, changed state to down
*Apr 10 05:37:05.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6, changed state to down
*Apr 10 05:37:05.867: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-3B
CE-3B(config)#INT F2/0
CE-3B(config-if)#IP ADDRESS 192.168.1.34 255.255.255.252
CE-3B(config-if)#NO SHUT
CE-3B(config-if)#INT LO9
CE-3B(config-if)#IP ADDRESS 9.9.9.9 255.255.255.255
CE-3B(config-if)#INT LO96
CE-3B(config-if)#IP ADDRESS 172.20.2.97 255.255.255.240
CE-3B(config-if)#DO WR
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
*Apr 10 05:44:54.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback9, changed state to up
*Apr 10 05:44:55.311: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback96, changed state to up
*Apr 10 05:44:56.431: %LINK-3-UPDOWN: Interface FastEthernet2/0, changed state to up
*Apr 10 05:44:57.431: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to up
Building configuration...
[OK]
CE-3B(config-if)#
```

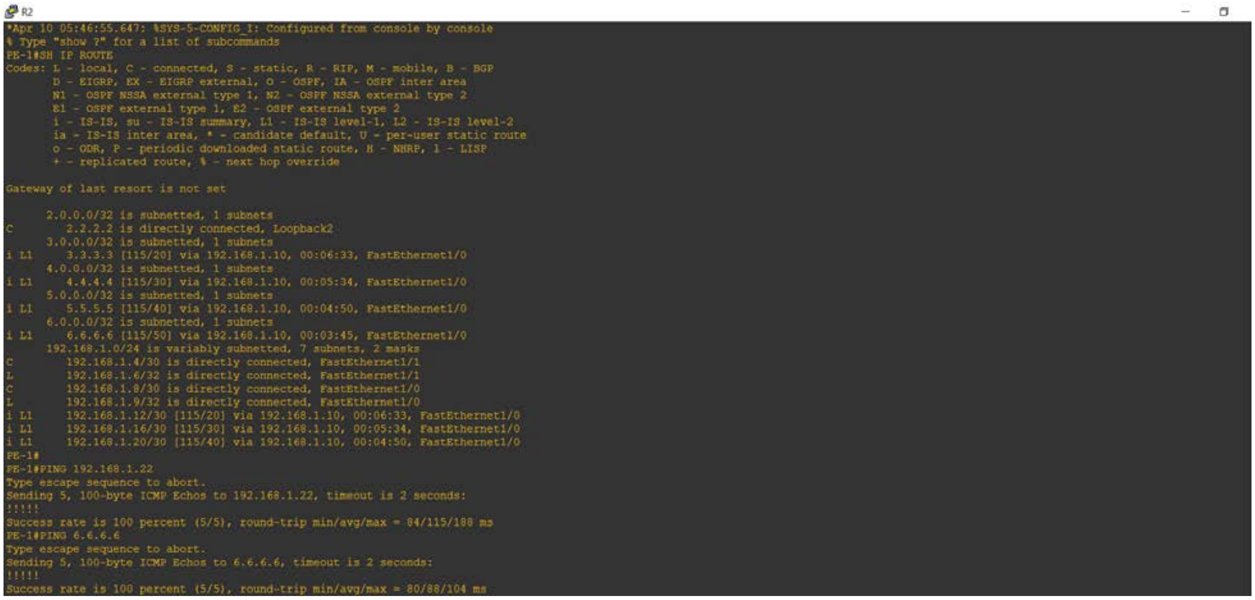
R10:

R10
```
*Apr 10 05:37:08.243: %SYS-5-CONFIG_I: Configured from memory by console
*Apr 10 05:37:08.531: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7, changed state to up
*Apr 10 05:37:10.251: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state to administratively down
*Apr 10 05:37:10.267: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state to administratively down
*Apr 10 05:37:10.271: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Apr 10 05:37:10.659: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:10.663: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:10.667: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:10.671: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:10.675: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:10.679: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:10.683: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:11.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:11.971: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:11.975: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:11.979: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:11.983: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:11.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:11.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
*Apr 10 05:37:11.995: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial5/0, changed state to down
*Apr 10 05:37:11.999: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial5/1, changed state to down
*Apr 10 05:37:12.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial5/2, changed state to down
*Apr 10 05:37:12.407: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/3, changed state to down
*Apr 10 05:37:12.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/4, changed state to down
*Apr 10 05:37:12.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5, changed state to down
*Apr 10 05:37:12.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6, changed state to down
*Apr 10 05:37:12.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-3A
CE-3A(config)#INT F2/1
CE-3A(config-if)#IP ADDRESS 192.168.1.38 255.255.255.252
CE-3A(config-if)#NO SHUT
CE-3A(config-if)#INT LO10
CE-3A(config-if)#IP ADDRESS 10.10.10.10 255.255.255.255
CE-3A(config-if)#INT LO32
CE-3A(config-if)#IP ADDRESS 172.16.1.49 255.255.255.240
CE-3A(config-if)#DO WR
*Apr 10 05:45:28.391: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback10, changed state to up
*Apr 10 05:45:28.879: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback32, changed state to up
*Apr 10 05:45:30.187: %LINK-3-UPDOWN: Interface FastEthernet2/1, changed state to up
*Apr 10 05:45:31.187: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
CE-3A(config-if)#
```

R11:

R11
```
*Apr 10 05:37:00.467: %SYS-5-CONFIG_I: Configured from memory by console
*Apr 10 05:37:01.535: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 7200 Software (C7200-ADVIPSERVICESK9-M), Version 15.2(4)S5, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2014 by Cisco Systems, Inc.
Compiled Thu 20-Feb-14 06:51 by prod_rel_team
*Apr 10 05:37:02.491: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state to administratively down
*Apr 10 05:37:02.503: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state to administratively down
*Apr 10 05:37:02.507: %LINK-5-CHANGED: Interface FastEthernet1/0, changed state to administratively down
*Apr 10 05:37:02.511: %LINK-5-CHANGED: Interface FastEthernet1/1, changed state to administratively down
*Apr 10 05:37:02.515: %LINK-5-CHANGED: Interface FastEthernet2/0, changed state to administratively down
*Apr 10 05:37:02.531: %LINK-5-CHANGED: Interface FastEthernet2/1, changed state to administratively down
*Apr 10 05:37:02.535: %LINK-5-CHANGED: Interface FastEthernet3/0, changed state to administratively down
*Apr 10 05:37:02.539: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*Apr 10 05:37:02.591: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*Apr 10 05:37:02.595: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*Apr 10 05:37:03.511: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to down
*Apr 10 05:37:03.519: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to down
*Apr 10 05:37:03.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to down
*Apr 10 05:37:03.527: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to down
*Apr 10 05:37:03.531: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to down
*Apr 10 05:37:03.535: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to down
*Apr 10 05:37:03.539: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/0, changed state to down
*Apr 10 05:37:03.539: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet3/1, changed state to down
*Apr 10 05:37:03.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/0, changed state to down
*Apr 10 05:37:03.603: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet4/1, changed state to down
Router>ENA
Router#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#HOSTNAME CE-3B
CE-3B(config)#INT F2/0
CE-3B(config-if)#IP ADDRESS 192.168.1.42 255.255.255.252
CE-3B(config-if)#NO SHUT
CE-3B(config-if)#INT LO11
CE-3B(config-if)#IP ADDRESS 11.11.11.11 255.255.255.255
CE-3B(config-if)#INT LO80
CE-3B(config-if)#IP ADDRESS 172.20.2.81 255.255.255.240
CE-3B(config-if)#DO WR
*Apr 10 05:45:58.311: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback11, changed state to up
*Apr 10 05:45:58.703: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback80, changed state to up
*Apr 10 05:46:00.091: %LINK-3-UPDOWN: Interface FastEthernet2/0, changed state to up
*Apr 10 05:46:01.091: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
CE-3B(config-if)#
```

After configuring IS-IS, message can be exchanged between configured peers. It is shown below,


```
R2
*Apr 10 05:46:55.647: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-1#SH 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

      2.0.0.0/32 is subnetted, 1 subnets
C        2.2.2.2 is directly connected, Loopback2
      3.0.0.0/32 is subnetted, 1 subnets
i L1     3.3.3.3 [115/20] via 192.168.1.10, 00:06:33, FastEthernet1/0
      4.0.0.0/32 is subnetted, 1 subnets
i L1     4.4.4.4 [115/30] via 192.168.1.10, 00:05:34, FastEthernet1/0
      5.0.0.0/32 is subnetted, 1 subnets
i L1     5.5.5.5 [115/40] via 192.168.1.10, 00:04:50, FastEthernet1/0
      6.0.0.0/32 is subnetted, 1 subnets
i L1     6.6.6.6 [115/50] via 192.168.1.10, 00:03:45, FastEthernet1/0
      192.168.1.0/24 is variably subnetted, 7 subnets, 2 masks
C        192.168.1.4/30 is directly connected, FastEthernet1/1
L        192.168.1.6/32 is directly connected, FastEthernet1/1
C        192.168.1.8/30 is directly connected, FastEthernet1/0
L        192.168.1.9/32 is directly connected, FastEthernet1/0
i L1     192.168.1.12/30 [115/20] via 192.168.1.10, 00:06:33, FastEthernet1/0
i L1     192.168.1.16/30 [115/30] via 192.168.1.10, 00:05:34, FastEthernet1/0
i L1     192.168.1.20/30 [115/40] via 192.168.1.10, 00:04:50, FastEthernet1/0
PE-1#
PE-1#PING 192.168.1.22
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.22, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/115/188 ms
PE-1#PING 6.6.6.6
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 6.6.6.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/88/104 ms
```

Now. Network has been connected. The next step is to configure MPLS,

MPLS Configuration

MPLS is created from R2 to R6 through R3, R4 and R5. The configuration is as follows,

Command Description

IP CEF:

CEF- Cisco express forwarding is advanced, layer-3 IP switching technology. It optimizes network performances and increases the network scalability. This makes the routing to happen faster.

R2:

```
R2
C        192.168.1.4/30 is directly connected, FastEthernet1/1
L        192.168.1.6/32 is directly connected, FastEthernet1/1
C        192.168.1.8/30 is directly connected, FastEthernet1/0
L        192.168.1.9/32 is directly connected, FastEthernet1/0
i L1     192.168.1.12/30 [115/20] via 192.168.1.10, 00:06:33, FastEthernet1/0
i L1     192.168.1.16/30 [115/30] via 192.168.1.10, 00:05:34, FastEthernet1/0
i L1     192.168.1.20/30 [115/40] via 192.168.1.10, 00:04:50, FastEthernet1/0
PE-1#
PE-1#PING 192.168.1.22
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.22, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/115/188 ms
PE-1#PING 6.6.6.6
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 6.6.6.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/88/104 ms
PE-1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-1(config)#MPLS IP
PE-1(config)#IP CEF
PE-1(config)#INT F1/0
PE-1(config-if)#MPLS IP
PE-1(config-if)#MPLS LABEL PROTOCOL LDP
PE-1(config-if)#DO WR
Building configuration...
[OK]
PE-1(config-if)#
*Apr 10 05:50:53.471: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (1) is UP
```

R3:

```
R3
PE-2(config-if)#DO WR
*Apr 10 05:40:20.283: %LINK-3-UPDOWN: Interface FastEthernet1/1, changed state to up
*Apr 10 05:40:20.847: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Apr 10 05:40:21.283: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/1, changed state to up
*Apr 10 05:40:21.847: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
*Apr 10 05:40:21.911: %LINK-3-UPDOWN: Interface FastEthernet2/0, changed state to up
*Apr 10 05:40:22.231: %LINK-3-UPDOWN: Interface FastEthernet2/1, changed state to up
*Apr 10 05:40:22.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/0, changed state to up
*Apr 10 05:40:23.231: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet2/1, changed state to up
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
[OK]
PE-2(config-if)#EXIT
PE-2(config)#MPLS IP
PE-2(config)#INT F1/1
PE-2(config-if)#MPLS IP
PE-2(config-if)#
*Apr 10 05:50:53.551: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
PE-2(config-if)#MPLS LABEL PROTOCOL LDP
PE-2(config-if)#INT F1/0
PE-2(config-if)#MPLS IP
PE-2(config-if)#MPLS LABEL PROTOCOL LDP
PE-2(config-if)#DO WR
Building configuration...
[OK]
PE-2(config-if)#
*Apr 10 05:53:04.223: %LDP-5-NBRCHG: LDP Neighbor 4.4.4.4:0 (2) is UP
```

R4:

```
P1>ENA
P1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
P1(config)#MPLS IP
P1(config)#IP CEF
P1(config)#INT F1/1
P1(config-if)#MPLS IP
P1(config-if)#
*Apr 10 05:53:03.067: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (1) is UP
P1(config-if)#MPLS LABEL PROTOCOL LDP
P1(config-if)#INT F1/0
P1(config-if)#MPLS IP
P1(config-if)#MPLS LABEL PROTOCOL LDP
P1(config-if)#DO WR
Building configuration...
[OK]
P1(config-if)#
*Apr 10 05:55:04.975: %LDP-5-NBRCHG: LDP Neighbor 5.5.5.5:0 (2) is UP
```

R5:

```
*Apr 10 05:52:36.175: %SYS-5-CONFIG_I: Configured from console by console
PE-3>
PE-3>
PE-3>ENA
PE-3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#MPLS IP
PE-3(config)#IP CEF
PE-3(config)#INT F1/1
PE-3(config-if)#MPLS IP
PE-3(config-if)#
*Apr 10 05:55:03.731: %LDP-5-NBRCHG: LDP Neighbor 4.4.4.4:0 (1) is UP
PE-3(config-if)#MPLS LABEL PROTOCOL LDP
PE-3(config-if)#INT F1/0
PE-3(config-if)#MPLS IP
PE-3(config-if)#MPLS LABEL PROTOCOL LDP
PE-3(config-if)#DO WR
Building configuration...
[OK]
PE-3(config-if)#
*Apr 10 05:57:02.259: %LDP-5-NBRCHG: LDP Neighbor 6.6.6.6:0 (2) is UP
```

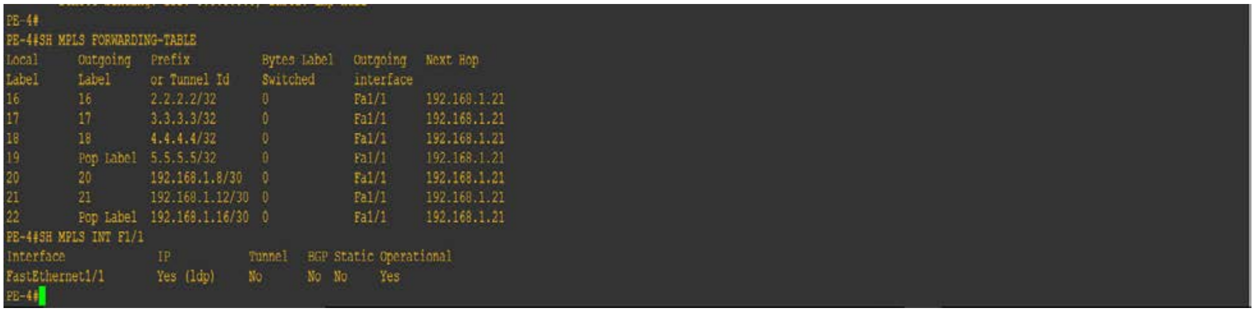
R6:

```
R6
*Apr 10 05:53:28.307: %SYS-5-CONFIG_I: Configured from console by console
PE-4>
PE-4>ENA
PE-4#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-4(config)#MPLS IP
PE-4(config)#IP CEF
PE-4(config)#INT F1/1
PE-4(config-if)#MPLS IP
PE-4(config-if)#
*Apr 10 05:57:01.199: %LDP-5-NBRCHG: LDP Neighbor 5.5.5.5:0 (1) is UP
PE-4(config-if)#MPLS LABEL PROTOCOL LDP
PE-4(config-if)#DO WR
Building configuration...
[OK]
PE-4(config-if)#EXIT
```

Now, to view the imposed MPLS bindings, use the following command

```
PE-4#
*Apr 10 05:57:39.331: %SYS-5-CONFIG_I: Configured from console by console
PE-4#SH MPLS LDP BINDINGS
  lib entry: 2.2.2.2/32, rev 2
        local binding:  label: 16
        remote binding: lsr: 5.5.5.5:0, label: 16
  lib entry: 3.3.3.3/32, rev 4
        local binding:  label: 17
        remote binding: lsr: 5.5.5.5:0, label: 17
  lib entry: 4.4.4.4/32, rev 6
        local binding:  label: 18
        remote binding: lsr: 5.5.5.5:0, label: 18
  lib entry: 5.5.5.5/32, rev 8
        local binding:  label: 19
        remote binding: lsr: 5.5.5.5:0, label: imp-null
  lib entry: 6.6.6.6/32, rev 10
        local binding:  label: imp-null
        remote binding: lsr: 5.5.5.5:0, label: 19
  lib entry: 192.168.1.8/30, rev 12
        local binding:  label: 20
        remote binding: lsr: 5.5.5.5:0, label: 20
  lib entry: 192.168.1.12/30, rev 14
        local binding:  label: 21
        remote binding: lsr: 5.5.5.5:0, label: 21
  lib entry: 192.168.1.16/30, rev 16
        local binding:  label: 22
        remote binding: lsr: 5.5.5.5:0, label: imp-null
  lib entry: 192.168.1.20/30, rev 18
        local binding:  label: imp-null
        remote binding: lsr: 5.5.5.5:0, label: imp-null
  lib entry: 192.168.1.24/30, rev 20
        local binding:  label: imp-null
```

Created MPLS forwarding table:



```
PE-4#
PE-4#SH MPLS FORWARDING-TABLE
Local      Outgoing    Prefix           Bytes Label   Outgoing   Next Hop
Label      Label       or Tunnel Id     Switched      interface
16         16          2.2.2.2/32       0             Fa1/1      192.168.1.21
17         17          3.3.3.3/32       0             Fa1/1      192.168.1.21
18         18          4.4.4.4/32       0             Fa1/1      192.168.1.21
19         Pop Label   5.5.5.5/32       0             Fa1/1      192.168.1.21
20         20          192.168.1.8/30   0             Fa1/1      192.168.1.21
21         21          192.168.1.12/30  0             Fa1/1      192.168.1.21
22         Pop Label   192.168.1.16/30  0             Fa1/1      192.168.1.21
PE-4#SH MPLS INT F1/1
Interface              IP            Tunnel   BGP Static Operational
FastEthernet1/1        Yes (ldp)     No       No  No     Yes
PE-4#
```

Pop tag: This is present because it reaches customer router and the labels are popped out here.

Advanced Lab VRF

It is an IP technology that allows multiple instances of a routing table to co-exist on the same router. Routing instances are independent in nature, this allows us to use overlapping IP address without any problem. Network path is segmented without using multiple devices. It increases network security and can eliminate the need for encryption and authentication. It is the key component of Layer-3 MPLS VPN. This will enable PE routers to appear like many routers to customer edge router. Separate routing table is maintained for each customer. PE routers will store and forward the packets irrespective of the fact that they have same IP addressing.

The key component of VRF are the VRF name and route distinguisher. Route distinguisher is used to distinguish between overlapping address. It maintains the uniqueness among identical routes in different VRF. Route target is used to share routes among different VRF's. It is used to control the import and export of routes among VRF's.

All PE router in this configuration will have VRF and one VRF is assigned per interface with unique route distinguisher.

Export: leaving VRF to go to BGP

Import: Coming from BGP into the VRF

Router 2 VRF Configuration:

```
PE-1(config)#ip vrf CUST-A
PE-1(config-vrf)#RD 1:1
PE-1(config-vrf)#ROUTE-TARGET ?
  ASN:nn or IP-address:nn  Target VPN Extended Community
  both                     Both import and export Target-VPN community
  export                   Export Target-VPN community
  import                   Import Target-VPN community

PE-1(config-vrf)#ROUTE-TARGET IMPORT 1:1
PE-1(config-vrf)#ROUTE-TARGET EXPORT 1:1
PE-1(config-vrf)#
PE-1(config-vrf)#
PE-1(config-vrf)#
PE-1(config-vrf)#
PE-1(config-vrf)#EXIT
PE-1(config)#IP VRF CUST-B
PE-1(config-vrf)#RD 1:2
PE-1(config-vrf)#ROUTE-TARGET IMPORT 1:2
PE-1(config-vrf)#ROUTE-TARGET EXPORT 1:2
PE-1(config-vrf)#DO WR
Building configuration...
[OK]
PE-1(config-vrf)#EXIT
PE-1(config)#EXIT
PE-1#
*Apr 10 06:10:48.831: %SYS-5-CONFIG_I: Configured from console by console
PE-1#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2
PE-1#
*Apr 10 06:17:02.191: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (1) is DOWN (Received error notification from peer
: Holddown time expired)
*Apr 10 06:17:05.211: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is UP
```

Router 3 VRF:

```
*Apr 10 06:02:10.171: %SYS-5-CONFIG_I: Configured from console by console
PE-2>
PE-2>ENA
PE-2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-2(config)#IP VRF CUST-A
PE-2(config-vrf)#RD 1:1
PE-2(config-vrf)#ROUTE-TARGET IMPORT 1:1
PE-2(config-vrf)#ROUTE-TARGET EXPORT 1:1
PE-2(config-vrf)#
PE-2(config-vrf)#
PE-2(config-vrf)#IP VRF CUST-B
PE-2(config-vrf)#RD 1:2
PE-2(config-vrf)#ROUTE-TARGET IMPORT 1:2
PE-2(config-vrf)#ROUTE-TARGET EXPORT 1:2
PE-2(config-vrf)#
PE-2(config-vrf)#EXIT
PE-2(config)#EXIT
PE-2#
*Apr 10 06:13:07.323: %SYS-5-CONFIG_I: Configured from console by console
PE-2#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2
PE-2#WR
Building configuration...
[OK]
PE-2#
*Apr 10 06:17:15.259: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is DOWN (Discovery Hello Hold Timer expired)
*Apr 10 06:17:25.327: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
```

Router R5 VRF:

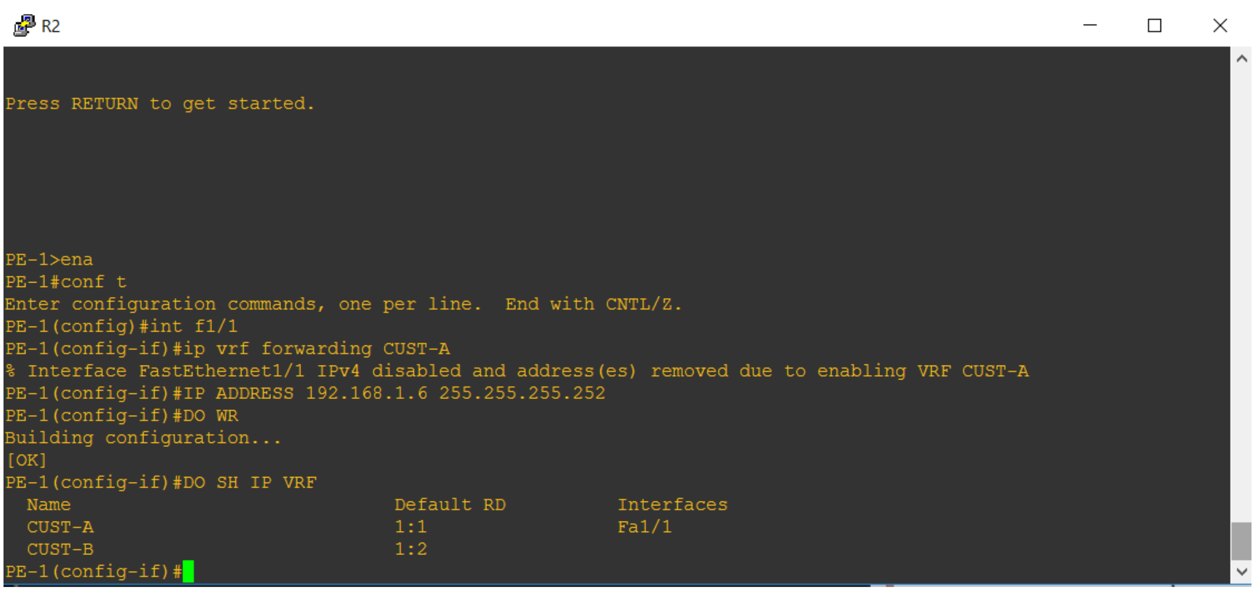
```
*Apr 10 06:06:07.023: %SYS-5-CONFIG_I: Configured from console by console
PE-3>
PE-3>ENA
PE-3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#IP VRF CUST-A
PE-3(config-vrf)#RD 1:1
PE-3(config-vrf)#ROUTE-TARGET IMPORT 1:1
PE-3(config-vrf)#ROUTE-TARGET EXPORT 1:1
PE-3(config-vrf)#
PE-3(config-vrf)#IP VRF CUST-B
PE-3(config-vrf)#RD 1:2
PE-3(config-vrf)#ROUTE-TARGET IMPORT 1:2
PE-3(config-vrf)#ROUTE-TARGET EXPORT 1:2
PE-3(config-vrf)#DO WR
Building configuration...
[OK]
PE-3(config-vrf)#EXIT
PE-3(config)#EXIT
PE-3#SH
*Apr 10 06:16:15.935: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-3#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2
PE-3#
```

Router R6 VRF:

```
PE-4>ENA
PE-4#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-4(config)#IP VRF CUST-A
PE-4(config-vrf)#RD 1:1
PE-4(config-vrf)#ROUTE-TARGET IMPORT 1:1
PE-4(config-vrf)#ROUTE-TARGET EXPORT 1:1
PE-4(config-vrf)#
PE-4(config-vrf)#IP VRF CUST-B
PE-4(config-vrf)#RD 1:2
PE-4(config-vrf)#ROUTE-TARGET IMPORT 1:2
PE-4(config-vrf)#ROUTE-TARGET EXPORT 1:2
PE-4(config-vrf)#DO DW
                     ^
% Invalid input detected at '^' marker.

PE-4(config-vrf)#DO WR
Building configuration...
[OK]
PE-4(config-vrf)#sh ip vrf
                    ^
% Invalid input detected at '^' marker.

PE-4(config-vrf)#exit
PE-4(config)#exit
PE-4#sh
*Apr 10 06:18:41.279: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-4#sh ip vrf
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2
PE-4#
```

Now, the interfaces in each router should be configured as follows,

R2:



```
R2

Press RETURN to get started.

PE-1>ena
PE-1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-1(config)#int f1/1
PE-1(config-if)#ip vrf forwarding CUST-A
% Interface FastEthernet1/1 IPv4 disabled and address(es) removed due to enabling VRF CUST-A
PE-1(config-if)#IP ADDRESS 192.168.1.6 255.255.255.252
PE-1(config-if)#DO WR
Building configuration...
[OK]
PE-1(config-if)#DO SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa1/1
  CUST-B                           1:2
PE-1(config-if)#
```

R6:

R6

```
PE-4(config-vrf)#exit
PE-4(config)#exit
PE-4#sh
*Apr 10 06:18:41.279: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-4#sh ip vrf
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2
PE-4#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-4(config)#INT F1/0
PE-4(config-if)#IP VRF FORWARDING CUST-B
% Interface FastEthernet1/0 IPv4 disabled and address(es) removed due to enabling VRF CUST-B
PE-4(config-if)#IP ADDRESS 192.168.1.25 255.255.255.252
PE-4(config-if)#DO WR
Building configuration...
[OK]
PE-4(config-if)#DO SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1
  CUST-B                           1:2                 Fa1/0
PE-4(config-if)#
```

R3:

```
PE-2(config-if)#INT F2/0
PE-2(config-if)#IP VRF FORWARDING CUST-B
% Interface FastEthernet2/0 IPv4 disabled and address(es) removed due to enabling VRF CUST-B
PE-2(config-if)#IP ADDRESS 192.168.1.33 255.255.255.252
PE-2(config-if)#EXIT
PE-2(config)#EXIT
PE-2#SH
*Apr 10 06:33:10.135: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-2#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa0/0
  CUST-B                           1:2                 Fa2/0
PE-2#WR
Building configuration...
[OK]
PE-2#
```

```
PE-2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-2(config)#mpls ip
PE-2(config)#int f2/1
PE-2(config-if)#ip vrf forwarding CUST-A
% Interface FastEthernet2/1 IPv4 disabled and address(es) removed due to enabling VRF CUST-A
PE-2(config-if)#IP address 192.168.1.29 255.255.255.252
PE-2(config-if)#exit
PE-2(config)#exit
PE-2#
*Apr 10 07:07:42.631: %SYS-5-CONFIG_I: Configured from console by console
PE-2#sh ip vrf
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa0/0
                                                       Fa2/1
  CUST-B                           1:2                 Fa2/0
PE-2#
```

R5:

```
PE-3(config-if)#INT F2/0
PE-3(config-if)#IP VRF FORWARDING CUST-B
% Interface FastEthernet2/0 IPv4 disabled and address(es) removed due to enabling VRF CUST-B
PE-3(config-if)#INT F2/0
PE-3(config-if)#IP VRF FORWARDING CUST-B
PE-3(config-if)#IP ADDRESS 192.168.1.41 255.255.255.252
PE-3(config-if)#DO WR
Building configuration...
[OK]
PE-3(config-if)#EXIT
PE-3(config)#EXIT
PE-3#
*Apr 10 06:37:47.379: %SYS-5-CONFIG_I: Configured from console by console
PE-3#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa0/0
  CUST-B                           1:2                 Fa2/0
PE-3#
```

```
PE-3>
PE-3>ena
PE-3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#int f2/1
PE-3(config-if)#ip vrf forwarding CUST-A
% Interface FastEthernet2/1 IPv4 disabled and address(es) removed due to enabling VRF CUST-A
PE-3(config-if)#IP ADDRESS 192.168.1.37 255.255.255.252
PE-3(config-if)#EXIT
PE-3(config)#EXIT
PE-3#SH
*Apr 10 07:12:37.283: %SYS-5-CONFIG_I: Configured from console by console
% Type "show ?" for a list of subcommands
PE-3#SH IP VRF
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa0/0
                                                       Fa2/1
  CUST-B                           1:2                 Fa2/0
```

IP Route R5:

```
PE-3#SH 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

      2.0.0.0/32 is subnetted, 1 subnets
i L1     2.2.2.2 [115/40] via 192.168.1.17, 00:55:55, FastEthernet1/1
      3.0.0.0/32 is subnetted, 1 subnets
i L1     3.3.3.3 [115/30] via 192.168.1.17, 00:55:55, FastEthernet1/1
      4.0.0.0/32 is subnetted, 1 subnets
i L1     4.4.4.4 [115/20] via 192.168.1.17, 00:55:55, FastEthernet1/1
      5.0.0.0/32 is subnetted, 1 subnets
C        5.5.5.5 is directly connected, Loopback5
      6.0.0.0/32 is subnetted, 1 subnets
i L1     6.6.6.6 [115/20] via 192.168.1.22, 00:00:25, FastEthernet1/0
      192.168.1.0/24 is variably subnetted, 8 subnets, 2 masks
i L1     192.168.1.8/30 [115/30] via 192.168.1.17, 00:55:55, FastEthernet1/1
i L1     192.168.1.12/30 [115/20] via 192.168.1.17, 00:55:55, FastEthernet1/1
C        192.168.1.16/30 is directly connected, FastEthernet1/1
L        192.168.1.18/32 is directly connected, FastEthernet1/1
C        192.168.1.20/30 is directly connected, FastEthernet1/0
L        192.168.1.21/32 is directly connected, FastEthernet1/0
C        192.168.1.40/30 is directly connected, FastEthernet2/1
L        192.168.1.41/32 is directly connected, FastEthernet2/1
```

```
PE-3#SH IP ROUTE CONNECTED
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

      5.0.0.0/32 is subnetted, 1 subnets
C        5.5.5.5 is directly connected, Loopback5
      192.168.1.0/24 is variably subnetted, 8 subnets, 2 masks
C        192.168.1.16/30 is directly connected, FastEthernet1/1
L        192.168.1.18/32 is directly connected, FastEthernet1/1
C        192.168.1.20/30 is directly connected, FastEthernet1/0
L        192.168.1.21/32 is directly connected, FastEthernet1/0
C        192.168.1.40/30 is directly connected, FastEthernet2/1
L        192.168.1.41/32 is directly connected, FastEthernet2/1
PE-3#
PE-3#SH IP VRF CUST-A
  Name                             Default RD          Interfaces
  CUST-A                           1:1                 Fa0/0
```

```
PE-3#PING VRF CUST-B 192.168.1.41
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.41, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/7/8 ms
```

Now, the router has one global routing table and separately for each interface. Same configuration should be on al routers.

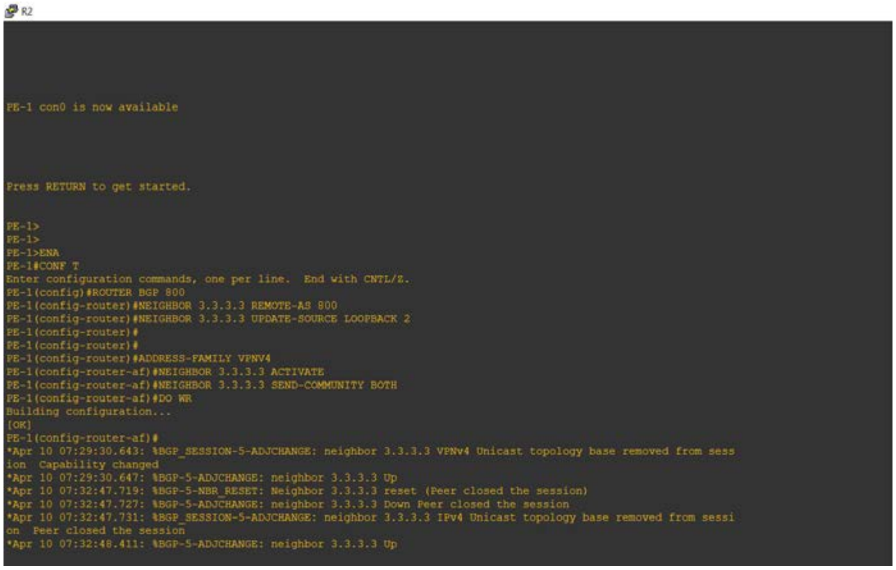
Configuring BGP for PE to PE communication

Pairing is done between

- PE-1(R2) and PE-2(R3)
- PE-3(R5) and PE-4(R6)
- PE-2(R3) and PE-3(R5)

This is the transport mechanism. The information in VRF is put into BGP. Neighbor relationship is created between all the routers. Though R4 is between R3 and R5, they can become neighbors by the concept of Route Reflectors.

R2 BGP:



ROUTER BGP 800 – In this command, 800 denotes the autonomous system number, this identifies the routing domain under the control that connects the internet.

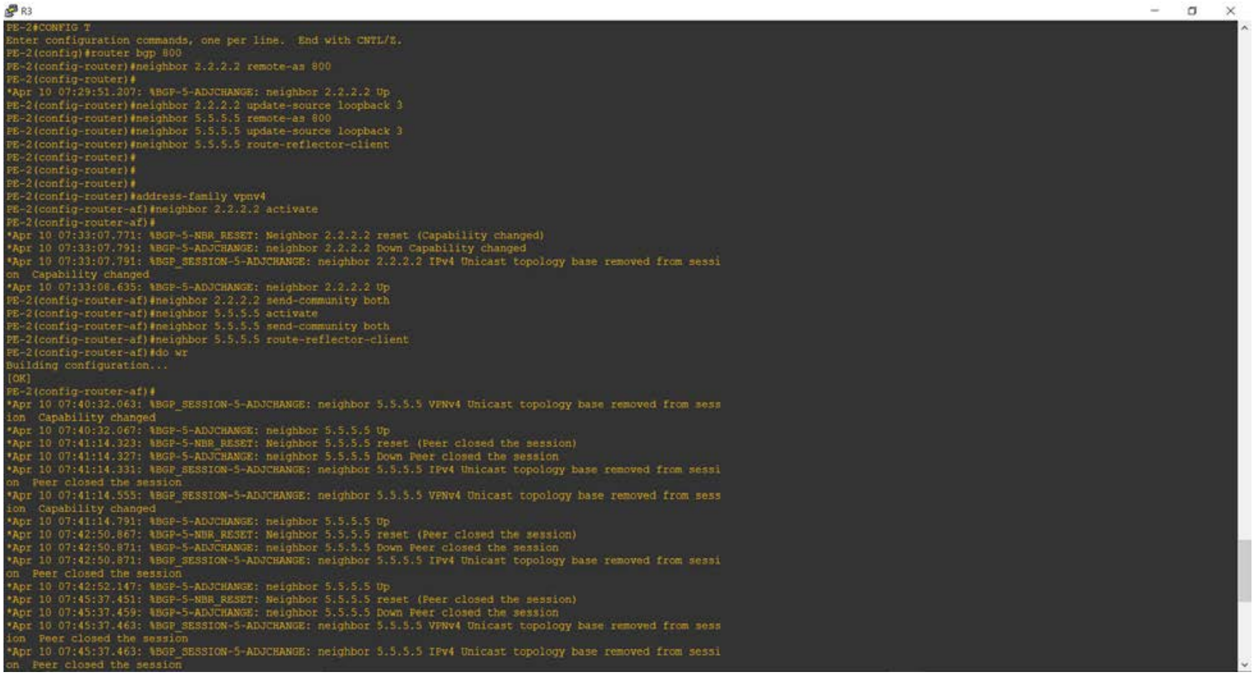
To communicate with BGP peer, router needs to be configured with neighbor statement and a route to that neighbor. Remote-as command specifies the neighbor’s AS number. This determines whether the neighbor is an internal or external BGP router. If same AS number, then it is internal.

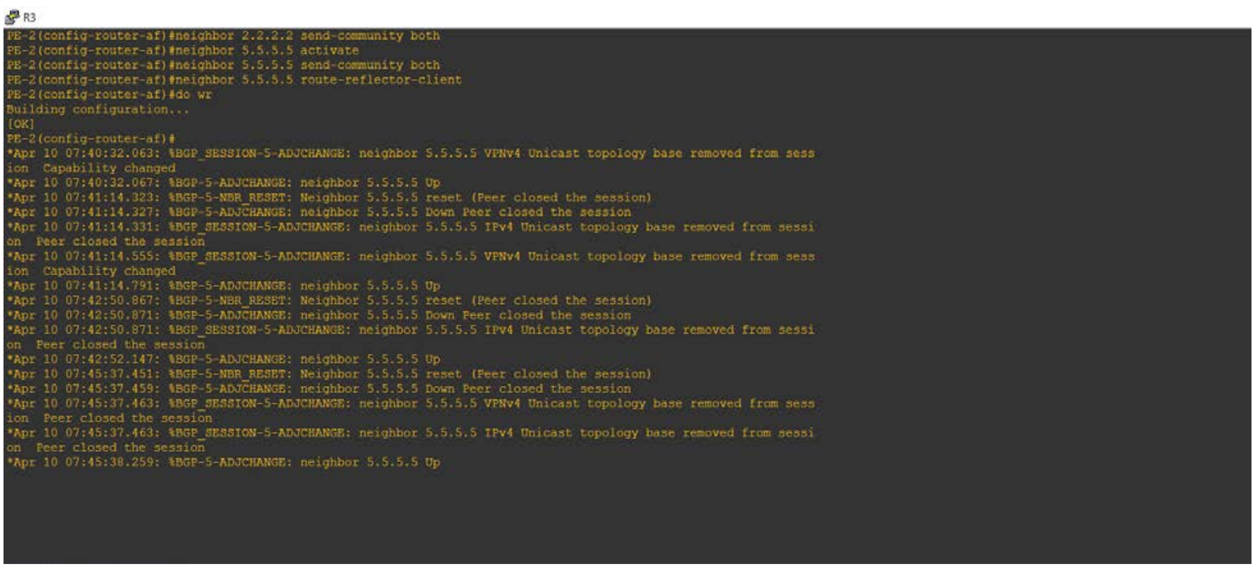
By using update-source, any interface such as loopback can be used for establishing TCP connections.

Address-family vpnv4 – It places the router in address family configuration mode, using this routing sessions can be configured that uses VPN version 4 address prefix

Send-community command: This specify that the community attribute should be sent to BGP neighbor.

R3 BGP:





One neighbor will be 2.2.2.2 and other will 5.5.5.5, provider router is bypassed here using the concept of route reflector. This route reflector is used to eliminate full mesh requirement and allow building BGP networks that scale easily.

R5 BGP:

```
PE-3>
PE-3>conf t
        ^
% Invalid input detected at '^' marker.

PE-3>ena
PE-3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#router bgp 800
PE-3(config-router)#neighbor 3.3.3.3 remote-as 800
PE-3(config-router)#neighbor
*Apr 10 07:40:31.463: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
% Incomplete command.

PE-3(config-router)#neighbor 3.3.3.3 update-source loopback 5
PE-3(config-router)#neighbor 3.3.3.3 route-reflector-client
PE-3(config-router)#
*Apr 10 07:41:13.479: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Down RR client config change
*Apr 10 07:41:13.479: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 IPv4 Unicast topology base removed from sessi
on  RR client config change
*Apr 10 07:41:14.299: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
PE-3(config-router)#neighbor 6.6.6.6 remote-as 800
PE-3(config-router)#neighbor 6.6.6.6 update-source loopback 5
PE-3(config-router)#address-family vpnv4
PE-3(config-router-af)#neighbor 3.3.3.3 activate
PE-3(config-router-af)#neig
*Apr 10 07:42:50.083: %BGP-5-NBR_RESET: Neighbor 3.3.3.3 reset (Capability changed)
*Apr 10 07:42:50.103: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Down Capability changed
*Apr 10 07:42:50.107: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 IPv4 Unicast topology base removed from sessi
on  Capability changedhbor
*Apr 10 07:42:51.415: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
% Incomplete command.
```

```
*Apr 10 07:42:50.107: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 IPv4 Unicast topology base removed from sessi
on  Capability changedhbor
*Apr 10 07:42:51.415: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
% Incomplete command.

PE-3(config-router-af)#neighbor 3.3.3.3 activate
PE-3(config-router-af)#neighbor 3.3.3.3 send-community both
PE-3(config-router-af)#
PE-3#
*Apr 10 07:44:05.379: %SYS-5-CONFIG_I: Configured from console by console
PE-3#router bgp 800
        ^
% Invalid input detected at '^' marker.

PE-3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#router bgp 800
PE-3(config-router)#address-family vpnv4
PE-3(config-router-af)#neighbor 3.3.3.3 route-refelector-client
                                                  ^
% Invalid input detected at '^' marker.

PE-3(config-router-af)#neighbor 3.3.3.3 route-reflector-client
PE-3(config-router-af)#
*Apr 10 07:45:36.567: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Down RR client config change
*Apr 10 07:45:36.571: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 VPNv4 Unicast topology base removed from sess
ion  RR client config change
*Apr 10 07:45:36.571: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 IPv4 Unicast topology base removed from sessi
on  RR client config change
*Apr 10 07:45:37.555: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
PE-3(config-router-af)#neighbor 6.6.6.6 activate
PE-3(config-router-af)#neighbor 6.6.6.6 send-
PE-3(config-router-af)#neighbor 6.6.6.6 send-community both
PE-3(config-router-af)#do wr
Building configuration...
[OK]
PE-3(config-router-af)#
*Apr 10 07:48:26.275: %BGP_SESSION-5-ADJCHANGE: neighbor 6.6.6.6 VPNv4 Unicast topology base removed from sess
ion  Capability changed
*Apr 10 07:48:26.279: %BGP-5-ADJCHANGE: neighbor 6.6.6.6 Up
*Apr 10 07:49:17.431: %BGP-5-NBR_RESET: Neighbor 6.6.6.6 reset (Peer closed the session)
*Apr 10 07:49:17.439: %BGP-5-ADJCHANGE: neighbor 6.6.6.6 Down Peer closed the session
*Apr 10 07:49:17.439: %BGP_SESSION-5-ADJCHANGE: neighbor 6.6.6.6 IPv4 Unicast topology base removed from sessi
on  Peer closed the session
*Apr 10 07:49:17.691: %BGP-5-ADJCHANGE: neighbor 6.6.6.6 Up
PE-3(config-router-af)#
PE-3(config-router-af)#
PE-3(config-router-af)#exit
PE-3(config-router)#exit
PE-3(config)#exit
```

R6 BGP:

```
R6
PE-4>
PE-4>
PE-4>conf t
        ^
% Invalid input detected at '^' marker.

PE-4>ena
PE-4#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-4(config)#router bgp 800
PE-4(config-router)#neighbor 5.5.5.5 remote-as 800
PE-4(config-router)#neighbor 5.5.5.5 update
*Apr 10 07:48:26.307: %BGP-5-ADJCHANGE: neighbor 5.5.5.5 Up
% Incomplete command.

PE-4(config-router)#neighbor 5.5.5.5 update-source loopback 6
PE-4(config-router)#address-family vpnv4
PE-4(config-router-af)#neighbor 5.5.5.5 activate
PE-4(config-router-af)#
*Apr 10 07:49:17.159: %BGP-5-NBR_RESET: Neighbor 5.5.5.5 reset (Capability changed)
*Apr 10 07:49:17.171: %BGP-5-ADJCHANGE: neighbor 5.5.5.5 Down Capability changed
*Apr 10 07:49:17.175: %BGP_SESSION-5-ADJCHANGE: neighbor 5.5.5.5 IPv4 Unicast topology base removed from sessi
on  Capability changed
*Apr 10 07:49:17.639: %BGP-5-ADJCHANGE: neighbor 5.5.5.5 Up
PE-4(config-router-af)#neighbor 5.5.5.5 send-community both
PE-4(config-router-af)#do wr
Building configuration...
[OK]
```

Configured neighbors:

R6: neighbor 5.5.5.5

```
PE-4#sh ip bgp neighbors
BGP neighbor is 5.5.5.5,  remote AS 800, internal link
  BGP version 4, remote router ID 5.5.5.5
  BGP state = Established, up for 00:01:59
  Last read 00:00:08, last write 00:00:12, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family VPNv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          2
    Keepalives:             4          4
    Route Refresh:          0          0
    Total:                  7          7
  Default minimum time between advertisement runs is 0 seconds

 For address family: IPv4 Unicast
  Session: 5.5.5.5
  BGP table version 1, neighbor version 1/0
  Output queue size : 0
  Index 2, Advertise bit 0
  2 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               0          0
    Prefixes Total:                 0          0
    Implicit Withdraw:              0          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          0
    Used as multipath:            n/a          0
```

R6

```
    Prefixes Current:               0          0
    Prefixes Total:                 0          0
    Implicit Withdraw:              0          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          0
    Used as multipath:            n/a          0

                                   Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Total:                                0          0
  Number of NLRIs in the update sent: max 0, min 0
  Last detected as dynamic slow peer: never
  Dynamic slow peer recovered: never
  Refresh Epoch: 1
  Last Sent Refresh Start-of-rib: never
  Last Sent Refresh End-of-rib: never
  Last Received Refresh Start-of-rib: never
  Last Received Refresh End-of-rib: never
                                       Sent       Rcvd
        Refresh activity:              ----       ----
          Refresh Start-of-RIB          0          0
          Refresh End-of-RIB            0          0

  Address tracking is enabled, the RIB does have a route to 5.5.5.5
  Connections established 2; dropped 1
  Last reset 00:01:59, due to Capability changed of session 1
  Transport(tcp) path-mtu-discovery is enabled
  Graceful-Restart is disabled
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled
Mininum incoming TTL 0, Outgoing TTL 255
Local host: 6.6.6.6, Local port: 38132
Foreign host: 5.5.5.5, Foreign port: 179
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x7B60D8):
Timer          Starts    Wakeups            Next
Retrans             5          0             0x0
TimeWait            0          0             0x0
AckHold             4          3             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            1          0        0x82B72C
DeadWait            0          0             0x0
Linger              0          0             0x0

 --More--
```

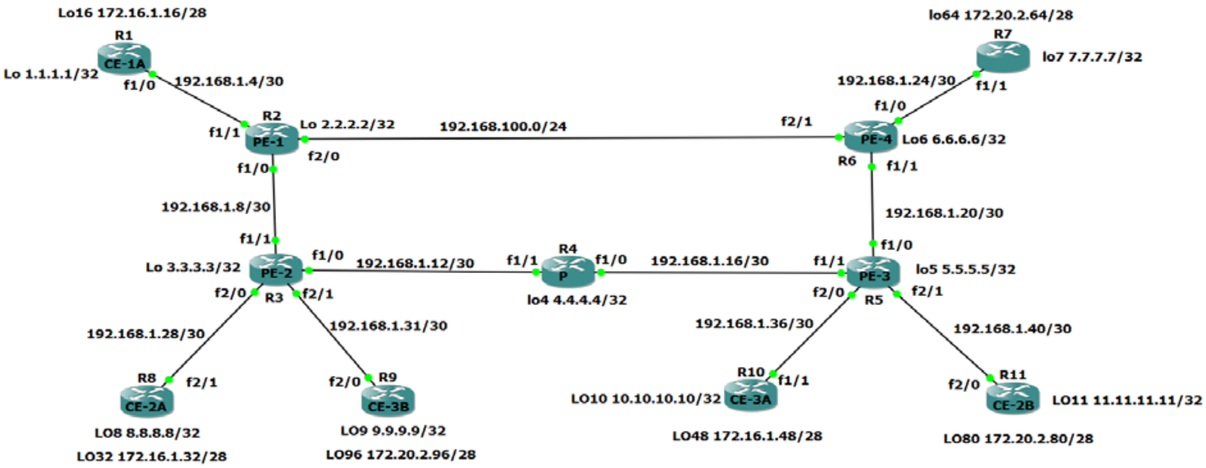
R5: Neighbor 3.3.3.3 and 6.6.6.6

```
PE-3#
*Apr 10 07:52:09.207: %SYS-5-CONFIG_I: Configured from console by console
PE-3#wr
Building configuration...
[OK]
PE-3#sh ip bgp neighbors
BGP neighbor is 3.3.3.3,  remote AS 800, internal link
  BGP version 4, remote router ID 3.3.3.3
  BGP state = Established, up for 00:07:09
  Last read 00:00:52, last write 00:00:54, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family VPNv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          2
    Keepalives:             9          9
    Route Refresh:          0          0
    Total:                 12         12
  Default minimum time between advertisement runs is 0 seconds

 For address family: IPv4 Unicast
  Session: 3.3.3.3
  BGP table version 1, neighbor version 1/0
  Output queue size : 0
  Index 4, Advertise bit 0
  Route-Reflector Client
  4 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               0          0
    Prefixes Total:                 0          0
    Implicit Withdraw:              0          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          0
    Used as multipath:            n/a          0
```

```
minRTT: 168 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: none
Option Flags: higher precendence, nagle, path mtu capable

Datagrams (max data segment is 1436 bytes):
Rcvd: 20 (out of order: 0), with data: 12, total data bytes: 288
Sent: 22 (retransmit: 0 fastretransmit: 0),with data: 12, total data bytes: 288


BGP neighbor is 6.6.6.6,  remote AS 800, internal link
  BGP version 4, remote router ID 6.6.6.6
  BGP state = Established, up for 00:03:29
  Last read 00:00:43, last write 00:00:49, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family VPNv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          2
    Keepalives:             5          5
    Route Refresh:          0          0
    Total:                  8          8
  Default minimum time between advertisement runs is 0 seconds

 For address family: IPv4 Unicast
  Session: 6.6.6.6
  BGP table version 1, neighbor version 1/0
  Output queue size : 0
  Index 6, Advertise bit 1
  6 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               0          0
    Prefixes Total:                 0          0
    Implicit Withdraw:              0          0
 --More--
```

Traffic Engineering in MPLS:

Topology



To demonstrate traffic engineering, the path from R3-R5 via R4 is taken. An alternate path is made from R3 to R5 via R2 and R6, if there is any bandwidth shortage. R4 is configured with less bandwidth so that diversion of traffic to R2-R6 can be seen.

R2 Config:

```
PE-1#CONFIG T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-1(config)#MPLS TRAFFIC-ENG TUNNELS
PE-1(config)#ROUTER ISIS
PE-1(config-router)#METRIC-STYLE WIDE
PE-1(config-router)#MPLS TRAFFIC-ENG LEVEL-2
PE-1(config-router)#MPLS TRAFFIC-ENG ROUTER-ID Lo2
PE-1(config-router)#INT F2/1
PE-1(config-if)#IP RSVP BANDWIDTH 256
PE-1(config-if)#INT F1/1
PE-1(config-if)#IP RSVP BANDWIDTH 256
PE-1(config-if)#
*Apr 10 15:48:15.125: %SYS-5-CONFIG_I: Configured from console by console
PE-1(config-if)#do wr
Building configuration...
[OK]
```

R3 config

```
PE-2>ena
PE-2#CONFIG T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-2(config)#MPLS TRAFFIC-ENG TUNNELS
PE-2(config)#ROUTER ISIS
PE-2(config-router)#METRIC-STYLE WIDE
PE-2(config-router)#MPLS TRAFFIC-ENG LEVEL-2
PE-2(config-router)#MPLS TRAFFIC-ENG ROUTER-ID Lo3
PE-2(config-router)#INT F1/0
PE-2(config-if)#IP RSVP BANDWIDTH 256
PE-2(config-if)#INT F1/1
PE-2(config-if)#IP RSVP BANDWIDTH 256
PE-2(config-if)#
*Apr 10 15:42:38.913: %BGP-5-ADJCHANGE: neighbor 2.2.2.2 Up
*Apr 10 15:42:38.953: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (2) is UP
PE-2(config-if)#do wr
Building configuration...
[OK]
```

R4:

```
P1>ena
P1#CONFIG T
Enter configuration commands, one per line.  End with CNTL/Z.
P1(config)#MPLS TRAFFIC-ENG TUNNELS
P1(config)#ROUTER ISIS
P1(config-router)#METRIC-STYLE WIDE
P1(config-router)#MPLS TRAFFIC-ENG LEVEL-2
P1(config-router)#MPLS TRAFFIC-ENG ROUTER-ID Lo4
P1(config-router)#INT F1/0
P1(config-if)#IP RSVP BANDWIDTH 70
P1(config-if)#INT F1/1
P1(config-if)#IP RSVP BANDWIDTH 70
P1(config-if)#
P1(config-if)#
*Apr 10 15:49:18.025: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (1) is DOWN (TCP connection closed by peer)
P1(config-if)#do
*Apr 10 15:49:21.845: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (3) is UP
% Incomplete command.

P1(config-if)#do wr
Building configuration...
[OK]
```

R5:

```
PE-3>ena
PE-3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PE-3(config)#CONFIG T
                    ^
% Invalid input detected at '^' marker.

PE-3(config)#MPLS TRAFFIC-ENG TUNNELS
PE-3(config)#ROUTER ISIS
PE-3(config-router)#METRIC-STYLE WIDE
PE-3(config-router)#MPLS TRAFFIC-ENG LEVEL-2
PE-3(config-router)#MPLS TRAFFIC-ENG ROUTER-ID Lo5
PE-3(config-router)#INT F1/0
PE-3(config-if)#IP RSVP BANDWIDTH 256
PE-3(config-if)#INT F1/1
PE-3(config-if)#IP RSVP BANDWIDTH 256
*Apr 10 15:48:08.005: %BGP-5-NBR_RESET: Neighbor 3.3.3.3 active reset (BGP Notification sent)
*Apr 10 15:48:08.009: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
*Apr 10 15:48:08.125: %LDP-5-NBRCHG: LDP Neighbor 4.4.4.4:0 (1) is UP
PE-3(config-if)#do wr
Building configuration...
[OK]
```

R6:

```
PE-4>
PE-4>ena
PE-4#CONFIG T
Enter configuration commands, one per line.  End with CNTL/Z.
PE-4(config)#MPLS TRAFFIC-ENG TUNNELS
PE-4(config)#ROUTER ISIS
PE-4(config-router)#METRIC-STYLE WIDE
PE-4(config-router)#MPLS TRAFFIC-ENG LEVEL-2
PE-4(config-router)#MPLS TRAFFIC-ENG ROUTER-ID Lo6
PE-4(config-router)#INT F2/1
PE-4(config-if)#IP RSVP BANDWIDTH 256
PE-4(config-if)#INT F1/1
PE-4(config-if)#IP RSVP BANDWIDTH 256
PE-4(config-if)#
PE-4(config-if)#
PE-4(config-if)#do wr
Building configuration...
[OK]
```

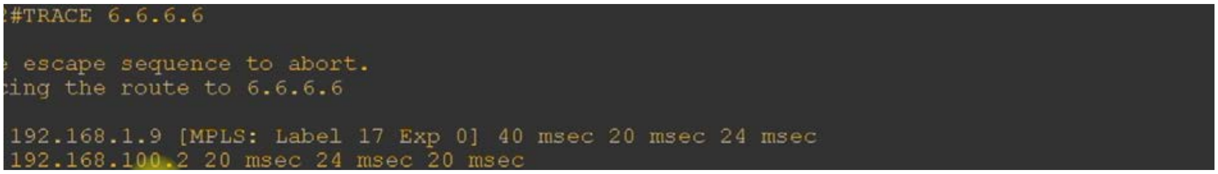
Tunnel in R3

```
PE-2(config)#INT TUN 0
PE-2(config-if)#IP UNNUMBERED LO3
PE-2(config-if)#MPLS IP
PE-2(config-if)#TUNNEL DESTINATION 5.5.5.5
PE-2(config-if)#TUNNEL MODE MPLS TRAFFIC-ENG
PE-2(config-if)#TUNNEL MPLS TRAFFIC-ENG AUTOROUTE ANNOUNCE
PE-2(config-if)#TUNNEL MPLS TRAFFIC-ENG PRIORITY 0 0
PE-2(config-if)#TUNNEL MPLS TRAFFIC-ENG BANDWIDTH 100
PE-2(config-if)#TUNNEL MPLS TRAFFIC-ENG PATH-OPTION 1 DYNAMIC
PE-2(config-if)#DO WR
Building configuration...
[OK]
```

R3

```
      2.0.0.0/32 is subnetted, 1 subnets
i L1     2.2.2.2 [115/20] via 192.168.1.9, 00:14:39, FastEthernet1/1
      3.0.0.0/32 is subnetted, 1 subnets
C        3.3.3.3 is directly connected, Loopback3
      4.0.0.0/32 is subnetted, 1 subnets
i L1     4.4.4.4 [115/20] via 192.168.1.14, 00:12:13, FastEthernet1/0
      5.0.0.0/32 is subnetted, 1 subnets
i L1     5.5.5.5 [115/30] via 192.168.1.14, 00:09:18, FastEthernet1/0
      6.0.0.0/32 is subnetted, 1 subnets
i L1     6.6.6.6 [115/40] via 192.168.1.14, 00:07:43, FastEthernet1/0
      192.168.1.0/24 is variably subnetted, 6 subnets, 2 masks
C        192.168.1.8/30 is directly connected, FastEthernet1/1
L        192.168.1.10/32 is directly connected, FastEthernet1/1
C        192.168.1.12/30 is directly connected, FastEthernet1/0
L        192.168.1.13/32 is directly connected, FastEthernet1/0
i L1     192.168.1.16/30 [115/20] via 192.168.1.14, 00:12:13, FastEthernet1/0
i L1     192.168.1.20/30 [115/30] via 192.168.1.14, 00:09:18, FastEthernet1/0
PE-2(config-if)#DO SH IP ROUTE 5.5.5.5
Routing entry for 5.5.5.5/32
  Known via "isis", distance 115, metric 30, type level-1
  Redistributing via isis
  Last update from 192.168.1.14 on FastEthernet1/0, 00:09:34 ago
  Routing Descriptor Blocks:
  * 192.168.1.14, from 5.5.5.5, 00:09:34 ago, via FastEthernet1/0
      Route metric is 30, traffic share count is 1
PE-2(config-if)#
```

If trace route is used, it can be observed that it is taking the newly created path to reach the destination.



MPLS traffic engineering has the following features:

- Packet transport using MPLS forwarding crossing a multihop label-switched path (LSP).
- Routing and signaling capability of LSPs across a backbone topology that can:
- Understand the backbone topology and available resources
- Account for link bandwidth and for the size of the traffic flow when determining routes for LSPs across the backbone.
- Has a dynamic adaptation mechanism that enables the backbone to be resilient to failures, even if several primary paths are pre-calculated off-line.
- Enhancements to the IGP (IS-IS or OSPF) SPF calculations to automatically calculate what traffic should be sent over what LSPs.

CONCLUSION

We understood and successfully implemented the basic MPLS and GNS3 configuration in this project. Basic MPLS topology was structured and labels were assigned between each pair of attached LSR. We now understand basics of MPLS network and simulation of simple network topologies in the GNS3 tool. Also, we understood advanced MPLS with VRF and BGP. In addition to this, we understood the concepts of traffic engineering and implemented them successfully.