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Seamless MPLS using BGP Label Unicast Deployment in Service Provider Network using GNS3 Simulator

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Abstract*: The objective of this paper was to interconnect different Service Provider Networks by using Seamless MPLS with BGP Label Unicast (BGP-LU- RFC3107) instead of traditional MPLS with Label Distribution Protocol (LDP-RFC3036) between two NNI. The proposed design was incorporated using BGP-LU as it untangled the complications of advertising MPLS Transport Path across different Autonomous Systems. BGP LU was achieved by injecting Label of the FEC (Field Equivalence Class) into BGP NLRI Field attribute and this was identified by SAFI (Subsequent Address Family Identifier) field. In most Service Provider Networks, scalability was a highlighted constraint. Hence, with the deployment of BGP-LU along with MPLS, the service providers were connected across various geographical locations through NNI (Network to Network Integration) that shared only the label of customer FEC via BGP VPNV4 Routes. The simulation results were demonstrated with two Customers who had their offices at different locations connected to different service providers on different AS. The communication between the two offices in different AS was established by using BGP-LU where the labels were exchanged without any LDP or IGP between them. Thus, BGP-LU was deployed to scale the network reachability for multiple customers in different service provider networks. In the proposed approach, Scalability and Modularity were achieved that enhanced the Service Provider Network Design.

Index Terms*-MPLS (Multi-Protocol Label Switching), BGP (Border Gateway Protocol), BGP-LU (Border Gateway Protocol Label Unicast), Redistribute, AS (Autonomous System), ASBR (Autonomous System Border Router), RR (Route Reflector).

I. INTRODUCTION

Service Providers are choosing MPLS over other legacy technologies to connect various networks around the globe. MPLS is now the most widely deployed technology by most of the service providers.

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The salient activities involved in MPLS are- Label Creation (through PUSH, SWAP & POP operations), Label Distribution, Label Switched Path creation and Packet Forwarding [1]. In MPLS, the devices are of two types- Label Edge Routers (LERs) and Label Switching Routers (LSRs).

The LERs (also called Provider Edge) perform Label creation and removal; the LSRs (also called the Provider Routers) do Label Switching and establishing LSP. To achieve this operation, Label Distribution Protocol is used to distribute the label created by the Provider Edge Router to the neighboring Provider Routers (P-Router).This basic activity will also create an

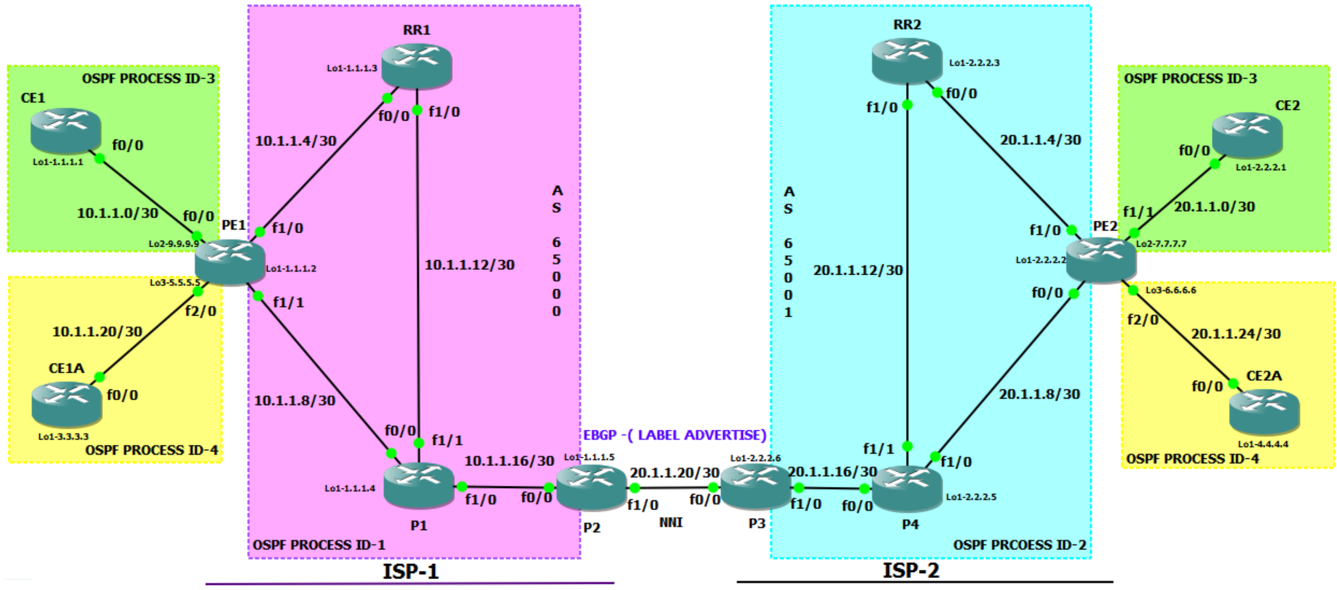


Fig.2. Topology for MPLS over BGP-LU Solution

SP (Label Switched Path), which is the path for the label to travel to reach the Forward Equivalence Class (FEC) from the Edge Source Router and to the Edge Destination Router. The LSP is formed with the governance of the IGP (Interior Gateway Protocol) deployed in the network. The forward table for the LSR is built with the local IGP. BGP (Border Gateway Protocol) is an efficient protocol which is used by the Provider's Network to carry routes along with the VRF details by using the IPv4 Address Family feature with the RD (Route Distinguisher) values to segregate different VRF routes while taking it across Networks [2]. This is a unique feature of BGP as compared to all other routing protocol [3]. MPLS is a very efficient service provider technology that is used to connect various regions around the world. However, it possesses difficulties in terms of larger aggregation nodes, geographical expansion and maintenance of the network. MPLS Network is distributed in Hierarchical Architecture with 3 layers - Core, Aggregation and Access layers. With respect to Standard Telecommunication Practice, a single AS (Autonomous System) is built across the network for the IGP connectivity, which gives way to multiple challenges like the ability to carry forward the forwarding plane in the entire Hierarchical network through Access, Aggregation and Core. While expanding the network in the Aggregation or Access layer, the provision of end-to-end LSP turns out to be a challenge. Especially, for Customers having the network across countries, having Under Sea Network is an expensive option. In such cases, ISP will have NNI with Tire-1 ISP, but using such NNI will break the MPLS. This needs to share entire customer routing table with the other Service Provider which will increase the processing load of the network. We have organized the whole paper as follows: Section II elaborates the need for MPLS - BGP-LU. Section III illustrates our proposed solution for customers at different sites connecting through two different service provider with multiple AS using BGP-LU, whereas Section IV explains and verifies the simulation results in GNS3 and shows how this design works successfully. The final section concludes and summarizes the whole paper.

II. WHY MPLS OVER BGP-LU

MPLS architecture can be made scalable and flexible using the existing protocols. One such major architecture involves the use of BGP-LU. BGP LU (BGP Labeled Unicast) helps in resolving the scalability problem [4]. BGP LU helps in transferring the MPLS label along with the BGP Route while advertising to the adjacent neighbors [5]. In a BGP-MPLS network, the routers which belong to same AS number are named as Interior Routers and the routers which speak to other AS number are named Exterior Router. For the communication between customers, the transaction happens as BGP Label as the delivered label will be carried forward by the IGP configured. As shown in Figure 1, two different ISPs belonging to different AS with B and C as the ASBRs. When A wants to send a packet to D; A will advertise the Route Label through BGP over MPLS LDP to B. Further, B will POP the LDP label and use the BGP-LU to redistribute the label to C. thereafter C will use the IGP_LDP and reach D.

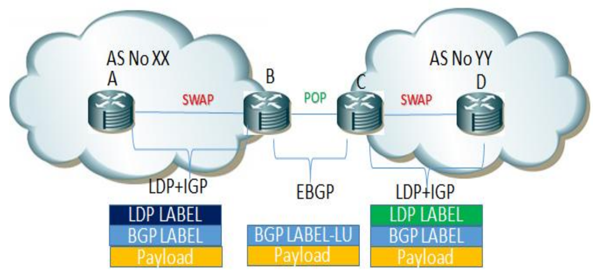


Fig.1. BGP-LU label

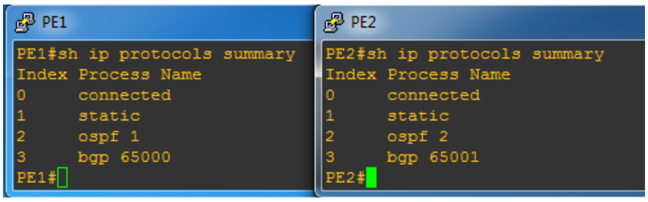
This demonstrates the peculiarity of BGP-LU between the two ASBRs. Hence, by using the BGP –LU technology, we can achieve implementation of Segmented Networks, enabling the expansion of the MPLS connectivity across the AS. This ensures that service provider expand the network without having much implication on the network or without modifying the network.

III. DESCRIPTION AND IMPLEMENTATION STEPS OF PROPOSED NETWORK

The MPLS Network which is implemented without deploying BGP-LU can be fine-tuned with BGP-LU as depicted in Figure 1. As shown, multiple process ids i.e. OSPF PROCESS ID-1 & PROCESS ID-2 are used. Considering PE-1 belongs to one ISP and PE-2 belongs to another ISP. In the experimental setup, we have proposed to showcase the working of MPLS BGP LU between two Autonomous Systems. The Topology is created considering two customers Cust_A and Cust_B who are geographically separated and need MPLS L3 VPN service across two Hence, the BGP-LU technology is implemented to distribute the labels across different ISP over MPLS, which is detailed in the following steps:

STEP1: Creating ISP-1 and ISP-2 in different Autonomous Systems

As described in the topology, we have created two ISP networks with OSPF as the Interior Gateway Protocol. ISP-1 is implemented with BGP AS 65000 & OSPF process id-1, whereas, ISP-2 is implemented with BGP AS 65001 & IGP as OSPF process id-2.

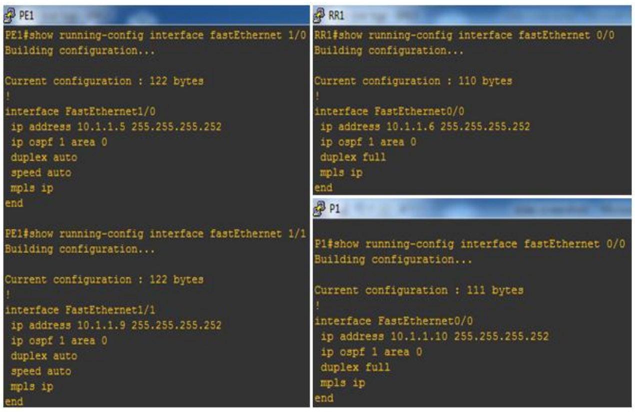


```
PE1
PE1#sh ip protocols summary
Index Process Name
0     connected
1     static
2     ospf 1
3     bgp 65000
PE1#
```

```
PE2
PE2#sh ip protocols summary
Index Process Name
0     connected
1     static
2     ospf 2
3     bgp 65001
PE2#
```

Fig.3.PE1 with OSPF-1 & BGP AS 65000 and PE2 with OSPF -2 &BGP AS 65001

The Provider Edge Routers of respective ISPs run LDP+IGP on the interfaces as shown below.



```
PE1
PE1#show running-config interface fastEthernet 1/0
Building configuration...

Current configuration : 122 bytes
!
interface FastEthernet1/0
 ip address 10.1.1.5 255.255.255.252
 ip ospf 1 area 0
 duplex auto
 speed auto
 mpls ip
end

PE1#show running-config interface fastEthernet 1/1
Building configuration...

Current configuration : 122 bytes
!
interface FastEthernet1/1
 ip address 10.1.1.9 255.255.255.252
 ip ospf 1 area 0
 duplex auto
 speed auto
 mpls ip
end
```

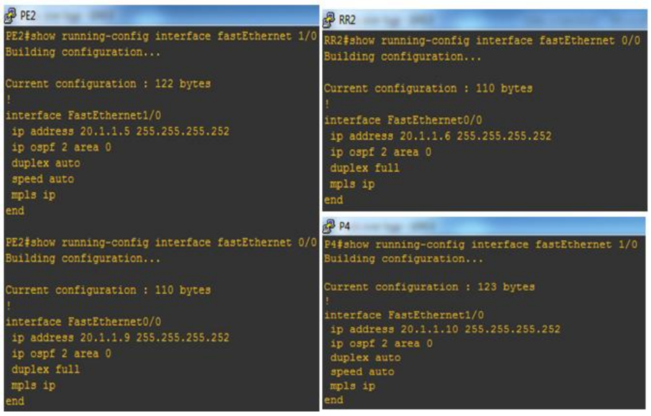
```
RR1
RR1#show running-config interface fastEthernet 0/0
Building configuration...

Current configuration : 110 bytes
!
interface FastEthernet0/0
 ip address 10.1.1.6 255.255.255.252
 ip ospf 1 area 0
 duplex full
 mpls ip
end
```

```
P1
P1#show running-config interface fastEthernet 0/0
Building configuration...

Current configuration : 111 bytes
!
interface FastEthernet0/0
 ip address 10.1.1.10 255.255.255.252
 ip ospf 1 area 0
 duplex full
 mpls ip
end
```

Fig.4. MPLS LDP & OSPF on the interfaces in ISP 1

The Fig.4 shows that interfaces connecting the PE1, RR1 and P1 routers configured with OSPF Process ID-1 Area 0 and MPLS LDP enabled.

autonomous systems. Customer A consists of two Customer Edge Routers- CE1 and CE2 geographically separated and running OSPF Process ID 3. Similarly, Customer B consists of two Customer Edge Routers -CE1A and CE2Ageographically separated and running OSPF Process ID 4. We have considered Cisco IOS 7200 Software version 12.4 for all the routers. The Topology consists of PE 1 & PE 2, where the former is connected to the AS 65000 and the latter is connected to AS 65001. We are running OSPF process ID as 1 for the network belonging to AS 65000 and OSPF process ID as 2 for the network belonging to AS 65001. There are two Router Reflectors; RR1 for AS 65000 and RR2 for AS 65001, both the Router Reflector (RFC-4456), will be connected via BGP VPNv4 Family. The Customers are connected to the nearest PE through their CE (Customer Edge Routers) at both the locations i.e. CE1 and CE1A connected to PE1; and CE2 and CE2A connected to PE2.



```
PE2
PE2#show running-config interface fastEthernet 1/0
Building configuration...

Current configuration : 122 bytes
!
interface FastEthernet1/0
 ip address 20.1.1.5 255.255.255.252
 ip ospf 2 area 0
 duplex auto
 speed auto
 mpls ip
end

PE2#show running-config interface fastEthernet 0/0
Building configuration...

Current configuration : 110 bytes
!
interface FastEthernet0/0
 ip address 20.1.1.9 255.255.255.252
 ip ospf 2 area 0
 duplex full
 mpls ip
end
```

```
RR2
RR2#show running-config interface fastEthernet 0/0
Building configuration...

Current configuration : 110 bytes
!
interface FastEthernet0/0
 ip address 20.1.1.6 255.255.255.252
 ip ospf 2 area 0
 duplex full
 mpls ip
end
```

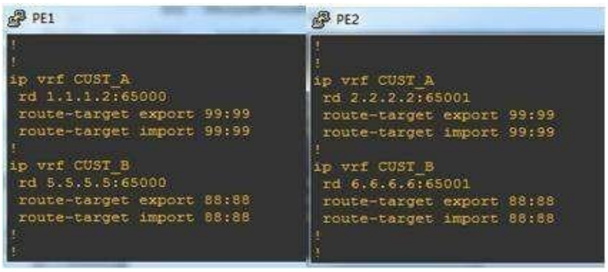
```
P4
P4#show running-config interface fastEthernet 1/0
Building configuration...

Current configuration : 123 bytes
!
interface FastEthernet1/0
 ip address 20.1.1.10 255.255.255.252
 ip ospf 2 area 0
 duplex auto
 speed auto
 mpls ip
end
```

Fig.5. MPLS LDP & OSPF on the interfaces in ISP 2

The Fig.5 shows that interfaces connecting the PE2, RR2 and P4 routers configured with OSPF Process ID-2 Area 0 and MPLS LDP enabled.

STEP2: Creating two Customers with offices connected to different ISPs

Two Customers, Cust_A and Cust_B are created. The customers connect to the Customer Edge routers. In the PE, a VRF is created for the interface towards the CE.



```
PE1
!
!
ip vrf CUST_A
 rd 1.1.1.2:65000
 route-target export 99:99
 route-target import 99:99
!
ip vrf CUST_B
 rd 5.5.5.5:65000
 route-target export 88:88
 route-target import 88:88
!
!
```

```
PE2
!
!
ip vrf CUST_A
 rd 2.2.2.2:65001
 route-target export 99:99
 route-target import 99:99
!
ip vrf CUST_B
 rd 6.6.6.6:65001
 route-target export 88:88
 route-target import 88:88
!
!
```

Fig.6. Creating VRF customer towards CE

The Fig.6 shows the VRFs created in PE1 and PE2 for Cust_A and Cust_B. As we can see, the PE has multiple VRFs in a single BGP table. Hence, an RD (Route Distinguisher) Value is created in each VRF that is used to make the route unique within the entire BGP table. This route is exported from that VRF into BGP and imported from BGP to VRF, which is specified as export route targets and import route targets in that customer VRF definition. The CE Router is connected to the PE router with OSPF as IGP. The Customer Routes are advertised to the Provider Edge Routers.

STEP3: Creating Route Reflectors for the ISPs

Each ISP consists of a Router Reflecting Router – RR that advertises the routes of its BGP peers to avoid full mesh connectivity with all routers[6]. The routes from the BGP Peers are redistributed into the RR as VPNV4 routes. As per the topology, we can see that- BGP Peers of RR1 are: PE1, P1 & P2 and BGP Peers of RR2 are: PE2, P4 & P3.

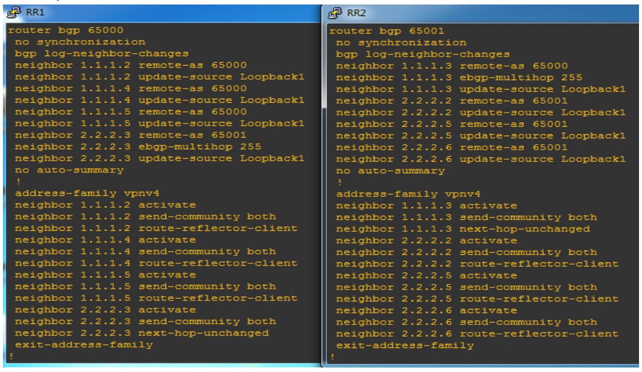


Fig.8.VPNv4 routes advertised in RR

As shown in the Fig.8, we can see that in the RR1 BGP address-family VPNV4, the PE1 (Lo-1.1.1.2), P1 (Lo-1.1.1.4) & P2 (Lo-1.1.1.5) are configured as Route-Reflector Clients and in the RR2 BGP address-family VPNV4, the PE2 (Lo-2.2.2.2), P4 (Lo-2.2.2.5) and P3 (Lo-2.2.2.6) are configured as Route-Reflector Clients.

STEP4: Using BGP-LU Technology, label transfer occurs between ISP1 and ISP2

The routers connecting the two AS are called Autonomous System Border Router (ASBR). Here P2 & P3 act as ASBR. The salient feature of BGP-LU is demonstrated by not using any IGP or LDP on the link between the ASBRs.

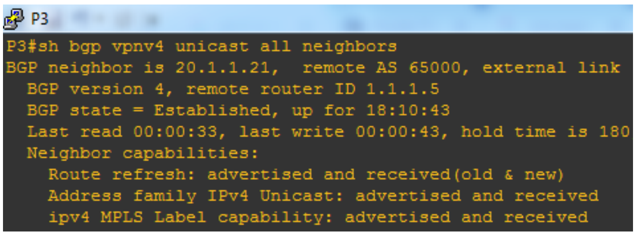


Fig.9.Interface connecting ASBRs P2 and P3

The above configurations prove that, there is no IGP or LDP established in the link between the ASBRs (P2 & P3).

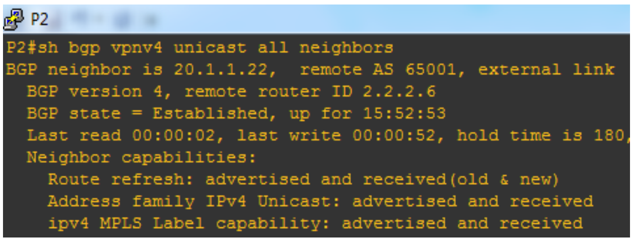


Fig.10.BGP Configuration in P2 towards P3

The Fig.10 shows the BGP neighbor in P2 router. It can be seen that, the route towards P3 (2.2.2.6) which belongs to other AS is reached through the BGP (B).

Fig.11.BGP Configuration in P3 towards P2

The Fig.11 shows the BGP neighbor in P3 router. It can be seen that, the route towards P2 (1.1.1.5) which belongs to other AS is reached through the BGP (B).Thus, it is clear that, the label is carried from one AS to another through BGP and not through any LDP or IGP.

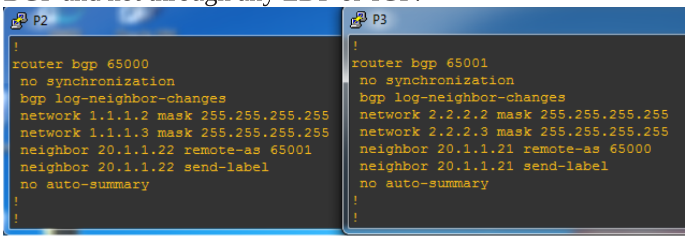


Fig.12.Sending Label via BGP (BGP-Label Unicast)

As shown in Fig.12, in P2 we send the MPLS Label in BGP 65000 through the interface connecting to P3 (20.1.1.22). Similarly, in P3 we send the MPLS Label in BGP 65001 through the interface connecting to P2 (20.1.1.21). The ASBRs have EBGP peering which piggy bags the label information to the other Autonomous System as shown in the figure above [4].

IV. SIMULATION RESULT

This section illustrates the simulation results of the label update for communication from CE1 to CE2. The below Figures show the MPLS Label Switching from PE1 to PE2 (2.2.2.2).

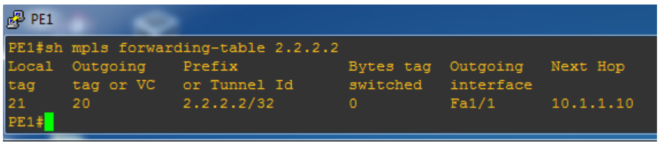


Fig.13. MPLS Label Pushing at PE1

As shown in Fig.13, for the packet destined to PE2 (2.2.2.2), at PE1 Router, it is forwarded with Label 20 to the Next Hop P1 (10.1.1.10) through the exit interface Fa1/1.

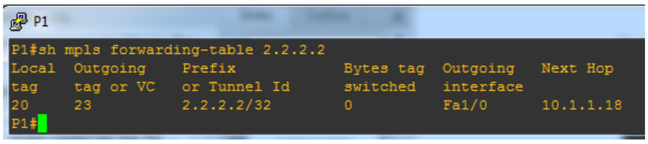
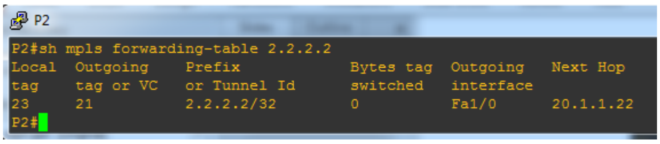


Fig.14. MPLS Label Pushing at P1

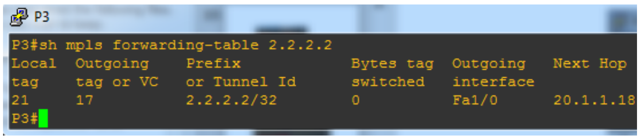
As shown in Fig.14, for the packet destined to PE2 (2.2.2.2), at P1 Router, it is forwarded with Label 23 to the Next Hop P2 (10.1.1.18) through the exit interface Fa1/0.



```
P2#sh mpls forwarding-table 2.2.2.2
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
23     21          2.2.2.2/32        0          Fa1/0      20.1.1.22
P2#
```

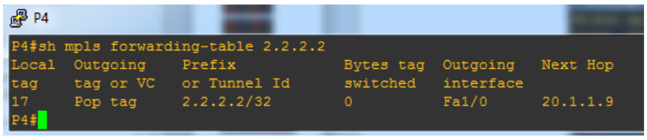
Fig.15.MPLS Label Pushing at P2

As shown in Fig.15, for the packet destined to PE2 (2.2.2.2), at P2 Router, it is forwarded with Label 21 to the Next Hop P3 (20.1.1.22) through the exit interface Fa1/0.



```
P3#sh mpls forwarding-table 2.2.2.2
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
21     17          2.2.2.2/32        0          Fa1/0      20.1.1.18
P3#
```

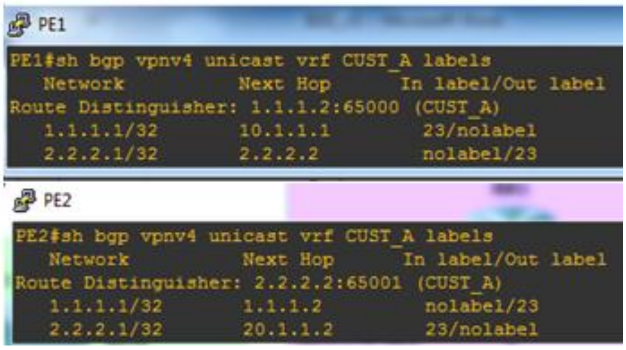
Fig.16.MPLS Label Pushing at P3 As shown in Fig.16, for the packet destined to PE2 (2.2.2.2), at P3 Router, it is forwarded with Label17 to the Next Hop P4 (20.1.1.18) through the exit interface Fa1/0.



```
P4#sh mpls forwarding-table 2.2.2.2
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
17     Pop tag     2.2.2.2/32        0          Fa1/0      20.1.1.9
P4#
```

Fig.17. MPLS Label Pushing at PE2

As shown in Fig.17, for the packet destined to PE2 (2.2.2.2), at P4 Router, the label is popped out and packet is sent to PE2 interface IP (20.1.1.9) through the exit interface Fa1/0. The above figures show the MPLS Label switching across two AS for communication between CE1 and CE2. The figure illustrates the MPLS Forwarding table that shows the Label swapped at each router to reach the destination Customer Edge. We can observe that, at PE1 Outgoing Label is 20, at P1 Label 20 is swapped with Label 23, at P2 Label 23 is swapped with Label 21, at P3 Label 21 is swapped with Label 17 and at P4 this Label is popped and sent to PE2.

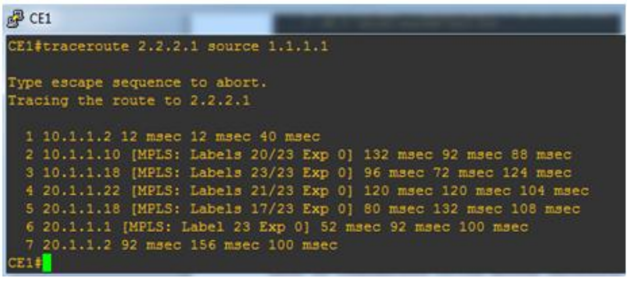


```
PE1#sh bgp vpnv4 unicast vrf CUST_A labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 1.1.1.2:65000 (CUST_A)
   1.1.1.1/32       10.1.1.1        23/nolabel
   2.2.2.1/32       2.2.2.2         nolabel/23
```

```
PE2#sh bgp vpnv4 unicast vrf CUST_A labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 2.2.2.2:65001 (CUST_A)
   1.1.1.1/32       1.1.1.2         nolabel/23
   2.2.2.1/32       20.1.1.2        23/nolabel
```

Fig.18. VPN Label for Cust_A

The above figure shows the VPN Label 23for communication between CE1 & CE2 in Cust_A. The figure illustrates the VPNV4 Unicast Label distributed through BGP.



```
CE1#traceroute 2.2.2.1 source 1.1.1.1

Type escape sequence to abort.
Tracing the route to 2.2.2.1

  1 10.1.1.2 12 msec 12 msec 40 msec
  2 10.1.1.10 [MPLS: Labels 20/23 Exp 0] 132 msec 92 msec 88 msec
  3 10.1.1.18 [MPLS: Labels 23/23 Exp 0] 96 msec 72 msec 124 msec
  4 20.1.1.22 [MPLS: Labels 21/23 Exp 0] 120 msec 120 msec 104 msec
  5 20.1.1.18 [MPLS: Labels 17/23 Exp 0] 80 msec 132 msec 108 msec
  6 20.1.1.1 [MPLS: Label 23 Exp 0] 52 msec 92 msec 100 msec
  7 20.1.1.2 92 msec 156 msec 100 msec
CE1#
```

Fig.19. Traceroute from CE1 (1.1.1.1) to CE2 (2.2.2.1)

The above figure shows the output for the trace route command for the ping from CE1 (1.1.1.1) to CE2 (2.2.2.1). It can be observed that, for every hop in the MPLS LSP the Label is swapped, whereas, the VPN label (Label 23) remains unchanged throughout the LSP. Similarly, for Cust_B, to enable communication between CE1A & CE2A, there is another VRF created in Provider Edge routers running OSPF. Thus, by redistributing the routes into BGP, Seamless MPLS connectivity is established between the two AS. In this manner, multiple customers can be added in the Aggregation Layer.

V. CONCLUSION

With the rising demand to expand the network in the Access and Aggregation layers, the ability to provide Seamless MPLS connectivity has become a challenge. Also, to provide Seamless MPLS connectivity, there is need for single Autonomous System. These constraints can be resolved by establishing the Label Update Attribute of BGP. The technique illustrated in this paper explains the label update technology using EBGP between the two Service Provider Networks of different Autonomous Systems. The implementation of BGP-LU to update the MPLS label has proven to be a highlighted advantage to enable communication between different Autonomous Systems. This feature also enables control on the network nodes and increases the manageability across networks distributed over various regions. Thus, this technology has proven to enhance the scalability for the service providers to expand their network across various Autonomous Systems. The deployment of this design in the Service Provider Network will makes way to address the growing demands of customers without any major modifications in the Core network.

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