MPLS BSED VPN Implementation in Corporate Environment

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Abstract: ***Multiprotocol label switching has become a key technology in today's Ip technology for service providers and corporations that prefer to use remote connectivity. Enterprise are attracted towards service providers which provide MPLS VPNs. It has large number of customers due to the certain advantages over other VPN technologies like Frame Relay and ATM. Due to the unique features possessed by MPLS VPN, such as VoIP by Cos, scalable bandwidth, voice and data on a single platform through various sources, today MPLS VPN has become the leading technology IP technology. The main objective of this thesis was to develop an understanding of the nature of MPLS VPN technology. The MPLS VPN technology is described briefly, and a network scenario is illustrated to examine the different communication protocols. The practical part was carried out in a GNS3 simulator. For the practical purpose, 3700 series router is used.***

Keywords: MPLS VPN, Qos, ATM, Frame Rely

1. Introduction

Nowadays many new technologies are developed to make our life easy. Enterprises and companies use these technologies to make their service easy and cost efficient. We can access and acquire any services from the internet distantly from anywhere. Employers provide a flexible work environment to their employees who could do their work staying at home or anywhere in this world.

Due to better reliability and increased performance, Multiprotocol Label Switching (MPLS) replacing another WAN technologies. In the past different technologies like Frame Relay, ATM, T1 or E1 dedicated links were used for WAN connectivity. To maintain the security issues, layer2 VPNs were used in enterprise network that are not scalable. The MPLS VPN provides scalability and can divide larger enterprises into smaller networks. It became very useful in IT enterprises that have to provide isolated networks to their departments. Large enterprises are interested in MPLS VPN since it provides a new option for WAN connectivity.

The main purpose of this paper is to discuss the implementation of MPLS VPN technology. This paper includes mainly the configuration needed for the establishment of MPLS VPN and explains how to implement a MPLS VPN over an IP4 network. The paper also explains the benefits of MPLS VPN over traditional IP routing and examines MPLS VPN network, protocols used for communication and illustrate a network scenario.[1]

2. Multiprotocol Label Switching

2.1 Overview of MPLS

Multiprotocol Label Switching (MPLS) IS AN ip technology developed by IETF to overcome the drawbacks of traditional IP routing. MPLS is technique used by service providers to provide better and single network infrastructure for real time traffic such as voice and video. In the past Frame Relay and ATM were used to transfer data in enterprise. MPLS operates in between the data link layer and network layer, So it is called layer 2.5 protocols.[3] MPLS works with Internet Protocol (IP), Frame-Relay and Asynchronous Transport Mode (ATM) network protocols to create a Label Switch Path (LSP). It provides scalability to VPNs.

Each router in a traditional IP technology makes their forwarding decision based on the study of packet's header and the result of the routing algorithm running in the network layer. Whenever the packets arrive at the router, it has to think where to send the packet. However, in MPLS every packet assigned to forwarding equivalence class (FEC) as a label that is used to make the forwarding decision without IP lookups in every node. Every router has a table that indicates how to handle FEC type of packets. Once the packet enters the network, subsequent routers use this label as an index to forward the packet with the help of table present in every router.

2.2 Benefits of MPLS

Multi-service Networks: The ability to implement multi-service networks is one of the main reasons behind the popularity of MPLS. It helps the network to carry all kinds of traffic. MPLS integrates different technologies, such as Layer2 VPNs, Layer3 VPNs, Traffic Engineering, QoS, GMPLS, and IPv6 which enables to develop scalable and secure networks that guarantee Service Level Agreement (SLA).

MPLS Virtual Private Network (MPLS VPN): - It provides private and secure networks called virtual private networks (VPN) over the same network topology to many customers. Large enterprises and service providers are interested in MPLS VPN due to its ability to divide network to smaller networks and scalability feature.

Scalability: In the past, most of the networks used to have a core ATM switches surrounded by routers that were totally meshed and had many adjacent networks. The MPLS network helped to fix this kind of problem. The core devices are not involved in any relationship with the other networks, and their task is only to switch packets.

Traffic Engineering: Traffic engineering is the ability to control the traffic that helps to use the network infrastructure optimally by spreading the traffic more evenly over the all available links.

2.3 MPLS Operation

Instead of the IP address or MAC address or MAC address, MPLS works on small labels. These labels are inserted between layer 2 and layer 3 of OSI. Forwarding decisions are based on these labels instead of having to look at complex IP tables. Thus, it reduces the overhead and makes forwarding decisions more efficient. The important considerations are MPLS is layer 2.5 it gives speed of layer 2 and dynamics of layer 3 technologies. The interesting factor is its flexibility of use as completely layer 2 or layer 3 technologies. In MPLS VPN it is solely used as layer 3 technology making labels based on IP address. While, in case of VPLS, It makes labels based on MAC address, making it is a layer 2 technology. Thus the adaptability of MPLS makes it charismatic for professionals. The MPLS label position in different types of technologies can be seen in figure 1.

It can be seen from figure 1 that MPLS label stack is inserted between IP header (layer 2) and corresponding layer 2 header of the particular technology. In case of MPLS based VPN the label stack consists of a MPLS label at the top and CPN label at the bottom. The size of label is 32 bit long as shown in figure 2. The field is 20 bit long label value. Labels are represented in decimal format. The second field is experimental bits. These 3 bits are reserved for experiments. 1 bit long set (s) is kept 1 if it is the last label in number otherwise kept 0. The last field of Time to Live (TTL) comprises 8 bits and is used to count the number of hops.

2.4 MPLS terminologies

It is important to know before the configuration it has no connection to customer sites and is deployed only in ISP networks.

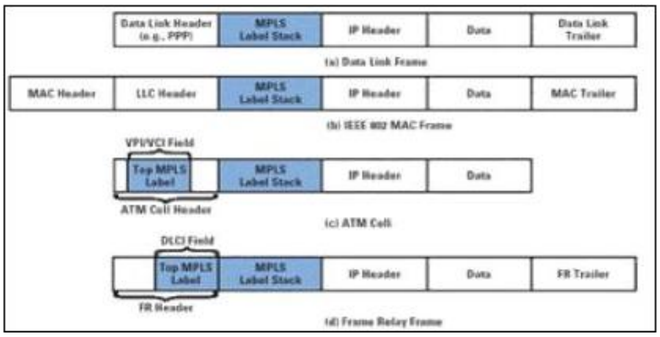


Figure 1: MPLS label Position indifferent technologies

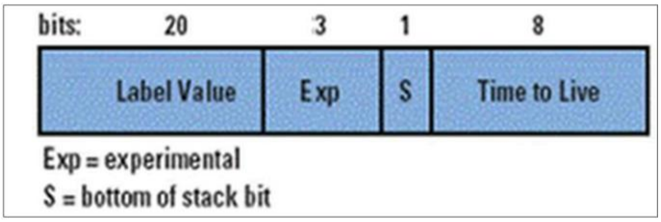


Figure 2: MPLS Label Format

R1 is named as Ingress router. It is node in the network MPLS starts. The very first MPLS label attached to an IP packet at this point. The insertion of label is called Push operation. Router R2 and R3 are label switched routers (LSR). Their functionality is to read the label of the incoming packet, remove it and assign it a new label based on the earlier label. This is called Swapping. They just swap the label nothing more. Router R4 is called as Egress router. It is the last router in the MPLS domain. It removes the label inserted into an IP packet and delivers the original packet to the connected network. The removing of the label is called as POP operation. In MPLS VPN environment POP operation is done at one node before the Egress router.

When packet enters into MPLS domain, it is assigned to a specific Forward Equivalency Class (FEC).The FEC assigns a label and a specific forwarding path to the packet. In the MPLS forwarding paradigm, once a packet is assigned to a FEC, no further header analysis is done by subsequent router; all forwarding is driven by the labels. This has a number of advantages over conventional network layer forwarding[5]. At Ingress router FEC is determined by the destination IP address, and corresponding label attached to the packet. The subsequent LSR matches the label of incoming packet with its Label Information Base (LIB) and assigns a new label to it. Same procedure is adopted till last router of MPLS domain where the label is removed from the packet. FECs are defined prior to the actual MPLS traffic flow in the network.

3. MPLS Based VPN Configuration using GNS3

The MPLS has major applications in VPN, VPLS and traffic Engineering (TE).

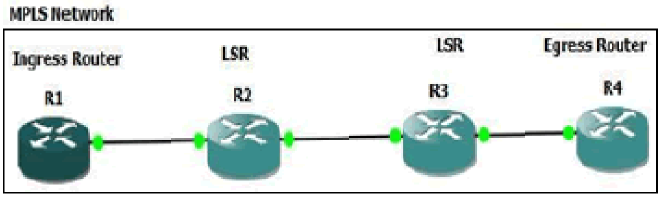


Figure 3: MPLS Network

MPLS based VPN has great importance in recent years. MPLS is technology used in WAN . It is deployed by ISPs in their cloud. IT has no direct linkage with the customer's network. MPLS VPN is a VPN network construction based on the MPLS core network[6]. A MPLS based VPN is the implementation of VPN using the MPLS cloud. All the customer sites communicate with each other using the MPLS enabled provider network. MPLS label make a tunnel in this scenario.

The configuration is carried out on the Graphical Network Simulator-3 (GNS3). It is a GUI- based open source network simulator. The task is implemented in a cisco environment. The scenario is in figure 4.
Routers; Cisco 3745
IOS Version: 12.4

Router R1- R5 constitutes the MPLS network. It is also called the provider's network. MPLS is running on this network. In the context of MPLS VPN, routers R1, R2 and R5 are called Provider Edge (PE) routers. They are the devices that have direct connectivity with a customer's network.

Whereas routers R6-R9 are called Customer Edge (CE) routers. They are gateways of customer's network and only device having connectivity with an ISP's network. The whole customer's network is called C-network.

Configuration at CE devices; At CE devices no special configuration is required. The only requirement is to assign IP addresses to interfaces and enable any IGP to carry the customer routes to connected PE devices.

Configurations at PE devices; In the context of MPLS VPN, most important configuration are done in PE devices. All the parameters should be configured carefully to establish the VPN connectivity. One of the most important parameters is the configuration of virtual Routing and Forwarding (VRF) instances. Inside, VRFs Route Distinguishers (RD) and route targets (export/imports) are defined.

RD is the unique ID given to a particular VPN site. It must be unique in the whole network, as a customer site is defined based on RD. It is a 64 bit long address and mainly has three formats which are used to assign RDs to a customer site by ISP's as shown in figure 5.To established connectivity to a particular customer site, route targets exposed from one VRF must be imported into the VRF of another customer site and Vice versa.
PE-CE routing; PE-CE routing that achieved by using a BGP protocol. Any another Interior Gateway Protocol (IGP) like

RIP, EIGRP or static routing can be used instead of BGP. If we use any another IGP, then we have to redistribute the routes from IGP to MP-BGP to share the VPN routes among the PE devices. This increases the complexity in configuration at PE devices. Hence, BGP is used because it shares the routes by default with MP-BGP and no routes re-distribution is required.

Provider network OSPF is configured as routing protocol in the provider network. The MPLS is enabled on all provider network routers. MPLS labels are assigned based on all provider network routers. MPLS labels are assigned based on routers of OSPF MPLS doesn't work without a routing protocol in a network. It can work with any IGP running in the network.

MP-BGP session; It is possible that some VPN have exactly the same IP address. To overcome this problem, VPNv4 addresses are used. In vpnv4 RD is added to the IP address to make a unique 96 bit long address. But the issue arising is that it no longer remains an IPV4 or IPV6 address. A normal routing protocol cannot carry this routing information. Hence, MP-BGP is used to carry the VPNV$ addresses to other PE devices. In this scenario, MP-BGP sessions are established from Router R1 and Router R2 to Router R5. As it hub and spoke topology, We don't need MP-BGP connectivity between R1 and R2. This situation is shown in figure 4.

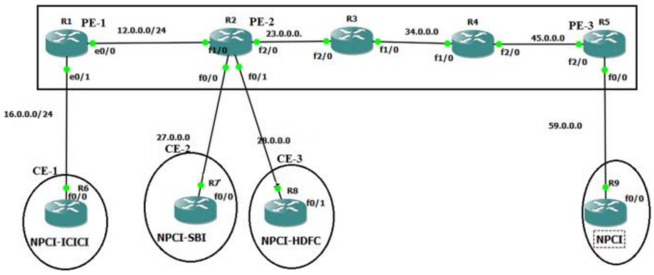
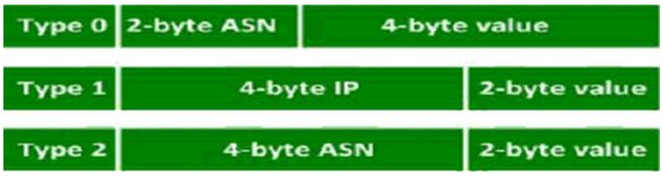


Figure 4: Network Diagram for MPLS Based VPN

4. Configuration Using GNS3

Configuration is done using GNS3. Hub and spoke technology is implemented in this scenario. The regional sites (R6-R9) only need connectivity with the central site (R9), as major network resources are available there. This is the reason why full mesh or partial mesh topologies are not implemented in this network scenario. Figure 4 gives complete illustration of IP addressing schemes used at corresponding interfaces.

Two of the customer sites (R7 and R8) are connected with the same PE router (R2). Despite having connected with the same device, they are in different VRFs and cannot communicate with each other unless their routes are imported and exported in a systematic way. The most important configurations of router R6 are shown in Table 1. All the other CE devices (R7-R9) will be configured in same way, only small changes will be made in IP addresses and corresponding BGP parameter values, as shown in Figure 4. There is no big difference of configurations in CE devices.
Configurations in PE devices significantly differ from each other. The configuration for PE devices R1, R2 and R5 are shown in Tables 2-4 respectively.

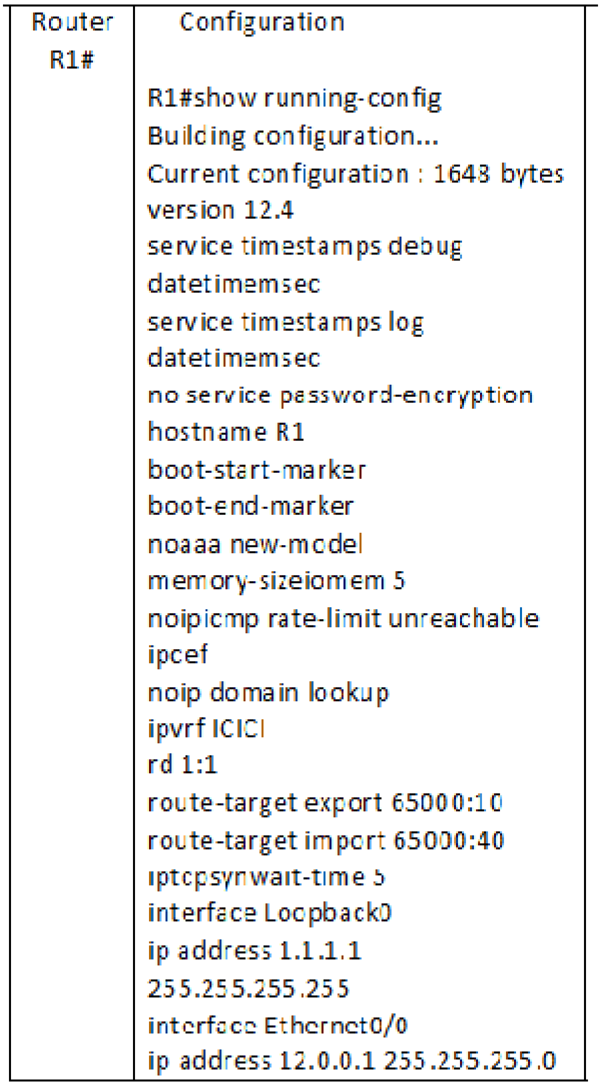


Type 0	2-byte ASN	4-byte value
Type 1	4-byte IP	2-byte value
Type 2	4-byte ASN	2-byte value

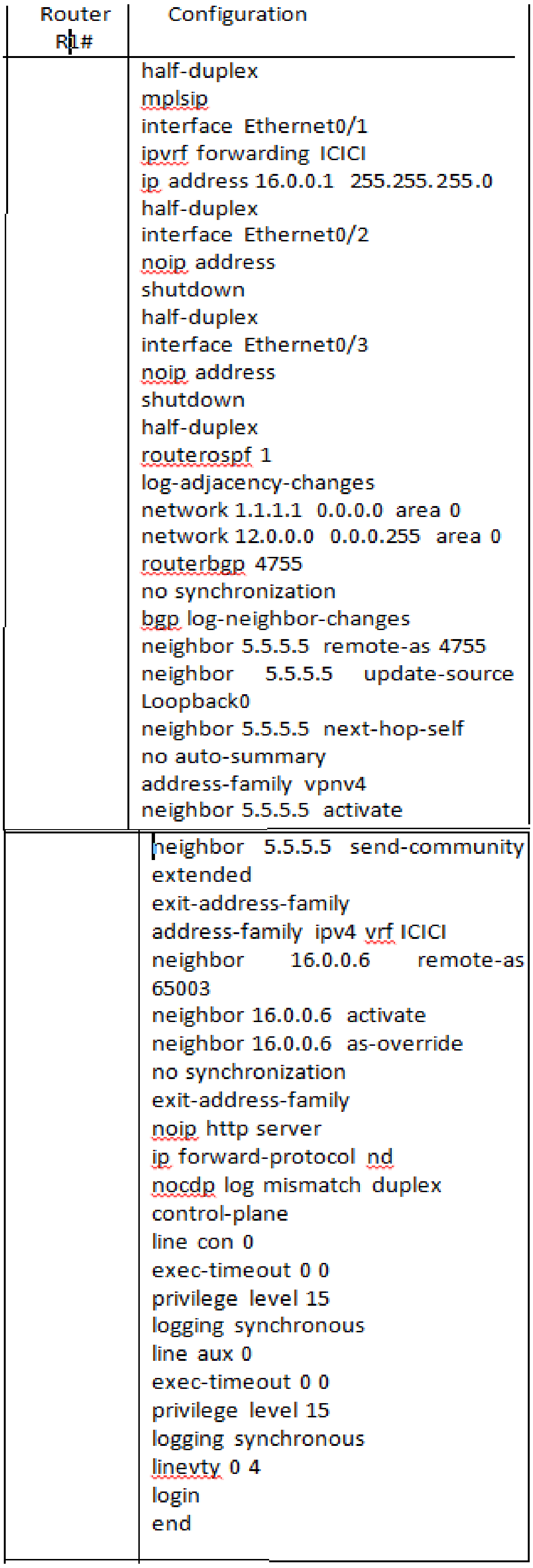
Figure 5: Different Types of RD

5. VPN Connectivity

The very first thing we can observe is the MPLS cloud forwarding decisions. As we know, packets are normally forwarded based on IP addresses. But in MPLS domain forwarding decisions are made on the basis of labels instead of IP address. Labels also change from hop to hop unlike the IP address which remains unchanged throughout the communication. The results are discussed in the following sections.



Router R1#	Configuration
	R1#show running-config Building configuration... Current configuration : 1643 bytes version 12.4 service timestamps debug datetimemsec service timestamps log datetimemsec no service password-encryption hostname R1 boot-start-marker boot-end-marker noaaa new-model memory-sizeiomem 5 noipicmp rate-limit unreachable ipcef noip domain lookup ipvrf ICICI rd 1:1 route-target export 65000:10 route-target import 65000:40 iptcpsynwait-time 5 interface Loopback0 ip address 1.1.1.1 255.255.255.255 interface Ethernet0/0 ip address 12.0.0.1 255.255.255.0



Router R1#	Configuration
	half-duplex mplsip interface Ethernet0/1 ipvrf forwarding ICICI ip address 16.0.0.1 255.255.255.0 half-duplex interface Ethernet0/2 noip address shutdown half-duplex interface Ethernet0/3 noip address shutdown half-duplex routerospf 1 log-adjacency-changes network 1.1.1.1 0.0.0.0 area 0 network 12.0.0.0 0.0.0.255 area 0 routerbgp 4755 no synchronization bgp log-neighbor-changes neighbor 5.5.5.5 remote-as 4755 neighbor 5.5.5.5 update-source Loopback0 neighbor 5.5.5.5 next-hop-self no auto-summary address-family vpnv4 neighbor 5.5.5.5 activate
	neighbor 5.5.5.5 send-community extended exit-address-family address-family ipv4 vrf ICICI neighbor 16.0.0.6 remote-as 65003 neighbor 16.0.0.6 activate neighbor 16.0.0.6 as-override no synchronization exit-address-family noip http server ip forward-protocol nd nocdp log mismatch duplex control-plane line con 0 exec-timeout 0 0 privilege level 15 logging synchronous line aux 0 exec-timeout 0 0 privilege level 15 logging synchronous linevty 0 4 login end

The title of the paper is centered 17.8 mm (0.67") below the top of the page in 24 point font. Right below the title (separated by single line spacing) are the names of the authors. The font size for the authors is 11pt. Author affiliations shall be in 9 pt.

6. MPLS Labels

Connectivity is established from R1 to R5. We can see that the MPLS labels are inserted in the packet along with the IP address, as shown in figure 8. The Ingress router inserts label 18 in the packet header. Then the first LSR removes label 18 and inserts new label 19. The second LSR replace the label 19 by 16 and forward it to the next router. The next router is the last router before destination. PHP done on this router and the packet is forwarded as a normal IP packet. This is done to reduce the processing at destination PE devoices. Otherwise, it has to process two labels, but after PHP it has to deal with just one VPN label. These label transformations indicate that MPLS is in operation. It can be seen that the value of labels change from hop to hop. It is also noticeable that the packet was generated inside the MPLS domain: that is why no VPN label was attached. BUT in the next section we can see how labels were generated as packets from a customer site.

7. Sites Connectivity

In figure 7, it can be seen that VPN connectivity is established between ICICI bank and NPCI. It can be observed that each node two labels are attached. One is to forward data to the next hop and the second label is called VPN label, which is assigned to the customer site. We can see first label changes according to next hop while the VPN label remains the same. Furthermore we can seen that when a packet enters the PE device, which is the first device of a MPLS network, labels are attached to it. A MPLS label is removed one hop before the destination PE device because of the PHP process. As it is hub and spoke topology, NPCI-ICICI are not connected with NPCI-SBI. It is evident from figure8. The results for the NPCI-SBI are shown in figure9. The attachment of labels and connectivity with NPCI can be seen. Furthermore, despite being connected with the same PE device, it cannot communicate with NPCI-HDFC. The results are similar for NPCI-HDFC as shown in figure10.

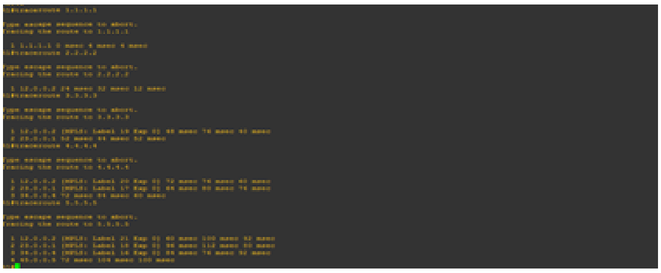
In VPN implementation the customer network is needed to hide from ISP's network. It is shown in Figure 11 that PE-1 has no route information of any customer sites. All it knows is the destination PE node. In a VPN, the customer information is not in the global routing table of the router. In fact, the information is present in VRFs and that is not accessible by the ISP network. That is why customer sites are hidden. Route targets are also defined in VRFs. Figure 12 shows the VRF information of PE-1.It is important to note that imports the RT which exported by PE-3.It exports RT 65000;10,which will be imported by PE-3.

Same observation can be made in VRFs of PE-2, as shown in Figure 15. It has two VRFs and both import the same RT 6500; 40 which is the export RF of PE-3. They also export their corresponding RTs, which must be imported at PE-3, all the RTs exported by VRFs in PE-1 and PE-2 must be imported. It should also export its RT of 65000; 40. This can be observed in Figure 13.

The IP addresses configured at the customer sites can be found using the connected shown in figure 14. If a customer site wants to connect with a node in an ISP'S network or vice versa, then this connectivity cannot be established because of the tunneling process. Customer sites are not exposed to public networks. In other words, all customer sites are hidden from an ISP network. This illustration can be seen in Figure 15.

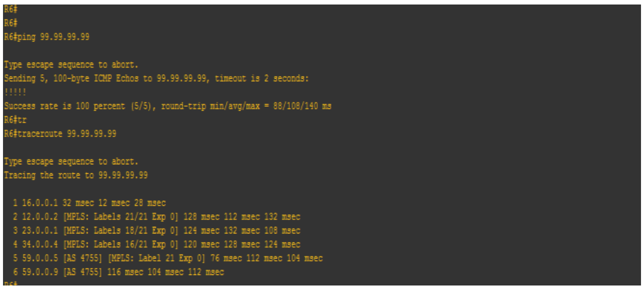
8. Conclusion

The MPLS based VPN is configured using GNS3. Three regional branches NPCI-ICICI, NPCI-SBI and NPCI-HDFC are connected with the central site of NPCI. Furthermore, Hub and spoke topology is implemented. It is evident from the results section that the forwarding decisions are made on the basis of MPLS labels instead IP addresses. Tunnels are created on the basis of labels instead IP addresses. Tunnels are created on the basis of labels. Concerning the security requirement, the customer network is hidden from the public network.



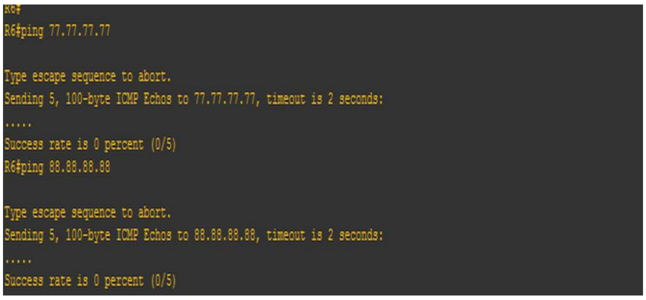
```
[illegible]#traceroute 1.1.1.1

Type escape sequence to abort.
Tracing the route to 1.1.1.1

  1 1.1.1.1 [illegible] msec [illegible] msec [illegible] msec
[illegible]#traceroute 2.2.2.2

Type escape sequence to abort.
Tracing the route to 2.2.2.2

  1 12.0.0.2 [illegible] msec [illegible] msec [illegible] msec
[illegible]#traceroute 3.3.3.3

Type escape sequence to abort.
Tracing the route to 3.3.3.3

  1 12.0.0.2 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  2 23.0.0.3 [illegible] msec [illegible] msec [illegible] msec
[illegible]#traceroute 4.4.4.4

Type escape sequence to abort.
Tracing the route to 4.4.4.4

  1 12.0.0.2 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  2 23.0.0.3 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  3 34.0.0.4 [illegible] msec [illegible] msec [illegible] msec
[illegible]#traceroute 5.5.5.5

Type escape sequence to abort.
Tracing the route to 5.5.5.5

  1 12.0.0.2 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  2 23.0.0.3 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  3 34.0.0.4 [MPLS: Label [illegible] Exp 0] [illegible] msec [illegible] msec [illegible] msec
  4 45.0.0.5 [illegible] msec [illegible] msec [illegible] msec
```

Figure 6: MPLS Labels in ISP's Network



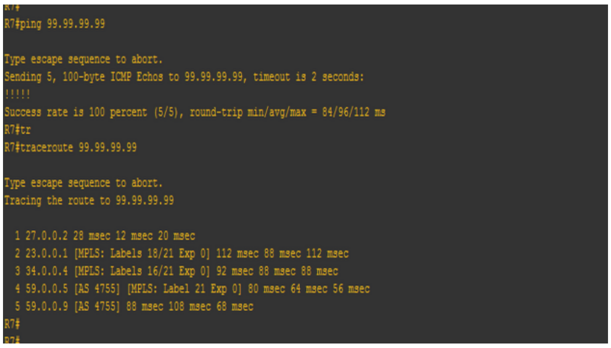
```
R6#
R6#
R6#ping 99.99.99.99

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 99.99.99.99, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 88/108/140 ms
R6#tr
R6#traceroute 99.99.99.99

Type escape sequence to abort.
Tracing the route to 99.99.99.99

  1 16.0.0.1 32 msec 12 msec 28 msec
  2 12.0.0.2 [MPLS: Labels 21/21 Exp 0] 128 msec 112 msec 132 msec
  3 23.0.0.1 [MPLS: Labels 18/21 Exp 0] 124 msec 132 msec 108 msec
  4 34.0.0.4 [MPLS: Labels 16/21 Exp 0] 120 msec 128 msec 124 msec
  5 59.0.0.5 [AS 4755] [MPLS: Label 21 Exp 0] 76 msec 112 msec 104 msec
  6 59.0.0.9 [AS 4755] 116 msec 104 msec 112 msec
```

Figure 7: VPN connectivity between ICICI bank and NPCI



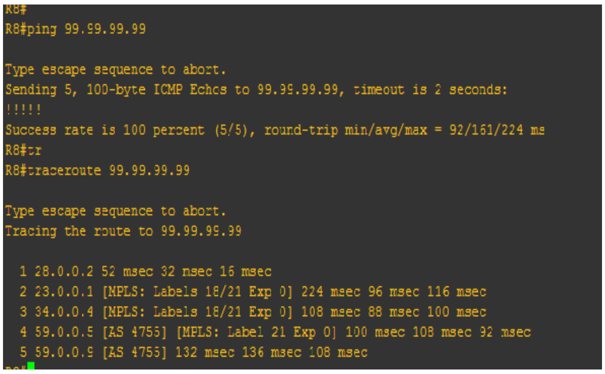
```
R6#
R6#ping 77.77.77.77

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 77.77.77.77, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
R6#ping 88.88.88.88

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 88.88.88.88, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

Figure 8: No Connectivity between NPCI-ICICI and NPCI-SBI



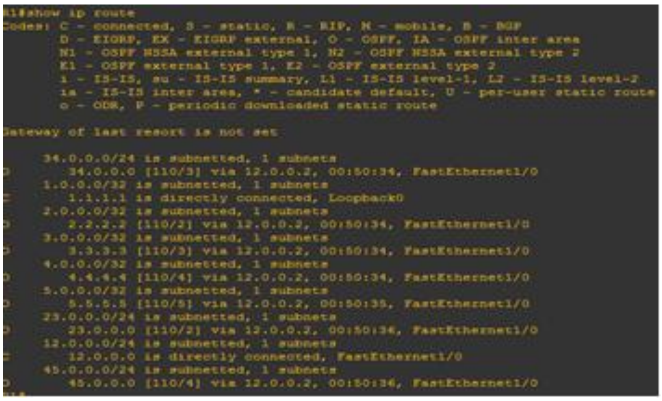
```
R7#
R7#ping 99.99.99.99

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 99.99.99.99, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/96/112 ms
R7#tr
R7#traceroute 99.99.99.99

Type escape sequence to abort.
Tracing the route to 99.99.99.99

  1 27.0.0.2 28 msec 12 msec 20 msec
  2 23.0.0.1 [MPLS: Labels 18/21 Exp 0] 112 msec 88 msec 112 msec
  3 34.0.0.4 [MPLS: Labels 16/21 Exp 0] 92 msec 88 msec 88 msec
  4 59.0.0.5 [AS 4755] [MPLS: Label 21 Exp 0] 80 msec 64 msec 56 msec
  5 59.0.0.9 [AS 4755] 88 msec 108 msec 68 msec
R7#
R7#
```

Figure 9: Connectivity of NPCI-SBI



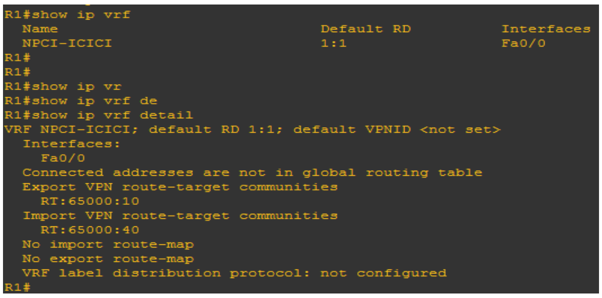
```
R8#
R8#ping 99.99.99.99

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 99.99.99.99, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 92/161/224 ms
R8#tr
R8#traceroute 99.99.99.99

Type escape sequence to abort.
Tracing the route to 99.99.99.99

  1 28.0.0.2 52 msec 32 msec 16 msec
  2 23.0.0.1 [MPLS: Labels 18/21 Exp 0] 224 msec 96 msec 116 msec
  3 34.0.0.4 [MPLS: Labels 18/21 Exp 0] 108 msec 88 msec 100 msec
  4 59.0.0.5 [AS 4755] [MPLS: Label 21 Exp 0] 100 msec 108 msec 92 msec
  5 59.0.0.9 [AS 4755] 132 msec 136 msec 108 msec
R8#
```

Figure10: Connectivity of NPCI-HDFC

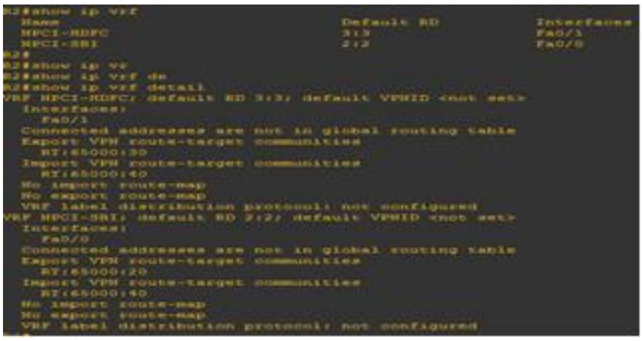


```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, 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

Gateway of last resort is not set

     34.0.0.0/24 is subnetted, 1 subnets
O       34.0.0.0 [110/3] via 12.0.0.2, 00:50:34, FastEthernet1/0
     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/2] via 12.0.0.2, 00:50:34, FastEthernet1/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/3] via 12.0.0.2, 00:50:34, FastEthernet1/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/4] via 12.0.0.2, 00:50:34, FastEthernet1/0
     5.0.0.0/32 is subnetted, 1 subnets
O       5.5.5.5 [110/5] via 12.0.0.2, 00:50:35, FastEthernet1/0
     23.0.0.0/24 is subnetted, 1 subnets
O       23.0.0.0 [110/2] via 12.0.0.2, 00:50:36, FastEthernet1/0
     12.0.0.0/24 is subnetted, 1 subnets
C       12.0.0.0 is directly connected, FastEthernet1/0
     45.0.0.0/24 is subnetted, 1 subnets
O       45.0.0.0 [110/4] via 12.0.0.2, 00:50:36, FastEthernet1/0
R1#
```

Figure 11: Routing Table of PE1

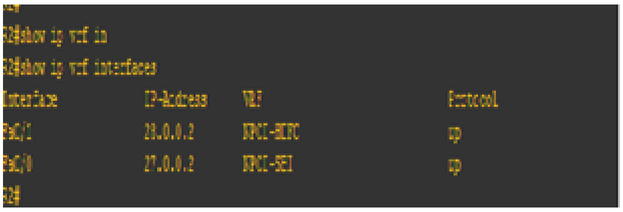


```
R1#show ip vrf
  Name                             Default RD          Interfaces
  NPCI-ICICI                       1:1                 Fa0/0
R1#
R1#
R1#show ip vr
R1#show ip vrf de
R1#show ip vrf detail
VRF NPCI-ICICI; default RD 1:1; default VPNID <not set>
  Interfaces:
    Fa0/0
  Connected addresses are not in global routing table
  Export VPN route-target communities
    RT:65000:10
  Import VPN route-target communities
    RT:65000:40
  No import route-map
  No export route-map
  VRF label distribution protocol: not configured
R1#
```



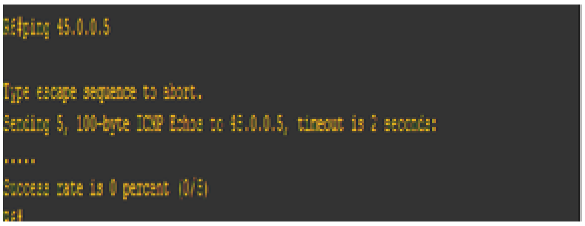
```
R2#show ip vrf
  Name                             Default RD          Interfaces
  NPCI-HDFC                        3:3                 Fa0/1
  NPCI-SBI                         2:2                 Fa0/0
R2#
R2#show ip vr
R2#show ip vrf de
R2#show ip vrf detail
VRF NPCI-HDFC; default RD 3:3; default VPNID <not set>
  Interfaces:
    Fa0/1
  Connected addresses are not in global routing table
  Export VPN route-target communities
    RT:65000:30
  Import VPN route-target communities
    RT:65000:40
  No import route-map
  No export route-map
  VRF label distribution protocol: not configured
VRF NPCI-SBI; default RD 2:2; default VPNID <not set>
  Interfaces:
    Fa0/0
  Connected addresses are not in global routing table
  Export VPN route-target communities
    RT:65000:20
  Import VPN route-target communities
    RT:65000:40
  No import route-map
  No export route-map
  VRF label distribution protocol: not configured
```

Figure 13: VRF OF PE-2



```
R2#
R2#show ip vrf in
R2#show ip vrf interfaces
Interface              IP-Address      VRF                              Protocol
Fa0/1                  28.0.0.2        NPCI-HDFC                        up
Fa0/0                  27.0.0.2        NPCI-SBI                         up
R2#
```

Figure 14: IP address of customer interface



```
R6#ping 45.0.0.5

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 45.0.0.5, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
R6#
```

Figure 15: No Connectivity of Customer network with ISP network

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