Implementation and Design Constraints of Provider Bridge (IEEE-802.1ad) and Provider Backbone Bridge (IEEE-802.1ah) Protocols.

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Comments:

“This Project will be handful for those who like in-depth understanding of Ethernet Protocols: 802.1ad, 802.1ah and VPLS Protocol. An extremely valuable configuration of VPLS, 802.1ah and 802.1ad on Alcatel lucent 77XX series routers and Cisco 3500/3700/2600”

“Uzair ur Rehman”

<Professor Comments Needed :>

"To my parents and my brothers who have given me so much love and always supported me to achieve my targets. Also I thanks to Dr.MacGregor and Shahnawaz Mir who have given me this opportunity to explore upcoming Ethernet Technology"

Topics need to be covered after this Project:

1. **Operation, Administration and Maintenance (OAM) (IEEE 802.1ag) in PBB+VPLS nework.**
2. **Provider Backbone Bridge + Traffic Engineering (PBB+TE) in PBB+VPLS**
3. **In-depth implementation of QoS in PBB network.**

Contents

Chapter 1: History of Ethernet

Introduction:

Ethernet- A technology which was developed to share data over LAN is now one of the most demanding technology in the next-generation carrier network market and especially in the presence of IP/MPLS it is gaining its popularity and become a fastest growing field, because emerging applications and services demands high-bandwidth with high availability, reliability and scalability. Together with IP/MPLS, Ethernet can fulfill all these demands. Service Providers provider provides Ethernet services based on combinations of IEEE 802.1Q, IEEE 802.1ad, VPLS and MPLS.

In this project I focus my discussion on need of evolution of IEEE 802.1ad (PB: Provider Bridging) and IEEE-802.1ah (PBB: Provider Backbone Bridging), QoS on 802.1ah and VPLS (Virtual Private LAN Services).

History of Ethernet:

In 1972, when Bob Metcalf was finalizing the invention of Ethernet technology has no idea and didn't anticipated that this technology is going to connect pretty much every device on the planet and will become the technology of choice for carriers. Ethernet was the Bob Metcalf PhD dissertation at Harvard university but it was rejected because at that time it was not theoretically sound enough. But later he finds something theoretically enough and justified his concept. On May 22, 1973 he and Dave Boggs finally present a memo describing the Ethernet to network personal computers, printer sharing and internet access. Bob and Dave Boggs has to wait for 8 years to introduce Ethernet because from 1973 up 1981 personal computers was not in public. They only did their research work at Xerox Park where they have some earliest personal computers. Then after that, there was a long battle through the 80's with IBM Token Ring Technology and IBM didn't want Ethernet to succeed. But in the end of 80's finally IBM's Token Ring went down and Ethernet went up. It started at 2.9 Mbps in 1973. Then it went to 10Mbps, it then went to 100Mbps and it went up at 10Gbps, and it's not done yet and going to keep going up.

To connect offices located at different places around the world administrator had to use slower WAN technologies such as fixed lines, Frame Relay and ATM. In general, these technologies are expensive and not sufficient enough to cope the bandwidth requirements which LAN users needs on daily basis. Ethernet technology gradually and predominantly evolved that it not only connects networks in LAN but can connect networks that are thousands miles away and solved the bandwidth needs.

1.1 Basic Ethernet Frame Format:

Basic IEEE 802.3 Ethernet Frame consists of minimum 64 bytes and maximum 1518 bytes

Fig:1.1 Ethernet Frame structure:

MAC DA	MAC SA	Length/Type	Payload	FCS
6 bytes	6 bytes	2 bytes	48-1500 bytes	4 bytes

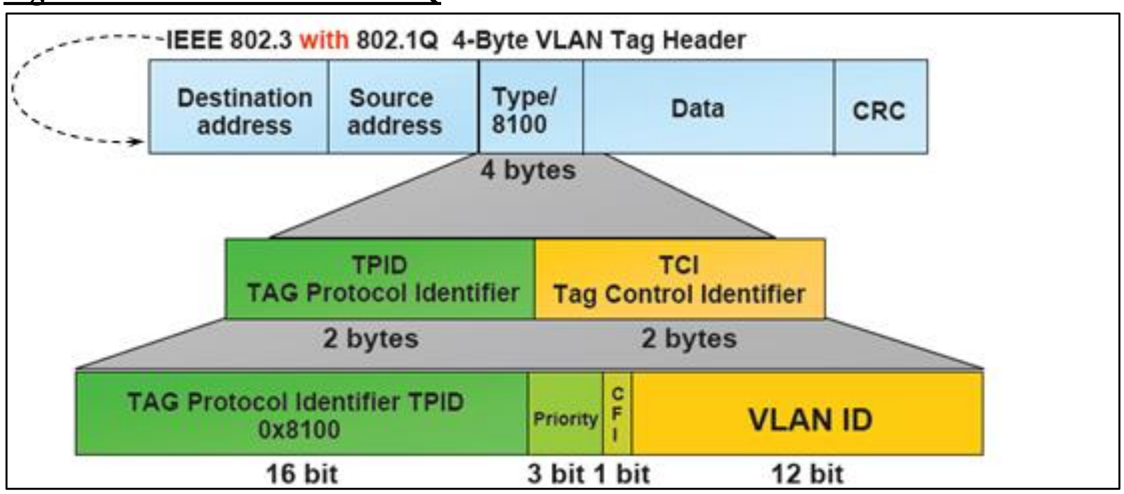
1. **Destination MAC address:** Identifies the receiver that receive the frame
2. **Source MAC address:** Identifies the source that originates the frame.
3. **Length/Type:** If the value is less or equal to 1500 then it show the number of bytes in the payload, however if the value is greater than or equal to 1500 then this show the protocol type.
4. **Payload:** This field contains the data from source node to destination node.
5. **Frame check Sequence:** Use for error checking.

Ethernet Evolution:

IEEE 802.1Q- VLAN Support:

It helps to achieve data separation and security between traffic of different sections of the network by creating separate logical networks in physical topology. This is achieved by assigning a unique VLAN-ID (4 bytes) to each section of the network. When a data frame arrives on a switch, it inserts VLAN tag to that frame (between source address and EtherType/Length field of the original 802.3 frame). Frame transmitted to a network and before the frame is transmitted to a particular destination VLAN tag is stripped off.

Fig 1.2.1: Frame Format of 802.1Q



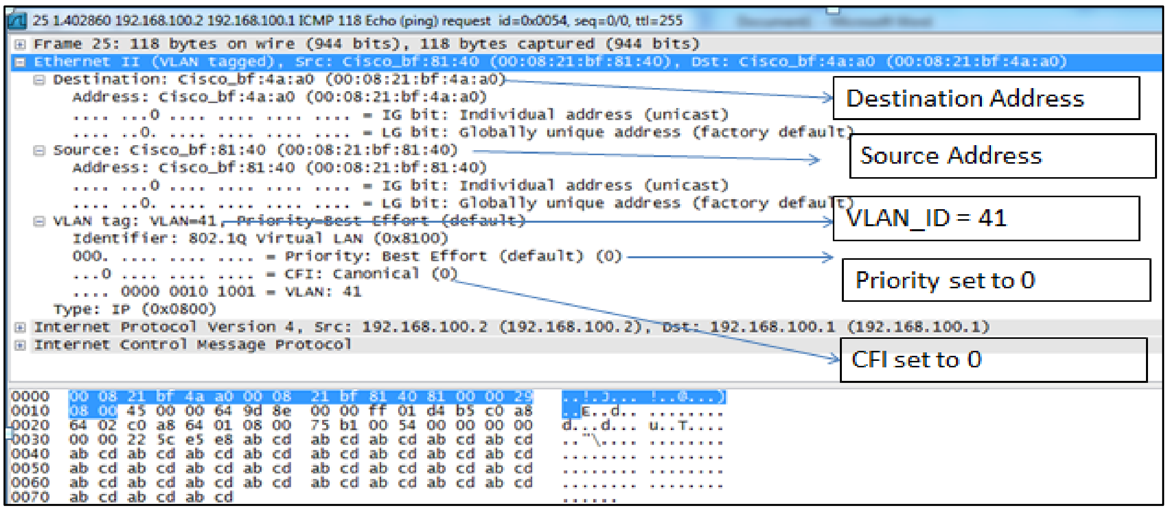
a) Tag Protocol Identifier (TPID): is set to a value 0x8100 so that it can be identify as IEEE 802.1Q frame.

b) Tag Control Identifier (TCI):
Priority Code point (PCP): is set to assign priority level from 0 (lowest) to 7 (highest).

c) Canonical Format Indicator (CFI): Used to be compatible between Ethernet and Token Ring. For Switch it is also set to 0 and for Token Ring it is set to 1.

d) VLAN Identifier (VID): use to assign VLAN_id to the frame. Value is from VLAN 1- 4096.

Fig: 1.2: capture result of tagged Ethernet frame:



IEEE 802.1Q solve the following problems:

- It solves the broadcast problem.
- Provide better security.
- Solve the physical location problems.

Since 802.1Q only supports total 4096 VLANs and that became a scalability constraints for the service providers because as network grows this problem become serious. Also two customer cannot have the same VLAN-ID's and that become more serious issue because customer are not ready to change and modify their existing network.

IEEE 802.1ad (Q-in-Q):

To solve the VLAN scalability problem of 802.1Q, IEEE introduces new protocol 802.1ad. A concept that add another VLAN tag to the existing tag. It define customer VLAN (C-VLAN) and service VLAN (S-VLAN). This allow service provider to support different services. Theoretically it support 4K S-VLAN * 4K C-VLAN= 16 million VLAN.

Note 1.2.3: Since in our lab we don't have switches that support 802.1ad, so I use VLAN stacking which work similar to the 802.1ad as per the requirement of this project.

VPLS (Virtual Private LAN Service):

A bridged layer 2 multipoint VPN also known as Metro-Ethernet Service. A layer 2 service to those customers who want to manage their own network. VPLS is an Ethernet service that connects multiple sites in a single switched domain over the IP/MPLS network. Each VPLS service has Virtual switching instance (VSI) that is similar to IEEE 802.1Q where frame is switched based on MAC addresses and provide transparent bridging service to geographically separate customers. Standard VPLS requires fully meshed pseudowires between all PE devices, which creates problem for multicast traffic and to maintain large number of pesudowires.

IEEE 802.1ah (mac-in-mac, PBB):

It provides extremely scalable solution to Ethernet services. Although combination of 802.1ad and VPLS provides scalable solutions but still forwarding decisions are based on customer MAC addresses, which means that PE routers must maintain the FDB table (forwarding database table). This becomes major problem in large network where PE routers maintain thousands of addresses in FDB. Especially in H-VPLS topology where nPE (network or Hub-PE) routers handle traffic of multiple uPE routers (Spoke PE routers) it must maintain large FDB.

PBB header encapsulates the customer frame and consist of source MAC address, destination MAC address, Backbone VLAN-ID (B-VID), Service instance identifier (I-SID) in Service instance (I-Tag). It also allow service providers to support 16 million service instances (2^24)

In the data communication, Ethernet is the fastest growing field. IEEE 802.1ah with VPLS is the most important development in the evolution of carrier Ethernet.

Overview of Ethernet Protocols:

Table 1.3 802.1Q, 802.1ad and 802.1ah

802.1q	**802.1ad**	**802.1ah**
Only one domain	One Customer domain and service domain	One customer domain and one service domain
Only one MAC address table	PE Only one MAC address table maintaining huge FDB	FDB maintaining only MAC-addresses of PE routers
Not able to separate customer traffic	Can guarantee customer separation but not guarantee transparency between customer and provider network	Can guarantee customer separation and transparency between customer and provider network
VLAN limited to 4096	VLAN limit ~16million	VLAN limit ~16million

Comparison of 802.1ad, 802.1ah, VPLS

Table 1.4: 802ad, 802.1ah and VPLS

	802.1ad	802.1ah	VPLS
Connectivity	P2P and Multipoint	P2P and Multi-point	Only Multipoint
Technology status	Complete	Early stages	Established
Overhead	8 bytes	22 bytes	22 bytes
Scalability	Scalable	Highly Scalable	Highly scalable
TE and QoS	Make use of 802.1p (Limited)	Make use of 802.1p (Limited)	Make use of MPLS TE(advance)
Availability on Equipment	All vendor support it	Very limited support	All vendor support it
Management	Less effort	Less effort	Complex
Resilience	High	High	High

Chapter 2: Virtual Private LAN Service:

Overview:

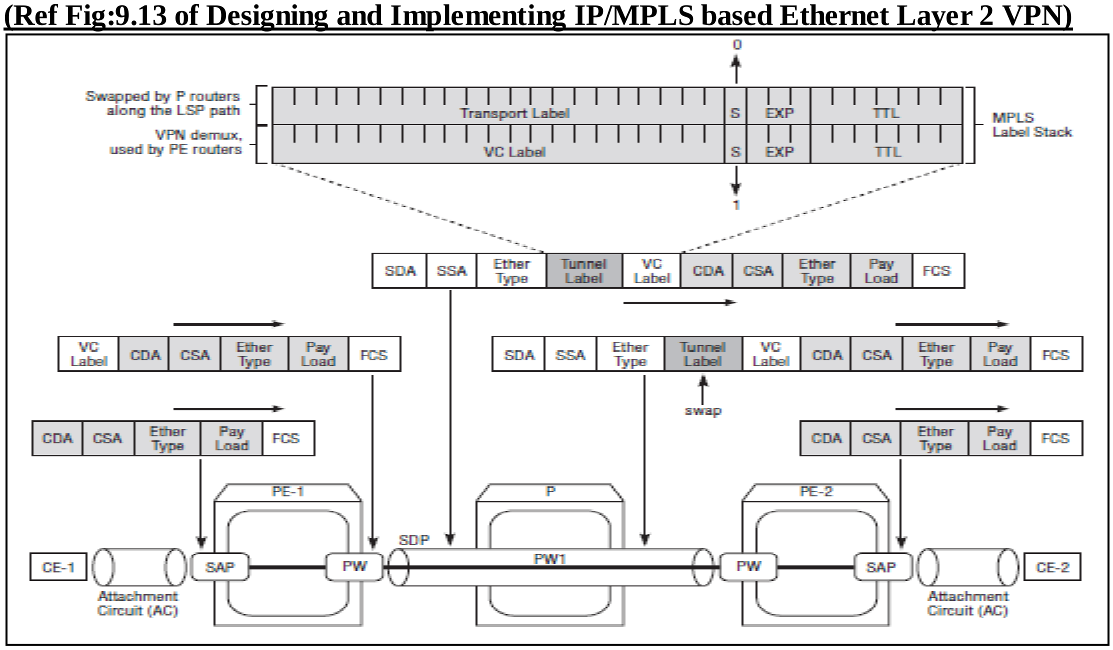
VPLS is introduced to provide LAN services over geographically separate locations. VPLS is a multipoint layer 2 VPN over IP/MPLS core. It inherits all the advantages of IP/MPLS service architecture (e.g flexibility, scalability, and reliability and quality of service). It is gaining its popularity because of following advantages:

- Provide 10Gbps or even higher bandwidth.
- Win-Win situation both for providers and customer perspective. On one hand Provider only provide layer 2 connectivity to the customer and on the other hand customer is not worried about the peering requirements from the service providers. This gives customer liberty to design its own network architecture.
- It can carry any traffic not just an IP.
- Inherits MPLS resilience and flexibility (e.g FRR and Traffic engineering: TE) and achieve tens of milliseconds failover performance.

VPLS Encapsulation Method:

- Upon received Ethernet frame VPLS service instance push a VC-LABLE through pseudowire and then pushes Transport lable use by SDP. VC-LABEL is used to differentiate traffic of customer and remain same throughout the IP/MPLS network and and transport lable is used to place traffic on particular SDP and will change by next PE routers.

<u>Fig:2.2.1 Encapsulation overview of VPLS:</u>
<u>(Ref Fig:9.13 of Designing and Implementing IP/MPLS based Ethernet Layer 2 VPN)</u>

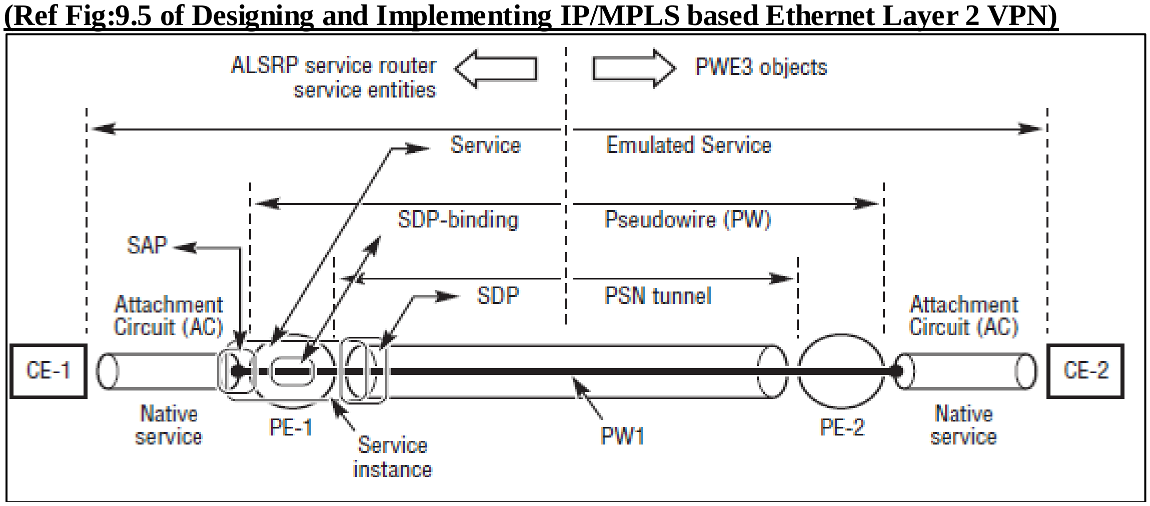


Before going into detail we have to understand components of VPLS service:

Table:2.2.1a Encapsulation overview of VPLS:

Components	Sub-components	Descriptions
Customer	Customer-ID	Customer at the edge of the network. Customer ID is used to uniquely identify a customer. Value range: (1–2,147,483,647).
Service Instance	Service-ID	Each PE router have Service instance that contain SAP, SDP and Pseudowire. Service-ID is used to identify a service for particular customer. **Value range**: (1–2,147,483,647).
	SAP:: sap-id	**Service Access Point** that connect PE to customer device. SAP-id is used to identify customer service attachment point. Consist of Port-id, encapsulation type. If port facing to customer then set as an access port else a network port
	SDP:: sdp-id	**Service Destination Point (SDP**) is a tunnel that connects two PE routers. Can contain one or more transport tunnels between PE routers and these tunnels carry VPN encapsulated traffic from PE to another PE. Full mesh SDP is necessary to provide VPLS architecture. SDPs are P2P and unidirectional. Types can be GRE, LDP-LSP, RSVP-TE LSP Value range: (1–17,407).
	Pseudowires:: <sdp-id:vc-id>	Connect member PE routers participating in the same VPLS. VC-Id is used to identify a pseudowire used between PE routers. VC-id and SDP-ID uniquely identify a pseudowire. Both end of PE routers must use the same Pseudowire
Forwarding Database		A MAC address table and every service instance must maintain its own Forwarding database table.
T-LDP		Targeted LDP session, use by Pseudowires to maintain signaling among PE routers.

Figure 2.2.1b Demonstrate the VPLS entities:
(Ref Fig:9.5 of Designing and Implementing IP/MPLS based Ethernet Layer 2 VPN)



Service Access Point and its components:

A logical entity that represent the attachment circuit where customer connect with Service Provider and need to configure under service instances. The mode of Ethernet should access if it is facing towards customer and network if it is facing to PE device.

Fig 2.3a: SAP configuration:

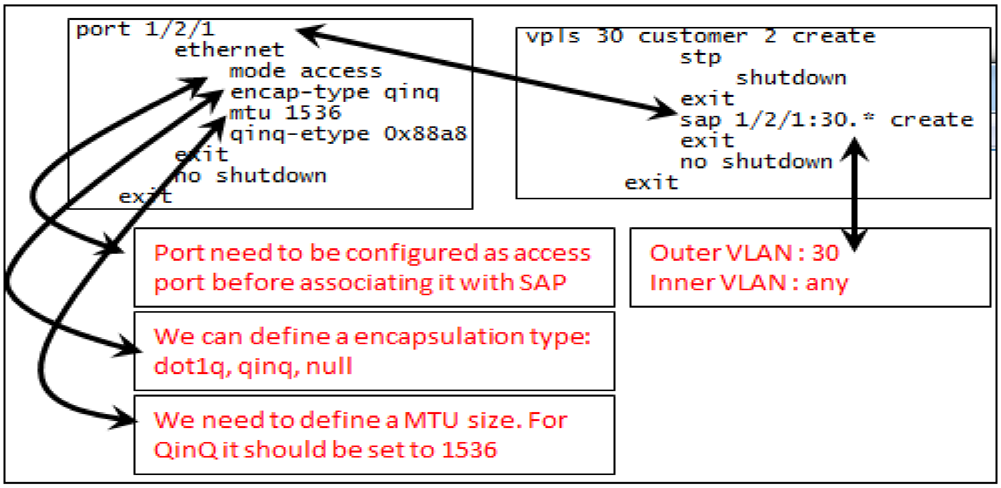


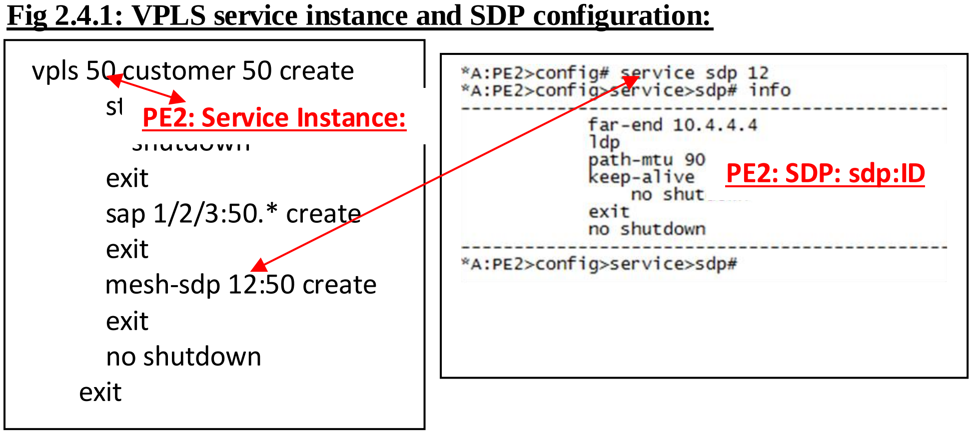
Table 2.3b: SAP components:

Component	Detail
SAP ID	Port number followed by VLAN ID
Encapsulation-type	Ethernet Value: Null, Dot1q, QinQ

Service Distribution Point: SDP:-

SDP build reachability from one PE router to another PE router and use to carry VPN encapsulated traffic between PE routers. It functions as a tunnel between PE devices and multiple P devices can be present in between the tunnel. Service instance is not aware of those intermediate P devices and service instances are not aware of changes in between these P devices. When a service instance on PE1 wants to send a traffic to PE2, it must specify the SDP (fig 2.4.1)

<u>Fig 2.4.1: VPLS service instance and SDP configuration:</u>



Multiple service instances can use the same SDP to reach the same far end PE router. SDP function as a virtual circuit multiplexer means traffic from multiple service instances are multiplexed using the same vc-lable and through SDP reach the far-end PE router. The far-end PE router uses the same vc-lable as Demux to distinguish the traffic flow and forward it to actual service instance. SDP is Unidirectional entity, which means that on both end we must define the SDP.

<u>Fig 2.4.2: Illustrate the SDP status:</u>

```
*A:PE2# show service sdp

===============================================================================
Services: Service Destination Points
===============================================================================
SdpId     Adm MTU  Opr MTU  IP address        Adm  Opr          Deliver   Signal
-------------------------------------------------------------------------------
12        9000     9000     10.4.4.4          Up   Up           LDP       TLDP
-------------------------------------------------------------------------------
Number of SDPs : 1
-------------------------------------------------------------------------------
===============================================================================
```

Signaling Method of SDP:

To maintain the SDP connectivity, that basically carries L2VPN traffic, it requires a signaling method to exchange VC-label and this done through Targeted LDP (T-LDP). This defines the pseudowire to the far-end PE router to pass the traffic over the SDP. In SDP configuration T-LDP is enabled by default.

Fig 2.5: Illustrate the Signaling Method use by SDP:

```
*A:PE2# show service sdp detail

===============================================================================
Services: Service Destination Points Details
===============================================================================
-------------------------------------------------------------------------------
 Sdp Id 12  -(10.4.4.4)
-------------------------------------------------------------------------------
Description            : (Not Specified)
SDP Id                 : 12                    SDP Source          : manual
Admin Path MTU         : 9000                  Oper Path MTU       : 9000
Far End                : 10.4.4.4              Delivery            : LDP
Tunnel Far End         : 10.4.4.4
Admin State            : Up                    Oper State          : Up
Signaling              : TLDP                  Metric              : 0
Acct. Pol              : None                  Collect Stats       : Disabled
Last Status Change     : 11/30/2011 23:58:23   Adv. MTU Over.      : No
Last Mgmt Change       : 11/30/2011 23:58:23   VLAN VC Etype       : 0x8100
```

T-LDP Signaling

SDP Keep-Alive:

SDP Keep-alive is unidirectional and must be same on both end of PE routers. SDP maintain its Operation status :UP by sending echo request message at every hello time and in response expect to receive SDP echo reply message.

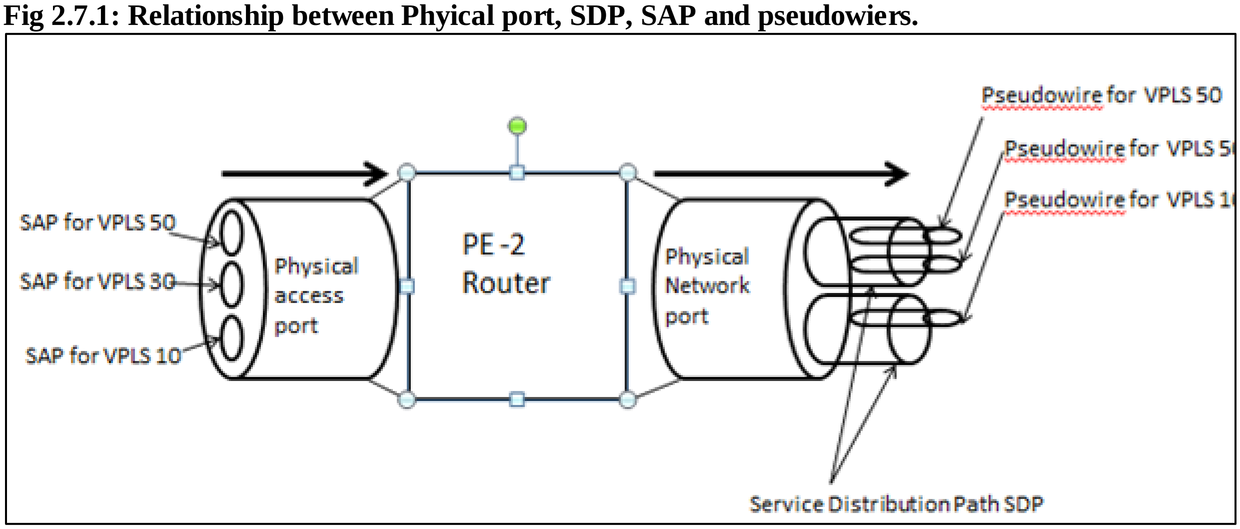
Fig 2.6: Illustrate SDP timing of keep-alive messages:

```
*A:PE2# show service sdp 12 detail

===============================================================================
Service Destination Point (Sdp Id : 12) Details
===============================================================================
-------------------------------------------------------------------------------
 Sdp Id 12  -(10.4.4.4)
-------------------------------------------------------------------------------

-- Output omitted---

KeepAlive Information :
Admin State          : Enabled                Oper State        : Alive
Hello Time           : 10                     Hello Msg Len     : 0
Hello Timeout        : 5                      Unmatched Replies : 0
Max Drop Count       : 3                      Hold Down Time    : 10
Tx Hello Msgs        : 67                     Rx Hello Msgs     : 67

-- Output omitted---
```

Pseudowire (PW):

As discussed above that SDP is a transport tunnel that logically connects two PE devices. The pseudowire is a logical entity that connects two service instances of two PE devices. A bidirectional point-to-point entity in L2VPN and multiple Pseudowires can share the same SDP. It is bind to SDP and signaled over the T-LDP session to the other end of PE device.

Fig 2.7.1: Relationship between Phyical port, SDP, SAP and pseudowiers.



The process of associating a pseudowire with the SDP is called a binding process. Actually during this process VC-LABELS are exchange using T-LDP signaling and that perform service multiplexing. This is an agreement between PE devices that agree by exchanging ***VC-lable,VC-type, VC-ID, and target interface.***

These agreed parameters uniquely identify the FEC service (Fig: 2.7.2). For example: PE-1 uses the received VC-label from PE2 to encapsulate the service instance traffic before sending it to PE2. Exactly similar process is performed by PE2 to send traffic to PE1. Agreed vc-labels perform function of de-multiplexer, when remote PE router received an encapsulated traffic, it uses these labels to identify the traffic of particular customer. The encapsulation is removed by PE router and then forward to the destined service instance.

Fig 2.7.2: showing VC-ID, VC-LABEL

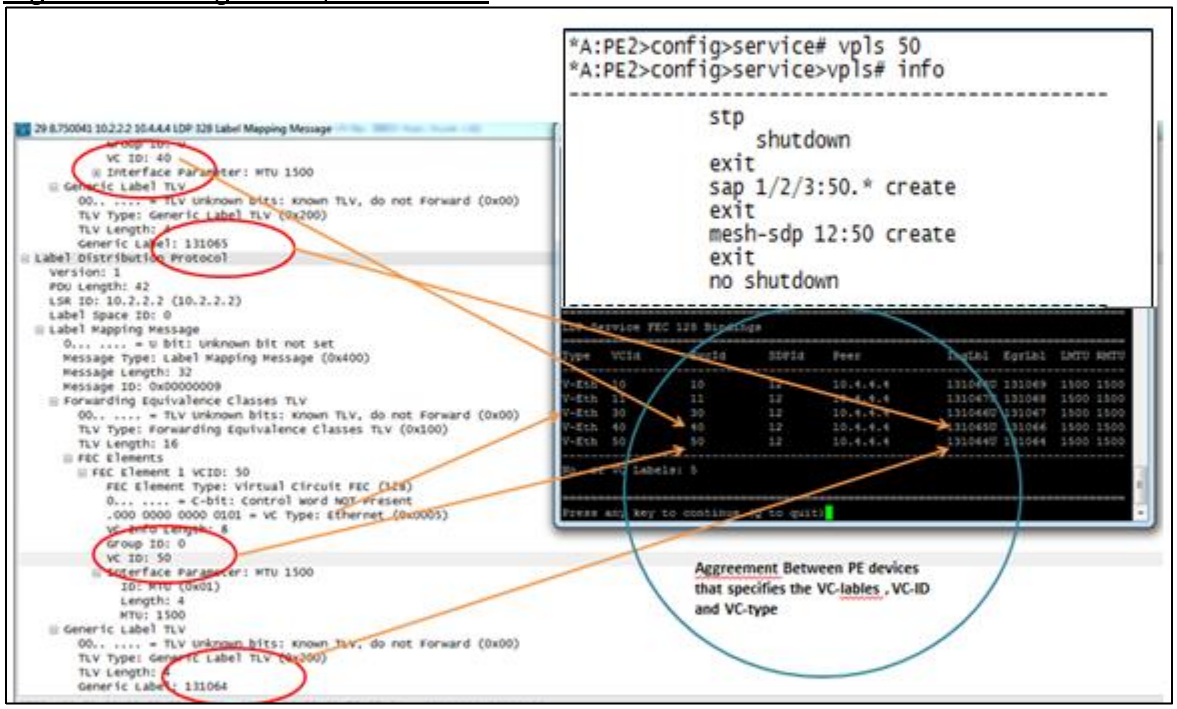
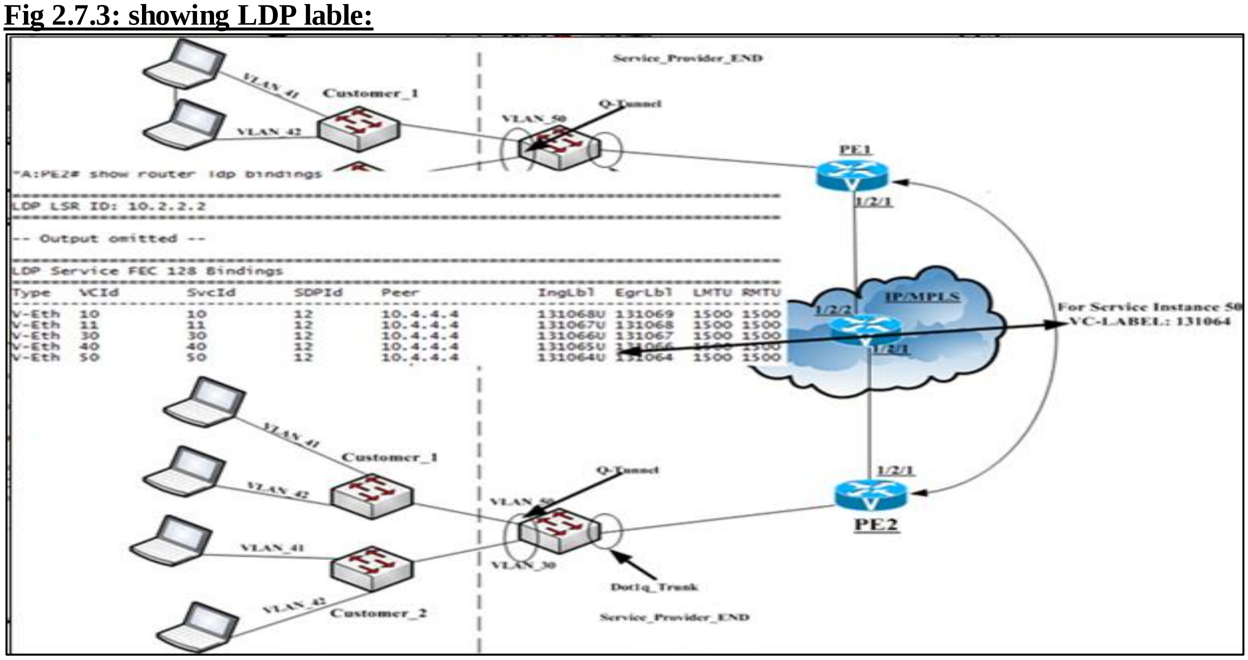


Fig 2.7.3: showing LDP lable:



Packet Walk-Through in VPLS service:

First I like to discuss only VPLS connectivity and how traffic moves through VPLS in IP/MPLS network

Fig 2.8.1 : VPLS+ 802.1ad topology Diagram:

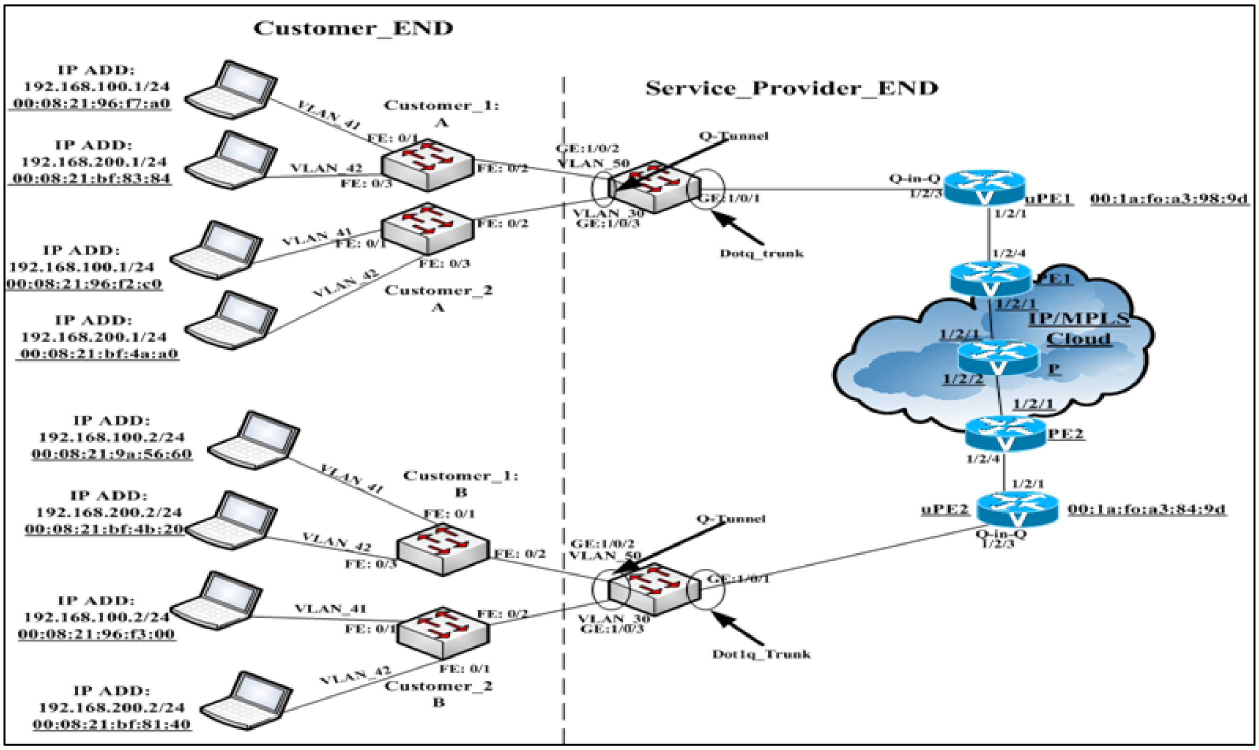


Table 2.8.2: Ports and their Types:

Point	EtherType	Ports	Port Type	Tag Type	Description
Devices are connect to these ports	0x800	0/1, 0/3	Access port	Tagged	IP= 0x8100
Customer to Service provider	0x8100	0/2	Trunk Port: 802.1Q	Tagged	802.1q
Service Provider connect to customer	0x8100	3700: Q-Tunnel port: 1/0/2, 10/3.	Tunnel Port: 802.1Q	Tagged	802.1q
S3750 connect to uPE.	0x8100	Trunk Port: 1/0/1	Trunk Port: 802.1Q	Tagged	802.1q
uPE connect to S37500	0x88a8	Q-in-Q port 1/2/3	Q-in-Q	Tagged	802.1ad
Service Provider connectivity	0x88e7	PE: 1/2/1, 1/2/4 uPE: 1/2/1, 1/2/3	Q-in-Q	Tagged	802.1ad

Table 2.8.3: IP addressing scheme of customers MAC address, C-VLAN, S-VLAN:

Customer	Device IP	Device Mac-address	C-VLAN	S-VLAN
1	192.168.100.1	00:08:21:9a:f7:a0	41	50
1	192.168.100.2	00:02:21:96: 56:60	41	50
1	192.168.200.1	00:08:21:bf:4b:20	42	50
1	192.168.200.2	00:08:21:bf:83:40	42	50
2	192.168.100.1	00:08:21:96:f2:c0	41	30
2	192.168.100.2	00:02:21:96:f3:00	41	30
2	192.168.200.1	00:08:21:bf:4a:a0	42	30
2	192.168.200.2	00:08:21:bf:81:40	42	30

VPLS Connectivity:

First I like to discuss only VPLS connectivity:

a) Send ping request from Customer_1 VLAN 41

Step #1: Trace Result on uPE1 ingress port 1/2/3:

<u>Customer_1 send a ping request from:</u>

IP: 192.168.100.1 --- 192.168.100.2

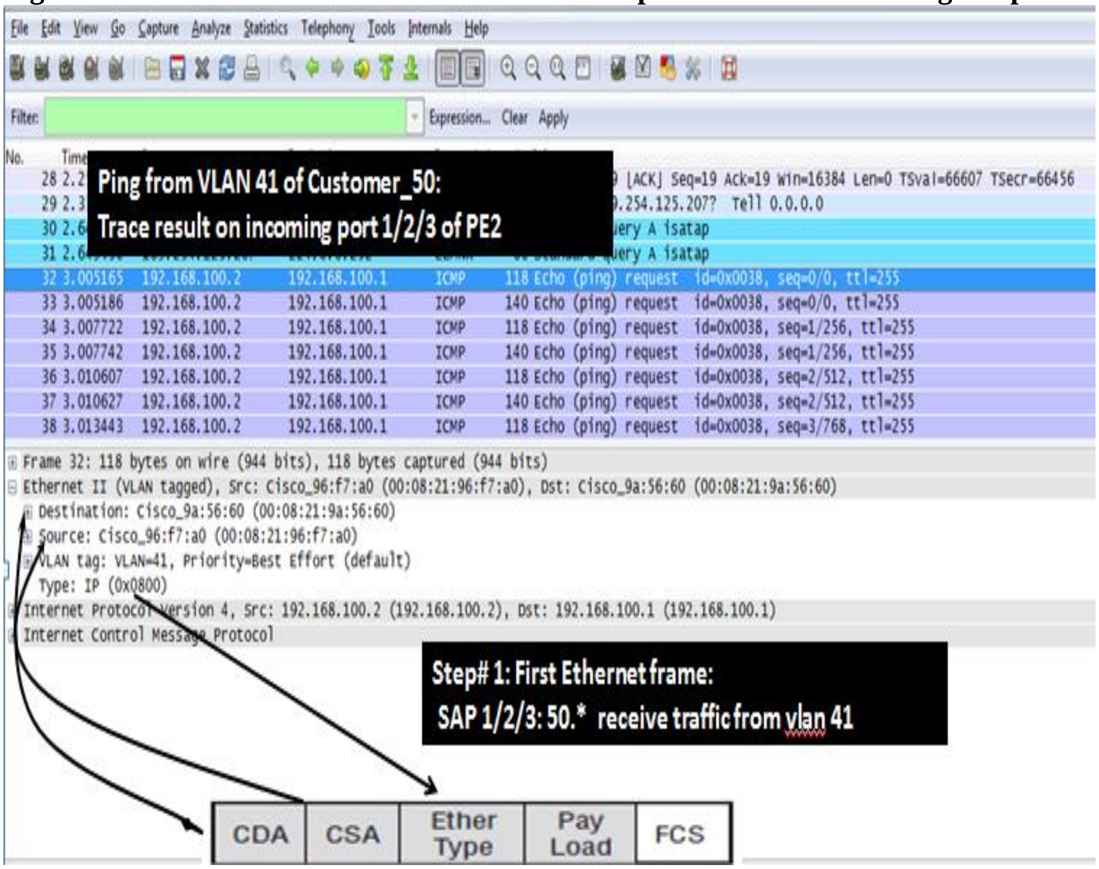
<**source address: 00:08:21:96:f7:a0** > --------------< **Dst address: 00:08:21:9a:56:60**>

Step#1:

PC_1 belongs to VLAN 41 of Customer _1 service VLAN 50 sends a Ping request. This is the first Ethernet frame on uPE router. When this request received on SAP 1/2/3:50.*, the request consists of following information. (Fig: 2.9.1).

Customer Destination address: 00:08:21:9a:56:60
Customer source Address: 00:08:21:96:f7:a0
VLAN ID: 41
Ether Type: 0x0800.

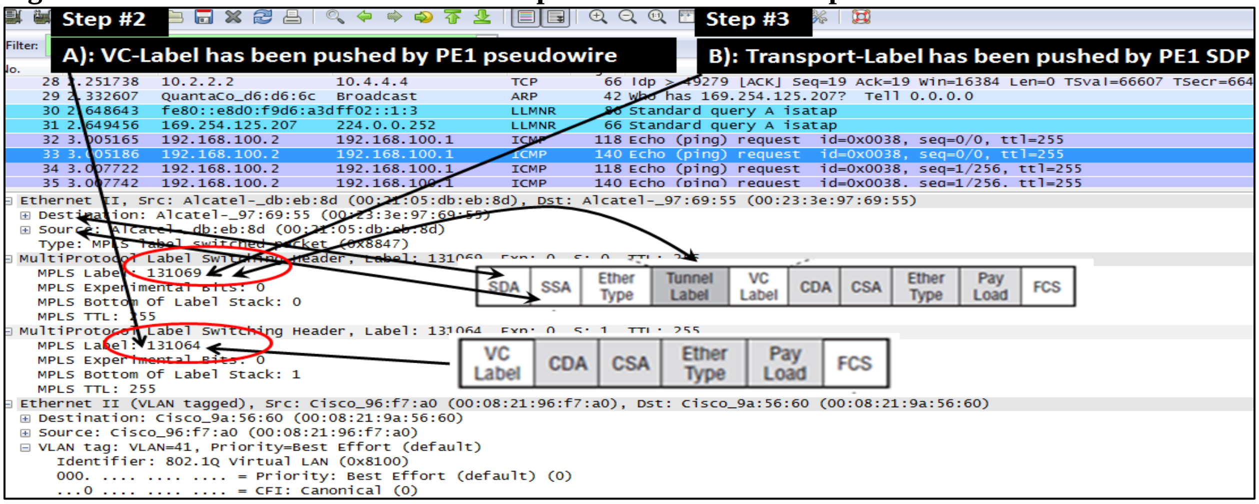
Fig 2.9.1: Received frame from customer. Trace capture on uPE1 router ingress port:



Step # 2 and Step # 3:

uPE forward the received frame to PE1. Upon Receiving Ethernet Frame psuedowire pushes a VC-Label (e.g 131064) and encapsulates the Ethernet frame with VC-Label. After that, SDP push a transport Label and encapsulates whole packet with transport lable (e.g: 131069). This VPN-encapsulated packet travel through the IP/MPLS core and the intermediate P routers swap the transport label.

Fig 2.9.2: Illustrate VC-LABEL and Transport LABEL. Trace Capture on PE1 router:

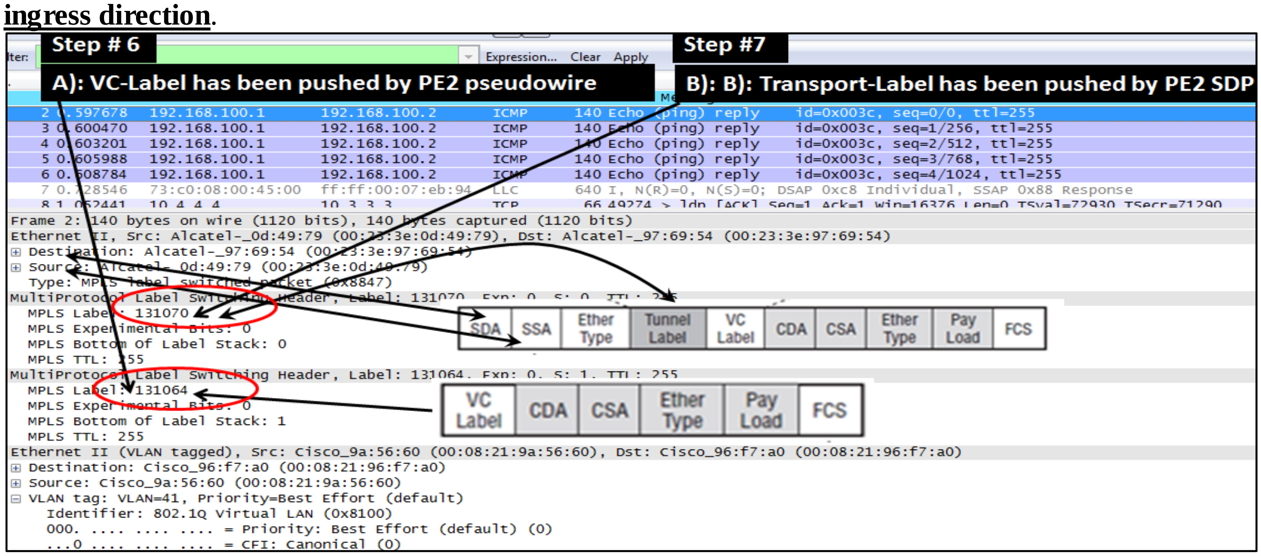


Step # 4 and Step # 5:

When the PE2 SDP received encapsulated traffic (double encapsulated traffic) it removes the transport label and uncover the VPN-encapsulated traffic. PE2 perform the de-multiplexing and stripped off the VC-label (131064) and forward the packet to service instance 50. From their service instance forward the de-encapsulated traffic to uPE2 and uPE2 forward the frame to customer.

Step # 6/7: Since during test we use Ping test, so exactly similar process from step 1 to 5 is performed by PE2 to reply a ping response as shown in Fig: 2.9.3

Fig 2.9.3 : Illustrate VC-LABEL and Transport Label on PE2 device: Trace capture at PE2 ingress direction.



VPLS Configuration and Verification:

1. To run a VPLS service we first need to deploy IP/MPLS service infrastructure.
2. Once we have IP/MPLS core, then we can create VPLS service.

Deployment of IP/MPLS core:

1. Configure IP addresses and run IGP (OSPF) protocol.
2. Configure MPLS and run LDP or RSVP- TE between PE routers.
3. Configure a full mesh SDP

Fig 2.10.1: Illustrate the routing table of PE2:

```
*A:PE2# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix                                     Type    Proto     Age         Pref
       Next Hop[Interface Name]                                        Metric
-------------------------------------------------------------------------------
10.2.2.2/32                                     Local   Local     10h45m17s   0
       system                                                        0
10.3.3.3/32                                     Remote  OSPF      04h00m27s   10
       192.168.3.1                                                   1000
10.4.4.4/32                                     Remote  OSPF      04h00m27s   10
       192.168.3.1                                                   2000
192.168.1.0/30                                  Remote  OSPF      04h00m27s   10
       192.168.3.1                                                   2000
192.168.3.0/30                                  Local   Local     04h00m33s   0
       to-P3                                                         0
-------------------------------------------------------------------------------
No. of Routes: 5
===============================================================================
```

Fig 2.10.2: Illustrate the status of MPLS:

```
*A:PE2>show>router>mpls# status

===============================================================================
MPLS Status
===============================================================================
Admin Status           : Up                  Oper Status          : Up
Oper Down Reason       : n/a
FR Object              : Enabled             Resignal Timer       : Disabled
Hold Timer             : 1 seconds           Next Resignal        : N/A

--- output is omitted --
```

Fig 2.10.3: Illustrate the status of SDP:

```
*A:PE2# show service sdp

===============================================================================
Services: Service Destination Points
===============================================================================
SdpId     Adm MTU  Opr MTU  IP address       Adm  Opr          Deliver   Signal
-------------------------------------------------------------------------------
12        9000     9000     10.4.4.4         Up   Up           LDP       TLDP
-------------------------------------------------------------------------------
Number of SDPs : 1
-------------------------------------------------------------------------------
```

Configuration of VPLS:

1. Configure access port connected to customer: If the port facing towards customer then it must be configure in access mode else it should be configure as network mode.

Fig 2.11.1: Illustrate the configuration of Port:

```
*A:PE2>config>port# info
-----------------------------------------------
        ethernet
            mode access
        exit
        no shutdown
-----------------------------------------------
```

2. Configure the Service Distribution Point. Here we need to define system IP of far-end PE router. Signaling method (LDP/RSVP) and the MTU size.

Fig 2.11.2: Illustrate the SDP configuration:

```
*A:PE2>config>service>sdp# info
-----------------------------------------------
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                no shutdown
            exit
            no shutdown
-----------------------------------------------
```

3. Configure VPLS instance and bind the SDP to the VPLS instance. Since this mesh SDP so we don't need to run STP. Here we define SAP and SAP QoS parameters.

Fig 2.11.3: Illustrate Service Instance configuration:

```
*A:PE2>config>service# vpls 50
*A:PE2>config>service>vpls# info
-----------------------------------------------
            stp
                shutdown
            exit
            sap 1/2/3:50.* create
            exit
            mesh-sdp 12:50 create
            exit
            no shutdown
-----------------------------------------------
```

4. Check whether the VLS service is operationally up or not.

Fig 2.11.4: Illustrate the Service instance operational and admin status

```
*A:PE2# show service id 50 base

===============================================================================
Service Basic Information
===============================================================================
Service Id          : 50                         Vpn Id             : 0
Service Type        : VPLS
Name                : (Not Specified)
Description         : (Not Specified)
Customer Id         : 50
Last Status Change: 12/01/2011 05:31:43
Last Mgmt Change    : 12/01/2011 00:10:57
Admin State         : Up                         Oper State         : Up
MTU                 : 1514                       Def. Mesh VC Id    : 50
SAP Count           : 1                          SDP Bind Count     : 1
Snd Flush on Fail   : Disabled                   Host Conn Verify   : Disabled
Propagate MacFlush: Disabled                     Per Svc Hashing    : Disabled
Allow IP Intf Bind: Disabled
Def. Gateway IP     : None
Def. Gateway MAC    : None

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                               Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sap:1/2/3:50.*                           qinq         1522    1522    Up   Up
sdp:12:50 M(10.4.4.4)                    Mesh         9000    9000    Up   Up
===============================================================================
```

5. Test the connectivity: Once we check the Service Instance and SDP Status, we now check the connectivity from client end.

Fig 2.11.5: Illustrate the Ping test from client end:

```
Top_Rack4#ping 192.168.100.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/4 ms
Top_Rack4#
```

6. Check the ARP table of CE-device. ARP table of CE device only have those entries that belong to VLAN.

Fig 2.11.6 : Illustrate the ARP entries at client end.

```
Top_Rack4#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.100.1          111  0008.219a.5660  ARPA   FastEthernet0/0
Internet  192.168.100.2            -  0008.2196.f7a0  ARPA   FastEthernet0/0
```

7. Check the Forwarding database table on PE routers. It includes MAC entries of all the devices of customer.

Fig 2.11.7: Illustrate the Forwarding Database Table.

```
*A:PE2# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC                 Source-Identifier        Type   Last Change
                                                       Age
-------------------------------------------------------------------------------
50        00:07:eb:94:73:c0 sdp:12:50                  L/0    12/01/2011 07:05:47
50        00:07:eb:b0:66:80 sap:1/2/3:50.*             L/0    12/01/2011 07:16:56
50        00:08:21:96:f7:a0 sap:1/2/3:50.*             L/210  12/01/2011 09:46:01
50        00:08:21:9a:56:60 sdp:12:50                  L/210  12/01/2011 07:05:45
50        00:08:21:bf:4b:20 sdp:12:50                  L/449  12/01/2011 07:05:59
50        00:08:21:bf:83:40 sap:1/2/3:50.*             L/293  12/01/2011 09:49:22
50        00:18:18:6e:47:81 sap:1/2/3:50.*             L/0    12/01/2011 07:16:19
-------------------------------------------------------------------------------
No. of Entries: 7
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
```

Conclusion and Drawback:-

Through VPLS, service provider is able to connect two LANs that are geographically thousands miles away. Problem arises when network grows and multiple customers want to avail this technology. Problem with VPLS is that it can carry 802.1Q traffic, which consist of single tag (Single VLAN) and that could only be up-to 4096. This cause scalability issue and the reason could be:

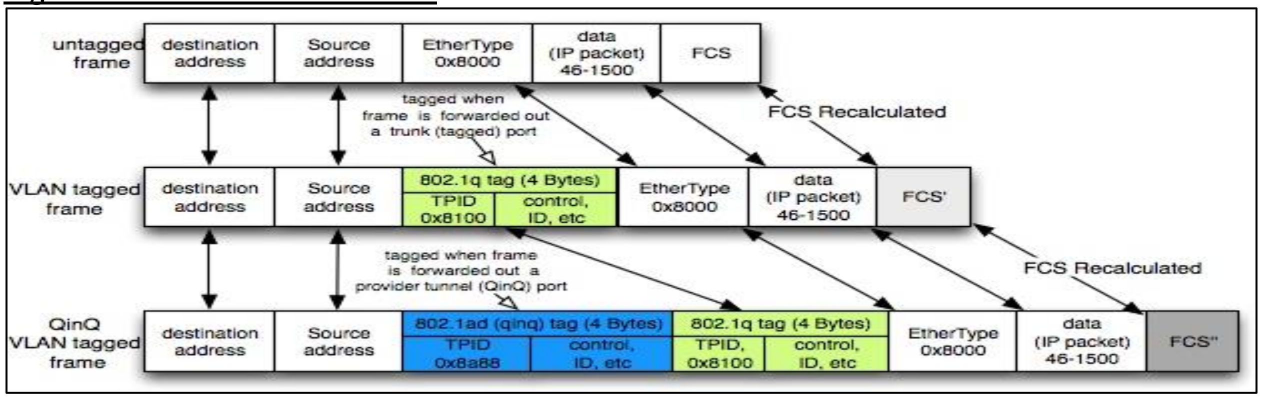
a) Service is limited to 4096 VLANs.
b) Two customers can’t have the same VLAN. And this is not possible because customers are reluctant to change their existing network topology.

Chapter 3: Q-in-Q (IEEE802.1ad)

802.1ad – Q-in-Q (VLAN-stacking)

To resolve the scalability issues which we discussed in chapter 2, In Dec, 2005 IEEE introduces another protocol name IEEE-802.1ad, which add S-VLAN in front of C-VLAN. This allow service provider to support different services. Theoretically it support 4K S-VLAN * 4K C-VLAN= 16 million VLANs.

Fig 3.1: Frame Format of 802.1ad:



This solution guarantees a separation between customer traffic in the service provider network. For example two customers have two different offices, which are located in different geographical places. Also both customers have same LAN_ID's. In this network design service provider can guaranty security to the traffic of both the customers. So using IEEE 802.1ad, service provider add another VLAN (e.g S-VLAN a for customer X and S-VLAN b for customer Y) on top of customer VLAN.

As shown in the below network topology customer 1 have two VLAN's (VLAN 41 and VLAN 42) Also customer 2 have two VLAN's (VLAN 41 and VLAN 40). Service Provider provides S-VLAN- 50 to customer 1 and S-VLAN to customer 2.

Fig 3.1.1 VPLS+ 802.1ad topology Diagram:

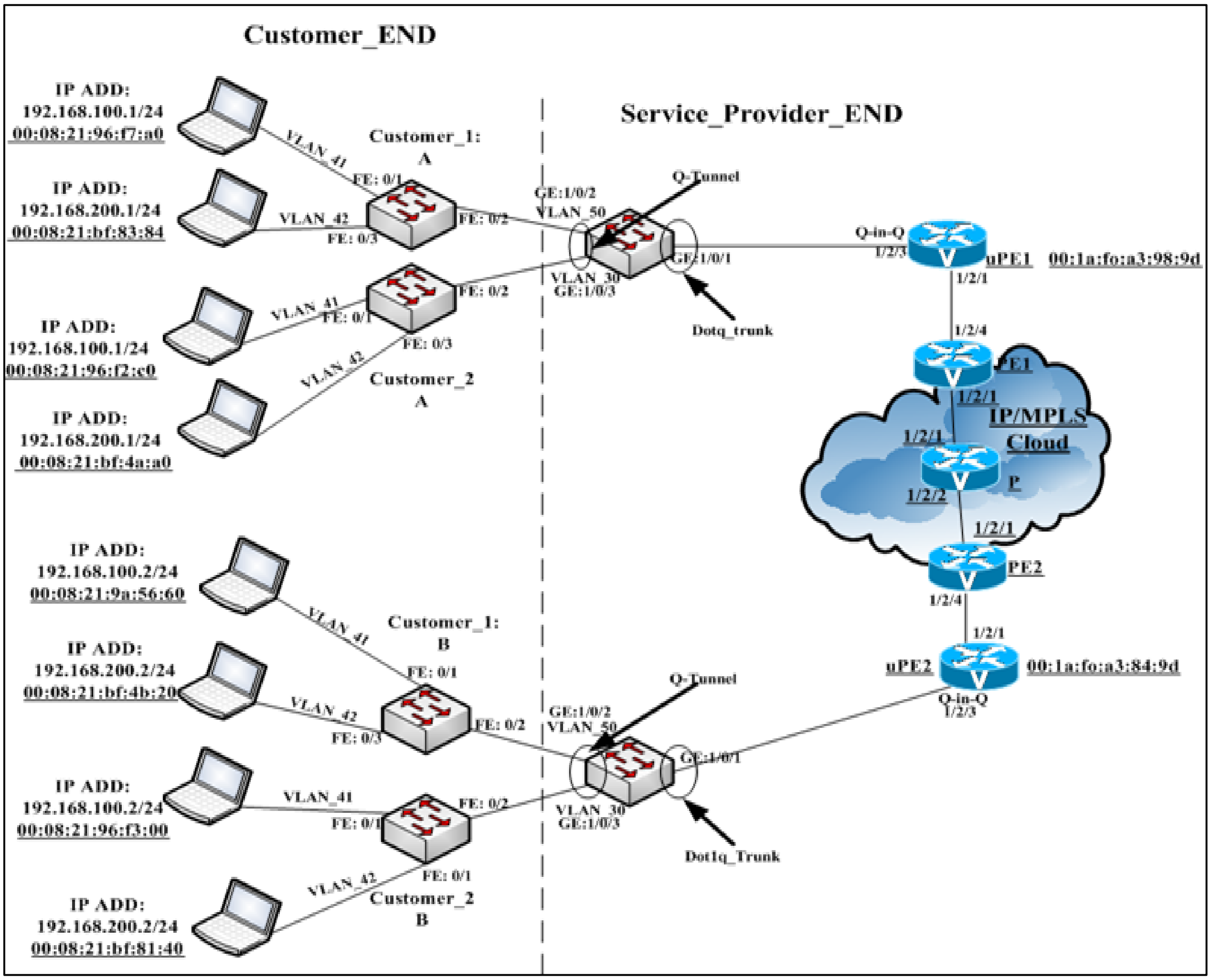


Table 3.1.2 Ports and their Types:

Point	EtherType	Ports	Port Type	Tag Type	Description
Devices are connect to these ports	0x800	0/1, 0/3	Access port	Tagged	IP= 0x8100
Customer to Service provider	0x8100	0/2	Trunk Port: 802.1Q	Tagged	802.1q
Service Provider connect to customer	0x8100	3700: Q-Tunnel port: 1/0/2, 10/3.	Tunnel Port: 802.1Q	Tagged	802.1q
S3750 connect to uPE.	0x8100	Trunk Port: 1/0/1	Trunk Port: 802.1Q	Tagged	802.1q
uPE connect to S37500	0x88a8	Q-in-Q port 1/2/3	Q-in-Q	Tagged	802.1ad
Service Provider connectivity	0x88a8	PE: 1/2/1, 1/2/4 uPE: 1/2/1, 1/2/3	Q-in-Q	Tagged	802.1ad

Packet Walk-Through of 802.1ad using VPLS service:

1. **Step #1:**
   Customer_1 and Customer_2 have two VLAN's (41/42). When traffic of these VLANS reaches to service provider switch 3750, it add a VLAN 50 on Customer_1 traffic and VLAN 30 on Customer_2 traffic.

Table 3.2.1: Illustrate the addressing and VLAN scheme.

Customer	Device IP	Device Mac-address	C-VLAN	S-VLAN
1	192.168.100.1	00:08:21:9a:56:60	41	50
1	192.168.100.2	00:02:21:96:f7:a0	41	50
1	192.168.200.1	00:08:21:bf:4b:20	42	50
1	192.168.200.2	00:08:21:bf:83:40	42	50
2	192.168.100.1	00:08:21:96:f2:c0	41	30
2	192.168.100.2	00:02:21:96:f3:00	41	30
2	192.168.200.1	00:08:21:bf:4a:a0	42	30
2	192.168.200.2	00:08:21:bf:81:40	42	30

Fig 3.2.2: Illustrate the AR tables at client end (PCs/routers)

```
Customer_1:Vlan_41

R3-Top#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.100.1           -   0008.219a.5660  ARPA   FastEthernet0/0
Internet  192.168.100.2           7   0008.2196.f7a0  ARPA   FastEthernet0/0
R3-Top#

Customer_1:vlan_42

R3_mid#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.200.1           -   0008.21bf.4b20  ARPA   FastEthernet0/0
Internet  192.168.200.2         230   0008.21bf.8340  ARPA   FastEthernet0/0
R3_mid#

Customer_2:vlan_41

R1_top#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.100.1           -   0008.2196.f2c0  ARPA   FastEthernet0/0
Internet  192.168.100.2          92   0008.2196.f300  ARPA   FastEthernet0/0
R1_top#

Customer_2:vlan_41

R1_Mid#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.200.1           -   0008.21bf.4aa0  ARPA   FastEthernet0/0
Internet  192.168.200.2         102   0008.21bf.8140  ARPA   FastEthernet0/0
R1_Mid#
```

2. Let's take an example when PC at Customer_1 VLAN_ID 41 and PC at Customer_2 VLAN_ID 41 send a ping request. When a request reaches to service provider end. Service provider adds S-VLAN 50 for the traffic of customer_1 and S-VLAN 30 for the traffic of customer_2. As shown in the below trace results.

Note 3.2.3 : Here I select a one trace result but packets from both the customers. (packet 190 and 192 is customer_2 traffic and packets 196 and 197 are customer_1 traffic)

Trace Result at uPE1:

Packet 190 of Customer_2:

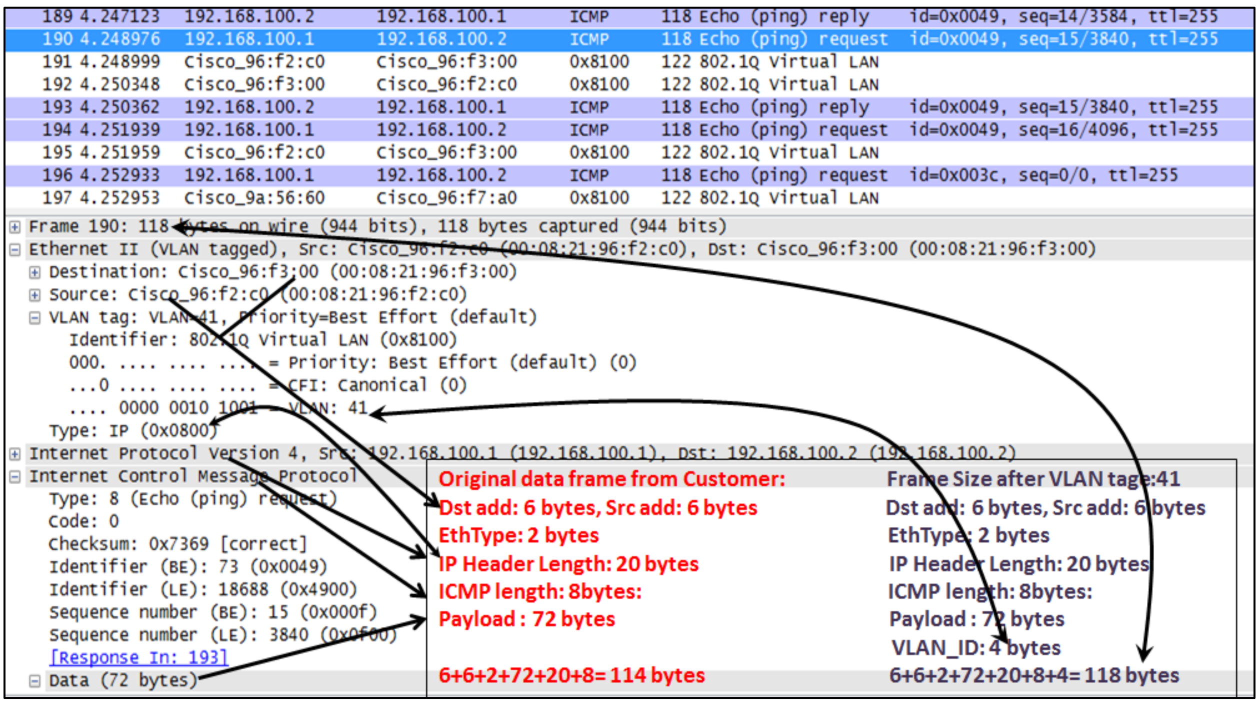
Customer_2 send a ping request from:

IP: 192.168.100.1 -- 192.168.100.2

<**source address: 00:08:21:96:f2:c0** > --------------< **Dst address: 00:08:21:96:f3:00**>

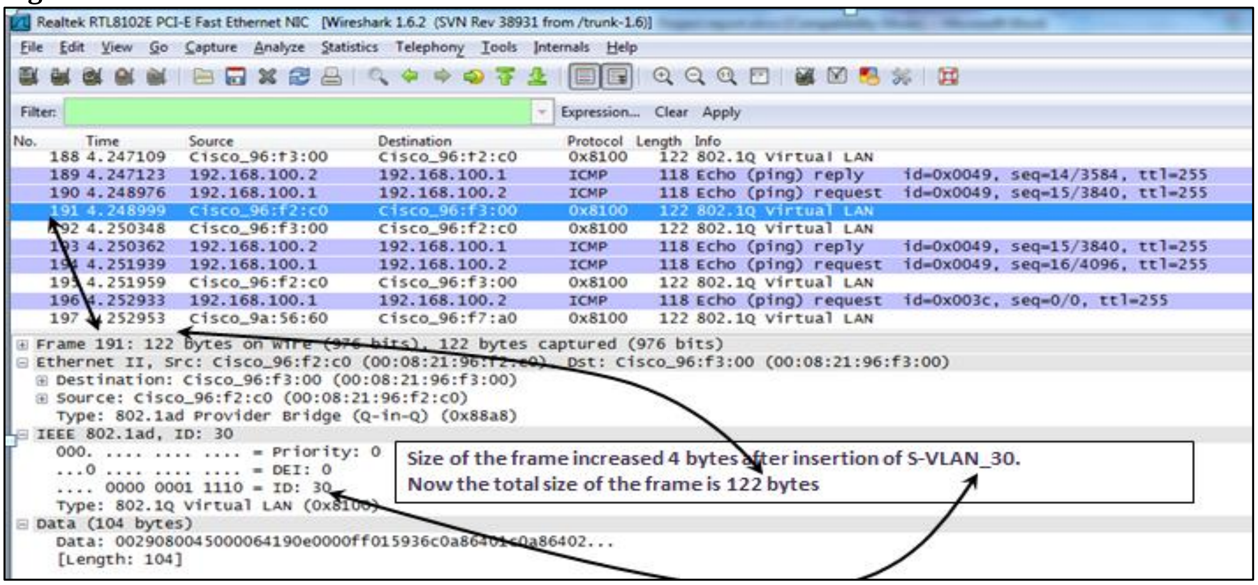
a) Customer sends traffic with a VLAN ID 41. Total size of the frame (including VLAN tag is 118 bytes. Calculation in the below trace result

Fig 3.3.1: Illustrate size of the Ethernet frame, with and without tag:



b) After receiving a frame Service Provider insert an S-VLAN: 30 in between Source address and etherType fields of the received frame. (Check Packet 191 of below trace result):

Fig 3.3.2: Illustrate the S-VLAN:



Packet 196 of Customer_1:

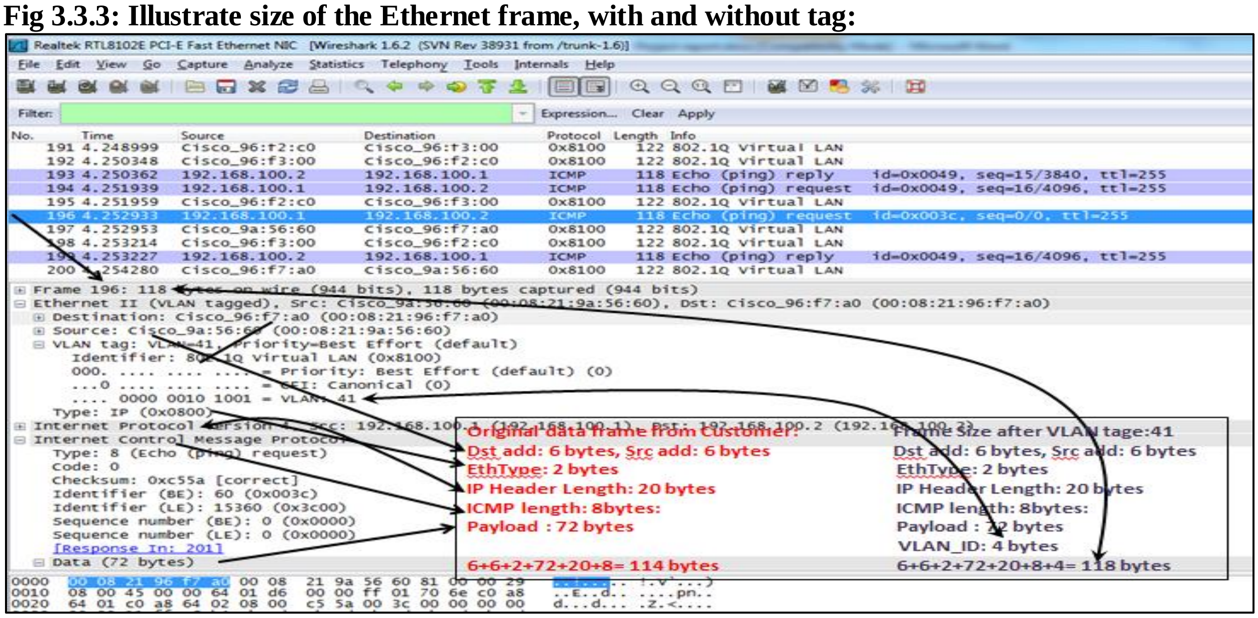
Customer_1 send a ping request from:

IP: 192.168.100.1 -- 192.168.100.2

<source address: 00:08:21:96:f7:a0 > --------------< Dst address: 00:08:21:9a:56:60 >

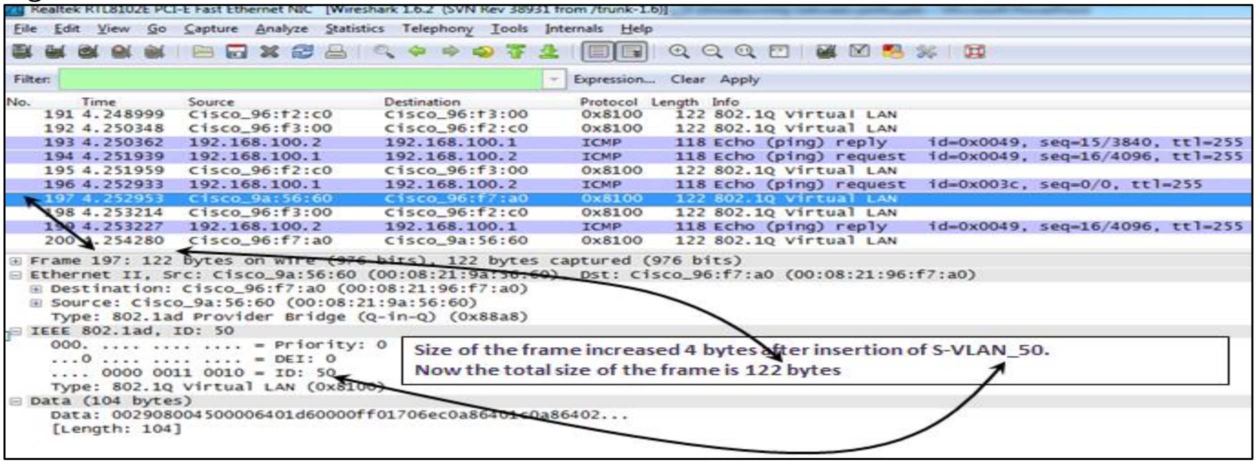
a) Customer sends traffic with a VLAN ID 41. Total size of the frame (including VLAN tag is 118 bytes. Calculation in the below trace result.

Fig 3.3.3: Illustrate size of the Ethernet frame, with and without tag:



b) After receiving a frame Service Provider insert an S-VLAN: 50 in between Source address and etherType fields of the received frame.

Fig 3.3.4: Illustrate the S-VLAN:



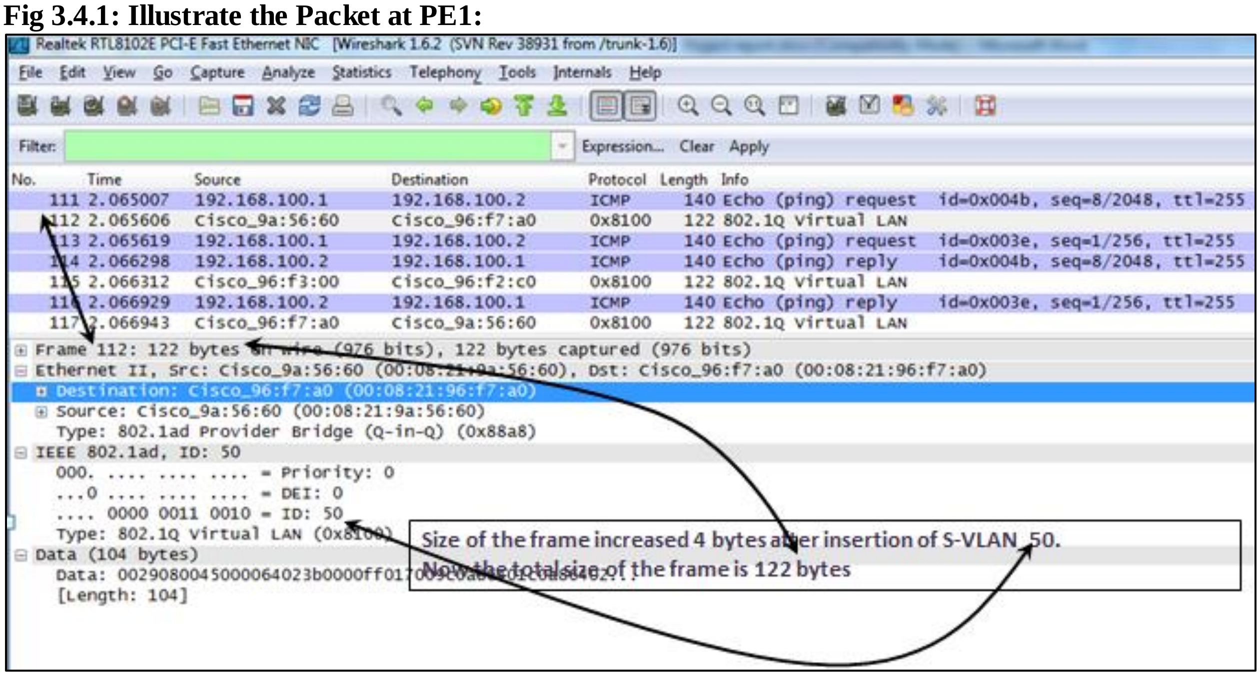
Trace Result at PE1: PING_ Request test:

<u>Packet 112 of Customer_1:</u>

1. Service Provider received a Ping request from Customer_1 IP:192.168.100.1(src add: 00:08:21:9a:56:60) to IP:192.168.100.2 (dst add: 00:08:21:96:f7:a0).

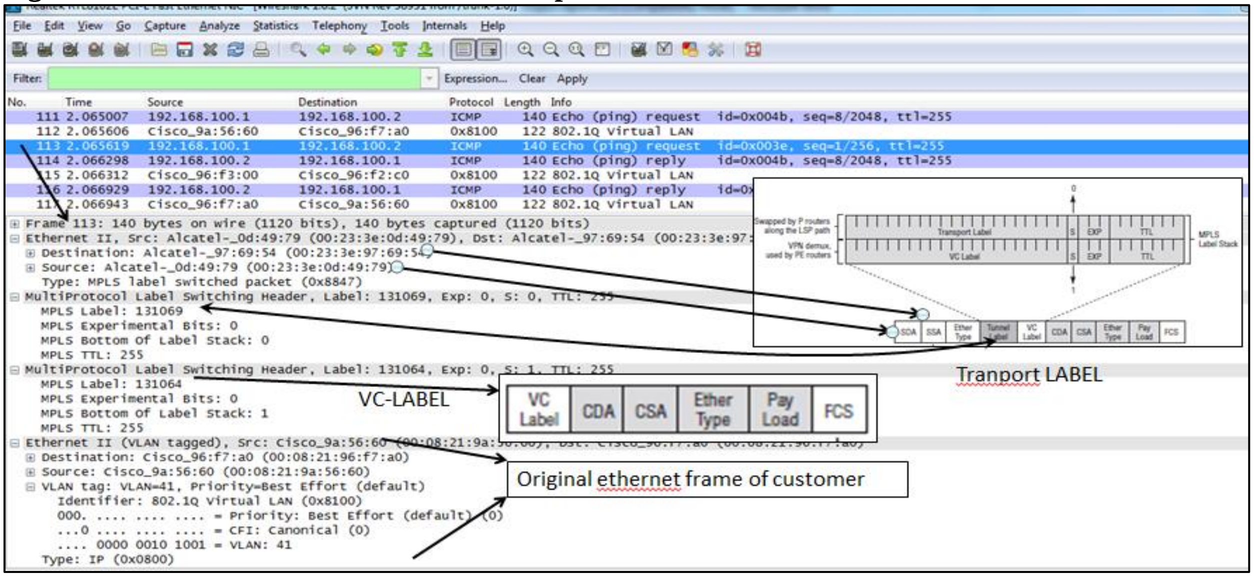
   a) PE1 received a 802.1ad frame from uPE1 (packet #112)

Fig 3.4.1: Illustrate the Packet at PE1:



b) PE1 stripped off the S-VLAN 50 and encapsulate it with **VC-LABEL : <131064>**, **S-Source Address< 00:23:3e:0d:49:79>**, **S-Destination Address< 00:23:3e:97:69:54> and Transport LABEL: <131069>.** And forward that to IP/MPLS core.

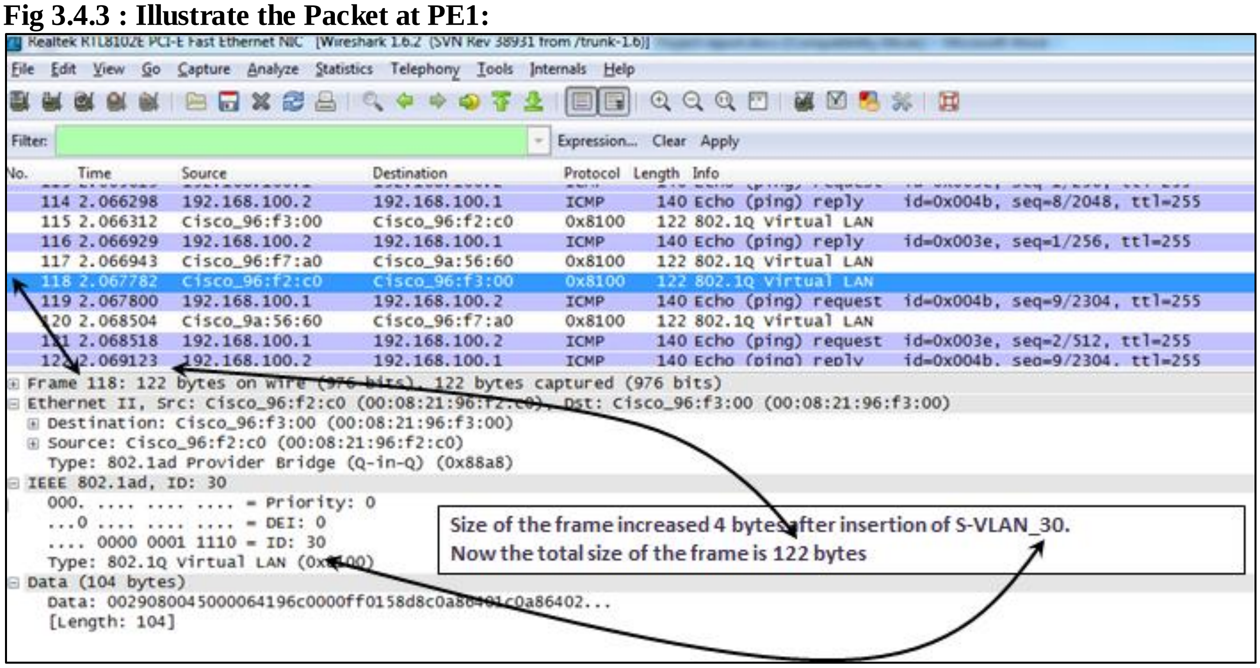
Fig 3.4.2: Illustrate the VC-Label and Transport Label:



2. Service Provider received a Ping request from Customer_2 IP:192.168.100.1(src add: 00:08:21:96:f2:c0) to IP:192.168.100.2 (dst add: 00:08:21:96:f3:00).

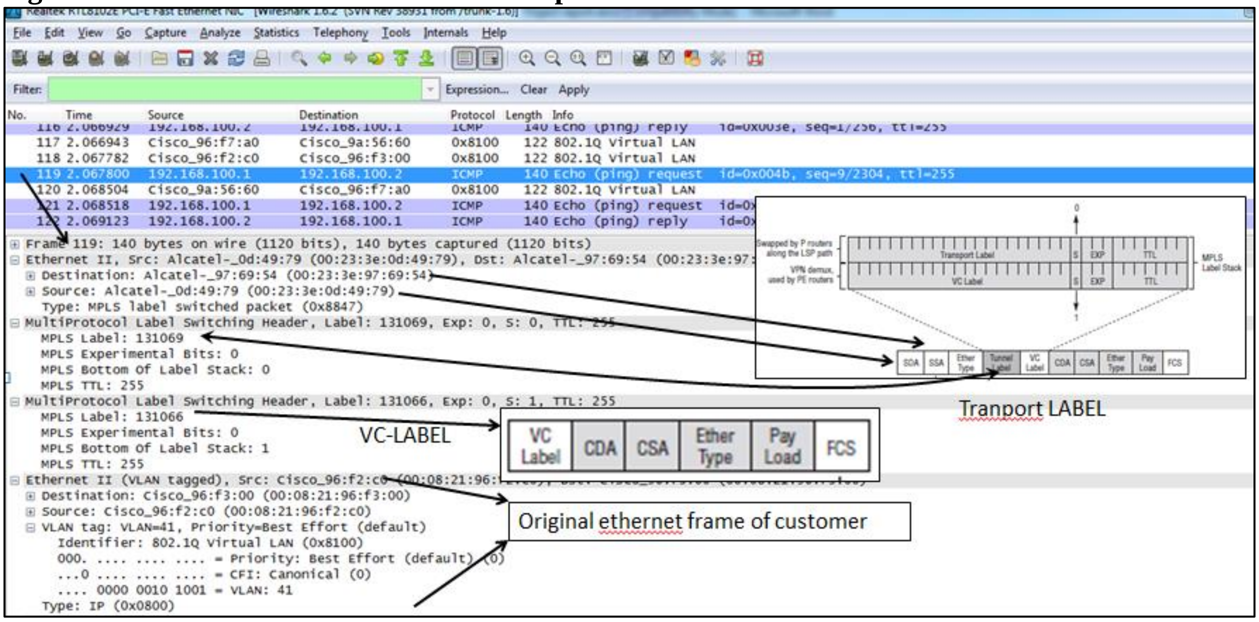
a) PE1 received a 802.1ad frame from uPE1 (packet #118).

Fig 3.4.3 : Illustrate the Packet at PE1:



b) PE1 stripped off the S-VLAN 30 and encapsulate it with **VC-LABEL : <131066>**, **S-source Address <00:23:3e:0d:49:79>, S-Destination Address <00:23:3e:97:69:54> and Transport LABEL: <131069>.** And forward that to IP/MPLS core.

Fig 3.4.4: Illustrate the VC-Label and Transport Label:



Exactly same process is performed in reply to the request packet. Service Provider at uPE2 inserts an S-VLAN-41 or S-VLAN_42 in between source address and Ethertype of customer packet. At PE2 Service Provider remove the S-VLAN and encapsulate the packet with S-Source address, S-Destination address, VC-Label and Transport Label. Through this process Service Provider can successfully resolve the VLAN scalability problem using 802.1ad (Q-in-Q).

Drawback and Conclusion:

IEEE 802.1ad got popularity and immediately got customers attention. Small and big customers like to connect their LANs through this method. But since using this protocol, service provider forward customer traffic based on customer MAC-addresses. PE devices have to maintain Forwarding Database Table and that is the problem with this protocol. As the network grows, this FDB easily climbs to 100,000s of MAC-addresses (Fig: 3.5.1 & Fig 3.5.2). During the link failure or link fluctuation, this extremely large forwarding database tables (FDB) result slow convergence that results reliability concerns. Other concerns like: Management issues and limited number of service instances (4094) also become problem for Service Providers.

<u>Fig 3.5.1Forwarding Database Table of PE1:</u>

```
A:PE1# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId     MAC               Source-Identifier        Type     Last Change
                                                      Age
-------------------------------------------------------------------------------
30         00:07:eb:94:72:00 sap:1/2/4:30.*           L/0      12/01/2011 04:27:06
30         00:07:eb:94:72:02 sap:1/2/4:30.*           L/0      12/01/2011 04:27:05
30         00:07:eb:94:72:40 sdp:12:30                L/0      12/01/2011 04:21:36
30         00:07:eb:94:72:42 sdp:12:30                L/30     12/01/2011 04:21:34
30         00:08:21:96:f2:c0 sap:1/2/4:30.*           L/270    12/01/2011 10:37:25
30         00:08:21:96:f3:00 sdp:12:30                L/434    12/01/2011 04:26:59
30         00:08:21:bf:4a:a0 sap:1/2/4:30.*           L/91     12/01/2011 10:50:52
30         00:08:21:bf:81:40 sdp:12:30                L/434    12/01/2011 04:22:02
30         00:18:18:6e:47:81 sdp:12:30                L/0      12/01/2011 02:05:03
50         00:07:eb:94:73:c0 sap:1/2/4:50.*           L/0      12/01/2011 02:05:07
50         00:07:eb:94:73:c2 sap:1/2/4:50.*           L/0      12/01/2011 02:05:07
50         00:07:eb:b0:66:80 sdp:12:50                L/0      12/01/2011 02:05:05
50         00:07:eb:b0:66:82 sdp:12:50                L/0      12/01/2011 02:05:01
50         00:08:21:96:f7:a0 sdp:12:50                L/120    12/01/2011 04:24:31
50         00:08:21:bf:4b:20 sap:1/2/4:50.*           L/243    12/01/2011 10:48:20
50         00:08:21:bf:83:40 sdp:12:50                L/30     12/01/2011 04:27:57
50         00:18:18:6e:47:81 sdp:12:50                L/0      12/01/2011 02:05:03
-------------------------------------------------------------------------------
No. of Entries: 17
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
A:PE1#
```

<u>Fig 3.5.2 Forwarding Database Table of PE2:</u>

```
A:PE2# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId     MAC               Source-Identifier        Type     Last Change
                                                      Age
-------------------------------------------------------------------------------
30         00:07:eb:94:72:00 sdp:12:30                L/0      12/02/2011 03:03:38
30         00:07:eb:94:72:02 sdp:12:30                L/0      12/02/2011 03:03:37
30         00:07:eb:94:72:40 sap:1/2/4:30.*           L/0      12/02/2011 03:22:00
30         00:07:eb:94:72:42 sap:1/2/4:30.*           L/15     12/02/2011 03:21:58
30         00:08:21:96:f2:c0 sdp:12:30                L/300    12/02/2011 03:08:49
30         00:08:21:bf:4a:a0 sdp:12:30                L/120    12/02/2011 03:27:49
30         00:18:18:6e:47:81 sap:1/2/4:30.*           L/0      12/02/2011 03:21:57
50         00:07:eb:94:73:c0 sdp:12:50                L/0      12/02/2011 01:05:31
50         00:07:eb:94:73:c2 sdp:12:50                L/0      12/02/2011 01:05:31
50         00:07:eb:b0:66:80 sap:1/2/4:50.*           L/0      12/02/2011 03:22:05
50         00:07:eb:b0:66:82 sap:1/2/4:50.*           L/0      12/02/2011 03:21:57
50         00:08:21:96:f7:a0 sap:1/2/4:50.*           L/165    12/02/2011 09:45:20
50         00:08:21:9a:56:60 sdp:12:50                L/479    12/02/2011 01:06:05
50         00:08:21:bf:4b:20 sdp:12:50                L/270    12/02/2011 01:06:42
50         00:08:21:bf:83:40 sap:1/2/4:50.*           L/77     12/02/2011 09:52:08
50         00:18:18:6e:47:81 sap:1/2/4:50.*           L/0      12/02/2011 03:21:59
-------------------------------------------------------------------------------
No. of Entries: 16
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
A:PE2#
```

Chapter 4: Provider Backbone Bridging + VPLS

Overview:

IEEE 802.1ah Task Group Define PBB as a protocol:

"To allow scaling for provider networks to at least 2^24 service Virtual LANs, this standard further specifies the operation of Provider Backbone Bridges (PBBs) by means of an architecture and bridge protocols compatible and interoperable with Provider Bridged Network protocols and equipment, allowing interconnection of multiple Provider Bridged Networks."

In June, 2008 IEEE introduces a new protocol named as 802.1ah (MAC-in-MAC or PBB). IEEE 802.1ah solved the FDB scaling issue of 802.1ad (Q-in-Q) by adding a Backbone header which consists of B-source and B-Destination MAC addresses to customer Ethernet frame. In PBB network PE routers are responsible to forward customer traffic based on B-MAC addresses, which are certainly quite less than those of C-MAC addresses.

Table 4.1 # Ethernet Frame Formate:

Protocol	**EtherType**	**Frame Formate**	**Detail**
802.1Q	0x8100	D-MAC+ S-MAC+ Etype + C-ID+Etype + Payload	In this protocol traffic travel based on VLAN-ID. Service Provider's faces scalability issues because only 4094 VLANs can be used. Forwarding decision is based on Customer MAC addresses.
802.1ad Q-in-Q	0x8a88 (Depend on vendor choice)	D-MAC+ S-MAC+ Etype + S-ID + Etype+ C-ID + Etype + Payload	Using this protocol Service Provider inserts an S-ID, that encapsulated the C-ID, that solve the scalability problem of 802.1Q and theoretically 802.1ad can provide 16million total VLANs. Forwarding decision is based on Customer MAC addresses. This become problem because on one side there is no complete transparency between customer and provider and on other side Service Provider has to maintain complete Forwarding Database Table and the size could be 100,000s of entries.
802.1ah PBB	0x88e7	D-BMAC + S-BMAC + Etype + B-ID + Etype + I-Tag + D-MAC+ S-MAC+ Etype + S-ID + Etype+ C-ID + Etype + Payload	Using this protocol Service Provider can guarantee complete transparency and separation of customer and Provider forwarding decisions. Also number of FDB entries dramatically reduces because it encapsulate complete Ethernet frame of customer with backbone header.

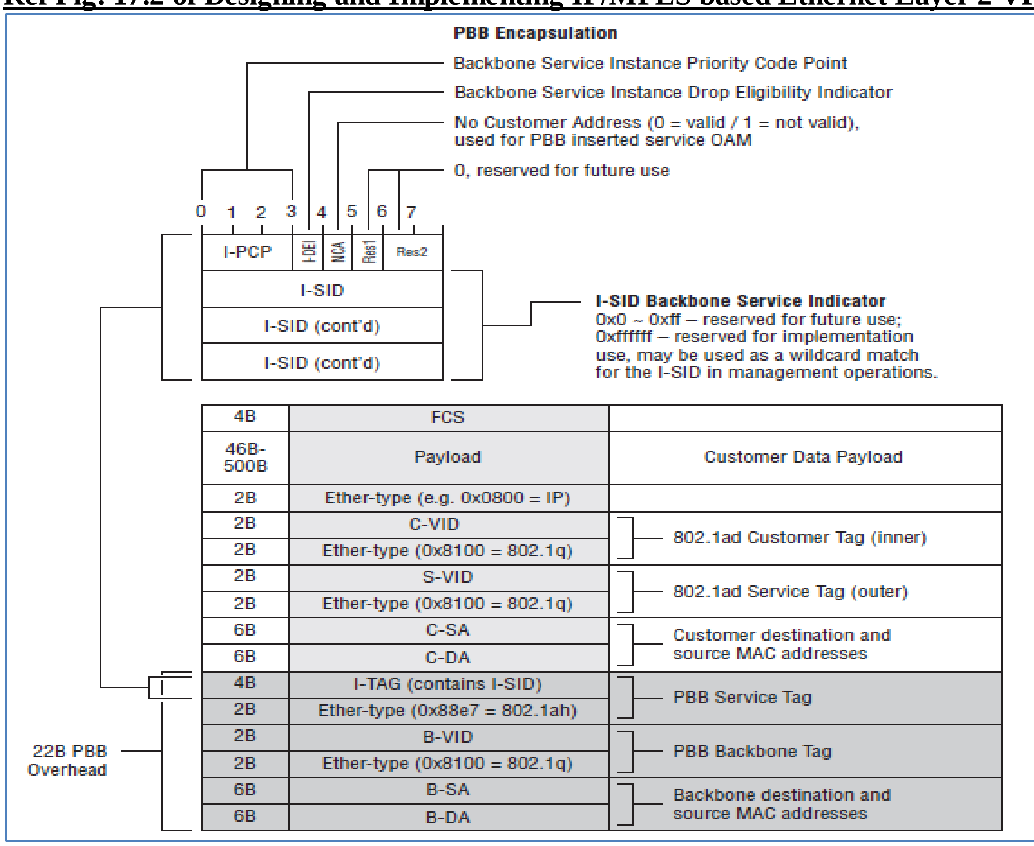
As describe in the above table: PE routers encapsulates the customer frames with B-Source address, B-Destination address, B-VID (optional), and Instance Tag(I-Tag) before it forward the traffic into core network, so forwarding are based on Provider MAC-addresses. This help to reduce the total entries (MAC-addresses) of FDB table on PE routers.

PBB Header detail:

PBB has 18 or 22 bytes of overhead and detail are below. Fig:

1. **B-Destination Address and B-Source Address:** B-DA and B-SA are the addresses of PE routers that perform learning and forwarding based on these address not based on customer MAC-address. Each of them is 6 bytes in size.
2. **B-VID**: A 2 bytes backbone VLAN-ID defines by Service Provider to define the broadcast domain.
3. **I-Tag:** A 4 byte tag and contain multiple fields:
   a. I-SID: define 2^24 backbone service instances and perform function similar to VC-LABEL (multiplex and de-multiplex traffic) in VPLS.
   b. I-PCP (Backbone Service Instance Priority Code point): 4 bit field define the priority.
   c. I-DEI: 1 bit field that define Backbone Service Instance Drop Eligibility Indicator
   d. NCA (No customer address): 1 Bit field used in PBB OAM. If valid then set to 0 and if not valid then set to 1.

<u>Fig 4.2.1: Illustrates the PBB header:</u>
<u>Ref Fig: 17.2 of Designing and Implementing IP/MPLS based Ethernet Layer 2 VPN</u>



PBB + VPLS Architecture:

This protocol consists of two components:

1. Backbone Component (B-Component): that operates in the backbone domain (B-domain or PE routers). The B-Component learns and forward PBB encapsulated frames through PBB network. B-domain contains PE routers. These routers are not responsible to encapsulate customer traffic. They only responsible to forward information that is specific to core network (backbone) using VPLS encapsulation method. These routers configure with B-VPLS (Backbone-VPLS) service instances and that B-VPLS is connected with other PE routers of B-domain through pseudowires and with the uPE devices through Spoke pseudowires.

2. Customer Component (I-Component): that operates in the Customer edge devices of Provider (uPE device). These components connected with customer sites and with the PE devices (nPE).
   I-component also responsible to add PBB header to the traffic coming from customer. In these devices we configure I-VPLS service instances that are connected with B-VPLS instance of PE routers.

I-VPLS Detail:

In PBB network topology I-VPLS is responsible to connect with the B-VPLS service instance in the B-domain and with the customer sites through SAP. . Here the learning and forwarding are based on C-MAC addresses. We can configure I-VPLS and B-VPLS in the same router or on different routers e.g uPE and nPE routers (Testing based on uPE and nPE routers). MTU size of I-VPLS is 1518 bytes. I-VPLS consists of three types of bridge ports and also have its own FDB table. The three bridge ports can be:

a) A link that is internally established connectivity with the B-VPLS. Here I-VPLS is responsible to encapsulate customer traffic with PBB header and send to B-VPLS and also de-encapsulate the receiving traffic from B-VPLS direction.
b) The SAP connected with customer site.
c) A spoke pesudowire that can connect with other VPLS site. Also if I-VPLS configured on uPE device then Spoke pseudowire connect with B-VPLS of the PE router.

B-VPLS Detail:

In PBB network topology B-VPLS service instance is responsible to connect with other PE routers in the B-domain and with I-VPLS service instance. Here the learning and forwarding are based on B-MAC addresses. Similar to I-VPLS service instance B-VPLS may have three types of bridge ports and Forwarding Database Table.

a) A link that is internally established connectivity with the I-VPLS. That link is responsible to send and receive traffic from and to the I-VPLS service instance. One B-VPLS can be connected with multiple I-VPLS service instance. PBB header contains I-SID tag, and B-VPLS uses this I-SID tag to differentiate traffic of different customers.
b) The SAP connected with customer site.
c) A spoke or mesh pesudowire that connect with other nPE router and carry PBB encapsulated traffic.

Since the PBB-encapsulated traffic include PBB header that is 18 bytes or 22 bytes (if B-VID present in the PBB header) more than the actual, so MTU size of B-VPLS should be 18bytes or 22 bytes greater than I-VPLS service.

Example: if MTU size of I-VPLS is 1518 bytes than the minimum MTU size of B-VPLS should be 1536, so that it can accommodate the I-VPLS traffic.

Frame Forwarding mechanism of B-VPLS and I-VPLS

To understand the frame forwarding mechanism we should understand the ingress and egress points of the devices means from where the frame is coming (ingress port) and to where is it is going (egress port). Forwarding are based on MAC addresses of the frame in B-VPLS and I-VPLS. But different MAC addresses in both the components, detail in the next section1.1.

1. B-VPLS always received PBB encapsulated frame from I-VPLS or through one of its SAP port. Here MAC addresses of the frames are always B-SA and B-DA address. It forward the frames to the core using these B-MAC addresses and using VPLS encapsulation method.
2. I-VPLS received frames either from SAP, VPLS encapsulated frames through pseudowire or through PBB encapsulated from B-domain.
3. I-VPLS build a FDB table in which it maintains C-MAC addresses and B-MAC addresses. Using this FDB it implements encapsulation, de-encapsulation and forwarding.

Detail steps of I-VPLS forwarding:

2. As discuss above, I-VPLS receive ingress traffic from I-VPLS SAP or through pseudowire and learn Customer Source address from ingress direction.
3. Process of Forwarding:
    a. If the C-DA (Customer Destination Address) is already in the FDB and it is for some local I-VPLS, than I-VPLS forward the frame to that I-VPLS through pseudowire or SAP.
    b. If the C-DA is in FDB and the destination is for far-end device and the B-DA is also known, then I-VPLS perform PBB encapsulation and forward frame to B-VPLS.This is logical that if I-VPLS have far-end MAC address of customer device this means that it also know B-MAC addresses.
    c. If the C-DA is not known, then I-VPLS perform PBB encapsulation and forward/flood frame to all I-VPLS instances and B-VPLS instances.

Detail steps of B-VPLS forwarding:

1. B-VPLS can receive traffic from I-VPLS or from far-end B-VPLS through SDPs.
2. Process of Forwarding:
    a. If the B-DA is known, it performs VPLS encapsulation and forwards it to remote PE router. After receiving the PBB+VPLS traffic, first remote PE router de-encapsulates the VPLS encapsulation using VC-LABLE and then forwards it to I-VPLS using I-SID in the PBB header.
    b. If the B-DA is not known, the B-VPLS flood it to backbone network using SDP that connect nPE routers. But with the consideration of Split Horizon rule.

PBB Configuration Examples:

To build PBB topology we need following configuration steps:

Step # 1: First we need to build connectivity between two nPE routers:

a. Configure SDP between nPE routers. E.g SDP 12 connect between PE1 and PE2. e.g: PE1 configure PE2 system IP and PE2 configure PE1 system IP. SDP ID and Path MTU should be same on both the PE's .

Fig 4.7.1: Illustrate the SDP configuration b/w PE devices:

```
*A:PE1>config>service# sdp 12
*A:PE1>config>service>sdp# info
            sdp 12 mpls create
            description "SDP Connect to Far_END PE router"
            far-end 10.2.2.2
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
```

```
*A:PE2>config>service# sdp 12
*A:PE2>config>service>sdp# info
        sdp 12 mpls create
            description "SDP Connect to Far_END PE router"
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
```

b. Configure SDP between nPE and uPE routers: e.g SDP 11 connect between uPE1 and PE1, same will done with uPE2 and PE2.

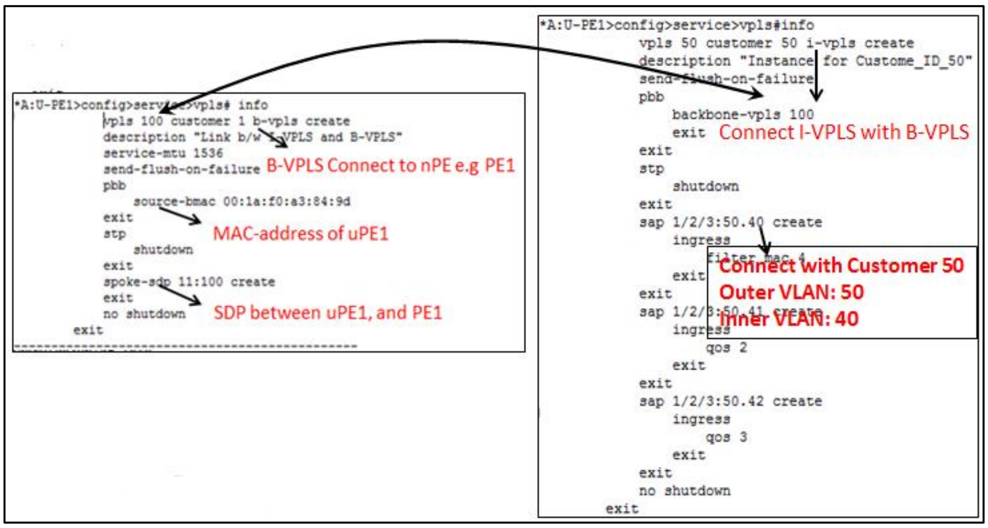
Fig 4.7.2: Illustrate the SDP configuration between uPE and PE devices:

```
*A:U-PE1>config>service# sdp 11
*A:U-PE1>config>service>sdp# info
----------------------------------------------
            description "connect to nPE router"
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
----------------------------------------------
```

```
*A:PE1>config>service# sdp 11
*A:PE1>config>service>sdp# info
            sdp 11 mpls create
            description "SDP Connect to uPE router"
            far-end 10.10.10.1
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
```

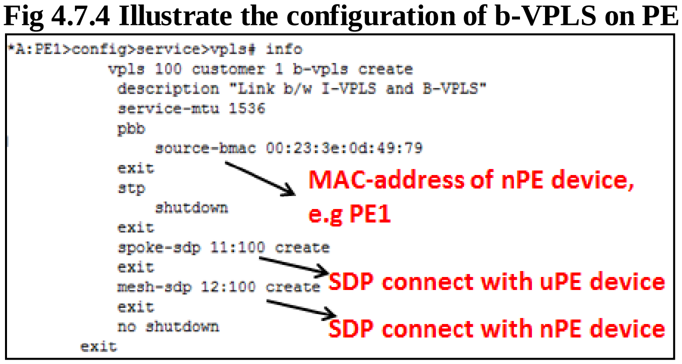
c. Configure B-Component (b-VPLS) and I-Component (i-VPLS) on uPE device: e.g I-VPLS: 50 facing customer side and also with B-VPLS and B-VPLS connect with uPE device. This allows I-Component to forward traffic to B-component and encapsulate traffic accordingly. . In I-VPLS we manually configure a B-MAC-address using command source-bmac aa:aa:aa:aa:aa:aa. And this should be unique in the network. When it receive traffic from other B-component (nPE) it learn the B-MAC address and update its Forwarding Database Table.

Fig 4.7.3 Illustrates configuration of i-vpls and its connectivity with B-vpls on uPE device:



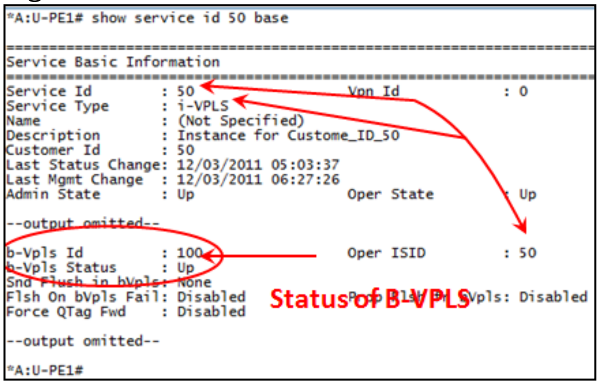
d. Configure B-Component on nPE device . MTU size should be 1536 bytes. In B-VPLS we manually configure a B-MAC-address using command sourc-bmac aa:aa:aa:aa:aa:aa. And this should be unique in the network. When it receive traffic from other B-component (nPE) it learn the B-MAC address and update its Forwarding Database Table.

Fig 4.7.4 Illustrate the configuration of b-VPLS on PE device:



Note 1: Each I-VPLS has its own I-SID and that value is used in multiplexing and de-multiplexing. By default I-SID is the same as the ID of I-VPLS service instance. In the below fig 4.7.5.

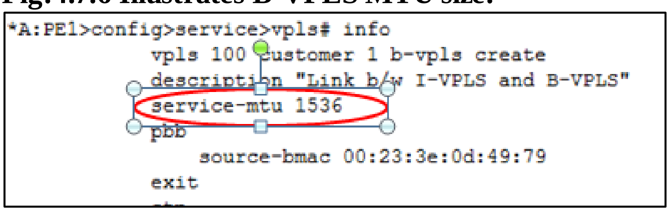
Fig 4.7.5: Illustrate the Status of I-VPLS and I-SID value:



Note 2: I-VPLS service ID range is <1 – 2,147,483,647> and I-SID range is <0-16,777,215>, so when I-VPLS ID is greater than I-SID than we have to configure I-SID manually.

Note 3: One thing that should be consider in configuration of B-VPLS is that, its MTU should be set to 1536 bytes or should be at least 18 bytes or 22 bytes if B-VID is used. In fig:4.7.6

Fig:4.7.6 Illustrates B-VPLS MTU size:



Encapsulation Process of PBB:

Whenever I-component (I-VPLS) receive a traffic to reach far-end I-component, it check its Forwarding Database table and try to find the correct B-MAC address. If there is no B-MAC address it forward using multicast address.

In PBB, encapsulation is performed in two steps. First I-VPLS encapsulates received traffic with PBB header and on next step B-VPLS perform VPLS encapsulation on PBB frame and then forward it to core network.

a. I-VPLS insert B-MAC address (e.g Source and Destionation address of the backbone) by consulting FDB table.
b. It then inserts an I-TAG. It contain I-SID which is by default is same as I-VPLS service instance. This I-SID is used to de-multiplex the receiving traffic from B-VPLS.
c. Optional : insert the B-VID.
d. When the far-end B-VPLS received a PBB encapsulated traffic through pseudowire it stripped off VPLS encapsulation using VC-LABEL and compare the B-DA and B-SA address. If the B-DA is same as its own address it finalize that traffic is for some I-VPLS customer, otherwise it drop that packet. It then check I-SID of the received PBB encapsulated traffic and compare it with I-VPLS ID and if matches, forward traffic to that SAP according to FDB table.

Packet walk through of 802.1ah.

Testing Topology: In this topology we have two customers (customer_1 and Customer_2) both have two LANS (41 and 42). Customer_1 and Customer_2 both have two offices located on different location. Customers connect to Service Provider through trunk ports (C-3500 switch and allows all VLANs). Service Provider connects to Customers through Q-Tunnel ports on C3750 switch. Allocate VLAN 50 to Customer 1 and VLAN 30 to Customer 2. C-3750 is connect to uPE device (ALU 7710) through Q-in-Q service port.

uPE and PEs make connectivity through spoke pseudowires and PEs make connectivity through mesh-pseudowires. One PE connect with other PE through P device. In IP core routing is done through OSPF. MPLS is enabled on PE, P and uPE devices and LDP is used as a signaling method.

Fig 4.9.1: 802.1ah Topology diagram:

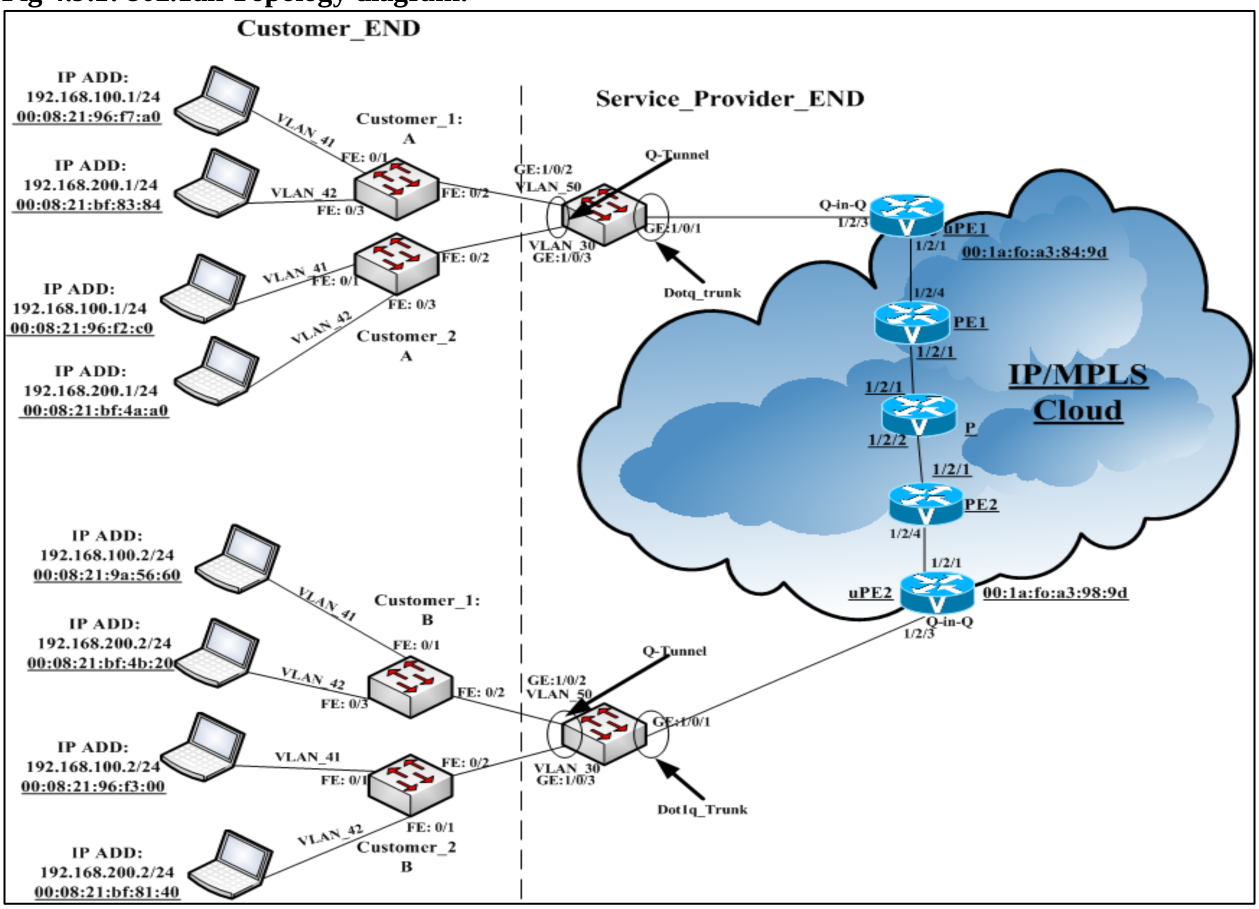


Table 4.9.2 : Ports and their Types:

Positions	EtherType	Ports	Port Type	Tag Type	Description
Devices are connect to these ports	0x800	0/1, 0/3	Access port	Tagged	IP= 0x8100
Customer to Service provider	0x8100	0/2	Trunk Port: 802.1Q	Tagged	802.1q
Service Provider connect to customer	0x8100	3700: Q-Tunnel port: 1/0/2, 10/3.	Tunnel Port: 802.1Q	Tagged	802.1q
S3750 connect to uPE.	0x8100	Trunk Port: 1/0/1	Trunk Port: 802.1Q	Tagged	802.1q
uPE connect to S37500	0x88a8	Q-in-Q port 1/2/3	Q-in-Q	Tagged	802.1ad
Service Provider connectivity	0x88e7	PE: 1/2/1, 1/2/4 uPE: 1/2/1, 1/2/3	802.1ah	PBB tagged	802.1ah

Table 4.9.2 : IP addressing scheme of customers MAC address, C-VLAN, S-VLAN:

Customer	Device IP	Device Mac-address	C-VLAN	S-VLAN
1	192.168.100.1	00:08:21:9a:f7:a0	41	50
1	192.168.100.2	00:02:21:96: 56:60	41	50
1	192.168.200.1	00:08:21:bf:4b:20	42	50
1	192.168.200.2	00:08:21:bf:83:40	42	50
2	192.168.100.1	00:08:21:96:f2:c0	41	30
2	192.168.100.2	00:02:21:96:f3:00	41	30
2	192.168.200.1	00:08:21:bf:4a:a0	42	30
2	192.168.200.2	00:08:21:bf:81:40	42	30

a) Send ping request from Customer_1 VLAN 41
b) Send ping request from Customer_2 VLAN 41

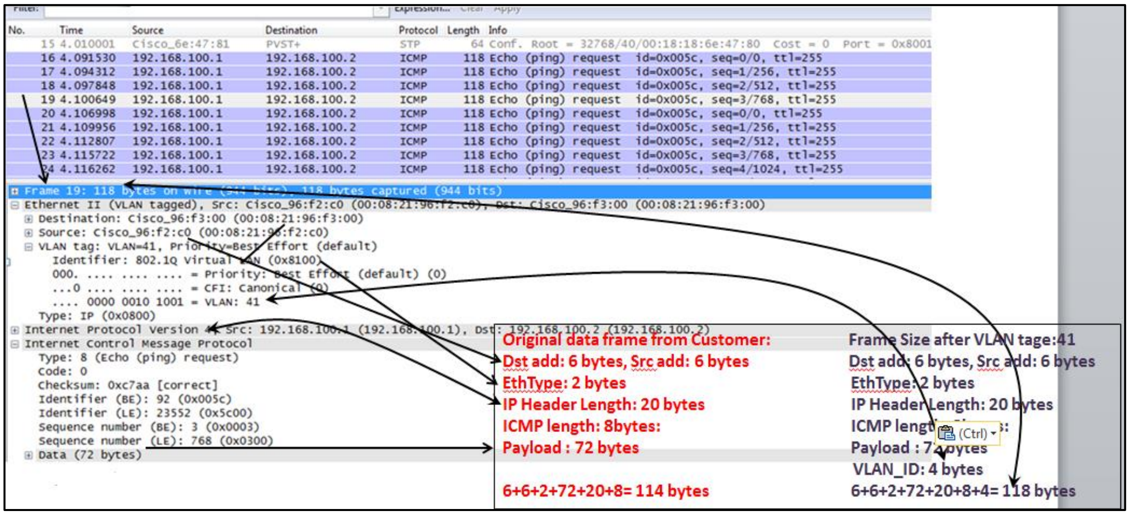
Step #1: Trace Result on uPE1 ingress port 1/2/3:

Customer_2 send a ping request from:

IP: 192.168.100.1 -- 192.168.100.2

<**source address: 00:08:21:96:f2:c0** > --------------< **Dst address: 00:08:21:96:f3:00**>

Fig 4.9.3: ping request from Customer_2: 192.168.100.1 that belong to VLAN_ID :41

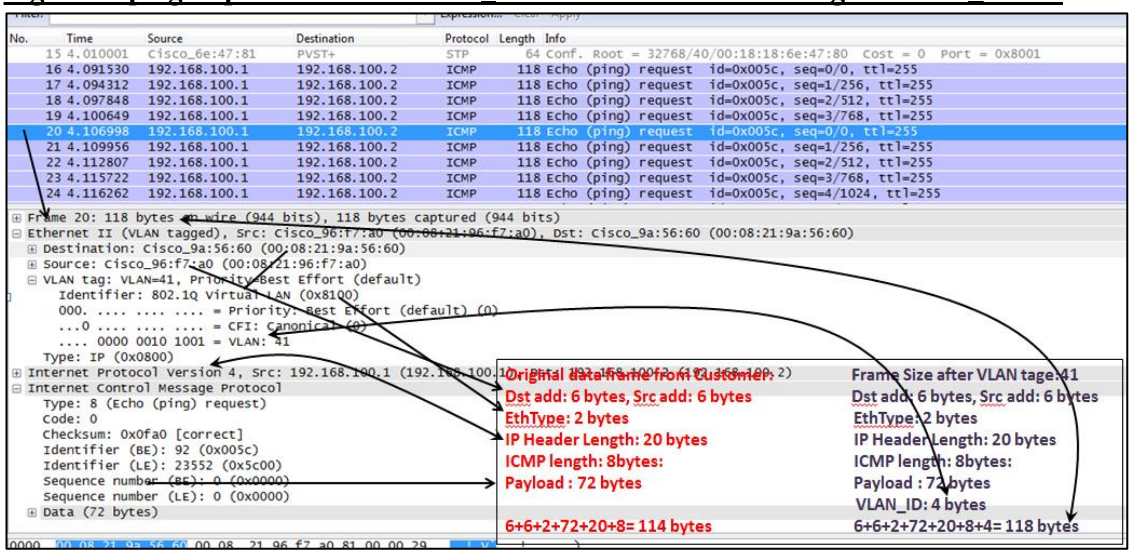


At the same time Customer_1 send a ping request from:

IP: 192.168.100.1 -- 192.168.100.2

<source address: 00:08:21:96:f7:a0 > --------------**< Dst address: 00:08:21:9a:56:60** >

Fig 4.9.4: ping request from Customer_1: 192.168.100.1 that belong to VLAN_ID :41



Step #2: Trace Result on uPE1 egress port 1/2/1:

When uPE received the traffic from ingress port 1/2/3, it encapsulate the PBB header, that include B-SA, B-DA,I-TAG (I-SID). Also add VC-LABLE and Transport label to make communication between uPE and nPE device. It then sends the traffic through egress 1/2/1 port to nPE router. Fig: 4.9.5

Note:Wireshark only able to grasp these fields and not showing all the fields.

Fig 4.9.5: ping request from Customer_1: 192.168.100.1 that belong to VLAN_ID:41.

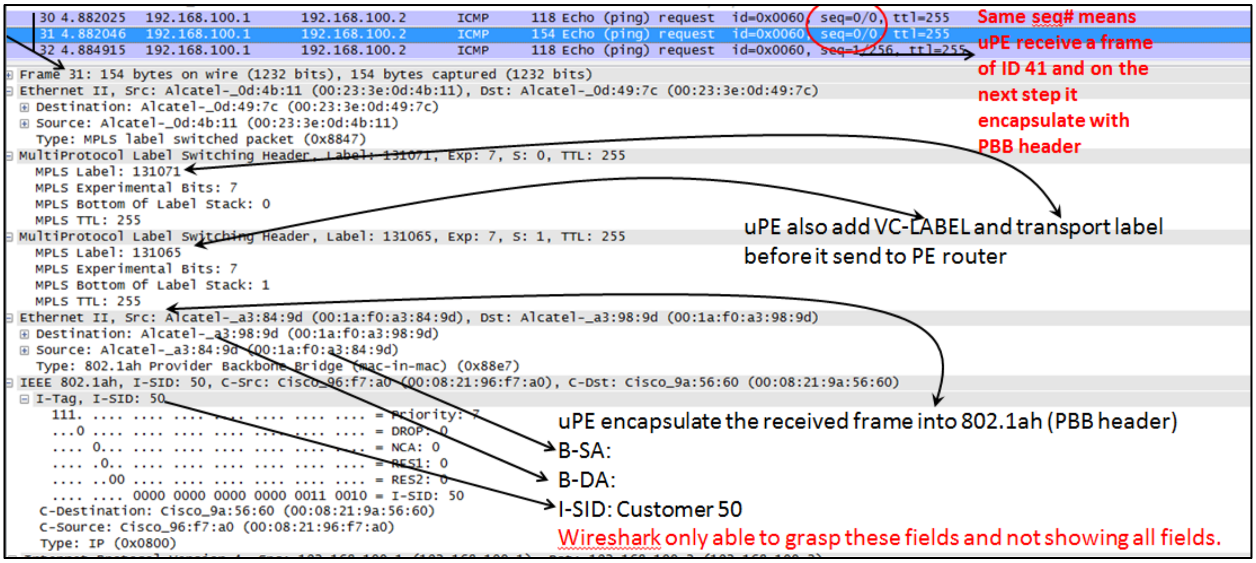


Fig 4.9.6: ping request from Customer_2: 192.168.100.1 that belong to VLAN_ID :41.

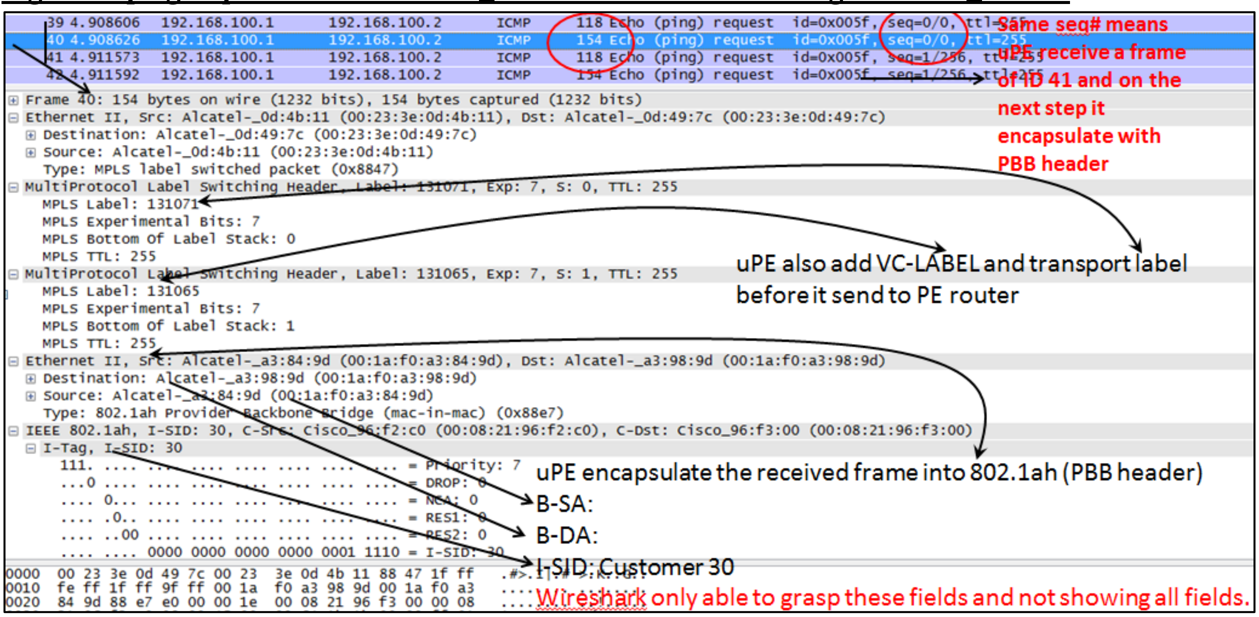


Fig 4.9.7: Forwarding Database table of uPE1:

```
*A:U-PE1# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
30        00:08:21:96:f2:c0 sap:1/2/3:30.41          L/0    12/03/2011 14:05:49
30        00:08:21:96:f3:00 b-sdp:11:100             L/0    12/03/2011 06:22:26
30        00:08:21:bf:4a:a0 sap:1/2/3:30.42          L/0    12/03/2011 14:05:18
30        00:08:21:bf:81:40 b-sdp:11:100             L/0    12/03/2011 06:22:50
30        00:18:18:6e:47:81 sap:1/2/3:30.*           L/0    12/03/2011 05:52:48
50        00:07:eb:94:73:c2 b-sdp:11:100             L/0    12/03/2011 06:12:05
50        00:08:21:96:f7:a0 sap:1/2/3:50.41          L/15   12/03/2011 14:06:03
50        00:08:21:9a:56:60 b-sdp:11:100             L/15   12/03/2011 05:52:30
50        00:08:21:bf:4b:20 b-sdp:11:100             L/15   12/03/2011 05:57:22
50        00:08:21:bf:83:40 sap:1/2/3:50.42          L/15   12/03/2011 14:00:13
100       00:1a:f0:a3:98:9d sdp:11:100               L/0    12/03/2011 05:51:44
-------------------------------------------------------------------------------
No. of Entries: 11
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:U-PE1#
```

Fig 4.9.8: Forwarding Database table of uPE2:

```
UP*A:U-PE2# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
30        00:08:21:96:f2:c0 b-sdp:11:100             L/0    11/09/2011 09:52:33
30        00:08:21:96:f3:00 sap:1/2/3:30.41          L/0    11/09/2011 17:39:48
30        00:08:21:bf:4a:a0 b-sdp:11:100             L/0    11/09/2011 09:43:05
30        00:08:21:bf:81:40 sap:1/2/3:30.42          L/0    11/09/2011 17:36:45
30        00:18:18:6e:47:81 b-sdp:11:100             L/0    11/09/2011 09:26:48
50        00:07:eb:94:73:c2 sap:1/2/3:50.41          L/0    11/09/2011 17:41:10
50        00:08:21:96:f7:a0 b-sdp:11:100             L/15   11/09/2011 09:29:04
50        00:08:21:9a:56:60 sap:1/2/3:50.41          L/15   11/09/2011 17:38:44
50        00:08:21:bf:4b:20 sap:1/2/3:50.42          L/0    11/09/2011 17:33:23
50        00:08:21:bf:83:40 b-sdp:11:100             L/0    11/09/2011 09:29:42
100       00:1a:f0:a3:84:9d sdp:11:100               L/0    11/09/2011 09:26:48
-------------------------------------------------------------------------------
No. of Entries: 11
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:U-PE2#
```

Step #3: Trace Result on PE1 1/2/4 egress direction:

When the B-VPLS on PE1 received the frame, it matches its FDB table and find a **B-SA <00:1a:f0:a3:84:9d** >and **B-DA < 00:1a:f0:a3:98:9d>**. It then forwards the frame to PE2.

Fig 4.9.9: PE1 Forwarding Database table:

```
*A:PE1# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
100       00:1a:f0:a3:84:9d sdp:11:100               L/0    12/02/2011 05:52:32
100       00:1a:f0:a3:98:9d sdp:12:100               L/0    12/02/2011 05:51:28
-------------------------------------------------------------------------------
No. of Entries: 2
-------------------------------------------------------------------------------
```

Fig 4.9.10: PE2 Forwarding Database Table.

```
*A:PE2# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type     Last Change
                                                      Age
-------------------------------------------------------------------------------
100       00:1a:f0:a3:84:9d sdp:12:100               L/0      12/03/2011 04:52:56
100       00:1a:f0:a3:98:9d sdp:11:100               L/0      12/03/2011 04:51:52
-------------------------------------------------------------------------------
No. of Entries: 2
-------------------------------------------------------------------------------
```

Fig4.9.11a: Trace Result on PE 1/2/4 egress direction: In frame PE received a frame from uPE.

```
19 2.157137   192.168.100.1    192.168.100.2    ICMP    154 Echo (ping) request  id=0x007a, seq=0/0, ttl=255
20 2.157152   192.168.100.1    192.168.100.2    ICMP    154 Echo (ping) request  id=0x007a, seq=0/0, ttl=255
21 2.158417   192.168.100.2    192.168.100.1    ICMP    154 Echo (ping) reply    id=0x007a, seq=0/0, ttl=255
Frame 19: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits)
Ethernet II, Src: Alcatel-_0d:4b:11 (00:23:3e:0d:4b:11), Dst: Alcatel-_0d:49:7c (00:23:3e:0d:49:7c)
  Destination: Alcatel-_0d:49:7c (00:23:3e:0d:49:7c)
  Source: Alcatel-_0d:4b:11 (00:23:3e:0d:4b:11)
  Type: MPLS label switched packet (0x8847)
MultiProtocol Label Switching Header, Label: 131071, Exp: 7, S: 0, TTL: 255
  MPLS Label: 131071
  MPLS Experimental Bits: 7                       VPLS encapsulation: VC-LABEL
  MPLS Bottom Of Label Stack: 0
  MPLS TTL: 255
MultiProtocol Label Switching Header, Label: 131065, Exp: 7, S: 1, TTL: 255
  MPLS Label: 131065
  MPLS Experimental Bits: 7                       VPLS encapsulation: VC-LABEL
  MPLS Bottom Of Label Stack: 1
  MPLS TTL: 255
Ethernet II, Src: Alcatel-_a3:84:9d (00:1a:f0:a3:84:9d), Dst: Alcatel-_a3:98:9d (00:1a:f0:a3:98:9d)
  Destination: Alcatel-_a3:98:9d (00:1a:f0:a3:98:9d)
  Source: Alcatel-_a3:84:9d (00:1a:f0:a3:84:9d)
  Type: 802.1ah Provider Backbone Bridge (mac-in-mac) (0x88e7)
IEEE 802.1ah, I-SID: 50, C-Src: Cisco_96:f7:a0 (00:08:21:96:f7:a0), C-Dst: Cisco_9a:56:60 (00:08:21:9a:56:60)
  I-Tag, I-SID: 50
    111. .... .... .... .... .... .... .... = Priority: 7
    ...0 .... .... .... .... .... .... .... = DROP: 0
    .... 0... .... .... .... .... .... .... = NCA: 0
    .... .0.. .... .... .... .... .... .... = RES1: 0
    .... ..00 .... .... .... .... .... .... = RES2: 0
    .... .... 0000 0000 0000 0000 0011 0010 = I-SID: 50
```

Fig 4.9.11b: Trace Result on PE 1/2/4 egress direction: In frame 20 PE received a frame from uPE and perform VPLS encapsulation and de-encapsulation:

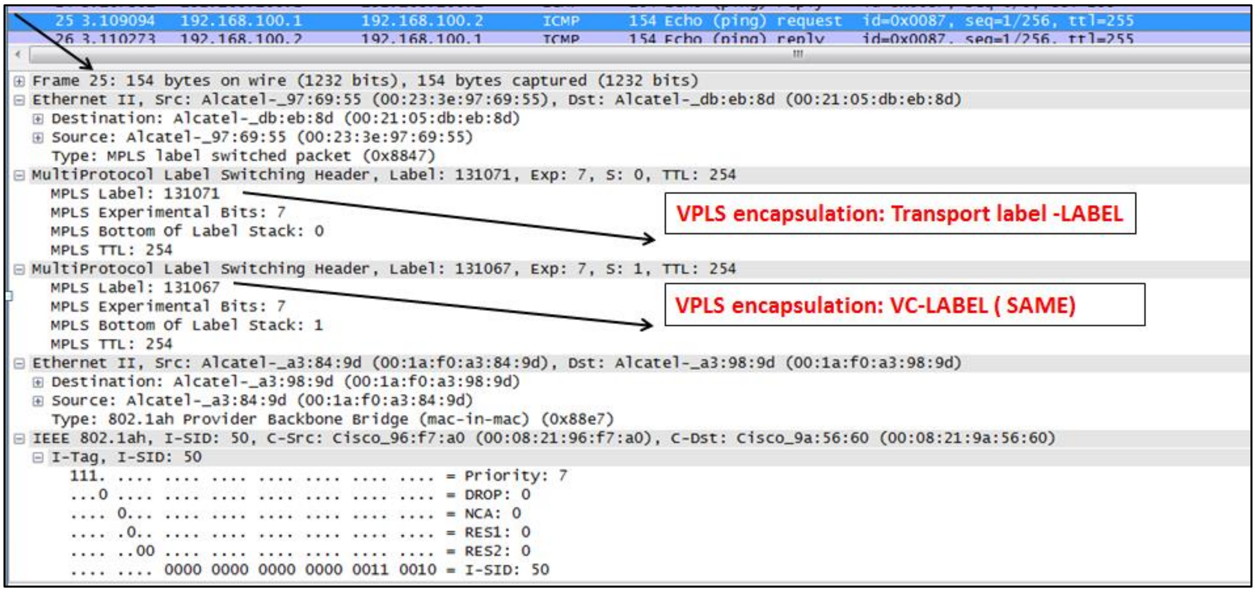
```
20 2.157152   192.168.100.1    192.168.100.2    ICMP    154 Echo (ping) request  id=0x007a, seq=0/0, ttl=25
21 2.158417   192.168.100.2    192.168.100.1    ICMP    154 Echo (ping) reply    id=0x007a, seq=0/0, ttl=25
Frame 20: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits)
Ethernet II, Src: Alcatel-_0d:49:79 (00:23:3e:0d:49:79), Dst: Alcatel-_97:69:54 (00:23:3e:97:69:54)
  Destination: Alcatel-_97:69:54 (00:23:3e:97:69:54)
  Source: Alcatel-_0d:49:79 (00:23:3e:0d:49:79)
  Type: MPLS label switched packet (0x8847)
MultiProtocol Label Switching Header, Label: 131070, Exp: 7, S: 0, TTL: 255
  MPLS Label: 131070
  MPLS Experimental Bits: 7                       VPLS encapsulation: Trasport-LABEL
  MPLS Bottom Of Label Stack: 0
  MPLS TTL: 255
MultiProtocol Label Switching Header, Label: 131067, Exp: 7, S: 1, TTL: 254
  MPLS Label: 131067
  MPLS Experimental Bits: 7                       VPLS encapsulation: VC-LABEL
  MPLS Bottom Of Label Stack: 1
  MPLS TTL: 254
Ethernet II, Src: Alcatel-_a3:84:9d (00:1a:f0:a3:84:9d), Dst: Alcatel-_a3:98:9d (00:1a:f0:a3:98:9d)
  Destination: Alcatel-_a3:98:9d (00:1a:f0:a3:98:9d)
  Source: Alcatel-_a3:84:9d (00:1a:f0:a3:84:9d)
  Type: 802.1ah Provider Backbone Bridge (mac-in-mac) (0x88e7)
IEEE 802.1ah, I-SID: 50, C-Src: Cisco_96:f7:a0 (00:08:21:96:f7:a0), C-Dst: Cisco_9a:56:60 (00:08:21:9a:56:60)
  I-Tag, I-SID: 50
    111. .... .... .... .... .... .... .... = Priority: 7
    ...0 .... .... .... .... .... .... .... = DROP: 0
    .... 0... .... .... .... .... .... .... = NCA: 0
    .... .0.. .... .... .... .... .... .... = RES1: 0
    .... ..00 .... .... .... .... .... .... = RES2: 0
    .... .... 0000 0000 0000 0000 0011 0010 = I-SID: 50
```

Step #4: Trace Result on PE2 1/2/1 egress direction:

When the B-VPLS on PE2 received the frame, it matches its FDB table and find a **B-SA <00:1a:f0:a3:84:9d >**and **B-DA < 00:1a:f0:a3:98:9d>**. It then forwards the frame to uPE2, because in the FDB table it find the B-DA address. But before forwarding traffic it also performs VPLS encapsulation. Fig:4.9.12

Also check that in the above fig 4.9.11a/b VC-LABEL is <131067> and it remains same when frame received on PE2 but transport label is different know.

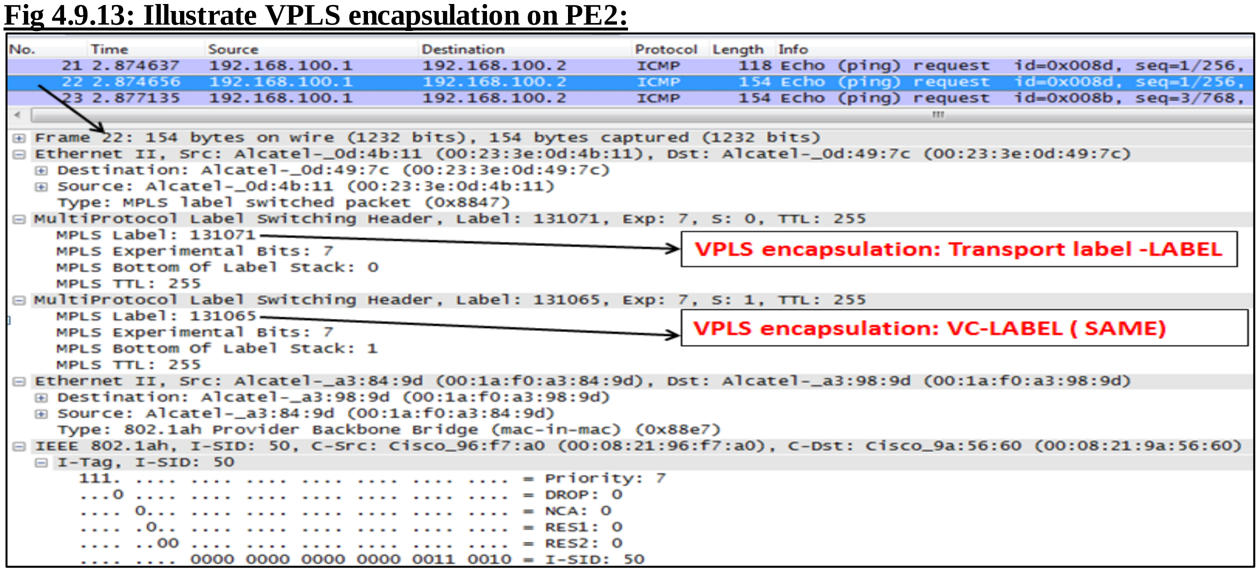
Fig 4.9.12: Illustrate VPLS encapsulation on PE2:



Step #5: Trace Result on uPE2 - 1/2/1 ingress direction:

When the uPE2 received the frame from PE2 , it received the PBB encapsulated frame with VPLS encapsulation.

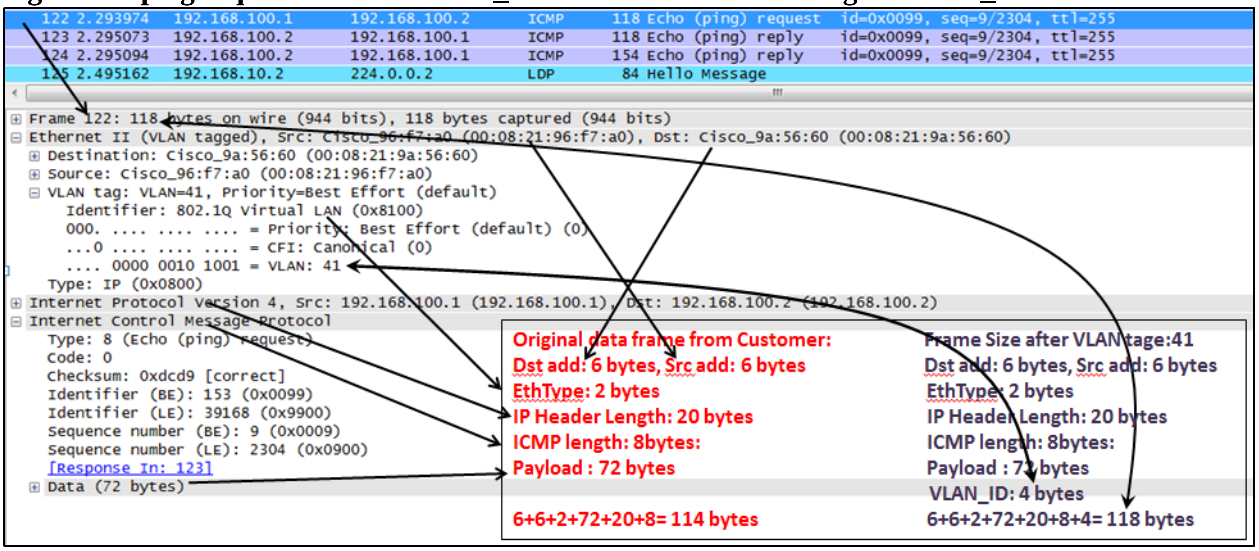
Fig 4.9.13: Illustrate VPLS encapsulation on PE2:



Step #5: Trace Result on uPE2 - 1/2/3 egress direction:

When the uPE2 received the frame from port uPE2: port 1/2/1 , it received the PBB encapsulated frame with VPLS encapsulation. Here it remove the PBB header and VPLS encapsulation. And forward it to Customer_1.

Fig 4.9.14: ping request from Customer_2: 192.168.100.1 that belong to VLAN_ID :41



Chapter 5 Quality of Service in PBB network:

Overview:

In the PBB network Providers can provide better QoS and filtering policies based on the contract with the customer. Either customer wants a bandwidth for high priority or mixture of high and low priority. If there is a high broadcast traffic coming from some particular client or from a specific VLAN than Provider can filter based on VLAN or mac-address.

As we learned in above chapters that Ethernet is the most deployed technology in LAN/MAN environment. With help of PBB+VPLS provider can carry voice, video and data services into one network infrastructure but it is also necessary to provide different level of QoS per VLAN or per service to the customer.

In this project we implement QoS policy as follows:

1. Customer_1 want high bandwidth (voice: priority level 5) for the entire network.
2. Customre_2 want High bandwidth for VLAN 41(voice: priority level 5) and low bandwidth for VLAN 42 (for FTP/TFTP: priority level 2).
3. Also Service Provider implement MAC based and VLAN based filtering so that only the allowed VLAN or device can transfer traffic through the provider network.

To implement above requirement, we have to understand the I-Tag field of PBB header Fig: 5.1.1.Because when the customer sends its Ethernet frame, service provider encapsulates the whole Ethernet frame with PBB header and I-Tag field is used to guarantee end-to-end QoS within service provider network.

The scenario work like this:

1. CE send a tagged Ethernet frame to uPE device, with or without setting 3 bit priority field of 802.1p and the values could be 0-7 (0 is the lowest and 7 is the highest).
2. uPE encapsulate the ingress Ethernet frame with PBB header and set the priority of field of I-TAG and send to PE device.
3. Upon receiving the PBB encapsulated frame, Far-end PE device send the frame to far-end uPE device.
4. uPE device de-capsulate the PBB header.
5. uPE device send the original frame to CE device.

So to analyze the above scenario, we notice that to implement QoS in PBB network, we have to apply QoS policies on the ingress point of uPE device.

Fig 5.1.1 : Illustrate Priority Code Point field

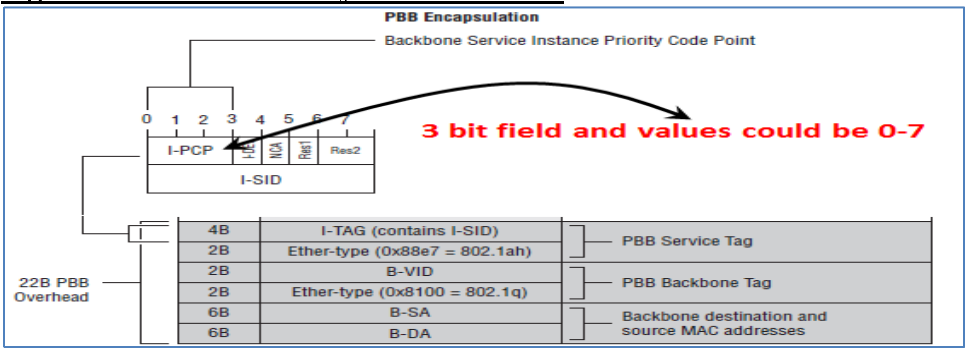


Fig 5.1.2: The 3 bit field of I-PCP indicate the QoS desired for the frame.

Marking		Traffic Type
Decimal	Binary	
7	111	Network control: for packets that must support network infrastructure and must be deliver as quickly as possible (OSPF, PIM, BGP, SNMP, etc.)
6	110	Internetwork Control
5	101	Real-time (IP Voice, 10ms latency)
4	100	Video < 100 ms Latency,
3	011	Critical Applications (Database)
2	010	Excellent Effort (FTP/TFTP)
1	001	Background (Traffic used by cutomer for backup application)
0	000	Best-effort (default)

Configuration:

To fulfill requirement of customer_1 we need to configure QoS on the ingress direction of port 1/2/3 of uPE devices. Service Provider assign VLAN 50 to Customer_1 and customer_1 is sending traffic from VLAN 41 and VLAN 42. Customer_1 want highest priority level of 5 for both the VLAN 41 and 42. Also service provider discard traffic from VLAN 40.

We configure a QoS for ingress traffic and using the mac-criteria we match Ethernet frame type II and also matching the dot1p priority from 0 to 7 and set the priority level to 5 (ef).
To discard/drop traffic we need to configure a filter policy. For this we created mac-filter that matches the Ethernet frame of type II have priority level from 0-7 and set the action to drop.
After configuration of QoS and filter policies we need to assign these policies to the ingress ports of uPE.

Fig 5.2.1: Illustrate the Qos/filter policies for Customer_1

```
vpls 50 customer 50 i-vpls create
    description "Instance for Custome_ID_50"
    send-flush-on-failure
    stp
        shutdown
    exit
    sap 1/2/3:50.40 create
        ingress
            filter mac 4
        exit
    exit
    sap 1/2/3:50.41 create
        ingress
            qos 2
        exit
    exit
    sap 1/2/3:50.42 create
        ingress
            qos 2
        exit
    exit
    no shutdown
```

```
filter
    mac-filter 4 create
        default-action forward
        entry 1 create
            match frame-type ethernet_II
                dot1p 0 7
            exit
            action drop
        exit
    exit
exit
```

```
qos
        sap-ingress 2 create
            description "For Highest priority"
            queue 1 create
            exit
            mac-creteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "ef" priority high
                exit
            exit
        exit
```

To fulfill requirement of customer_2 we need to configure QoS on the ingress direction of port 1/2/3 of uPE devices. Service Provider assign VLAN 30 to Customer_2 and customer_2 is sending traffic from VLAN 41 and VLAN 42. Customer_2 want highest priority level of 5 for VLAN 41 and low priority level for 42. Also service provider discards traffic from VLAN 40.

For high priority traffic we configure a QoS for ingress traffic and using the mac-criteria we match Ethernet frame type II and also matching the dot1p priority from 0 to 7 and set the priority level to 5 (ef).
For low priority traffic we configure a QoS for ingress traffic and using the mac-criteria we match Ethernet frame type II and also matching the dot1p priority from 0 to 7 and set the priority level to 2 (af).

To discard/drop traffic we need to configure a filter policy. For this we created mac-filter that matches the Ethernet frame of type II have priority level from 0-7 and set the action to drop. After configuration of QoS and filter policies we need to assign these policies to the ingress ports of uPE.

Fig 5.2.2: Illustrate the QoS and Filter policeis for Customer_2:

```
vpls 30 customer 30 i-vpls create
            description "Instance for Customer_ID_30"
            sap 1/2/3:30.40 create
            exit
            sap 1/2/3:30.41 create
                ingress
                    qos 2
                exit
            exit
            sap 1/2/3:30.42 create
                ingress
                    qos 3
                exit
            exit
            sap 1/2/3:30.* create
                ingress
                    filter mac 4
                exit
            exit
            no shutdown
        exit
```

```
qos
        sap-ingress 2 create
            description "For Highest priority"
            queue 1 create
            exit
            mac-criteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "ef" priority high
                exit
            exit
        exit
```

```
sap-ingress 3 create
            description "For Low Priority"
            mac-criteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "af" priority low
                exit
            exit
        exit
```

```
filter
    mac-filter 4 create
        default-action forward
        entry 1 create
            match frame-type ethernet_II
                dot1p 0 7
            exit
            action drop
        exit
    exit
exit
```

Packet walk through for Customer_1:

When customer_1 send a traffic from both the vlans 41 and 42, uPE1 device assign the priority level 5 (ef) to both frames at SAP: 1/2/3:50.41 and SAP:1/2/3:50.42. Below trace results are capture on uPE2 to confirm QoS .

Table 5.3.1: Addressing scheme of Customer_1:

Provider VLAN	Customer VLAN	Client source IP address	Client Dst IP address	Client source MAC address	Client Dst MAC-address
50	41	192.168.100.1	192.168.100.2	00:08:21:96:f7:a0	00:08:21:9a:56:60
	42	192.168.200.1	192.168.200.2	00:08:21:bf:83:40	00:08:21:bf:4b:20

Fig 5.3.2: Traffic Received from uPE1 From VLAN 41.

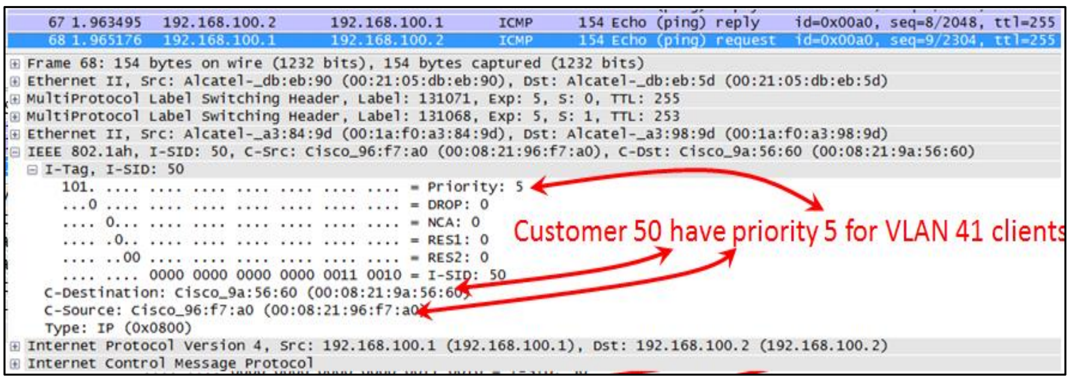
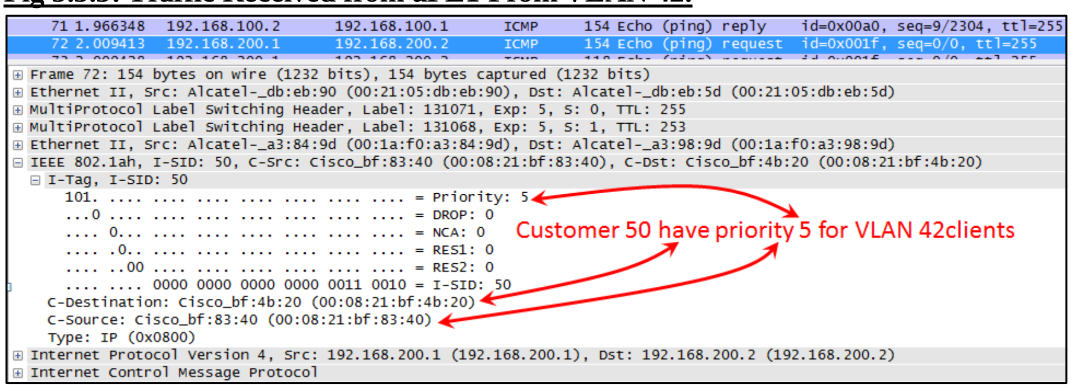


Fig 5.3.3: Traffic Received from uPE1 From VLAN 42.



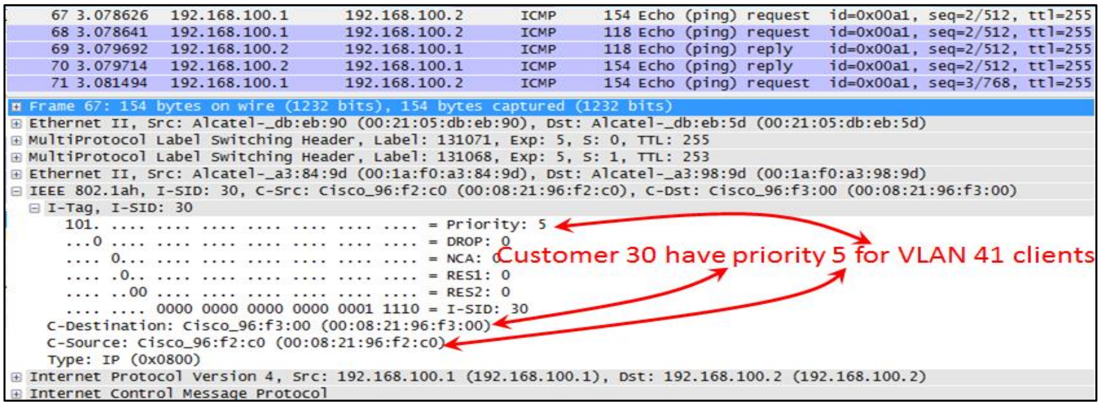
Packet walk through for Customer_2:

When customer_2 send a traffic from both the vlans 41 and 42, uPE1 device assign the priority level 5 (ef) to VLAN 41 at SAP: 1/2/3:30.41 and priority level 2 (af) at SAP:1/2/3:30.42. Below trace results are capture on uPE2 to confirm QoS .

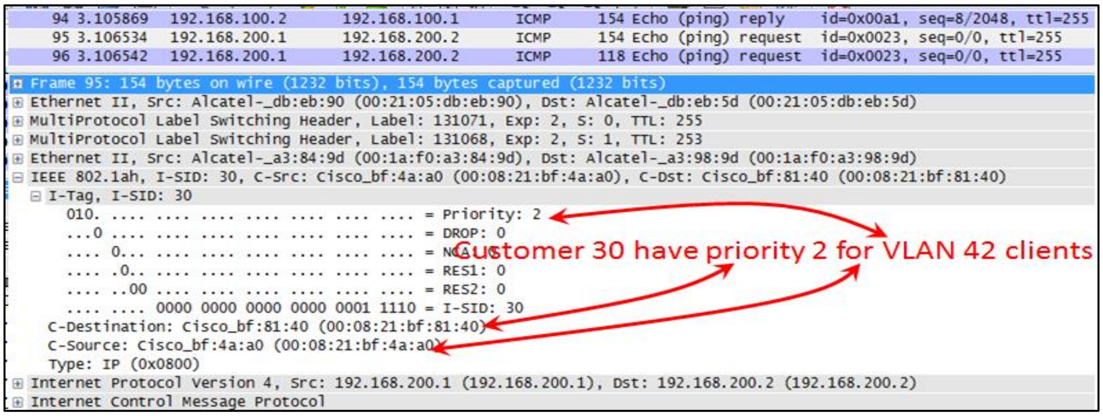
Table 5.4.1: Addressing scheme of Customer_1:

Provider VLAN	Customer VLAN	Client source IP address	Client Dst IP address	Client source MAC address	Client Dst MAC-address
30	41	192.168.100.1	192.168.100.2	00:08:21:96:f2:c0	00:08:21:96:f3:00
	42	192.168.200.1	192.168.200.2	00:08:21:bf:4a:a0	00:08:21:bf:81:40

<u>Fig 5.4.2: Traffic Received from uPE1 From VLAN 41.</u>



<u>Fig 5.4.2: Traffic Received from uPE1 From VLAN 42.</u>



Conclusion:

In this chapter we concluded that PBB enabled network can support different types of services Like: voice, video and data services and can guarantees different level of QoS to customer according to the service level agreement. When QoS is enabled Service provider can utilize a network infrastructure in more efficient manner. It helps to categories the traffic into high and low priorities and treat them accordingly.

Chapter 6: Configuration for VPLS + IEEE 802.1ad:

PE2 Configuration

```
A:PE1# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
        port 1/2/3
        ethernet
            mode access
            encap-type qinq
            qinq-etype 0x88a8
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
            mode access
            encap-type qinq
            mtu 1536
            qinq-etype 0x88a8
        exit
        no shutdown
    exit
        port 1/2/8
        ethernet
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.4.4.4/32
        exit
        interface "to-P3"
            address 192.168.1.1/30
            port 1/2/1
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
```

```
            exit
            interface "to-P3"
                interface-type point-to-point
            exit
        exit
    exit
#--------------------------------------------------
echo "MPLS Configuration"
#--------------------------------------------------
    mpls
        interface "system"
        exit
    exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
    ldp
        interface-parameters
            interface "to-P3"
            exit
        exit
        targeted-session
        exit
    exit
exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
  service
    customer 1 create
        description "Default customer"
    exit
    customer 30 create
                description "Customer_id_30"
    exit
    customer 50 create
        description "Customer_id_50"
    exit
    sdp 12 mpls create
        far-end 10.2.2.2
        ldp
        path-mtu 9000
        keep-alive
            no shutdown
        exit
        no shutdown
    exit
    vpls 30 customer 30 create
        stp
            shutdown
        exit
        sap 1/2/4:30.* create
        exit
        mesh-sdp 12:30 create
        exit
        no shutdown
    exit
    vpls 50 customer 50 create
        stp
            shutdown
        exit
        sap 1/2/4:50.* create
        exit
        mesh-sdp 12:50 create
```

```
        exit
        no shutdown
    exit
exit
#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
        exit
    exit

exit all
A:PE1#
```

PE2 configuration:

```
A:PE2# admin display-config
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
    exit
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
            qinq-etype 0x88a8
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
            mode access
            encap-type qinq
            mtu 1536
            qinq-etype 0x88a8
        exit
        no shutdown
    exit
```

```
    port 1/2/8
        ethernet
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.2.2.2/32
        exit
        interface "to-P3"
            address 192.168.3.2/30
            port 1/2/1
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
                exit
                interface "to-P3"
                    interface-type point-to-point
                exit
            exit
        exit
#--------------------------------------------------
echo "MPLS Configuration"
#--------------------------------------------------
        mpls
            interface "system"
            exit
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "to-P3"
                exit
            exit
            targeted-session
            exit
        exit
    exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 30 create
                description "Customer_id_30"
        exit
        customer 50 create
            description "Customer_id_50"
            contact "VPLS_customer_50"
            phone "XXX-XXX-XXXX"
        exit
```

```
        sdp 12 mpls create
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                no shutdown
            exit
            no shutdown
        exit
        vpls 30 customer 30 create
            stp
                shutdown
            exit
            sap 1/2/4:30.* create
            exit
            mesh-sdp 12:30 create
            exit
            no shutdown
        exit
        vpls 50 customer 50 create
            stp
                shutdown
            exit
            sap 1/2/4:50.* create
            exit
            mesh-sdp 12:50 create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
        exit
    exit

exit all

# Finished FRI DEC 02 09:50:37 2011 UTC
A:PE2#
```

P3 Configuration

```
A:P3# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-20g
        mda 1
            mda-type m20-1gb-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
```

```
#--------------------------------------------------
    port 1/1/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
    port 1/1/2
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
            exit
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.3.3.3/32
        exit
        interface "to-PE1"
            address 192.168.1.2/30
            port 1/1/1
        exit
        interface "to-PE2"
            address 192.168.3.1/30
            port 1/1/2
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
                exit
                interface "to-PE1"
                    interface-type point-to-point
                exit
                interface "to-PE2"
                    interface-type point-to-point
                exit
            exit
        exit
#--------------------------------------------------
echo "MPLS Configuration"
#--------------------------------------------------
        mpls
            interface "system"
            exit
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "to-PE1"
                exit
                interface "to-PE2"
                exit
            exit
            targeted-session
            exit
```

```
    exit
  exit

exit all

# Finished FRI DEC 02 10:52:41 2011 UTC
A:P3#
```

UPE1 Configuraton

```
A:CE-2# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
  card 1
    card-type iom-9g
    mda 2
      mda-type c8-10/100eth-tx
    exit
  exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
  port 1/2/1
    ethernet
      mode access
      encap-type qinq
      mtu 1536
      qinq-etype 0x88a8
    exit
    no shutdown
  exit
  port 1/2/3
    ethernet
      mode access
      encap-type qinq
      mtu 1536
    exit
    no shutdown
  exit
  port 1/2/8
    ethernet
      mode access
    exit
    no shutdown
  exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
  service
    customer 1 create
      description "Default customer"
    exit
    customer 2 create
    exit
    vpls 30 customer 2 create
          description "For customer_30"
      stp
        shutdown
      exit
      sap 1/2/1:30.* create
```

```
            exit
            sap 1/2/3:30.* create
            exit
            no shutdown
        exit
        vpls 50 customer 1 create
                        description "For customer_50"
            stp
                shutdown
            exit
            sap 1/2/1:50.* create
            exit
            sap 1/2/3:50.* create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
        exit
    exit

exit all

# Finished TUE NOV 08 14:25:01 2011 UTC
A:CE-2#
```

---

uPE2 Configuration:

```
A:CE-1# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mode access
            encap-type qinq
            mtu 1536
            qinq-etype 0x88a8
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
```

```
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/8
        ethernet
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
        exit
        interface "to-PE1"
            shutdown
        exit
    exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 2 create
        exit
        vpls 30 customer 2 create
            stp
                shutdown
            exit
            sap 1/2/1:30.* create
            exit
            sap 1/2/3:30.* create
            exit
            no shutdown
        exit
        vpls 50 customer 1 create
            stp
                shutdown
            exit
            sap 1/2/1:50.* create
            exit
            sap 1/2/3:50.* create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
    exit

#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
```

```
    exit
  exit

exit all
```

S_3700 configuration:

```
S_3700# #show running-config
Building configuration...

Current configuration : 1802 bytes
!
version 12.2
!
interface GigabitEthernet1/0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface GigabitEthernet1/0/2
 switchport access vlan 50
 switchport mode dot1q-tunnel
 no cdp enable
!
interface GigabitEthernet1/0/3
 switchport access vlan 30
 switchport mode dot1q-tunnel
 no cdp enable
!

S_3700#
```

CE_3500 configuration

```
CE3_3_3500#show running-config
Building configuration...

Current configuration:
!
interface FastEthernet0/1
        description "connected to client 41"
        switchport access vlan 41
!
interface FastEthernet0/2
        description "connected to S_3700"
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/3
        description "connected to client 42"
        switchport access vlan 42
!

CE3_3_3500#
```

Chapter 7 PBB + VPLS configuration and testing outputs

PE1 configuration:

```
A:PE1# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.4.4.4/32
        exit
        interface "to-P3"
            address 192.168.1.1/30
            port 1/2/1
        exit
        interface "to-uPE1"
            address 192.168.11.1/30
            port 1/2/4
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
                exit
                interface "to-P3"
```

```
                interface-type point-to-point
            exit
            interface "to-uPE1"
                interface-type point-to-point
            exit
        exit
    exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
    ldp
        interface-parameters
            interface "to-P3"
            exit
            interface "to-uPE1"
            exit
        exit
        targeted-session
        exit
    exit
exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 2 create
        exit
        customer 30 create
        exit
        customer 50 create
        exit
        sdp 11 mpls create
            description "SDP Connect to uPE router"
            far-end 10.10.10.1
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        sdp 12 mpls create
            description "SDP Connect to Far_END PE router"
            far-end 10.2.2.2
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 100 customer 1 b-vpls create
            description "Link b/w I-VPLS and PE2"
            service-mtu 1536
            pbb
                source-bmac 00:23:3e:0d:49:79
            exit
            stp
                shutdown
            exit
            spoke-sdp 11:100 create
```

```
        exit
        mesh-sdp 12:100 create
        exit
        no shutdown
      exit
   exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
   router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
      ospf
      exit
   exit

#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
   mirror
      mirror-dest 99 create
        sap 1/2/8 create
        exit
        no shutdown
      exit
   exit

exit all

# Finished FRI DEC 02 14:13:57 2011 UTC
A:PE1#
```

PE2 Configuration:

```
A:PE2# admin display-config
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
   card 1
      card-type iom-9g
      mda 2
        mda-type c8-10/100eth-tx
      exit
   exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
   port 1/2/1
      ethernet
        mtu 1536
      exit
      no shutdown
   exit
   port 1/2/3
      ethernet
        mode access
        encap-type qinq
      exit
      no shutdown
   exit
```

```
   port 1/2/4
       ethernet
           mtu 1536
       exit
       no shutdown
   exit
   port 1/2/8
       ethernet
           mode access
       exit
       no shutdown
   exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
   router
       interface "system"
           address 10.2.2.2/32
       exit
       interface "to-P3"
           address 192.168.3.2/30
           port 1/2/1
       exit
       interface "to-uPE3"
           address 192.168.10.1/30
           port 1/2/4
       exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
       ospf
           traffic-engineering
           area 0.0.0.0
               interface "system"
               exit
               interface "to-P3"
                   interface-type point-to-point
               exit
               interface "to-uPE3"
                   interface-type point-to-point
               exit
           exit
       exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
       ldp
           interface-parameters
               interface "to-P3"
               exit
               interface "to-uPE3"
               exit
           exit
           targeted-session
           exit
       exit
   exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
   service
       customer 1 create
           description "Default customer"
```

```
        exit
            sdp 11 mpls create
            description "SDP Connect to uPE router"
            far-end 10.10.10.2
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        sdp 12 mpls create
            description "SDP Connect to Far_END PE router"
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 100 customer 1 b-vpls create
            description "Link b/w I-VPLS and B-VPLS"
            service-mtu 1536
            pbb
                source-bmac 00:21:05:db:eb:8d
            exit
            stp
                shutdown
            exit
            spoke-sdp 11:100 create
            exit
            mesh-sdp 12:100 create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
        exit
    exit

#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
        exit
    exit

exit all

# Finished SAT DEC 03 13:15:05 2011 UTC
A:PE2#
```

uPE1 Configuration:

```
A:U-PE1# admin display-config
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/2
        shutdown
        ethernet
        exit
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
            mtu 1536
        exit
        no shutdown
    exit
      port 1/2/8
        ethernet
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
        sap-ingress 2 create
            description "For Highest priority"
            queue 1 create
            exit
            queue 11 multipoint create
            exit
            mac-criteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "ef" priority high
                exit
            exit
        exit
        sap-ingress 3 create
            description "For Low Priority"
            queue 1 create
            exit
            queue 11 multipoint create
            exit
```

```
            mac-criteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "af" priority low
                exit
            exit
        exit
    exit
#--------------------------------------------------
echo "Filter Configuration"
#--------------------------------------------------
    filter
        mac-filter 4 create
            default-action forward
            entry 1 create
                match frame-type ethernet_II
                    dot1p 0 7
                exit
                action drop
            exit
        exit
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
    router management
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.10.10.1/32
        exit
        interface "to-PE1"
            address 192.168.11.2/30
            port 1/2/1
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
                exit
                interface "to-PE1"
                    interface-type point-to-point
                exit
            exit
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "to-PE1"
                exit
            exit
            targeted-session
            exit
        exit
```

```
    exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 2 create
        exit
        customer 30 create
        exit
        customer 50 create
        exit
        sdp 11 mpls create
            description "connect to nPE router"
            far-end 10.4.4.4
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 30 customer 30 i-vpls create
            description "Instance for Customer_ID_30"
            send-flush-on-failure
            stp
                shutdown
            exit
            sap 1/2/3:30.40 create
            exit
            sap 1/2/3:30.41 create
                ingress
                    qos 2
                exit
            exit
            sap 1/2/3:30.42 create
                ingress
                    qos 3
                exit
            exit
            sap 1/2/3:30.* create
                ingress
                    filter mac 4
                exit
            exit
            no shutdown
        exit
        vpls 50 customer 50 i-vpls create
            description "Instance for Custome_ID_50"
            send-flush-on-failure
            stp
                shutdown
            exit
            sap 1/2/3:50.40 create
                ingress
                    filter mac 4
                exit
            exit
            sap 1/2/3:50.41 create
                ingress
                    qos 2
                exit
```

```
            exit
            sap 1/2/3:50.42 create
                ingress
                    qos 2
                exit
            exit
            no shutdown
        exit
        vpls 100 customer 1 b-vpls create
            description "Link b/w I-VPLS and B-VPLS"
            service-mtu 1536
            send-flush-on-failure
            pbb
                source-bmac 00:1a:f0:a3:84:9d
            exit
            stp
                shutdown
            exit
            spoke-sdp 11:100 create
            exit
            no shutdown
        exit
        vpls 30
            pbb
                backbone-vpls 100
                exit
            exit
        exit
        vpls 50
            pbb
                backbone-vpls 100
                exit
            exit
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
        exit
    exit

#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
    mirror
        mirror-dest 99 create
            sap 1/2/8 create
            exit
            no shutdown
        exit
    exit

exit all

# Finished SAT DEC 03 14:16:41 2011 UTC
A:U-PE1#
```

UPE2 configuration:

```
A:U-PE2# admin display-config

#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 2
            mda-type c8-10/100eth-tx
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/2/1
        ethernet
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
            mtu 1536
        exit
        no shutdown
    exit
    port 1/2/8
        ethernet
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
        sap-ingress 2 create
            description "For Highest priority"
            queue 1 create
            exit
            queue 11 multipoint create
            exit
            mac-criteria
                entry 10 create
                    match frame-type ethernet-II
                        dot1p 0 7
                    exit
                    action fc "ef" priority high
                exit
            exit
        exit
        sap-ingress 3 create
            description "For Low Priority"
            queue 1 create
            exit
            queue 11 multipoint create
            exit
            mac-criteria
                entry 10 create
```

```
                match frame-type ethernet-II
                    dot1p 0 7
                exit
                action fc "af" priority low
            exit
        exit
    exit
exit
#--------------------------------------------------
echo "Filter Configuration"
#--------------------------------------------------
    filter
        mac-filter 4 create
            default-action forward
            entry 1 create
                match frame-type ethernet_II
                    dot1p 0 7
                exit
                action drop
            exit
        exit
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
    router management
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.10.10.2/32
        exit
        interface "to-PE2"
            address 192.168.10.2/30
            port 1/2/1
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            traffic-engineering
            area 0.0.0.0
                interface "system"
                exit
                interface "to-PE2"
                    interface-type point-to-point
                exit
            exit
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "to-PE2"
                exit
            exit
            targeted-session
            exit
        exit
    exit
```

```
#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 2 create
        exit
        customer 30 create
        exit
        customer 50 create
        exit
        customer 100 create
        exit
        sdp 11 mpls create
            description "connect to nPE router"
            far-end 10.2.2.2
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 30 customer 30 i-vpls create

            stp
                shutdown
            exit
            sap 1/2/3:30.41 create
                ingress
                    qos 2
                exit
            exit
            sap 1/2/3:30.42 create
                ingress
                    qos 3
                exit
            exit
            sap 1/2/3:30.* create
                ingress
                    filter mac 4
                exit
            exit
            no shutdown
        exit
        vpls 50 customer 50 i-vpls create
            description "Instance for Custome_ID_50"

            stp
                shutdown
            exit
            sap 1/2/3:50.40 create
                ingress
                    filter mac 4
                exit
            exit
            sap 1/2/3:50.41 create
                ingress
                    qos 2
                exit
            exit
            sap 1/2/3:50.42 create
                ingress
```

```
                qos 2
            exit
        exit
        no shutdown
    exit
    vpls 100 customer 1 b-vpls create
        description "Link b/w I-VPLS and B-VPLS"
        service-mtu 1536

        pbb
            source-bmac 00:1a:f0:a3:98:9d
        exit
        stp
            shutdown
        exit
        spoke-sdp 11:100 create
        exit
        no shutdown
    exit
  exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
   router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
       ospf
       exit
   exit

#--------------------------------------------------
echo "Mirror Configuration"
#--------------------------------------------------
   mirror
       mirror-dest 99 create
           sap 1/2/8 create
           exit
           no shutdown
       exit
   exit

exit all

# Finished WED NOV 09 17:49:58 2011 UTC
A:U-PE2#
```

S_3700 configuration:

```
S_3700# #show running-config
Building configuration...

Current configuration : 1802 bytes
!
version 12.2
!
interface GigabitEthernet1/0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface GigabitEthernet1/0/2
 switchport access vlan 50
```

```
 switchport mode dot1q-tunnel
 no cdp enable
!
interface GigabitEthernet1/0/3
 switchport access vlan 30
 switchport mode dot1q-tunnel
 no cdp enable
!

S_3700#
```

CE_3500 configuration

```
CE3_3_3500#show running-config
Building configuration...

Current configuration:
!
interface FastEthernet0/1
		description "connected to client 41"
		switchport access vlan 41
!
interface FastEthernet0/2
		description "connected to S_3700"
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/3
		description "connected to client 42"
		switchport access vlan 42
!

CE3_3_3500#
```

Chapter 8 Verification output:

PE1 Verification output:

```
*A:PE1# show service id 100 fdb detail

===============================================================================
Forwarding Database, Service 100
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
100       00:1a:f0:a3:84:9d sdp:11:100               L/0    12/02/2011 05:52:32
100       00:1a:f0:a3:98:9d sdp:12:100               L/0    12/02/2011 05:51:28
-------------------------------------------------------------------------------
No. of MAC Entries: 2
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:PE1#


*A:PE1# show router ldp bindings

===============================================================================
LDP LSR ID: 10.4.4.4
===============================================================================
Legend: U - Label In Use, N - Label Not In Use, W - Label Withdrawn
        S - Status Signaled Up,  D - Status Signaled Down
        E - Epipe Service, V - VPLS Service, M - Mirror Service
        A - Apipe Service, F - Fpipe Service, I - IES Service, R - VPRN service
        P - Ipipe Service, WP - Label Withdraw Pending, C - Cpipe Service
        TLV - (Type, Length: Value)
===============================================================================
LDP Prefix Bindings
===============================================================================
Prefix          Peer            IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                                 LspId
-------------------------------------------------------------------------------
10.2.2.2/32     10.3.3.3        131069N   131070 1/2/1       192.168.1.2
10.2.2.2/32     10.10.10.1      131069U   131070   --          --
10.3.3.3/32     10.3.3.3          --      131071 1/2/1       192.168.1.2
10.3.3.3/32     10.10.10.1      131068U   131069   --          --
10.4.4.4/32     10.3.3.3        131071U     --     --          --
10.4.4.4/32     10.10.10.1      131071U     --     --          --
10.10.10.1/32   10.3.3.3        131066U   131067   --          --
10.10.10.1/32   10.10.10.1        --      131071 1/2/4       192.168.11.2
10.10.10.2/32   10.3.3.3        131067N   131069 1/2/1       192.168.1.2
10.10.10.2/32   10.10.10.1      131067U   131067   --          --
-------------------------------------------------------------------------------
No. of Prefix Bindings: 10

===============================================================================
LDP P2MP Bindings
===============================================================================
P2MP-Id         RootAddr
Interface       Peer            IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                                 LspId
-------------------------------------------------------------------------------
No Matching Entries Found
```

```
===============================================================================
LDP Service FEC 128 Bindings
===============================================================================
Type   VCId      SvcId      SDPId    Peer           IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
V-Eth  100       100        12       10.2.2.2       131070U 131067  1522 1522
V-Eth  100       100        11       10.10.10.1     131065U 131066S 1522 1522
-------------------------------------------------------------------------------
No. of VC Labels: 2

===============================================================================
LDP Service FEC 129 Bindings
===============================================================================
AGI                          SAII                 TAII
Type            SvcId      SDPId    Peer          IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
===============================================================================
*A:PE1#  .


*A:PE1#  show service sdp

===============================================================================
Services: Service Destination Points
===============================================================================
SdpId   Adm MTU  Opr MTU  IP address      Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------
11      9000     9000     10.10.10.1      Up   Up         LDP       TLDP
12      9000     9000     10.2.2.2        Up   Up         LDP       TLDP
-------------------------------------------------------------------------------
Number of SDPs : 2
-------------------------------------------------------------------------------
===============================================================================
*A:PE1#  show service sdp-using

===============================================================================
SDP Using
===============================================================================
SvcId      SdpId            Type    Far End       Opr S* I.Label  E.Label
-------------------------------------------------------------------------------
100        11:100           Spok    10.10.10.1    Up     131065   131066
100        12:100           Mesh    10.2.2.2      Up     131070   131067
-------------------------------------------------------------------------------
Number of SDPs : 2
-------------------------------------------------------------------------------
===============================================================================
* indicates that the corresponding row element may have been truncated.
*A:PE1#

*A:PE1#  show router ldp session

===============================================================================
LDP Sessions
===============================================================================
Peer LDP Id        Adj Type   State         Msg Sent  Msg Recv  Up Time
-------------------------------------------------------------------------------
10.2.2.2:0         Targeted   Established   5918      5917      0d 08:59:54
10.3.3.3:0         Link       Established   11870     11869     0d 09:10:55
10.10.10.1:0       Both       Established   13604     13607     0d 08:44:09
-------------------------------------------------------------------------------
No. of Sessions: 3
===============================================================================
```

*A:PE1#

PE2 Verfication output

```
*A:PE2# show service id 100 fdb detail

===============================================================================
Forwarding Database, Service 100
===============================================================================
ServId   MAC            Source-Identifier       Type   Last Change
                                                Age
-------------------------------------------------------------------------------
100      00:1a:f0:a3:84:9d sdp:12:100           L/0    12/03/2011 04:52:56
100      00:1a:f0:a3:98:9d sdp:11:100           L/0    12/03/2011 04:51:52
-------------------------------------------------------------------------------
No. of MAC Entries: 2
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:PE2#

*A:PE2# show service id 100 fdb

===============================================================================
Forwarding Database, Service 100
===============================================================================
Service Id        : 100              Mac Move           : Disabled
Primary Factor    : 3                Secondary Factor   : 2
Mac Move Rate     : 2                Mac Move Timeout   : 10
Mac Move Retries  : 3
Table Size        : 250              Total Count        : 2
Learned Count     : 2                Static Count       : 0
OAM-learned Count : 0                DHCP-learned Count: 0
Host-learned Count: 0                Intf-learned Count: 0
Remote Age        : 900              Local Age          : 300
High Watermark    : 95%              Low Watermark      : 90%
Mac Learning      : Enabled          Discard Unknown    : Disabled
Mac Aging         : Enabled          Relearn Only       : False
Mac Subnet Len    : 48
===============================================================================
*A:PE2#   .

*A:PE2#    show service id 100 base

===============================================================================
Service Basic Information
===============================================================================
Service Id        : 100              Vpn Id             : 0
Service Type      : b-VPLS
Name              : (Not Specified)
Description       : Link b/w I-VPLS and B-VPLS
Customer Id       : 1
Last Status Change: 12/03/2011 03:54:28
Last Mgmt Change  : 12/03/2011 05:53:22
Admin State       : Up               Oper State         : Up
MTU               : 1536             Def. Mesh VC Id    : 100
SAP Count         : 0                SDP Bind Count     : 2
Snd Flush on Fail : Disabled         Host Conn Verify   : Disabled
Propagate MacFlush: Disabled         Per Svc Hashing    : Disabled
Allow IP Intf Bind: Disabled
Oper Backbone Src : 00:21:05:db:eb:8d
i-Vpls Count      : 0
Epipe Count       : 0

-------------------------------------------------------------------------------
```

```
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                       Type       AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sdp:11:100 S(10.10.10.2)              Spok       9000    9000    Up   Up
sdp:12:100 M(10.4.4.4)                Mesh       9000    9000    Up   Up
===============================================================================
*A:PE2#

*A:PE2#  show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC             Source-Identifier       Type   Last Change
                                   Age
-------------------------------------------------------------------------------
100      00:1a:f0:a3:84:9d sdp:12:100            L/0    12/03/2011 04:52:56
100      00:1a:f0:a3:98:9d sdp:11:100            L/0    12/03/2011 04:51:52
-------------------------------------------------------------------------------
No. of Entries: 2
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:PE2#

*A:PE2# show service  sdp 11

===============================================================================
Service Destination Point (Sdp Id : 11)
===============================================================================
SdpId    Adm MTU  Opr MTU  IP address      Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------
11      9000     9000     10.10.10.2      Up   Up         LDP       TLDP
===============================================================================
*A:PE2#


*A:PE2#  show service service-using

===============================================================================
Services
===============================================================================
ServiceId     Type      Adm  Opr  CustomerId Service Name
-------------------------------------------------------------------------------
99          Mirror    Up   Down 1
100         b-VPLS    Up   Up   1
2147483648   IES       Up   Down 1         _tmnx_InternalIesService
-------------------------------------------------------------------------------
Matching Services : 3
-------------------------------------------------------------------------------
===============================================================================
*A:PE2#


*A:PE2# show router ldp bindings

===============================================================================
LDP LSR ID: 10.2.2.2
===============================================================================
Legend: U - Label In Use, N - Label Not In Use, W - Label Withdrawn
       S - Status Signaled Up,  D - Status Signaled Down
       E - Epipe Service, V - VPLS Service, M - Mirror Service
       A - Apipe Service, F - Fpipe Service, I - IES Service, R - VPRN service
       P - Ipipe Service, WP - Label Withdraw Pending, C - Cpipe Service
```

```
    TLV - (Type, Length: Value)
===============================================================================
LDP Prefix Bindings
===============================================================================
Prefix          Peer          IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                               LspId
-------------------------------------------------------------------------------
10.2.2.2/32     10.3.3.3      131071U     --     --          --
10.2.2.2/32     10.10.10.2    131071U     --     --          --
10.3.3.3/32     10.3.3.3        --      131071 1/2/1       192.168.3.1
10.3.3.3/32     10.10.10.2    131070U   131069   --          --
10.4.4.4/32     10.3.3.3      131066N   131068 1/2/1       192.168.3.1
10.4.4.4/32     10.10.10.2    131066U   131066   --          --
10.10.10.1/32   10.3.3.3      131065N   131067 1/2/1       192.168.3.1
10.10.10.1/32   10.10.10.2    131065U   131065   --          --
10.10.10.2/32   10.3.3.3      131069U   131069   --          --
10.10.10.2/32   10.10.10.2      --      131071 1/2/4       192.168.10.2
-------------------------------------------------------------------------------
No. of Prefix Bindings: 10

===============================================================================
LDP P2MP Bindings
===============================================================================
P2MP-Id         RootAddr
Interface       Peer          IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                               LspId
-------------------------------------------------------------------------------
No Matching Entries Found

===============================================================================
LDP Service FEC 128 Bindings
===============================================================================
Type   VCId       SvcId      SDPId    Peer          IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
V-Eth  100        100        12       10.4.4.4      131067U 131070  1522 1522
V-Eth  100        100        11       10.10.10.2    131068U 131068S 1522 1522
?-Eth  300        Ukwn       R. Src   10.10.10.2      --    131067D 0    1522
-------------------------------------------------------------------------------
No. of VC Labels: 3

===============================================================================
LDP Service FEC 129 Bindings
===============================================================================
AGI                          SAII               TAII
Type          SvcId      SDPId    Peer          IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
===============================================================================
*A:PE2# ..

*A:PE2# show service sdp

============================================================================
Services: Service Destination Points
============================================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr        Deliver   Signal
----------------------------------------------------------------------------
11       9000     9000     10.10.10.2       Up   Up         LDP       TLDP
12       9000     9000     10.4.4.4         Up   Up         LDP       TLDP
----------------------------------------------------------------------------
Number of SDPs : 2
----------------------------------------------------------------------------
============================================================================
*A:PE2#
```

```
*A:PE2# show service sdp-using

===============================================================================
SDP Using
===============================================================================
SvcId      SdpId            Type   Far End       Opr S* I.Label  E.Label
-------------------------------------------------------------------------------
100        11:100           Spok   10.10.10.2    Up     131068   131068
100        12:100           Mesh   10.4.4.4      Up     131067   131070
-------------------------------------------------------------------------------
Number of SDPs : 2
-------------------------------------------------------------------------------
===============================================================================
* indicates that the corresponding row element may have been truncated.
*A:PE2#
*A:PE2#  show router ldp session

==============================================================================
LDP Sessions
==============================================================================
Peer LDP Id        Adj Type   State         Msg Sent  Msg Recv  Up Time
------------------------------------------------------------------------------
10.3.3.3:0         Link       Established   11907     11908     0d 09:09:23
10.4.4.4:0         Targeted   Established   5962      5965      0d 09:04:02
10.10.10.2:0       Both       Established   14245     14246     0d 09:08:50
------------------------------------------------------------------------------
No. of Sessions: 3
==============================================================================
*A:PE2#
```

UPE1 Verification Output:

```
UP*A:U-PE2# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                  Age
-------------------------------------------------------------------------------
30        00:08:21:96:f2:c0 b-sdp:11:100             L/0    11/09/2011 09:52:33
30        00:08:21:96:f3:00 sap:1/2/3:30.41          L/0    11/09/2011 17:39:48
30        00:08:21:bf:4a:a0 b-sdp:11:100             L/0    11/09/2011 09:43:05
30        00:08:21:bf:81:40 sap:1/2/3:30.42          L/0    11/09/2011 17:36:45
30        00:18:18:6e:47:81 b-sdp:11:100             L/0    11/09/2011 09:26:48
50        00:07:eb:94:73:c2 sap:1/2/3:50.41          L/0    11/09/2011 17:41:10
50        00:08:21:96:f7:a0 b-sdp:11:100             L/15   11/09/2011 09:29:04
50        00:08:21:9a:56:60 sap:1/2/3:50.41          L/15   11/09/2011 17:38:44
50        00:08:21:bf:4b:20 sap:1/2/3:50.42          L/0    11/09/2011 17:33:23
50        00:08:21:bf:83:40 b-sdp:11:100             L/0    11/09/2011 09:29:42
100       00:1a:f0:a3:84:9d sdp:11:100               L/0    11/09/2011 09:26:48
-------------------------------------------------------------------------------
No. of Entries: 11
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================


*A:U-PE2# show service id 30 base
```

```
===============================================================================
Service Basic Information
===============================================================================
Service Id        : 30                Vpn Id            : 0
Service Type      : i-VPLS
Name              : (Not Specified)
Description       : (Not Specified)
Customer Id       : 30
Last Status Change: 11/09/2011 08:26:45
Last Mgmt Change  : 11/09/2011 08:25:58
Admin State       : Up                Oper State        : Up
MTU               : 1514              Def. Mesh VC Id   : 30
SAP Count         : 3                 SDP Bind Count    : 0
Snd Flush on Fail : Enabled           Host Conn Verify  : Disabled
Propagate MacFlush: Disabled          Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
b-Vpls Id         : 100               Oper ISID         : 30
b-Vpls Status     : Up
Snd Flush in bVpls: None
Flsh On bVpls Fail: Disabled          Prop Flsh fr bVpls: Disabled
Force QTag Fwd    : Disabled

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                       Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sap:1/2/3:30.41                  qinq         1536    1536    Up   Up
sap:1/2/3:30.42                  qinq         1536    1536    Up   Up
sap:1/2/3:30.*                   qinq         1536    1536    Up   Up
===============================================================================
*A:U-PE2# show service id 50 base

===============================================================================
Service Basic Information
===============================================================================
Service Id        : 50                Vpn Id            : 0
Service Type      : i-VPLS
Name              : (Not Specified)
Description       : Instance for Custome_ID_50
Customer Id       : 50
Last Status Change: 11/09/2011 08:26:45
Last Mgmt Change  : 11/09/2011 10:28:31
Admin State       : Up                Oper State        : Up
MTU               : 1514              Def. Mesh VC Id   : 50
SAP Count         : 3                 SDP Bind Count    : 0
Snd Flush on Fail : Enabled           Host Conn Verify  : Disabled
Propagate MacFlush: Disabled          Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
b-Vpls Id         : 100               Oper ISID         : 50
b-Vpls Status     : Up
Snd Flush in bVpls: None
Flsh On bVpls Fail: Disabled          Prop Flsh fr bVpls: Disabled
Force QTag Fwd    : Disabled

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                       Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sap:1/2/3:50.40                  qinq         1536    1536    Up   Up
sap:1/2/3:50.41                  qinq         1536    1536    Up   Up
sap:1/2/3:50.42                  qinq         1536    1536    Up   Up
===============================================================================
*A:U-PE2# show service id 100 base
```

```
===============================================================================
Service Basic Information
===============================================================================
Service Id        : 100                Vpn Id            : 0
Service Type      : b-VPLS
Name              : (Not Specified)
Description       : Link b/w I-VPLS and B-VPLS
Customer Id       : 1
Last Status Change: 11/09/2011 08:28:19
Last Mgmt Change  : 11/09/2011 10:28:51
Admin State       : Up                 Oper State        : Up
MTU               : 1536               Def. Mesh VC Id   : 100
SAP Count         : 0                  SDP Bind Count    : 1
Snd Flush on Fail : Enabled            Host Conn Verify  : Disabled
Propagate MacFlush: Disabled           Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
Oper Backbone Src : 00:1a:f0:a3:98:9d
i-Vpls Count      : 2
Epipe Count       : 0

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                          Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sdp:11:100 S(10.2.2.2)              Spok         9000    9000    Up   Up
===============================================================================
*A:U-PE2# show service id 11 base
MINOR: CLI Invalid service id "11".
*A:U-PE2# show service sdp
sdp        sdp-using
*A:U-PE2# show service sdp 11

===============================================================================
Service Destination Point (Sdp Id : 11)
===============================================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------
11       9000     9000     10.2.2.2         Up   Up         LDP       TLDP
===============================================================================
*A:U-PE2# show service sdp 12

===============================================================================
Service Destination Point (Sdp Id : 12)
===============================================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================
*A:U-PE2#

*A:U-PE2# show service service-using

===============================================================================
Services
===============================================================================
ServiceId     Type      Adm  Opr  CustomerId Service Name
-------------------------------------------------------------------------------
30            i-VPLS    Up   Up   30
50            i-VPLS    Up   Up   50
99            Mirror    Up   Up   1
100           b-VPLS    Up   Up   1
300           b-VPLS    Down Down 30
2147483648    IES       Up   Down 1          _tmnx_InternalIesService
```

```
-------------------------------------------------------------------------------
Matching Services : 6
-------------------------------------------------------------------------------
===============================================================================
*A:U-PE2#
*A:U-PE2# show router ldp bindings

===============================================================================
LDP LSR ID: 10.10.10.2
===============================================================================
Legend: U - Label In Use, N - Label Not In Use, W - Label Withdrawn
        S - Status Signaled Up,  D - Status Signaled Down
        E - Epipe Service, V - VPLS Service, M - Mirror Service
        A - Apipe Service, F - Fpipe Service, I - IES Service, R - VPRN service
        P - Ipipe Service, WP - Label Withdraw Pending, C - Cpipe Service
        TLV - (Type, Length: Value)
===============================================================================
LDP Prefix Bindings
===============================================================================
Prefix          Peer            IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                                 LspId
-------------------------------------------------------------------------------
10.2.2.2/32       10.2.2.2          --      131071 1/2/1       192.168.10.1
10.3.3.3/32       10.2.2.2        131069N   131070 1/2/1       192.168.10.1
10.4.4.4/32       10.2.2.2        131066N   131066 1/2/1       192.168.10.1
10.10.10.1/32     10.2.2.2        131065N   131065 1/2/1       192.168.10.1
10.10.10.2/32     10.2.2.2        131071U     --    --          --
-------------------------------------------------------------------------------
No. of Prefix Bindings: 5

===============================================================================
LDP P2MP Bindings
===============================================================================
P2MP-Id           RootAddr
Interface         Peer            IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                                 LspId
-------------------------------------------------------------------------------
No Matching Entries Found

===============================================================================
LDP Service FEC 128 Bindings
===============================================================================
Type   VCId      SvcId     SDPId    Peer          IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
V-Eth  100       100       11       10.2.2.2      131068U 131068S 1522 1522
V-Eth  300       300       11       10.2.2.2      131067U   --    1522 0
-------------------------------------------------------------------------------
No. of VC Labels: 2

===============================================================================
LDP Service FEC 129 Bindings
===============================================================================
AGI                            SAII               TAII
Type             SvcId     SDPId    Peer          IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
===============================================================================
*A:U-PE2#

*A:U-PE2#  show service sdp

==============================================================================
Services: Service Destination Points
==============================================================================
```

```
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr       Deliver   Signal
-------------------------------------------------------------------------------
11      9000     9000     10.2.2.2         Up   Up         LDP       TLDP
-------------------------------------------------------------------------------
Number of SDPs : 1
-------------------------------------------------------------------------------
===============================================================================
*A:U-PE2#
A:U-PE2#  show service sdp

===============================================================================
Services: Service Destination Points
===============================================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr       Deliver   Signal
-------------------------------------------------------------------------------
11      9000     9000     10.2.2.2         Up   Up         LDP       TLDP
-------------------------------------------------------------------------------
Number of SDPs : 1
-------------------------------------------------------------------------------
===============================================================================
*A:U-PE2#   show router ldp session

===============================================================================
LDP Sessions
===============================================================================
Peer LDP Id        Adj Type   State        Msg Sent  Msg Recv  Up Time
-------------------------------------------------------------------------------
10.2.2.2:0         Both       Established   14479     14480     0d 09:18:16
-------------------------------------------------------------------------------
No. of Sessions: 1
===============================================================================
*A:U-PE2#
```

UPE1 Verification Output:

```
*A:U-PE1# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
30       00:08:21:96:f2:c0 sap:1/2/3:30.41          L/0    12/03/2011 14:05:49
30       00:08:21:96:f3:00 b-sdp:11:100             L/0    12/03/2011 06:22:26
30       00:08:21:bf:4a:a0 sap:1/2/3:30.42          L/0    12/03/2011 14:05:18
30       00:08:21:bf:81:40 b-sdp:11:100             L/0    12/03/2011 06:22:50
30       00:18:18:6e:47:81 sap:1/2/3:30.*           L/0    12/03/2011 05:52:48
50       00:07:eb:94:73:c2 b-sdp:11:100             L/0    12/03/2011 06:12:05
50       00:08:21:96:f7:a0 sap:1/2/3:50.41          L/15   12/03/2011 14:06:03
50       00:08:21:9a:56:60 b-sdp:11:100             L/15   12/03/2011 05:52:30
50       00:08:21:bf:4b:20 b-sdp:11:100             L/15   12/03/2011 05:57:22
50       00:08:21:bf:83:40 sap:1/2/3:50.42          L/15   12/03/2011 14:00:13
100       00:1a:f0:a3:98:9d sdp:11:100              L/0    12/03/2011 05:51:44
-------------------------------------------------------------------------------
No. of Entries: 11
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:U-PE1#
```

```
*A:U-PE1# show service id 30 fdb detail

===============================================================================
Forwarding Database, Service 30
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                      Age
-------------------------------------------------------------------------------
30        00:08:21:96:f2:c0 sap:1/2/3:30.41          L/254  12/03/2011 14:05:49
30        00:08:21:96:f3:00 b-sdp:11:100             L/239  12/03/2011 06:22:26
30        00:08:21:bf:4a:a0 sap:1/2/3:30.42          L/254  12/03/2011 14:05:18
30        00:08:21:bf:81:40 b-sdp:11:100             L/253  12/03/2011 06:22:50
30        00:18:18:6e:47:81 sap:1/2/3:30.*           L/0    12/03/2011 05:52:48
-------------------------------------------------------------------------------
No. of MAC Entries: 5
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:U-PE1# show service id 50 fdb detail

===============================================================================
Forwarding Database, Service 50
===============================================================================
ServId    MAC               Source-Identifier        Type   Last Change
                                      Age
-------------------------------------------------------------------------------
50        00:07:eb:94:73:c2 b-sdp:11:100             L/0    12/03/2011 06:12:05
50        00:08:21:96:f7:a0 sap:1/2/3:50.41          L/104  12/03/2011 14:06:03
50        00:08:21:9a:56:60 b-sdp:11:100             L/269  12/03/2011 05:52:30
50        00:08:21:bf:4b:20 b-sdp:11:100             L/15   12/03/2011 05:57:22
50        00:08:21:bf:83:40 sap:1/2/3:50.42          L/268  12/03/2011 14:00:13
-------------------------------------------------------------------------------
No. of MAC Entries: 5
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================

*A:U-PE1# show service id 100 base

===============================================================================
Service Basic Information
===============================================================================
Service Id        : 100                Vpn Id            : 0
Service Type      : b-VPLS
Name              : (Not Specified)
Description       : Link b/w I-VPLS and B-VPLS
Customer Id       : 1
Last Status Change: 12/03/2011 05:14:43
Last Mgmt Change  : 12/03/2011 06:39:32
Admin State       : Up                 Oper State        : Up
MTU               : 1536               Def. Mesh VC Id   : 100
SAP Count         : 0                  SDP Bind Count    : 1
Snd Flush on Fail : Enabled            Host Conn Verify  : Disabled
Propagate MacFlush: Disabled           Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
Oper Backbone Src : 00:1a:f0:a3:84:9d
i-Vpls Count      : 2
Epipe Count       : 0

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                       Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
```

```
sdp:11:100 S(10.4.4.4)              Spok        9000    9000    Up    Up
===============================================================================
*A:U-PE1# show service id 30 base

===============================================================================
Service Basic Information
===============================================================================
Service Id        : 30                Vpn Id            : 0
Service Type      : i-VPLS
Name              : (Not Specified)
Description       : Instance for Customer_ID_30
Customer Id       : 30
Last Status Change: 12/03/2011 05:03:37
Last Mgmt Change  : 12/03/2011 06:26:57
Admin State       : Up                Oper State        : Up
MTU               : 1514              Def. Mesh VC Id   : 30
SAP Count         : 4                 SDP Bind Count    : 0
Snd Flush on Fail : Enabled           Host Conn Verify  : Disabled
Propagate MacFlush: Disabled          Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
b-Vpls Id         : 100               Oper ISID         : 30
b-Vpls Status     : Up
Snd Flush in bVpls: None
Flsh On bVpls Fail: Disabled          Prop Flsh fr bVpls: Disabled
Force QTag Fwd    : Disabled

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                              Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sap:1/2/3:30.40                         qinq         1536    1536    Up   Up
sap:1/2/3:30.41                         qinq         1536    1536    Up   Up
sap:1/2/3:30.42                         qinq         1536    1536    Up   Up
sap:1/2/3:30.*                          qinq         1536    1536    Up   Up
===============================================================================
*A:U-PE1# show service id 50 base

===============================================================================
Service Basic Information
===============================================================================
Service Id        : 50                Vpn Id            : 0
Service Type      : i-VPLS
Name              : (Not Specified)
Description       : Instance for Custome_ID_50
Customer Id       : 50
Last Status Change: 12/03/2011 05:03:37
Last Mgmt Change  : 12/03/2011 06:27:26
Admin State       : Up                Oper State        : Up
MTU               : 1514              Def. Mesh VC Id   : 50
SAP Count         : 3                 SDP Bind Count    : 0
Snd Flush on Fail : Enabled           Host Conn Verify  : Disabled
Propagate MacFlush: Disabled          Per Svc Hashing   : Disabled
Allow IP Intf Bind: Disabled
b-Vpls Id         : 100               Oper ISID         : 50
b-Vpls Status     : Up
Snd Flush in bVpls: None
Flsh On bVpls Fail: Disabled          Prop Flsh fr bVpls: Disabled
Force QTag Fwd    : Disabled

-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                              Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
```

```
sap:1/2/3:50.40                 qinq       1536   1536   Up   Up
sap:1/2/3:50.41                 qinq       1536   1536   Up   Up
sap:1/2/3:50.42                 qinq       1536   1536   Up   Up
===============================================================================
*A:U-PE1# show service sdp 11

===============================================================================
Service Destination Point (Sdp Id : 11)
===============================================================================
SdpId    Adm MTU  Opr MTU  IP address      Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------
11      9000     9000     10.4.4.4        Up   Up         LDP       TLDP
===============================================================================

*A:U-PE1# show service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC              Source-Identifier        Type   Last Change
                                  Age
-------------------------------------------------------------------------------
30       00:08:21:96:f2:c0 sap:1/2/3:30.41         L/30   12/03/2011 14:05:49
30       00:08:21:96:f3:00 b-sdp:11:100            L/298  12/03/2011 06:22:26
30       00:08:21:bf:81:40 b-sdp:11:100            L/312  12/03/2011 06:22:50
30       00:18:18:6e:47:81 sap:1/2/3:30.*          L/0    12/03/2011 05:52:48
50       00:07:eb:94:73:c2 b-sdp:11:100            L/0    12/03/2011 06:12:05
50       00:08:21:96:f7:a0 sap:1/2/3:50.41         L/163  12/03/2011 14:06:03
50       00:08:21:9a:56:60 b-sdp:11:100            L/328  12/03/2011 05:52:30
50       00:08:21:bf:4b:20 b-sdp:11:100            L/74   12/03/2011 05:57:22
100       00:1a:f0:a3:98:9d sdp:11:100             L/0    12/03/2011 05:51:44
-------------------------------------------------------------------------------
No. of Entries: 9
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
*A:U-PE1# show router ldp bindings

===============================================================================
LDP LSR ID: 10.10.10.1
===============================================================================
Legend: U - Label In Use, N - Label Not In Use, W - Label Withdrawn
       S - Status Signaled Up,  D - Status Signaled Down
       E - Epipe Service, V - VPLS Service, M - Mirror Service
       A - Apipe Service, F - Fpipe Service, I - IES Service, R - VPRN service
       P - Ipipe Service, WP - Label Withdraw Pending, C - Cpipe Service
       TLV - (Type, Length: Value)
===============================================================================
LDP Prefix Bindings
===============================================================================
Prefix            Peer            IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                         LspId
-------------------------------------------------------------------------------
10.2.2.2/32        10.4.4.4        131070N   131069 1/2/1       192.168.11.1
10.3.3.3/32        10.4.4.4        131069N   131068 1/2/1       192.168.11.1
10.4.4.4/32        10.4.4.4          --      131071 1/2/1       192.168.11.1
10.10.10.1/32      10.4.4.4        131071U    --    --          --
10.10.10.2/32      10.4.4.4        131067N   131067 1/2/1       192.168.11.1
-------------------------------------------------------------------------------
No. of Prefix Bindings: 5

===============================================================================
LDP P2MP Bindings
===============================================================================
P2MP-Id           RootAddr
```

```
Interface         Peer           IngLbl    EgrLbl EgrIntf/    EgrNextHop
                                           LspId
-------------------------------------------------------------------------------
No Matching Entries Found

===============================================================================
LDP Service FEC 128 Bindings
===============================================================================
Type   VCId      SvcId      SDPId    Peer           IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
V-Eth  100       100        11       10.4.4.4       131066U 131065S 1522 1522
-------------------------------------------------------------------------------
No. of VC Labels: 1

===============================================================================
LDP Service FEC 129 Bindings
===============================================================================
AGI                              SAII                  TAII
Type            SvcId      SDPId    Peer           IngLbl  EgrLbl  LMTU RMTU
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
===============================================================================
*A:U-PE1# show service sdp
sdp        sdp-using
*A:U-PE1# show service sdp

==============================================================================
Services: Service Destination Points
==============================================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr        Deliver   Signal
------------------------------------------------------------------------------
11       9000     9000     10.4.4.4         Up   Up         LDP       TLDP
------------------------------------------------------------------------------
Number of SDPs : 1
------------------------------------------------------------------------------
==============================================================================
*A:U-PE1#  show service service-using

===============================================================================
Services
===============================================================================
ServiceId    Type      Adm  Opr  CustomerId Service Name
-------------------------------------------------------------------------------
30           i-VPLS    Up   Up   30
50           i-VPLS    Up   Up   50
99           Mirror    Up   Down 1
100          b-VPLS    Up   Up   1
2147483648   IES       Up   Down 1          _tmnx_InternalIesService
-------------------------------------------------------------------------------
Matching Services : 5
-------------------------------------------------------------------------------
===============================================================================
*A:U-PE1#  show service sdp
sdp        sdp-using
*A:U-PE1#  show service sdp-using

===============================================================================
SDP Using
===============================================================================
SvcId       SdpId              Type    Far End        Opr S* I.Label  E.Label
-------------------------------------------------------------------------------
100         11:100             Spok    10.4.4.4       Up     131066   131065
-------------------------------------------------------------------------------
Number of SDPs : 1
```

```
-------------------------------------------------------------------------------
===============================================================================
* indicates that the corresponding row element may have been truncated.
*A:U-PE1# show router ldp session

===============================================================================
LDP Sessions
===============================================================================
Peer LDP Id       Adj Type   State        Msg Sent  Msg Recv  Up Time
-------------------------------------------------------------------------------
10.4.4.4:0        Both       Established  13985     13985     0d 08:58:45
-------------------------------------------------------------------------------
No. of Sessions: 1
===============================================================================
*A:U-PE1#
```

CE_3500 verification output

```
CE_4_3500#show mac-address-table
Dynamic Address Count:                 11
Secure Address Count:                  0
Static Address (User-defined) Count:   0
System Self Address Count:             51
Total MAC addresses:                   62
Maximum MAC addresses:                 8192
Non-static Address Table:
Destination Address  Address Type  VLAN  Destination Port
-------------------  ------------  ----  --------------------
0007.eb94.73c2       Dynamic         40  FastEthernet0/2
0007.eb94.73c2       Dynamic         41  FastEthernet0/2
0007.eb94.73c2       Dynamic         42  FastEthernet0/2
0008.2196.f7a0       Dynamic         40  FastEthernet0/2
0008.2196.f7a0       Dynamic         41  FastEthernet0/1
0008.2196.f7a0       Dynamic         42  FastEthernet0/2
0008.219a.5660       Dynamic         40  FastEthernet0/2
0008.219a.5660       Dynamic         41  FastEthernet0/2
0008.219a.5660       Dynamic         42  FastEthernet0/2
0008.21bf.8340       Dynamic         42  FastEthernet0/3
0018.186e.4782       Dynamic          1  FastEthernet0/2
CE_4_3500#
```

S_3700 Verification output:

```
3750#show mac-address-table
          Mac Address Table
-------------------------------------------

Vlan    Mac Address       Type        Ports
----    -----------       --------    -----
 All    0100.0ccc.cccc    STATIC      CPU
 All    0100.0ccc.cccd    STATIC      CPU
 All    0180.c200.0000    STATIC      CPU
 All    0180.c200.0001    STATIC      CPU
 All    0180.c200.0002    STATIC      CPU
 All    0180.c200.0003    STATIC      CPU
 All    0180.c200.0004    STATIC      CPU
 All    0180.c200.0005    STATIC      CPU
 All    0180.c200.0006    STATIC      CPU
 All    0180.c200.0007    STATIC      CPU
 All    0180.c200.0008    STATIC      CPU
 All    0180.c200.0009    STATIC      CPU
```

```
 All    0180.c200.000a    STATIC      CPU
 All    0180.c200.000b    STATIC      CPU
 All    0180.c200.000c    STATIC      CPU
 All    0180.c200.000d    STATIC      CPU
 All    0180.c200.000e    STATIC      CPU
 All    0180.c200.000f    STATIC      CPU
 All    0180.c200.0010    STATIC      CPU
 All    ffff.ffff.ffff    STATIC      CPU
  50    0007.eb94.73c2    DYNAMIC     Gi1/0/1
  50    0007.ebb0.6680    DYNAMIC     Gi1/0/2
  50    0007.ebb0.6682    DYNAMIC     Gi1/0/2
  50    0008.2196.f7a0    DYNAMIC     Gi1/0/1
  50    0008.219a.5660    DYNAMIC     Gi1/0/1
  50    0008.21bf.8340    DYNAMIC     Gi1/0/1
  30    0007.eb94.7200    DYNAMIC     Gi1/0/3
  30    0007.eb94.7202    DYNAMIC     Gi1/0/3
  30    0008.2196.f300    DYNAMIC     Gi1/0/1
  30    0008.21bf.4aa0    DYNAMIC     Gi1/0/1
  30    0008.21bf.8140    DYNAMIC     Gi1/0/1
Total Mac Addresses for this criterion: 31
3750#
```

QoS verification on uPE2 for Customer_1:

```
*A:U-PE2#   clear service statistics sap 1/2/3:50.42 all
*A:U-PE2# show service id 50 sap 1/2/3:50.42 detail

===============================================================================
Service Access Points(SAP)
===============================================================================
Service Id         : 50
SAP                : 1/2/3:50.42              Encap             : qinq
QinQ Dot1p         : Default
Description        : (Not Specified)
Admin State        : Up                       Oper State        : Up
Flags              : None
Multi Svc Site     : None
Last Status Change : 11/09/2011 08:26:45
Last Mgmt Change   : 11/09/2011 16:43:26
-------------------------------------------------------------------------------
Sap Statistics
-------------------------------------------------------------------------------
Last Cleared Time     : 11/09/2011 17:17:56

                        Packets                 Octets
Forwarding Engine Stats
Dropped               : 0                       0
Off. HiPrio           : 1005                    126630
Off. LowPrio          : 0                       0
Off. Uncolor          : 0                       0

Queueing Stats(Ingress QoS Policy 2)
Dro. HiPrio           : 0                       0
Dro. LowPrio          : 0                       0
For. InProf           : 0                       0
For. OutProf          : 1035                    128910

Queueing Stats(Egress QoS Policy 1)
Dro. InProf           : 0                       0
Dro. OutProf          : 0                       0
For. InProf           : 1006                    126756
For. OutProf          : 70                      5320
```

```
-------------------------------------------------------------------------------
Sap per Queue stats
-------------------------------------------------------------------------------
                    Packets             Octets

Ingress Queue 1 (Unicast) (Priority)
Off. HiPrio          : 1005                126630
Off. LoPrio          : 0                   0
Dro. HiPrio          : 0                   0
Dro. LoPrio          : 0                   0
For. InProf          : 0                   0
For. OutProf         : 1005                126630

===============================================================================
*A:U-PE2#



*A:U-PE2# show service id 50 sap 1/2/3:50.41 detail

===============================================================================
Service Access Points(SAP)
===============================================================================
Service Id         : 50
SAP                : 1/2/3:50.41             Encap             : qinq
QinQ Dot1p         : Default
Description        : (Not Specified)
Admin State        : Up                      Oper State        : Up
Flags              : None
Multi Svc Site     : None
Last Status Change : 11/09/2011 08:26:45
Last Mgmt Change   : 11/09/2011 08:25:58
-------------------------------------------------------------------------------
Sap Statistics
-------------------------------------------------------------------------------
Last Cleared Time     : 11/09/2011 17:17:54

                    Packets             Octets
Forwarding Engine Stats
Dropped              : 0                   0
Off. HiPrio          : 1020                128520
Off. LowPrio         : 0                   0
Off. Uncolor         : 0                   0

-------------------------------------------------------------------------------
Sap per Queue stats
-------------------------------------------------------------------------------
                    Packets             Octets

Ingress Queue 1 (Unicast) (Priority)
Off. HiPrio          : 1020                128520
Off. LoPrio          : 0                   0
Dro. HiPrio          : 0                   0
Dro. LoPrio          : 0                   0
For. InProf          : 0                   0
For. OutProf         : 1020                128520

===============================================================================
*A:U-PE2#
```

UPE2 Qos Verification for Customer_2

*A:U-PE2# show service id 30 sap 1/2/3:30.42 detail

```
===============================================================================
Service Access Points(SAP)
===============================================================================
Service Id        : 30
SAP               : 1/2/3:30.42          Encap           : qinq
QinQ Dot1p        : Default
Description       : (Not Specified)
Admin State       : Up                   Oper State      : Up
Flags             : None
Multi Svc Site    : None
Last Status Change : 11/09/2011 08:26:45
Last Mgmt Change   : 11/09/2011 08:25:58
Sub Type          : regular
-------------------------------------------------------------------------------
Last Cleared Time     : 11/09/2011 17:13:27

                    Packets               Octets
Forwarding Engine Stats
Dropped             : 0                   0
Off. HiPrio         : 0                   0
Off. LowPrio        : 1000                126000
Off. Uncolor        : 0                   0

Queueing Stats(Ingress QoS Policy 3)
Dro. HiPrio         : 0                   0
Dro. LowPrio        : 0                   0
For. InProf         : 0                   0
For. OutProf        : 1000                126000

Queueing Stats(Egress QoS Policy 1)
Dro. InProf         : 0                   0
Dro. OutProf        : 0                   0
For. InProf         : 1                   89
For. OutProf        : 1045                129420
-------------------------------------------------------------------------------
Sap per Queue stats
-------------------------------------------------------------------------------
                    Packets               Octets

Ingress Queue 1 (Unicast) (Priority)
Off. HiPrio         : 0                   0
Off. LoPrio         : 1000                126000
Dro. HiPrio         : 0                   0
Dro. LoPrio         : 0                   0
For. InProf         : 0                   0
For. OutProf        : 1000                126000

Ingress Queue 11 (Multipoint) (Priority)
Off. HiPrio         : 0                   0
Off. LoPrio         : 0                   0
Off. Managed        : 0                   0
Dro. HiPrio         : 0                   0
Dro. LoPrio         : 0                   0
```

```
For. InProf          : 0                     0
For. OutProf         : 0                     0

Egress Queue 1
For. InProf          : 1                     89
For. OutProf         : 1055                  130180
Dro. InProf          : 0                     0
Dro. OutProf         : 0                     0
===============================================================================
*A:U-PE2#
*A:U-PE2# show service id 30 sap 1/2/3:30.42 detail

===============================================================================
Service Access Points(SAP)
===============================================================================
Service Id         : 30
SAP                : 1/2/3:30.42              Encap             : qinq
QinQ Dot1p         : Default
Description        : (Not Specified)
Admin State        : Up                       Oper State        : Up
Flags              : None
Multi Svc Site     : None
Last Status Change : 11/09/2011 08:26:45
Last Mgmt Change   : 11/09/2011 08:25:58
Sub Type           : regular
-------------------------------------------------------------------------------
Sap Statistics
-------------------------------------------------------------------------------
Last Cleared Time     : 11/09/2011 17:13:27

                     Packets                 Octets
Forwarding Engine Stats
Dropped              : 0                     0
Off. HiPrio          : 0                     0
Off. LowPrio         : 1000                  126000
Off. Uncolor         : 0                     0

Queueing Stats(Ingress QoS Policy 3)
Dro. HiPrio          : 0                     0
Dro. LowPrio         : 0                     0
For. InProf          : 0                     0
For. OutProf         : 1000                  126000

Queueing Stats(Egress QoS Policy 1)
Dro. InProf          : 0                     0
Dro. OutProf         : 0                     0
For. InProf          : 1                     89
For. OutProf         : 1070                  131320
-------------------------------------------------------------------------------
Sap per Queue stats
-------------------------------------------------------------------------------
                     Packets                 Octets

Ingress Queue 1 (Unicast) (Priority)
Off. HiPrio          : 0                     0
Off. LoPrio          : 1000                  126000
Dro. HiPrio          : 0                     0
Dro. LoPrio          : 0                     0
```

```
For. InProf          : 0                    0
For. OutProf         : 1000                 126000

Ingress Queue 11 (Multipoint) (Priority)
Off. HiPrio          : 0                    0
Off. LoPrio          : 0                    0
Off. Managed         : 0                    0
Dro. HiPrio          : 0                    0
Dro. LoPrio          : 0                    0
For. InProf          : 0                    0
For. OutProf         : 0                    0

Egress Queue 1
For. InProf          : 1                    89
For. OutProf         : 1070                 131320
Dro. InProf          : 0                    0
Dro. OutProf         : 0                    0
===============================================================================
*A:U-PE2#


*A:U-PE2# show service id 30 sap 1/2/3:30.41 detail

===============================================================================
Service Access Points(SAP)
===============================================================================
Service Id         : 30
SAP                : 1/2/3:30.41              Encap             : qinq
QinQ Dot1p         : Default
Description        : (Not Specified)
Admin State        : Up                       Oper State        : Up
Flags              : None
Multi Svc Site     : None
Last Status Change : 11/09/2011 08:26:45
Last Mgmt Change   : 11/09/2011 08:25:58
Sub Type           : regular
-------------------------------------------------------------------------------
Sap Statistics
-------------------------------------------------------------------------------
Last Cleared Time    : 11/09/2011 17:13:31

                        Packets                 Octets
Forwarding Engine Stats
Dropped              : 0                    0
Off. HiPrio          : 1000                 126000
Off. LowPrio         : 0                    0
Off. Uncolor         : 0                    0

Queueing Stats(Ingress QoS Policy 2)
Dro. HiPrio          : 0                    0
Dro. LowPrio         : 0                    0
For. InProf          : 0                    0
For. OutProf         : 1000                 126000

Queueing Stats(Egress QoS Policy 1)
Dro. InProf          : 0                    0
Dro. OutProf         : 0                    0
For. InProf          : 1001                 126089
```

```
For. OutProf         : 96                    7309
-------------------------------------------------------------------------------
Sap per Queue stats
-------------------------------------------------------------------------------
                        Packets                 Octets

Ingress Queue 1 (Unicast) (Priority)
Off. HiPrio          : 1000                  126000
Off. LoPrio          : 0                     0
Dro. HiPrio          : 0                     0
Dro. LoPrio          : 0                     0
For. InProf          : 0                     0
For. OutProf         : 1000                  126000

Ingress Queue 10 (Unicast) (Priority)
Off. HiPrio          : 0                     0
Off. LoPrio          : 0                     0
Dro. HiPrio          : 0                     0
Dro. LoPrio          : 0                     0
For. InProf          : 0                     0
For. OutProf         : 0                     0

Ingress Queue 11 (Multipoint) (Priority)
Off. HiPrio          : 0                     0
Off. LoPrio          : 0                     0
Off. Managed         : 0                     0
Dro. HiPrio          : 0                     0
Dro. LoPrio          : 0                     0
For. InProf          : 0                     0
For. OutProf         : 0                     0

Egress Queue 1
For. InProf          : 1001                  126089
For. OutProf         : 96                    7309
Dro. InProf          : 0                     0
Dro. OutProf         : 0                     0
===============================================================================
*A:U-PE2#
```

References:

Balakrishnan, R. (2008). In R. [1] Balakrishnan, *Advance QoS for Multi-Service IP/MPLS Networks.* Wiley Publishing Inc.

Bob-metcalfe. (n.d.). Bob-metcalfe-on-the-evolution-of-ethernet. (E. D. Manek Dubash, Interviewer)

IEEE Draft 3.7, “IEEE 802.1ah — Provider Backbone Bridges. (n.d.).

Luyuan Fang, C. S., Raymond Zhang, British Telecom, & Michael Taylor, AT&T. (n.d.). NEXT-GENERATION CARRIER ETHERNET TRANSPORT TECHNOLOGIES. *The Evolution of Carrier Ethernet Services — Requirements and Deployment Case Studies*.

Offering_Scalable_Layer2_Services_with_VPLS_and_VLL.pdf. (n.d.). Retrieved 09 2011, from http://www.brocade.com: http://www.brocade.com/downloads/documents/white_papers/Offering_Scalable_Layer2_Services_with_VPLS_and_VLL.pdf

QinqResults. (n.d.). Retrieved from http://groups.geni.net/geni/wiki/QinqResults

Xu, Z. (. (2010). In Z. (. Xu, *Designing and Implementating IP/MPLS Based Ethernet Layer 2 VPN Services.* Wiley Publishing Inc.