UNIVERSITY OF ALBERTA

Master of Science in Internetworking

MINT 709
Capstone Project

Implementation of the OAM (Operations, Administration, and Maintenance) over Provider Backbone Bridge (802.1ah) etwork.

By

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Chapter 1
Introduction to OAM

1.1 Introduction

OAM (Operation, Administration, and Maintenance) is a protocol, which can be used for monitoring the networks for faults and errors. OAM can be used to detect the faults and then raise the alarms, which can help in lowering the downtime of the network. If the OAM is not configured there will be requirement of more manual intervention, which in terms raises the expenses.

The OAM can be implemented as per various network end points such as Service provider, ISP and customer network domains without intervention of each other. We can run the OAM in three different networks without the intervention of other networks.

OAM has various functions, which include Fault Indication, Security management, Performance indication, diagnostic Functions.

1.2 OAM for Ethernet

In the increasing world of more deployment of vast enterprise Virtual Networks there is a huge need for maintaining the networks and is very critical. These networks can be maintained if there is a very good understanding between all the providers and OAM which helps in reducing the down time and make the packets flow smoothly, it is like the stethoscope which monitors the traffic and generates the unusual noise/alarm when something bad/ faults are Detected.

The OAM functions such as MPLS and VPLS OAM tools are used by the service providers for troubleshooting of networks. It also performs the continuity verification from one end of the customer to the Service provider network. It covers multiple domains.

With the increasing demand of Ethernet services in the backbone / core networks, providing Layer 2 VPN services brings more challenging to maintain then even. The OAM is an Ethernet tool to find out the faults in the entire network. Some of the functions of the OAM are discovery (Demark Point discovery and loopback capabilities), Remote Failure Indication (Faults in link), Fault Isolation (Network fault identification), Performance and Status Monitoring (Generates Alarm).

The tools used for OAM for monitoring and finding the faults are:

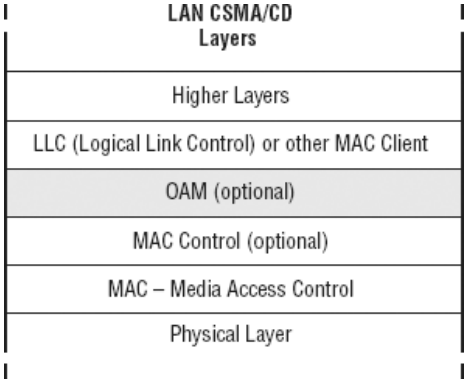
EFM OAM (802.3ah) – This is a Link layer protocol, monitors and troubleshooting any point-to-point Ethernet link used for connectivity verification between two locations .

CFM (802.1ag) – This is a Plain Ethernet, end-to-end protocol, monitors and troubleshooting all endpoints with the other domain or levels such as customer and Service provider. Customer, Service providers and ISP can define OAM as per their requirements in the same Network and this will not interfere with any other.

1.3 Ethernet in the First Mile (EFM) OAM (802.3ah)

This is a Link layer protocol, monitors and troubleshooting any point-to-point Ethernet link used for connectivity verification between two locations .Link Failure and Faults can be found by the Operators or service providers. EFM OAM is categorized in the Data Link layer of the OSI model.

Figure 1.1 OAM Sub layer in the Data Link Layer of OSI Model



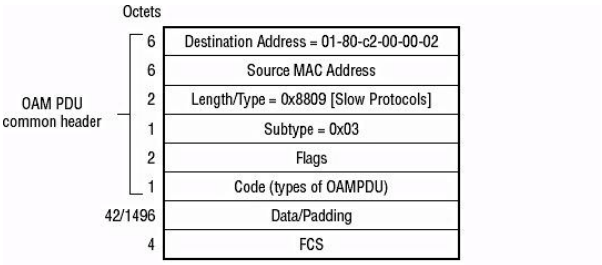
OAM PDU's are the hello packets that are sent to the peering devices to find the failure and health of the link, if there is no response in a certain time limit from the other end of the device then it puts the local port to down state. This can then generate the alarm too which will signify there is a faulty in the link.

1.3.1 EFM OAM PDUs

EFM OAM Protocol Data Units (PDUs) carry the information for the EFM OAM that is being sent form one device to the other device. When broadcasting the PDU's they are sent to the broadcast address of the OAM. All EFM OAM PDUs must be untagged.

The PDU are Ethernet frames slow protocols (protocol type 0x8809) with a subtype of 0x03 (OAM).

Figure 1.2 Packet Format for EFM OAM PDU



Flag

Bit	Flag
0	Link Fault
1	Dying Gasp
2	Critical Event
3	Local Evaluating
4	Local Stable
5	Remote Evaluating
6	Remote Stable
7-15	Reserved

Code

Code	OAMPDU
0x00	Informational
0x01	Event Notification
0x02	Variable Request
0x03	Variable Response
0x04	Loopback Control
0x05-0xFD	Reserved
0xFE	Organization Specific
0xFF	Reserved

There are three critical events that can affect the operation of link which are necessary to include in OAM PDU flag fields and need to be signaled. The events are Link Fault, Dying Gasp and critical Event. Link Fault signals if there is any fault in the receive direction flow of the local device, dying gasp indicates if there is unrecoverable failure and Critical Event tells us about unspecified critical Event

The code field in the OAM PDU indicates the types and EFM OAM peer signals other events using the type-length value (TLV) in the OAM PDUs.

Reference: Zhou Xu [5] says on page 777

“The informational OAM PDU (0x00) is used in the discovery process, and as the Hello packet to monitor the link health. The event notification OAM PDU (0x01) is used to signal link events (other than the three critical events represented in the flag bits).”

1.4 Ethernet Connectivity Fault Management

To monitor one or more than one service instance in terms of health conditions Ethernet CFM is used as it has the capability to cross multiple domains. CFM which is connectivity fault management is a connectivity checking mechanism with its own Ether-type value and hardware address to validate the health of EVC. We can also deploy in various network such as broadband where it becomes easy to detect any circuit failure in service domain and customer domain.

1.4.1 CFM Terminology

Reference: Zhou Xu [5] says on page 787
“

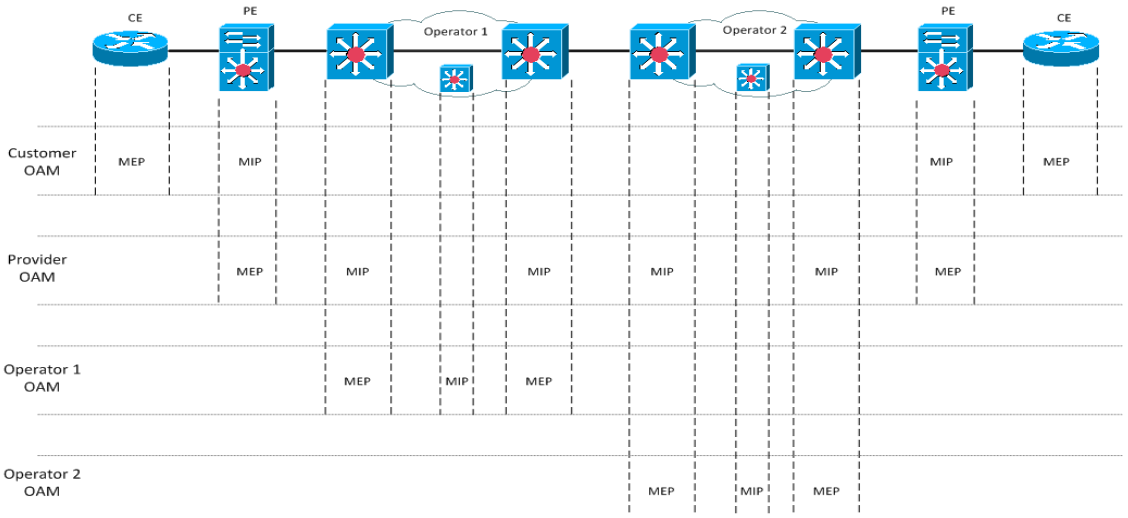
- **Maintenance Association (MA)** - A set of MEPs that have the same MA identifier and MD level within one service instance to verify the integrity of the service.

“

- **Maintenance Domain (MD)** - The Management Domain owned by maintenance entity and a management space for monitoring and administration of the network a unique maintenance level from 0 to 7 is assigned to each domain. The value depends on the type of domain; larger is the domain higher is the value. For the customer the value will be 7 and for the operator the value will be 0.
- **MA Endpoint (MEP)** - It defines the Boundary of a MD, initiate and terminate CFM messages.
- **MD Intermediate Point (MIP)** - It responds to Originating MEP. MIP only initiates the messages which are the response of loopback and link trace messages.
- **MIP Half-Function (MHF)** - It only gives the response to received PDU.

The following diagram shows the Ethernet CFM components described above with the MIP and MEP for the Customer network, provider network, Operator 1 and operator 2 networks. The largest domain is for customer and has the level 7

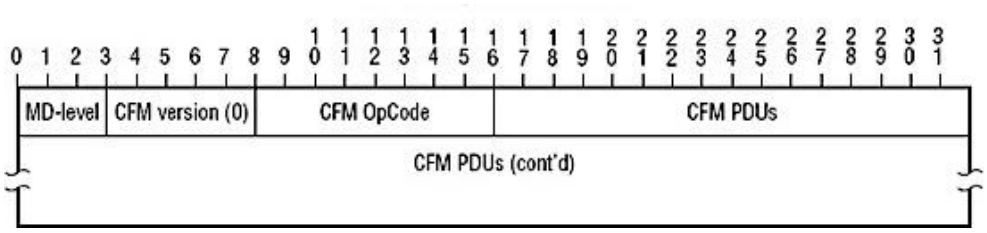
Figure 1.3 Ethernet CFM Components



1.4.2 CFM Messages

It has the protocol type 0x8902 for the CFM messages. All the CFM messages contain the common CFM header after every MAC header and CFM Opcode indicates the type of message. The CFM Message header is shown below which contains MD-level, CFM version, CFM Opcode and CFM PDU. It is of 32 bit long.

Figure 1.4 CFM Message Header



All the different PDU have different types associated with them and consists of five different CFM messages.

The following table describes the CFM Message types

Reference: Zhou Xu [5] says on page 791
“

Table 1.1 802.1ag CFM Message Types

OpCode	Type	PDUs in the Message	Function
1	Continuity Check Message (CCM)	CCM PDU contains flag, MAID, MEP-id, and status counters defined by ITU-T Y.1731. Contains CFM TLV: port status TLV, interface status TLV.	A MEP generates CCM messages to announce its local port and interface status. If the CCM is enabled, an MA tracks CCM messages from all MEPs. If an MA finds a CCM message missing or receives unexpected CCM messages, it sets corresponding error flags. CCM messages always use a protocol multicast MAC address as the destination MAC address.
2	Loopback Reply (LBR)	CFM LBR PDU with 8-bit flags contains an End TLV.	A MEP/MIP responds with a CFM LBR message when it receives an LBM destined to its own MAC address. The packet destination MAC address is the source MAC address of the LBM.
3	Loopback Message (LBM)	CFM LBM PDU with 8-bit flags contains an End TLV.	A MEP generates a CFM LBM when the CFM loopback test is performed. The packet is destined to the MAC address the loopback test intends to reach.
4	Link Trace	CFM LTR PDU	A MEP responds with a CFM LTR message

	Reply (LTR)	contains an LTR Egress Identifier TLV, a Reply Egress TLV, an LTM Egress Identifier TLV, and an End TLV.	when it receives a Link Trace Message (LTM) destined to its own MAC address. The packet destination MAC address is the source MAC address of the LTM.
5	Link Trace Message (LTM)	CFM LTM PDU contains an LTM Egress Identifier TLV and an End TLV.	A MEP generates a CFM LTM message when the CFM link trace test is performed. The packet is destined to the protocol multicast MAC address

“

Chapter 2
CFM Functions

2.1 Introduction

The three basic functions supported by CFM are

1. Loopback test
2. Link Trace Test
3. Continuity test

To perform the end to end fault management it is important to use these tests to find the failure point.

2.1.1 Loopback Test

This is a test to perform the availability of a MAC address destination as we perform the IP ping test normally. When the loopback test is performed we need to know the MAC address of the destination. The MIP in front of the fault in the path will report and LBR which indicates us what is the failure point. By issuing the command show *eth-efm cfm-stack-table* we can determine the different management points are configured in the system. The following figures show the stack stable table for both the UPE Routers.

Figure 2.1 CFM Stack Table for UPE-1

```
*A:uPE1#  show eth-cfm cfm-stack-table
===============================================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================================
CFM SAP Stack Table
===============================================================================
Sap                Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
1/2/3:50.*           5   Up          1          1   20 00:21:05:db:eb:8f ------
1/2/3:50.*           7 Both         10         10  MIP 00:21:05:db:eb:8f ------
===============================================================================
```

Figure 2.2 CFM Stack Table for UPE-2

```
*A:uPE2# show eth-cfm cfm-stack-table
===============================================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================================
CFM SAP Stack Table
===============================================================================
Sap                Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
1/2/3:50.*           5   Up          1          1   30 00:23:3e:0d:4b:13 ------
1/2/3:50.*           7 Both         10         10  MIP 00:23:3e:0d:4b:13 ------
===============================================================================
```

The command ‘ show eth-cfm mep 2- domain 1 association 1 loopback’ shows the MEP loopback information .It shows the number of replies that are received by sending the command for the particular mac address and number of counts to be send.

Figure 2.3 CFM Loopback Test on UPE-1

```
*A:uPE1# show eth-cfm mep 20 domain 1 association 1 loopback
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index          : 1                       Direction         : Up
Ma-index          : 1                       Admin             : Enabled
MepId             : 20                      CCM-Enable        : Enabled
IfIndex           : 37847040                PrimaryVid        : 268369970
FngState          : fngReset                ControlMep        : False
LowestDefectPri   : macRemErrXcon           HighestDefect     : none
Defect Flags      : None
Mac Address       : 00:21:05:db:eb:8f       CcmLtmPriority    : 7
CcmTx             : 84441                   CcmSequenceErr    : 0
Fault Propagation : disabled
Eth-1Dm Threshold : 3(sec)
Eth-Ais:          : Disabled
Eth-Tst:          : Disabled
CcmLastFailure Frame:
    None
XconCcmFailure Frame:
    None                                          Replies Received
-------------------------------------------------------------------------------
Mep Loopback Information
-------------------------------------------------------------------------------
LbRxReply         : 10                      LbRxBadOrder      : 0
LbRxBadMsdu       : 0                       LbTxReply         : 5
LbSequence        : 11                      LbNextSequence    : 16
LbStatus          : False                   LbResultOk        : True
DestIsMepId       : False                   DestMepId         : 0
DestMac           : 00:00:00:00:00:00       SendCount         : 0
VlanDropEnable    : True                    VlanPriority      : 7
Data TLV:
    None
*A:uPE1#
```

Figure 2.4 Test Command for CFM Loopback on UPE-1 and UPE-2

```
*A:uPE1# oam eth-cfm loopback 00:23:3e:0d:4b:13 mep 20 domain 1 association 1 send-count 5
Eth-Cfm Loopback Test Initiated: Mac-Address: 00:23:3e:0d:4b:13, out sap: 1/2/3:50.*
Sent 5 packets, received 5 packets [0 out-of-order, 0 Bad Msdu]
|

*A:uPE2#  oam eth-cfm loopback 00:21:05:db:eb:8f mep 30 domain  1 association  1 send-count 5
Eth-Cfm Loopback Test Initiated: Mac-Address: 00:21:05:db:eb:8f, out sap: 1/2/3:50.*
Sent 5 packets, received 5 packets [0 out-of-order, 0 Bad Msdu]
```

2.1.2 Link Trace Test

This test is used to get the information of the path till the MAC address. In the link trace test the MEP launches the LTM the same way loopback test but in this case MIP or MEP along the path sends a response and if there is a fault then the LBR is sent.

Figure 2.5 CFM Link Trace Test for uPE1 and uPE2

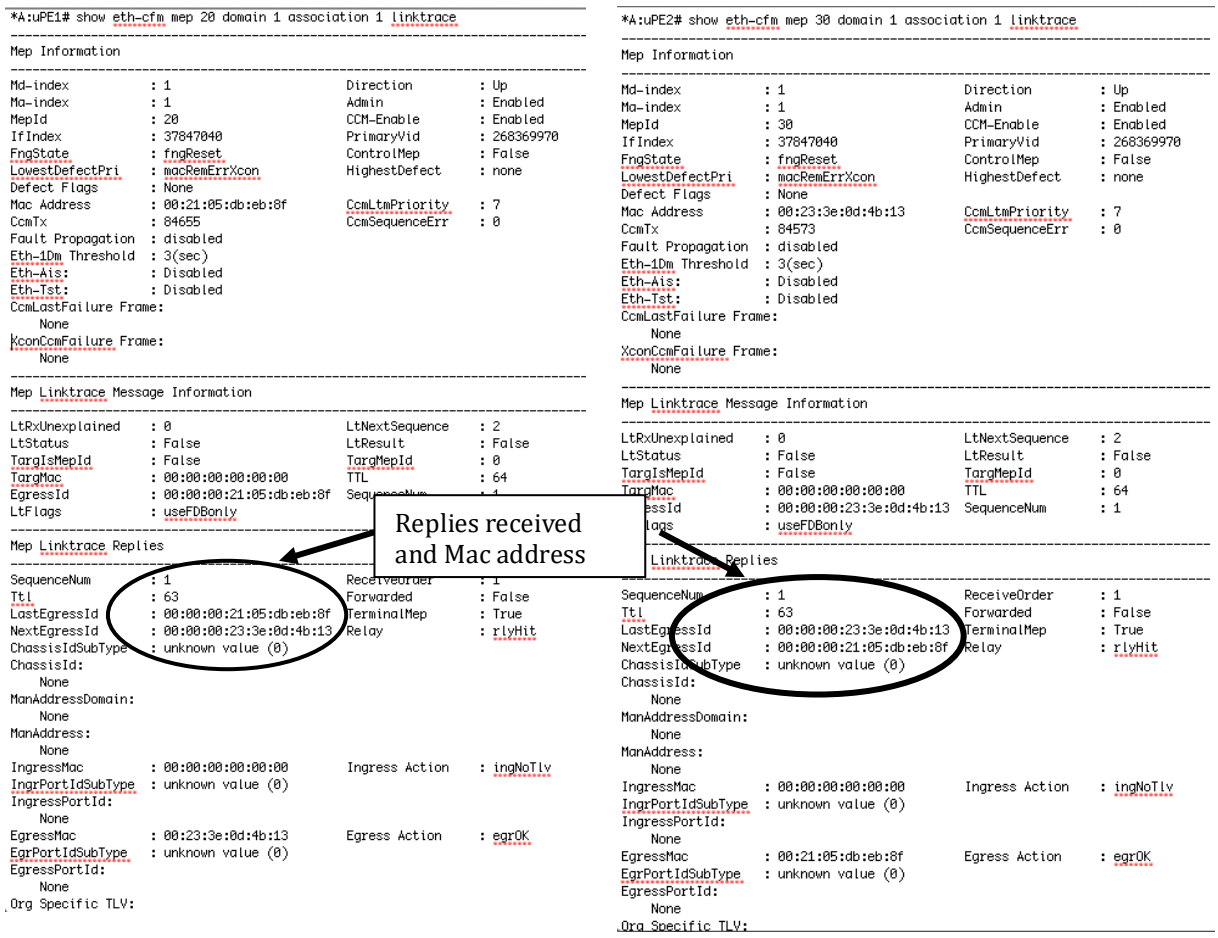


Figure 2.6 CFM Link Trace Test result for UPE-1

```
*A:uPE1#  oam eth-cfm linktrace 00:23:3e:0d:4b:13 mep 20 domain 1 association 1
Index Ingress Mac          Egress Mac          Relay      Action
----- -------------------- -------------------- ---------- ----------
1     00:00:00:00:00:00    00:23:3E:0D:4B:13    rlyHit     terminate
----- -------------------- -------------------- ---------- ----------
No more responses received in the last 6 seconds.
```

2.1.3 Continuity Check Test

The Continuity check test send continuity check message to every MEP in the defined direction as shown below

```
sap 1/2/3:50.* create
        eth-cfm
            mep 20 domain 1 association 1 direction up
                ccm-enable
                no shutdown
            exit
        exit
```

Continuity check messages use the group destination MAC address as the message destination MAC address to send the messages. These messages are received and seen by the MEP's in the same MA. If the Continuity check test is enabled on both the PE with similar values then they send the continuous messages to all MEP.MA keeps the messages and buy using these received messages check the network failure accordingly. The network failure can be as:

- Loss of Connectivity
- Incorrect Configuration of Service (Merging of Services)
- Forwarding Loops
- Unidirectional Failure

Reference: Zhou Xu [5] says on page 804
"

Table 2.1 CFM CCM Error Flags		
Error	**Priority**	**Description**
None	0	No defect reported.
defRDICCM	1	The last CCM received by this MEP from a remote MEP contained a Remote Defect Indication (RDI) bit.
defMACstatus	2	The last CCM received by this MEP from a remote MEP indicated that the MAC address associated with the transmitting MEP is reporting an error status via the Port Status TLV or Interface Status TLV.
defRemoteCCM	3	This MEP is not receiving CCMs from other MEPs in its configured list (remote-MEP-id list).
defErrorCCM	4	This MEP is receiving invalid CCMs.
defXconCCM	5	This MEP is receiving CCMs that belong to some other MA.

"

CHAPTER 3
OAM Functions (IP/MPLS network)

3.1 Introduction

In the IP/MPLS network OAM is a tool to verify the connectivity and perform the tests.OAM functions such as IP, LSP, SDP, CPE, SVC Ping and IP, LSP Trace.

3.2 OAM Tools

The following are the OAM tools that are used to check connectivity and report the problem. Some of them are Alcatel-Lucent proprietary tools.

Reference: Zhou Xu [5] says on page 805

“

Table 3.1 OAM Tools in IP/MPLS Networks

Function	Description
IP-ping	Used to test the router's IP connectivity using ICMP Echo Request/Reply packets
IP-trace-route	Used to locate the failure in IP routing or to discover the forwarding path to a particular IP prefix
LSP-ping	Used to test the connectivity of the LSP (created by RSVP-TE or LDP) using MPLS Echo Request/Reply packets
LSP-trace	Used to locate a failure of an LSP or to discover the path of an LSP
SDP-ping	Used to test the service reachability of the SDP from one PE router to another. The SDP-ping packet is always sent through the data plane using the SDP's tunnel encapsulation with an MPLS RA (1) label. The reply packet can come from the control plane or the data plane depending on the request specified in the SDP-ping packet (Alcatel-Lucent proprietary)
CPE-ping	Used to locate a PE router that is locally attached to a particular customer IP station (IP address) (Alcatel-Lucent proprietary)
SVC-ping	Used to test the connectivity and attributes of VPN services (Alcatel-Lucent proprietary)

“

3.2.1 LSP-ping

LSP ping is a troubleshooting mechanism tool to find data plane failure in MPLS Network. It does not work as the normal ICMP ping because with that it becomes hard to detect any data plane failure in end-to-end LSP. The LSP ping data packet is encapsulated the same way as data traffic is and is sent to the destination of FEC. The Edge LER router responses to the Echo Request packet with the Echo reply packet The figure below shows the Response from the 10.1.1.50/32 with the 0 packet loss.

Figure 3.1 LSP test on UPE 1 towards UPE2

```
*A:uPE1# oam lsp-ping prefix 10.1.1.50/32
LSP-PING 10.1.1.50/32: 80 bytes MPLS payload
Seq=1, send from intf to-PE1, reply from 10.1.1.50
       udp-data-len=32 ttl=255 rtt=1.19ms rc=3 (EgressRtr)

---- LSP 10.1.1.50/32 PING Statistics ----
1 packets sent, 1 packets received, 0.00% packet loss
round-trip min = 1.19ms, avg = 1.19ms, max = 1.19ms, stddev = 0.000ms
```

3.2.2 LSP-trace

LSP trace is used to find the path and we can use it to get the failure point location to. We will get the reply back till the failure point and using that we can determine the defects. The router sends the MPLS echo request packets with the incremental TTL value from 1. Each router reply backs with MPLS echo reply packets on the receipt f the MPLS request packets. This gives us the information if the router is LSR or the ELSR. We can find the downstream interface as the packets are constantly sent till the recipient of error code or the response from ELSR The following is the figure showing the trace till 10.1.1.50/32, which is the system IP of the UPE2. When it gets the reply from 10.1.1.50 it shows it is the Egress router. The same way is the trace taken from UPE2 towards UPE1.

Figure 3.2 LSP Trace on UPE1 and UPE2

```
*A:uPE1# oam lsp-tr prefix 10.1.1.50/32
lsp-trace to 10.1.1.50/32: 0 hops min, 0 hops max, 104 byte packets
1  10.1.1.15  rtt=1.26ms rc=8(DSRtrMatchLabel)
2  10.1.1.3  rtt=1.21ms rc=8(DSRtrMatchLabel)
3  10.1.1.12  rtt=1.29ms rc=8(DSRtrMatchLabel)
4  10.1.1.50  rtt=1.37ms rc=3(EgressRtr)
*A:uPE1#
```

```
*A:uPE2#  oam lsp-tr prefix 10.1.1.20/32
lsp-trace to 10.1.1.20/32: 0 hops min, 0 hops max, 104 byte packets
1  10.1.1.12  rtt=1.18ms rc=8(DSRtrMatchLabel)
2  10.1.1.3  rtt=11.2ms rc=8(DSRtrMatchLabel)
3  10.1.1.15  rtt=2.88ms rc=8(DSRtrMatchLabel)
4  10.1.1.20  rtt=1.27ms rc=3(EgressRtr)
*A:uPE2#
```

3.2.3 SDP-ping

To check the SDP Tunnel connectivity from one PE to other PE we use the SDP Ping. It performs in-band unidirectional or round trip connectivity test by carrying the traffic over the backbone network. The SDP ping response can be received in two ways:

- Out-of-band in the control plane.
- In-band using the data plane for a round-trip test.

Using the SDP transport tunnel encapsulation the packet is generated from one PE for the other end PE, same way the VPN data traffic with only the exception if there is any lag. When the PE receives the SDP ping packet, it removes the transport label and sent to the control panel for processing. Now the PE has two options to reply to the received packet and these are the out of band i.e. Control plane and Out of band i.e. Data plane.

The figure below shows the SDP ping taken from UPE 1 with SDP 20 to SP 14. It shows the actual IP address with the Path MTU. The status both administrative and operative is up.This is a round trip test i.e. data plane test as you can see the profile is out means out of band. The out of band uses the local egress SDP ID and an expected remote SDP ID. The local SDP is 20 and the remote SDP is 14.

Figure 3.3 SDP –Ping Test on UPE 1 from SDP 20 to SDP 14

```
*A:uPE1# oam sdp-ping 20 resp-sdp 14
Err SDP-ID Info             Local           Remote
-------------------------------------------------
    SDP-ID:                 20              14
    Administrative State:   Up              Up
    Operative State:        Up              Up
    Path MTU:               9000            N/A
    Response SDP Used:                      Yes

    IP Interface State:     Up
    Actual IP Address:      10.1.1.20       10.1.1.15
    Expected Peer IP:       10.1.1.15       10.1.1.20

    Forwarding Class        be              be
    Profile                 Out             Out

Request Result: Sent - Reply Received
RTT: 1.01(ms)
```

This is the other test done from PEW with the local SDP 12 to the Remote SDP 15.

Figure 3.4 SDP – Ping Test on PE 2 from SDP 12 to SDP 15

```
*A:PE2# oam sdp-ping 12 resp-sdp 15
Err SDP-ID Info              Local           Remote
-------------------------------------------------------
    SDP-ID:                  12              15
    Administrative State:    Up              Up
    Operative State:         Up              Up
    Path MTU:                9000            N/A
    Response SDP Used:                       Yes

    IP Interface State:      Up
    Actual IP Address:       10.1.1.12       10.1.1.15
    Expected Peer IP:        10.1.1.15       10.1.1.12

    Forwarding Class         be              be
    Profile                  Out             Out

Request Result: Sent - Reply Received
RTT: 1.11(ms)
```

3.2.4 Service Ping

The type of test performs the end-to-end connectivity test for the specific service instead of bunch of services in the SDP. This is a level higher than SDP ping test as it is more focused on the individual service between the two PE. The service ping verifies the round trip connectivity with the delay from the far-end PE router. It is similar to pseudo wire ping. Some of the tests like round trip path verification, service existence, service dynamic configuration verification, tunnel connectivity and VC label mapping verification is done using the service ping on GRE and MPLS tunnels.

The following figure shows the service ping using the IP address of the Far end PE router on the SDP 100.

Figure 3.5 SVC - Ping on PE1 and PE2

```
*A:PE2# oam svc-ping 10.1.1.15 service 100 local-sdp remote-sdp
Service-ID: 100

Err Info                 Local           Remote
-------------------------------------------------------
    Type:                VPLS            VPLS
    Admin State:         Up              Up
    Oper State:          Up              Up
    Service-MTU:         1536            1536
    Customer ID:         1               1

    IP Interface State: Up
    Actual IP Addr:      10.1.1.12       10.1.1.15
    Expected Peer IP:    10.1.1.15       10.1.1.12

    SDP Path Used:       Yes             Yes
    SDP-ID:              12              15
    Admin State:         Up              Up
    Operative State:     Up              Up
    Binding Admin State:Up               Up
    Binding Oper State: Up               Up
    Binding VC ID:       100             100
    Binding Type:        Mesh            Mesh
    Binding Vc-type:     Ether           Ether
    Binding Vlan-vc-tag:N/A              N/A

    Egress Label:        131066          131065
    Ingress Label:       131065          131066
    Egress Label Type:  Signaled         Signaled
    Ingress Label Type: Signaled         Signaled

Request Result: Sent - Reply Received
```

```
*A:PE1# oam svc-ping 10.1.1.12 service 100 local-sdp remote-sdp
Service-ID: 100

Err Info                 Local           Remote
-------------------------------------------------------
    Type:                VPLS            VPLS
    Admin State:         Up              Up
    Oper State:          Up              Up
    Service-MTU:         1536            1536
    Customer ID:         1               1

    IP Interface State: Up
    Actual IP Addr:      10.1.1.15       10.1.1.12
    Expected Peer IP:    10.1.1.12       10.1.1.15

    SDP Path Used:       Yes             Yes
    SDP-ID:              15              12
    Admin State:         Up              Up
    Operative State:     Up              Up
    Binding Admin State:Up               Up
    Binding Oper State: Up               Up
    Binding VC ID:       100             100
    Binding Type:        Mesh            Mesh
    Binding Vc-type:     Ether           Ether
    Binding Vlan-vc-tag:N/A              N/A

    Egress Label:        131065          131066
    Ingress Label:       131066          131065
    Egress Label Type:  Signaled         Signaled
    Ingress Label Type: Signaled         Signaled

Request Result: Sent - Reply Received
```

CHAPTER 4
OAM Functions (VPLS Network)

4.1 Introduction

Reference: Zhou Xu [5] says on page 820

"Ethernet OAM tools can be used to test the health of the data-forwarding path of the ACs and the pseudo wires. The purpose of VPLS FDB OAM tools is to test the health of the FDB and to verify the forwarding behavior of the VPLS services.

Table 4.1 VPLS FDB OAM Tools

Function	Description
MAC-ping	Used to find the egress PE router (the router that has a local SAP) for a particular customer MAC address.
MAC-trace	Used to find the VPLS forwarding path to the egress PE router to a particular customer MAC address.
MAC Populate	Used to add MAC addresses to the FDB of a VSI for OAM purposes.
MAC Purge	Used to remove MAC addresses from the FDB of a VSI.
CPE-ping	Used to locate a PE router that is locally attached to a particular customer IP station (IP address).

"

4.2 MAC-ping

As the UPE routers knows about the MAC address of their customers site, it becomes easy to for the MAC ping from other sides. The MAC ping is a mechanism to know if the particular MAC address exists or not. The MAC ping is the extension of the LSP Ping. The UPE sends the MAC ping packet to the other end UPE and then the router checks if it has the matching MAC address in the local SAP and then it responds to the other UPE. If the destination MAC address is in its own database, it does not forward any packet. The Mac ping is never forwarded to the customer's network. The following figure shows the MAC ping test for the broadcast MAC address in service 30 and 50. When this command is sent with the broadcast mac address it is flooded to all the PE routers will respond to the query if it has in local SAP.

Figure 4.1 MAC Ping for SDP 50 to broadcast MAC Address

```
*A:uPE1# oam mac-ping service 50 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                                    Path     RTT
------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.20:sap1/2/3:50.*                  No FIB on Egress Self     3.65ms
1   10.1.1.50:sap1/2/3:50.*                  No FIB on Egress In-Band  1.03ms
------------------------------------------------------------------------------
*A:uPE1# oam mac-ping service 30 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                                    Path     RTT
------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.20:sap1/2/3:30.*                  No FIB on Egress Self     2.98ms
1   10.1.1.50:sap1/2/3:30.*                  No FIB on Egress In-Band  3.17ms
```

Figure 4.2 MAC Ping for SDP 30 to broadcast MAC Address

```
*A:uPE2# oam mac-ping service 30 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                                    Path     RTT
------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.50:sap1/2/3:30.*                  No FIB on Egress Self     3.52ms
1   10.1.1.20:sap1/2/3:30.*                  No FIB on Egress In-Band  3.22ms
------------------------------------------------------------------------------
*A:uPE2# oam mac-ping service 50 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                                    Path     RTT
------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.50:sap1/2/3:50.*                  No FIB on Egress Self     3.03ms
1   10.1.1.20:sap1/2/3:50.*                  No FIB on Egress In-Band  3.25ms
------------------------------------------------------------------------------
*A:uPE2#
```

4.3 MAC – Trace

Mac trace is to get the detailed information regarding the packets being sent to the destination PE router. The MAC trace is not sent to the customer's network. The MAC trace increments the TTL value by each hop from source to the destination but this TTL increment is in the CV-label TTL not in the transport label. The MAC trace can be done for both the control plane and the data plane as per the requirement. MAC trace is very helpful in H-VPLS services as there are more PE routers in the path and it becomes easy to find the easy hop in the route to the particular destination. The following figure clearly shows the Mac trace in service 50 to the destination broadcast Mac address. The command is initiated from the UPE1 and trace is made till the UPE2. It clearly shows the type of VPLS service is responding to it and what are the SDP it is being transferred to. It also shows the upstream SDP and downstream SDP VPLS too.

Figure 4.3 Mac trace for SDP 50 on UPE 1

```
*A:uPE1# oam mac-trace service 50 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id         Rcvd-on                  Path     Nexthop RTT
------------------------------------------------------------------------------
[Send request TTL: 1, Seq. 1, Size 186]
1     1   1   10.1.1.20       sap:1/2/3:50.*           Self     Flood   1.44ms

2     1   1   10.1.1.15       cpm-bvpls                In-Band  Flood   2.15ms
    Upstream Spoke-sdp 14:100 To: n/a, Ing-label: 131065, Sig: LDP
    Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
    Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 186]
3     2   1   10.1.1.12       cpm-bvpls                In-Band  Flood   2.29ms
    Upstream Mesh-sdp 12:100 To: n/a, Ing-label: 131065, Sig: LDP
    Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
    Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 186]
4     3   1   10.1.1.50       cpm                      In-Band  Flood   2.60ms
    Upstream Spoke-sdp 30:100 To: n/a, Ing-label: 131066, Sig: LDP
    Downstream Spoke-sdp 30:100 To: 10.1.1.12, Egr-label: 131071, Sig: LDP

[Send request TTL: 4, Seq. 1, Size 186]
5     4   1   10.1.1.50       sap:1/2/3:50.*           In-Band  Flood   1.20ms
```

CHAPTER 5
Network Topology

5.1 Summary

The network consists of Alcatel routers and the cisco switches for configurations and implementation of the network. Alcatel routers are being used as P, PE and UPE because these routers can implement 802.1ah in our lab.

5.2 Wiring

Item	Description
Wired By	Arsh Saini
Cable Type	Twisted Pair Cable CAT-5e
Central Wiring Location	MINT LAB

The Network used for this project has following devices:

1. Alcatel 7710 Router
2. Alcatel 7750 Router
3. Cisco 3560-x Switch
4. Cisco 3750 Switch
5. PC having Ubuntu OS
6. Alcatel Card type iom-9g and mda type c8-10/100eth-tx for PE and UPE routers
7. Alcatel Card type iom-20g and mda type m20-1gb-tx for P router

Abbreviations used in the Network Diagram:

1. P- Provider Router
2. PE- Provider Edge Router
3. UPE- User Provider Edge Router
4. CE- Customer Edge Router
5. SDP- Service Distribution Path
6. IP- Internet Protocol
7. MPLS- Multi Protocol Label Switching
8. R1 – Rack

The table below shows the type of ports associated in the network and their type from the end point to the service provider.

Table 5.1 Types of Port

Point		Ether Type	Ports	Tag Type	Port Type	Description
From	**To**					
Internal Provider connectivity		0x88e7	uPE: 1/2/1, 1/2/3 PE: 1/2/1, 1/2/4	Tagged	Q-in-Q	802.1ag
UPE	CE Switch	0x88a8	Q-in-Q port 1/2/3	Tagged	Q-in-Q	802.1ad
CE	UPE	0x8100	Trunk Port: 1/0/1	Tagged	Trunk Port: 802.1Q	802.1q
CE	Customer Switch	0x8100	Q-Tunnel port: 1/0/2, 10/3.	Tagged	Tunnel Port: 802.1Q	802.1q
Customer Switch	CE	0x8100	0/2	Tagged	Trunk Port: 802.1Q	802.1q
Customer Switch	End Point	0x800	0/1, 0/3	Tagged	Access port	0x8100

IP addressing for the end points for two customers in Service - VLAN 50,30 and Customer - VLAN 41, 42are described below. End point was connected to only S-VLAN 50 and C-VLAN 41 for the tests as required by the project.

Table 5.2 IP addressing and VLAN associated.

Customer	Device IP	Device Mac-address	C-VLAN	S-VLAN
1	172.16.4.1	00:22:4d:69:79:0a	41	50
1	172.16.4.2	00:22:4d:6a:05:cb	41	50
1	172.16.4.1	Same Ports (computers) were used for testing purposes.	42	50
1	172.16.4.2		42	50
2	172.16.4.1		41	30
2	172.16.4.2		41	30
2	172.16.4.1		42	30
2	172.16.4.2		42	30

The tests performed in the above chapters has been initiated from and terminated as below:

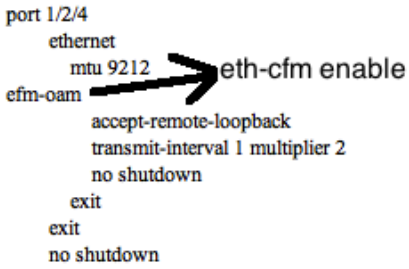
Table 5.3: Initiation and termination of tests

Test	End Points 1	End Point 2
CFM Stack test	UPE1	UPE2
CFM loopback Test	UPE1	UPE2
CFM Link Trace Test	UPE1	
LSP Test	UPE1	UPE2
LSP Trace	UPE1	UPE2 (10.1.1.50/32)
LSP Trace	UPE2	UPE1 (10.1.1.20/32)
SDP Ping Test	UPE1- SDP 20	UPE1-SDP 14
SDP Ping Test	PE2- SDP 12	PE2 – SDP 15
Service Ping	PE1 – SDP 100	PE2 - SDP100
SVC Ping	PE2 – SDP 100	PE2 - SDP 100
Mac Ping	SDP 50	Broadcast Mac
Mac Ping	SDP 30	Broadcast Mac
Mac Trace	UPE1 – SDP 50	Broadcast Mac

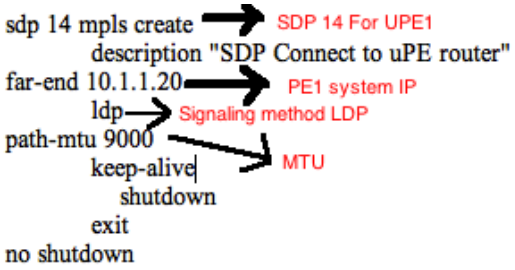
5.3 Implementation

Implementation of 802.1ag and 802.1ah

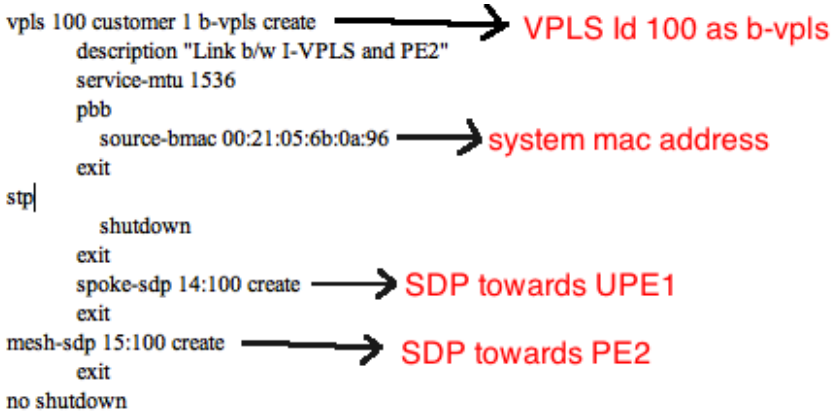
1. Setup a Network so that we have at least two locations for the customer.
2. Configure the IP address and run OSPF routing protocol.
3. Setup different VLANs for service provider and Customers at CE and customer switch respectively. Here VLAN 50 and 30 has been added as a service provider VLAN for different customer and VLAN 41 and 42.
4. Configure MPLS and run LDP or RSVP- TE between PE routers.
5. Configure port as access ports if it is connected to the customer end otherwise configure it as network port. Enable efm-oam on the port.



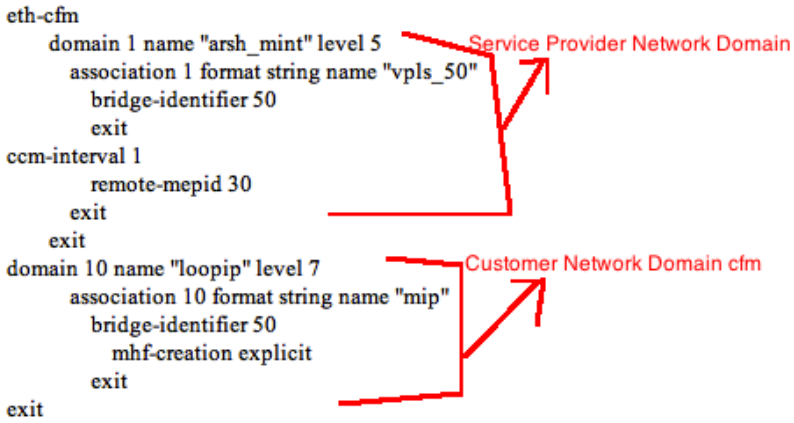
6. Configure SDP (service distribution point) defining the far end, MTU and signaling method



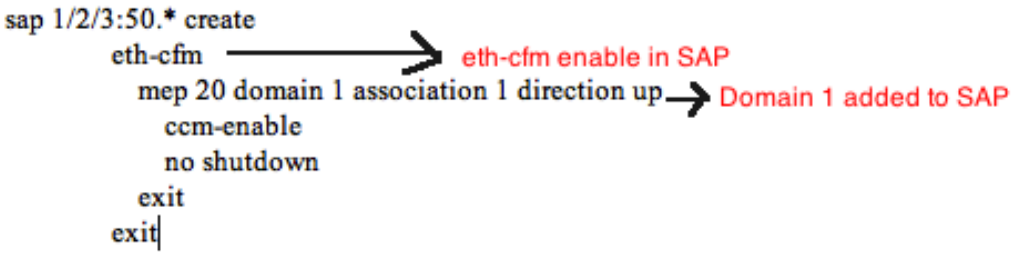
7. Configure i-VPLS and b-VPLS. Bind the mesh SDP (for other end PE router) and spoke SDP (for UPE router) in b-VPLS.



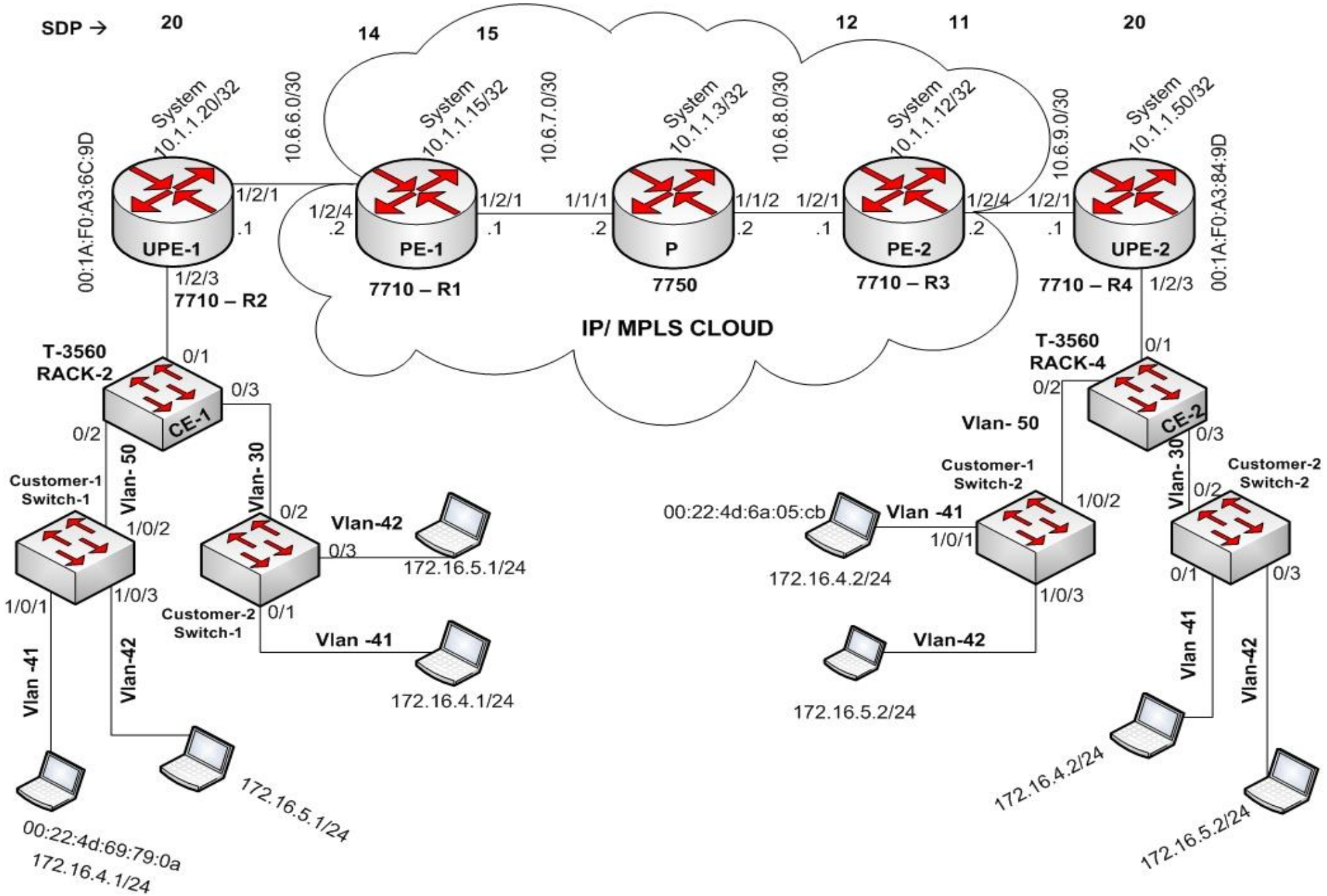
8. Configure Eth- CFM (Ethernet - Connectivity Fault Management) with two different domains one for the service provider and other for the customer. Here the domain has been created with name arsh_mint with level 5 for service provider network and loopip for the customer network with level 7. The VPLS 50 as a bridge-identifier has been added.



9. MEP (Maintenance End Point) with domain 1 will be added to the VPLS 50 in SAP.



5.4 Network Diagram

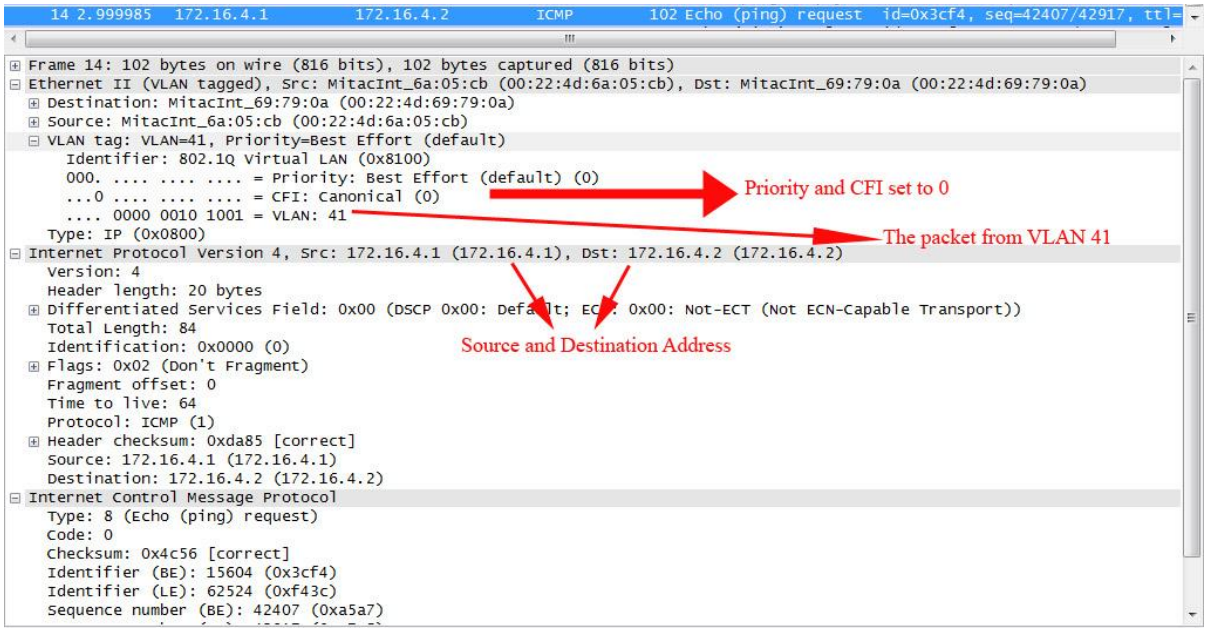


CHAPTER 6
Wire Shark Traces and Conclusion

6.1 Packet walkthrough

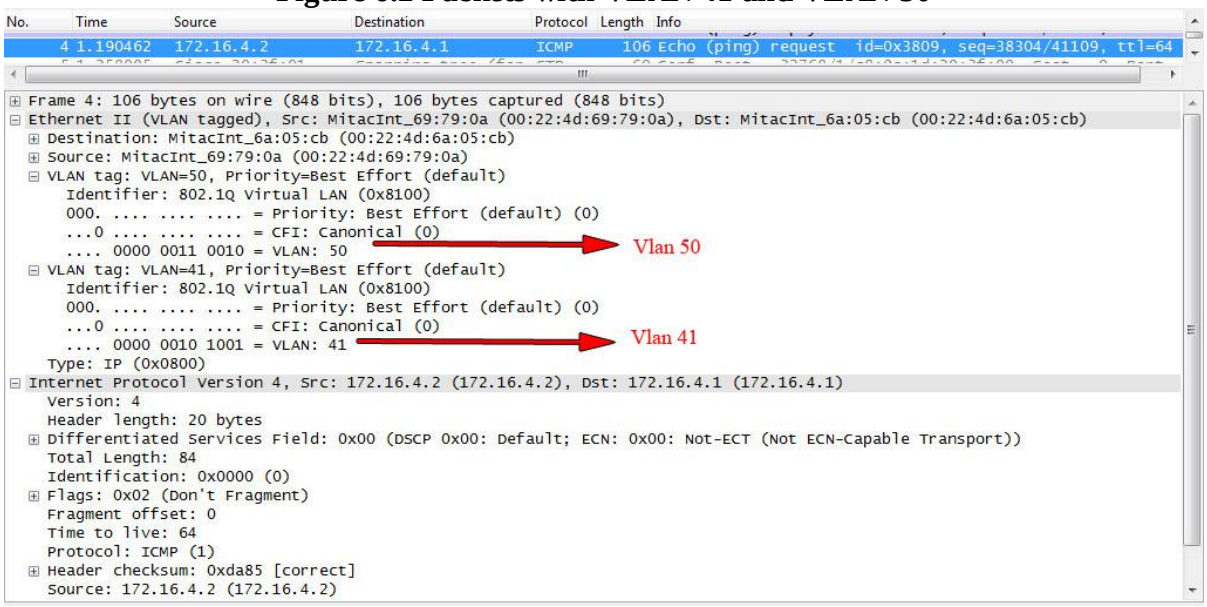
The packet is generated from client 1 on the Customer 1 Switch 1 VLAN 41.
Source IP address → 172.16.4.1
Destination IP address → 172.16.4.2
Packet Type → ICMP (Ping)
VLAN → 41
Priority → Best Effort

Figure 6.1 Packet from the client



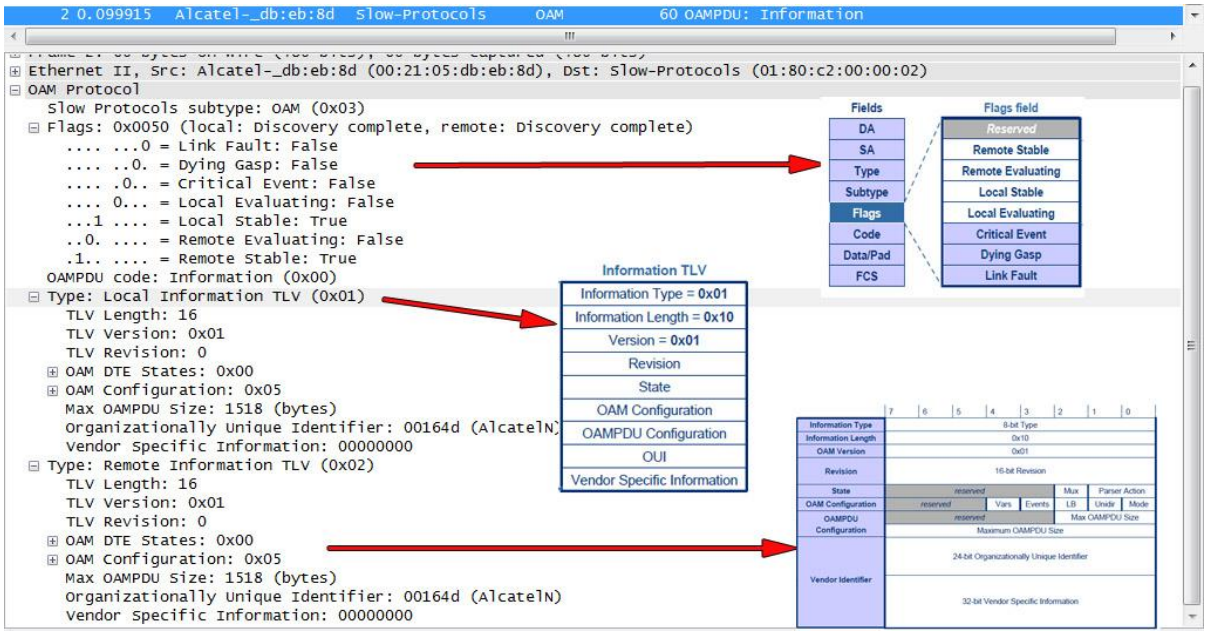
The packet moves from the CE switch to the UPE router. At this point the CE attaches the VLAN 50 tag to VLAN 41 tagged packet. This makes S-Vlan as 50 and C-Vlan as 41. This way we can carry 4096 X 4096 VLANS. The type is 0x08100 ie for 802.1aq for Virtual Vlan.

Figure 6.2 Packets with VLAN 41 and VLAN 50



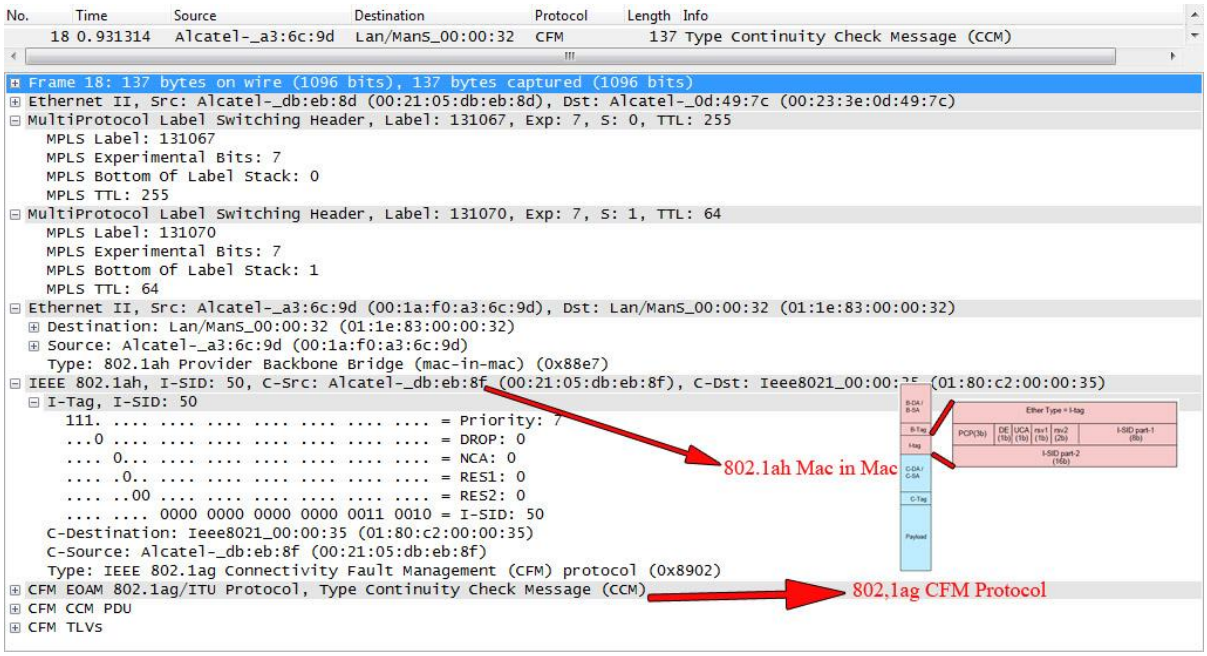
OAM (operation, administration and management) packet is being send between the routers to get to know about the link status and then can generate the alarm if any issues are found. The OAM protocol has Flags, local information TLV and Remote Information TLV. The Flag bit sets to 0 or 1 as per the fault or event. The local and remote discovery is completed and is shown in the packet below. OAM packets are slow protocols and these protocols are used to control operational characteristics of the Ethernet device.

Figure 6.3 OAM packets



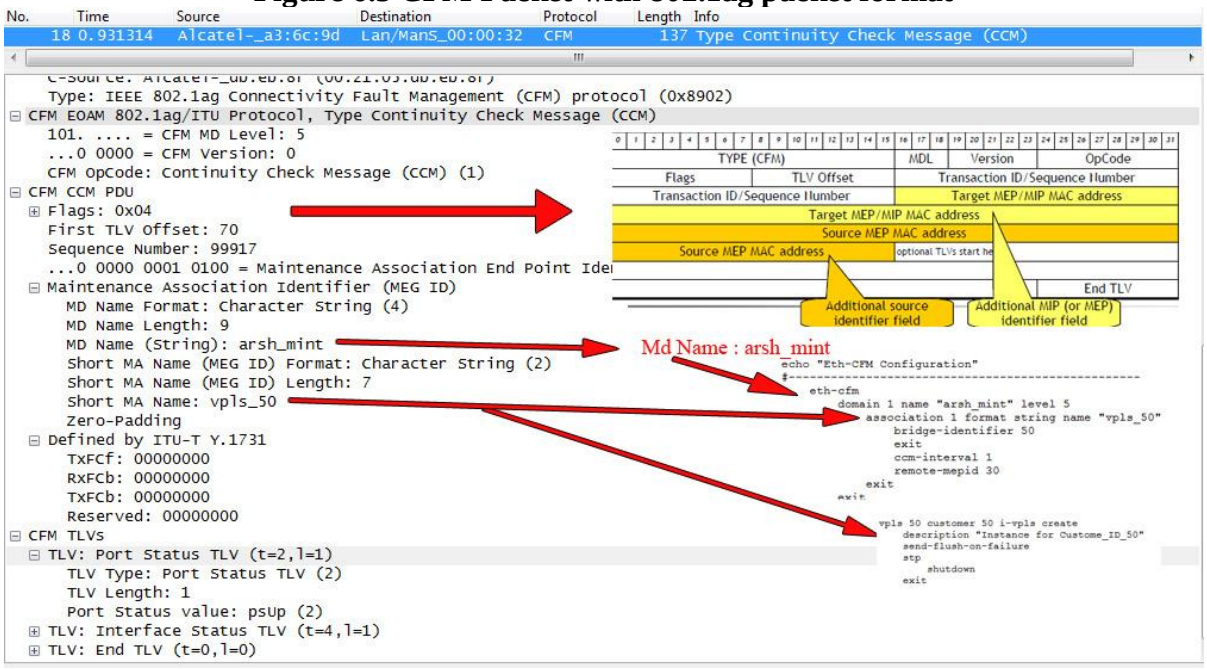
The packet below shows CFM (Connectivity fault management) packet. MPLS Label 131067 as a transport label and 131070 as a VC-label is added to the packet send by UPE router to the PE router. UPE Encapsulates the Received frame in 802.1ah mac-in-mac as shown in figure 7.4. The packet has I-SID= 50 with B-source address and B-destination address. The packet includes the 802.1ag/ITU protocol message, the type is known as Continuity Check Message

Figure 6.4 CFM Packet with 802.1ah packet format



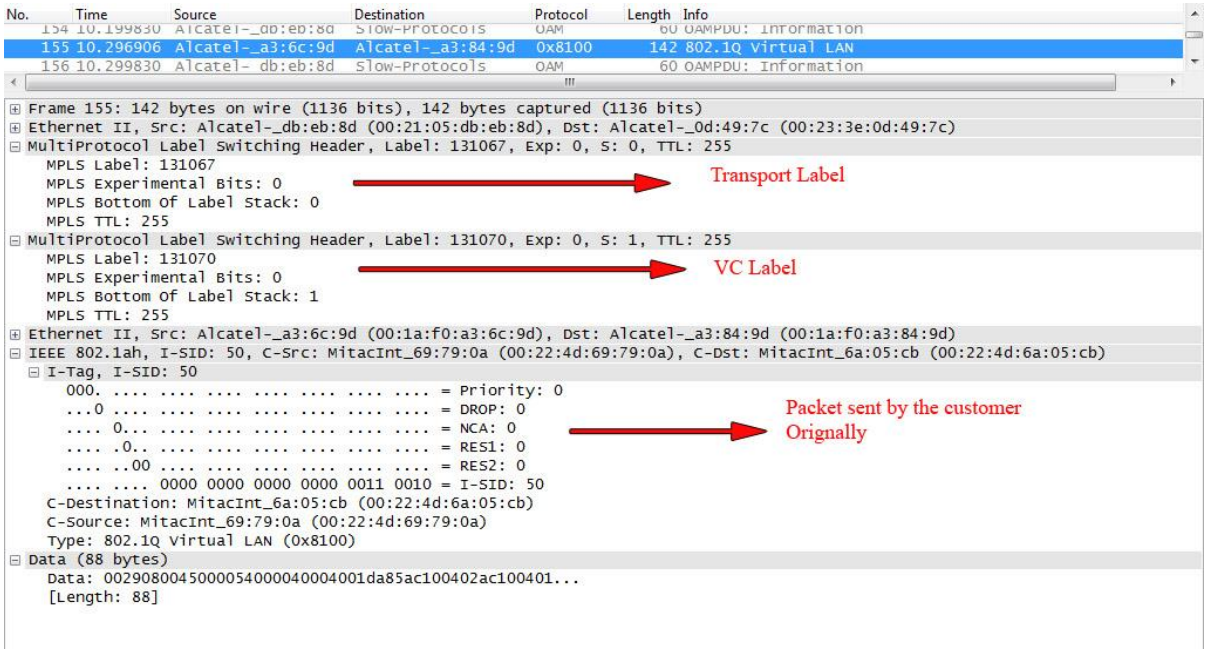
In the figure 6.5 it shows the CFM Packet that shows 802.1ag packet format in extended form. In the Maintenance association Identifier (MEG ID) it shows the packet is being sent for the arsh_mint domain, which is the domain 1. The short name, which is described as Vpls_50, is also included in the packet. The CFM TLV's shows the status of the port and related information. The CFM messages are sent in sequence numbers, which is 99917 for the packet shown here.

Figure 6.5 CFM Packet with 802.1ag packet format



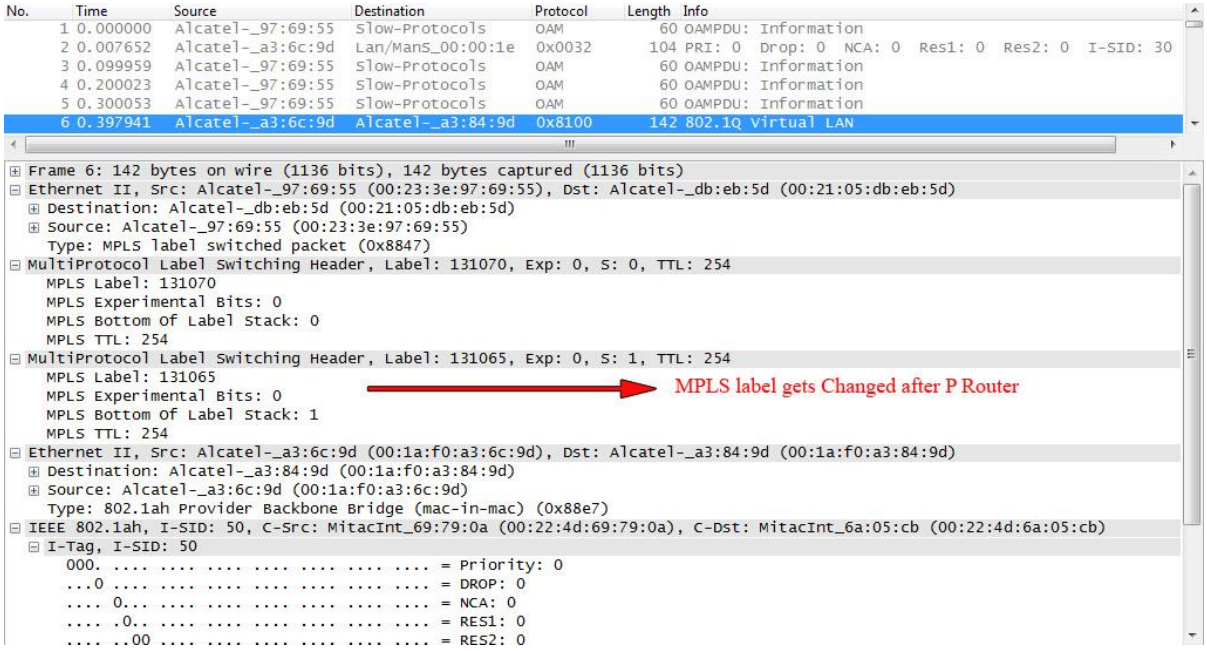
This is the similar packet that is received to the PE on the other end with the transport and the VC label attached to the packet. The MPLS label gets changed as it moves from one MPLS P router to other, until the packet is reached at PE or UPE router, which trims off the MPLS Label. The packet shows the MPLS label as 131067 and 131070 as below.

Figure 6.6 Packets with MPLS Detail



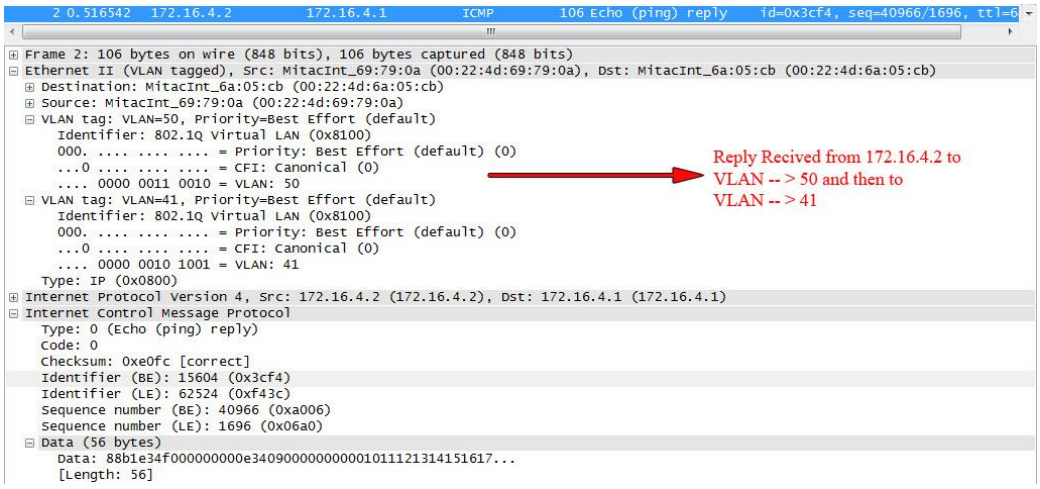
In the figure 6.7 if we compare it with Figure 6.6 it shows MPLS tags changed. This is the packet received by the UPE from the PE router. These shows the MPLS labels are exchanged. The new MPLS labels are 131070 and label 131065

Figure 6.7 MPLS Label Switching



In the last step the packet is sent to the CE2, which removes all the extra MPLS and 802.1ag information attached.

Figure 6.8 Reply ICMP packets with both S-Vlan and C-Vlan



6.2 Conclusion

The OAM is a tool for monitoring and alarming when we get problem in our network. To simplify and make it easy to find the errors and faults in the network is very important. OAM is a tool which intimates about fault indication, performance monitoring, diagnostic functions, security management, configuration and service provision. OAM covers from Management plane to network plane.

802.1ag CFM is an end-to-end service management over any infrastructure. There is no interference of customer domain, service domain and operator's domains and can run on different levels of management tool.CFM uses the Ethernet frames and not sub Ethernet control information. The layer 2 network is increasing and we need to troubleshoot when failure occurs, CFM makes it easy especially when the components networks belong to different organizations

It can perform end to end service manageability which eliminates the finger pointing between carriers along with Physical connectivity verification, pro-active service status. This is a simple deployment of Ethernet Wan services as per the increase in the market of resources with less technical sophisticated customers.

There are various tools through which we can manage our network real time without manual intervention and lower downtimes. It is getting important in all the service providers to implement the CFM OAM for better service assurance and quality.

Appendix – A

Configuration of 802.1ag and QOS

Configuration of Provider Router (P router)

```
A:P# admin display-config
exit all
configure
#--------------------------------------------------
echo "System Security Configuration"
#--------------------------------------------------
    system
        security
            per-peer-queuing
            cpu-protection
                policy 254 create
                exit
                policy 255 create
                exit
            exit
        exit
    exit
#--------------------------------------------------
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
            efm-oam
                accept-remote-loopback
                transmit-interval 1 multiplier 2
                no shutdown
            exit
        exit
        no shutdown
    exit
    port 1/1/2
```

```
        ethernet
            efm-oam
                accept-remote-loopback
                transmit-interval 1 multiplier 2
                no shutdown
            exit
        exit
        no shutdown
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.1.1.3/32
        exit
        interface "to-PE1"
            address 10.6.7.2/30
            port 1/1/1
        exit
        interface "to-PE2"
            address 10.6.8.2/30
            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
            shutdown
            interface "system"
```

```
            exit
        exit
#------------------------------------------------
echo "RSVP Configuration"
#------------------------------------------------
        rsvp
            shutdown
            interface "system"
            exit
        exit
#------------------------------------------------
echo "MPLS LSP Configuration"
#------------------------------------------------
        mpls
        exit
#------------------------------------------------
echo "LDP Configuration"
#------------------------------------------------
        ldp
            interface-parameters
                interface "to-PE1"
                exit
                interface "to-PE2"
                exit
            exit
            targeted-session
            exit
        exit
    exit

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

Configuration for PE (Provider Edge) Routers.

PE-1 Router

```
A:PE1# admin display-config
exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "PE1"
        ccm 1
        exit
        snmp
            shutdown
        exit
        time
            sntp
                shutdown
            exit
            zone UTC
        exit
        thresholds
            rmon
            exit
        exit
    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
        description "to P"
        ethernet
            mtu 9212
            efm-oam
                accept-remote-loopback
```

```
            transmit-interval 1 multiplier 2
            no shutdown
         exit
      exit
      no shutdown
   exit
   port 1/2/2
      shutdown
      ethernet
      exit
   exit
   port 1/2/3
      shutdown
      ethernet
         mode access
         encap-type qinq
      exit
   exit
   port 1/2/4
      ethernet
         mtu 9212
         efm-oam
            accept-remote-loopback
            transmit-interval 1 multiplier 2
            no shutdown
         exit
      exit
      no shutdown
   exit
  port 1/2/8
      ethernet
         mode access
      exit
      no shutdown
   exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
   router
      interface "system"
         address 10.1.1.15/32
      exit
      interface "to-P3"
         address 10.6.7.1/30
         port 1/2/1
      exit
      interface "to-uPE1"
```

```
            address 10.6.6.2/30
            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 14 mpls create
            description "SDP Connect to uPE router"
            far-end 10.1.1.20
            ldp
            path-mtu 9000
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        sdp 15 mpls create
            description "SDP Connect to Far_END PE router"
            far-end 10.1.1.12
            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 00:21:05:6b:0a:96
            exit
            stp
                shutdown
            exit
            spoke-sdp 14:100 create
            exit
            mesh-sdp 15:100 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

PE2 Router

```
A:PE2# admin display-config
exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "PE2"
        ccm 1
        exit
        snmp
            shutdown
        exit
        time
            sntp
                shutdown
            exit
            zone UTC
        exit
        thresholds
            rmon
            exit
        exit
    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
        description "to_p"
        ethernet
            mtu 9212
            efm-oam
```

```
            accept-remote-loopback
            transmit-interval 1 multiplier 2
            no shutdown
        exit
    exit
    no shutdown
exit
port 1/2/2
    shutdown
    ethernet
    exit
exit
port 1/2/3
    shutdown
    ethernet
        mode access
        encap-type qinq
    exit
exit
port 1/2/4
    ethernet
        mtu 9212
        efm-oam
            accept-remote-loopback
            transmit-interval 1 multiplier 2
            no shutdown
        exit
    exit
    no shutdown
exit
port 1/2/5
    shutdown
    ethernet
    exit
exit
port 1/2/6
    shutdown
    ethernet
    exit
exit
port 1/2/7
    shutdown
    ethernet
    exit
exit
port 1/2/8
    ethernet
```

```
            mode access
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.1.1.12/32
        exit
        interface "to-P3"
            address 10.6.8.1/30
            port 1/2/1
        exit
        interface "to-uPE3"
            address 10.6.9.2/30
            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
        customer 10 create
        exit
        customer 30 create
        exit
        customer 40 create
        exit
        customer 50 create
        exit
        sdp 11 mpls create
            description "SDP Connect to uPE router"
            far-end 10.1.1.50
            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 10.1.1.15
            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 00:1a:f0:a3:98:9d
            exit
            stp
                shutdown
            exit
```

```
            spoke-sdp 11:100 create
            exit
            mesh-sdp 12:100 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 SUN MAY 27 12:26:45 2012 UTC
A:PE2#
```

Configuration of UPE Router (User End PE router)

UPE 1 Router

```
A:uPE1# admin display-config
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "uPE1"
        ccm 1
        exit
        snmp
            shutdown
        exit
        time
            sntp
                shutdown
            exit
            zone UTC
```

```
        exit
        thresholds
            rmon
            exit
        exit
    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 9212
            efm-oam
                accept-remote-loopback
                transmit-interval 1 multiplier 2
                no shutdown
            exit
        exit
        no shutdown
    exit
    port 1/2/2
        shutdown
        ethernet
        exit
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
            mtu 9212
        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
        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 "Eth-CFM Configuration"
#--------------------------------------------------
    eth-cfm
        domain 1 name "arsh_mint" level 5
```

```
            association 1 format string name "vpls_50"
                bridge-identifier 50
                exit
                ccm-interval 1
                remote-mepid 30
            exit
        exit
        domain 10 name "loopip" level 7
            association 10 format string name "mip"
                bridge-identifier 50
                    mhf-creation explicit
                exit
            exit
        exit
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.1.1.20/32
        exit
        interface "to-PE1"
            address 10.6.6.1/30
            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
         customer 100 create
         exit
         sdp 20 mpls create
            description "connect to npe"
            far-end 10.1.1.15
            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.* 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.* create
               eth-cfm
                  mep 20 domain 1 association 1 direction up
                     ccm-enable
                     no shutdown
                  exit
               exit
               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:a3:6c:9d
            exit
            stp
               shutdown
            exit
            spoke-sdp 20:100 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 "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
```

UPE-2 Router

```
A:uPE2# admin display-config
exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "uPE2"
        ccm 1
        exit
        snmp
            shutdown
        exit
        time
            sntp
                shutdown
            exit
            zone UTC
        exit
        thresholds
            rmon
            exit
        exit
    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 9212
            efm-oam
                accept-remote-loopback
                transmit-interval 1 multiplier 2
                no shutdown
            exit
        exit
        no shutdown
    exit
    port 1/2/2
        shutdown
        ethernet
        exit
    exit
    port 1/2/3
        ethernet
            mode access
            encap-type qinq
            mtu 9212
        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 "Eth-CFM Configuration"
#--------------------------------------------------
      eth-cfm
         domain 1 name "arsh_mint" level 5
            association 1 format string name "vpls_50"
               bridge-identifier 50
```

```
            exit
            ccm-interval 1
            remote-mepid 20
         exit
      exit
      domain 10 name "loopip" level 7
         association 10 format string name "mip"
            bridge-identifier 50
               mhf-creation explicit
            exit
         exit
      exit
   exit
#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
   router
      interface "system"
         address 10.1.1.50/32
      exit
      interface "to-PE2"
         address 10.6.9.1/30
         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 30 mpls create
            description "connect to nPE router"
            far-end 10.1.1.12
            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.* 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.* create
                eth-cfm
```

```
                mep 30 domain 1 association 1 direction up
                   ccm-enable
                   no shutdown
                exit
             exit
             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 30:100 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 "Mirror Configuration"
#--------------------------------------------------
    mirror
       mirror-dest 99 create
          sap 1/2/8 create
          exit
          no shutdown
       exit
```

exit

Configuration of 3750 Switch (Customer Edge)

The configuration on the both side of the PE1 and PE2 routers for the CE1 and CE2 switches respectively are the same as the port numbers and the VLAN numbers are kept identical. The VLAN for the Customers are kept different. Customer-1 has a VLAN of 41 and Customer-2 has a VLAN of 42.

```
Demark-R4-Sw1#sh run
!
hostname Demark-R4-Sw1
!
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
interface FastEthernet0
 no ip address
!
interface GigabitEthernet0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface GigabitEthernet0/2
 switchport access vlan 50
 switchport mode dot1q-tunnel
 no cdp enable
!
interface GigabitEthernet0/3
 switchport access vlan 30
 switchport mode dot1q-tunnel
 no cdp enable
!
interface Vlan1
 no ip address
!
ip classless
ip http server
ip http secure-server
!
ip sla enable reaction-alerts
!
```

```
monitor session 1 source interface Gi0/1
monitor session 1 destination interface Gi0/10
monitor session 2 source interface Gi0/2
monitor session 2 destination interface Gi0/11
```

Configuration of Customer Switch Access Layer (3560-x)

The configuration is same for the both sides i.e. for the both sites of both customers. The VLAN has been configured as 30 and 50 for both Customer1 and Customer2 as their Internal VLAN's.

```
Customer_1-Sw1-R2#sh run
!
hostname Customer_1-Sw1-R2
!
spanning-tree mode pvst
spanning-tree etherchannel guard misconfig
spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
interface GigabitEthernet1/0/1
 description "Connected to Cus-1-Vlan41"
 switchport access vlan 41
 switchport mode access
!
interface GigabitEthernet1/0/2
 description "Connected to Demark-top3560-R2"
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface GigabitEthernet1/0/3
 description "Connected to Cus-1-Vlan42"
 switchport access vlan 42
 switchport mode access
!
interface Vlan1
 no ip address
!
monitor session 1 source interface Gi1/0/1
monitor session 1 destination interface Gi1/0/10
monitor session 2 source interface Gi1/0/2
monitor session 2 destination interface Gi1/0/11
```

Appendix- B
Verification Outputs

UPE1 Outputs

*A: uPE1# show service sdp-using 20

```
===============================================================================
Service Destination Point (Sdp Id : 20)
===============================================================================
SvcId      SdpId             Type    Far End       Opr S* I.Label  E.Label
-------------------------------------------------------------------------------
100        20:100            Spok    10.1.1.15     Up     131067   131065
-------------------------------------------------------------------------------
Number of SDPs : 1
-------------------------------------------------------------------------------
===============================================================================
```

- indicates that the corresponding row element may have been truncated.

---

*A:uPE1# show service sdp

```
===============================================================
Services: Service Destination Points
===============================================================
SdpId    Adm MTU  Opr MTU  IP address       Adm  Opr        Deliver   Signal
-------------------------------------------------------------------------------------------------------------
20       9000     9000     10.1.1.15        Up   Up         LDP       TLDP
-------------------------------------------------------------------------------------------------------------
Number of SDPs : 1
```

---

*A:uPE1# show service id 50 fdb detail

```
===============================================================================
Forwarding Database, Service 50
===============================================================================
ServId    MAC               Source-Identifier       Type   Last Change
                                                            Age
-------------------------------------------------------------------------------
50       00:22:4d:69:79:0a sap:1/2/3:50.*          L/0    06/20/2012 19:48:12
50       00:22:4d:6a:05:cb b-sdp:20:100            L/0    06/20/2012 21:58:37
50       00:23:3e:0d:4b:13 b-sdp:20:100            L/0    06/20/2012 21:58:37
50       c8:9c:1d:20:3f:01 sap:1/2/3:50.*          L/0    06/20/2012 19:47:42
-------------------------------------------------------------------------------
No. of MAC Entries: 4
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
```

```
*A:uPE1# show  service id 30 fdb detail

===============================================================================
Forwarding Database, Service 30
===============================================================================
ServId    MAC               Source-Identifier       Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
30        c8:9c:1d:20:3f:01 sap:1/2/3:30.*          L/0    06/20/2012 19:47:42
-------------------------------------------------------------------------------
No. of MAC Entries: 1
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
```

```
*A:uPE1# 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:20:100              L/0    06/21/2012 20:26:37
-------------------------------------------------------------------------------
No. of MAC Entries: 1
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
===============================================================================
```

```
*A:uPE1# show  service fdb-mac

===============================================================================
Service Forwarding Database
===============================================================================
ServId    MAC               Source-Identifier       Type   Last Change
                                                     Age
-------------------------------------------------------------------------------
30        c8:9c:1d:20:3f:01 sap:1/2/3:30.*          L/0    06/20/2012 19:47:42
50        00:22:4d:69:79:0a sap:1/2/3:50.*          L/0    06/20/2012 19:48:12
50        00:22:4d:6a:05:cb b-sdp:20:100            L/0    06/20/2012 21:58:37
50        00:23:3e:0d:4b:13 b-sdp:20:100            L/0    06/20/2012 21:58:37
50        c8:9c:1d:20:3f:01 sap:1/2/3:50.*          L/0    06/20/2012 19:47:42
100       00:1a:f0:a3:84:9d sdp:20:100              L/0    06/21/2012 20:26:37
-------------------------------------------------------------------------------
No. of Entries: 6
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
```

```
*A:uPE1# oam sdp-ping 20 resp-sdp 14

Err SDP-ID Info                  Local        Remote
-------------------------------------------------
   SDP-ID:                       20           14
   Administrative State:         Up           Up
   Operative State:              Up           Up
   Path MTU:                     9000          N/A
   Response SDP Used:                         Yes

   IP Interface State:           Up
   Actual IP Address:            10.1.1.20     10.1.1.15
   Expected Peer IP:             10.1.1.15     10.1.1.20

   Forwarding Class              be           be
   Profile                       Out           Out

Request Result: Sent - Reply Received
RTT: 1.01(ms)
```

```
*A:uPE1# oam sdp-ping 20 resp-sdp 30
Err SDP-ID Info                  Local        Remote
-------------------------------------------------
   SDP-ID:                       20           N/A
   Administrative State:         Up           N/A
   Operative State:              Up           N/A
   Path MTU:                     9000          N/A
==> Response SDP Used:                        No

   IP Interface State:           Up
   Actual IP Address:            10.1.1.20     10.1.1.15
   Expected Peer IP:             10.1.1.15     10.1.1.20

   Forwarding Class              be           be
   Profile                       Out           Out

Request Result: Sent - Reply Received: Responder Sdp Id Unknown
RTT: 1.04(ms)
```

```
*A:uPE1# oam sdp-ping 20 resp-sdp 14 size 1514 count 5
Request     Response    RTT
-------------------------------------------------
```

1 Success 1.39ms
2 Success 1.41ms
3 Success 1.36ms
4 Success 1.44ms
5 Success 1.48ms

Sent: 5 Received: 5
Min: 1.36ms Max: 1.48ms Avg: 1.42ms

---
*A:uPE1# oam mac-trace service 50 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id Rcvd-on Path Nexthop RTT

[Send request TTL: 1, Seq. 1, Size 186]
1 1 1 10.1.1.20 sap:1/2/3:50.* Self Flood 1.44ms

2 1 1 10.1.1.15 cpm-bvpls In-Band Flood 2.15ms
Upstream Spoke-sdp 14:100 To: n/a, Ing-label: 131065, Sig: LDP
Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 186]
3 2 1 10.1.1.12 cpm-bvpls In-Band Flood 2.29ms
Upstream Mesh-sdp 12:100 To: n/a, Ing-label: 131065, Sig: LDP
Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 186]
4 3 1 10.1.1.50 cpm In-Band Flood 2.60ms
Upstream Spoke-sdp 30:100 To: n/a, Ing-label: 131066, Sig: LDP
Downstream Spoke-sdp 30:100 To: 10.1.1.12, Egr-label: 131071, Sig: LDP

[Send request TTL: 4, Seq. 1, Size 186]
5 4 1 10.1.1.50 sap:1/2/3:50.* In-Band Flood 1.20ms

*A:uPE1# oam mac-trace service 30 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id Rcvd-on Path Nexthop RTT

[Send request TTL: 1, Seq. 1, Size 186]
1 1 1 10.1.1.20 sap:1/2/3:30.* Self Flood 3.16ms

2 1 1 10.1.1.15 cpm-bvpls In-Band Flood 2.76ms

```
   Upstream Spoke-sdp 14:100 To: n/a, Ing-label: 131065, Sig: LDP
   Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
   Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 186]
3    2   1   10.1.1.12       cpm-bvpls              In-Band  Flood   2.25ms
   Upstream Mesh-sdp 12:100 To: n/a, Ing-label: 131065, Sig: LDP
   Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
   Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 186]
4    3   1   10.1.1.50       cpm                  In-Band  Flood   6.40ms
   Upstream Spoke-sdp 30:100 To: n/a, Ing-label: 131066, Sig: LDP
   Downstream Spoke-sdp 30:100 To: 10.1.1.12, Egr-label: 131071, Sig: LDP

[Send request TTL: 4, Seq. 1, Size 186]
5    4   1   10.1.1.50       sap:1/2/3:30.*         In-Band  Flood   1.07ms

-------------------------------------------------------------------------------
*A:uPE1#
```

```
*A:uPE1# oam mac-ping service 50 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                    Path     RTT
-------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.20:sap1/2/3:50.*            No FIB on Egress Self     3.65ms
1   10.1.1.50:sap1/2/3:50.*            No FIB on Egress In-Band  1.03ms
```

```
*A:uPE1# oam mac-ping service 30 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                    Path     RTT
-------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.20:sap1/2/3:30.*            No FIB on Egress Self     2.98ms
1   10.1.1.50:sap1/2/3:30.*            No FIB on Egress In-Band  3.17ms
-------------------------------------------------------------------------------

*A:uPE1# oam lsp-ping prefix 10.1.1.50/32
LSP-PING 10.1.1.50/32: 80 bytes MPLS payload
Seq=1, send from intf to-PE1, reply from 10.1.1.50
      udp-data-len=32 ttl=255 rtt=1.19ms rc=3 (EgressRtr)

---- LSP 10.1.1.50/32 PING Statistics ----
```

```
1 packets sent, 1 packets received, 0.00% packet loss
round-trip min = 1.19ms, avg = 1.19ms, max = 1.19ms, stddev = 0.000ms
```

```
*A:uPE1# oam lsp-tr prefix 10.1.1.50/32
lsp-trace to 10.1.1.50/32: 0 hops min, 0 hops max, 104 byte packets
1  10.1.1.15  rtt=1.26ms rc=8(DSRtrMatchLabel)
2  10.1.1.3  rtt=1.21ms rc=8(DSRtrMatchLabel)
3  10.1.1.12  rtt=1.29ms rc=8(DSRtrMatchLabel)
4  10.1.1.50  rtt=1.37ms rc=3(EgressRtr)
*A:uPE1#
```

```
*A:uPE1# show eth-cfm mep 20 domain 1 association 1
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index            : 1                 Direction           : Up
Ma-index            : 1                 Admin               : Enabled
MepId               : 20                CCM-Enable          : Enabled
IfIndex             : 37847040          PrimaryVid          : 268369970
FngState            : fngReset          ControlMep          : False
LowestDefectPri     : macRemErrXcon     HighestDefect       : none
Defect Flags        : None
Mac Address         : 00:21:05:db:eb:8f CcmLtmPriority      : 7
CcmTx               : 83927             CcmSequenceErr      : 0
Fault Propagation   : disabled
Eth-1Dm Threshold   : 3(sec)
Eth-Ais:            : Disabled
Eth-Tst:            : Disabled
CcmLastFailure Frame:
   None
XconCcmFailure Frame:
   None


*A:uPE1#  show eth-cfm cfm-stack-table
===============================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================
CFM SAP Stack Table
```

```
===============================================================================
Sap              Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
1/2/3:50.*         5   Up         1          1   20 00:21:05:db:eb:8f ------
1/2/3:50.*         7 Both         10         10  MIP 00:21:05:db:eb:8f ------
===============================================================================

===============================================================================
CFM Ethernet Tunnel Stack Table
===============================================================================
Eth-tunnel       Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================

===============================================================================
CFM SDP Stack Table
===============================================================================
Sdp              Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================

===============================================================================
CFM Virtual Stack Table
===============================================================================
Service          Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================
*A:uPE1#
```

```
*A:uPE1# show eth-cfm mep 20 domain 1 association 1 loopback
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index                : 1                 Direction               : Up
```

Ma-index : 1 Admin : Enabled
MepId : 20 CCM-Enable : Enabled
IfIndex : 37847040 PrimaryVid : 268369970
FngState : fngReset ControlMep : False
LowestDefectPri : macRemErrXcon HighestDefect : none
Defect Flags : None
Mac Address : 00:21:05:db:eb:8f CcmLtmPriority : 7
CcmTx : 84441 CcmSequenceErr : 0
Fault Propagation : disabled
Eth-1Dm Threshold : 3(sec)
Eth-Ais: : Disabled
Eth-Tst: : Disabled
CcmLastFailure Frame:
None
XconCcmFailure Frame:
None

Mep Loopback Information

LbRxReply : 10 LbRxBadOrder : 0
LbRxBadMsdu : 0 LbTxReply : 5
LbSequence : 11 LbNextSequence : 16
LbStatus : False LbResultOk : True
DestIsMepId : False DestMepId : 0
DestMac : 00:00:00:00:00:00 SendCount : 0
VlanDropEnable : True VlanPriority : 7
Data TLV:
None

*A:uPE1# show eth-cfm mep 20 domain 1 association 1 linktrace
---
Mep Information

```
Md-index            : 1                 Direction              : Up
Ma-index            : 1                 Admin                  : Enabled
MepId               : 20                CCM-Enable             : Enabled
IfIndex             : 37847040          PrimaryVid             : 268369970
FngState            : fngReset          ControlMep             : False
LowestDefectPri     : macRemErrXcon     HighestDefect          : none
Defect Flags        : None
Mac Address         : 00:21:05:db:eb:8f CcmLtmPriority         : 7
CcmTx               : 84655             CcmSequenceErr         : 0
Fault Propagation   : disabled
Eth-1Dm Threshold   : 3(sec)
Eth-Ais:            : Disabled
Eth-Tst:            : Disabled
CcmLastFailure Frame:
   None
XconCcmFailure Frame:
   None
--------------------------------------------------------------------------------
Mep Linktrace Message Information
--------------------------------------------------------------------------------
LtRxUnexplained     : 0                 LtNextSequence         : 2
LtStatus            : False             LtResult               : False
TargIsMepId         : False             TargMepId              : 0
TargMac             : 00:00:00:00:00:00 TTL                    : 64
EgressId            : 00:00:00:21:05:db:eb:8f SequenceNum      : 1
LtFlags             : useFDBonly
--------------------------------------------------------------------------------
Mep Linktrace Replies
--------------------------------------------------------------------------------
SequenceNum         : 1                 ReceiveOrder           : 1
Ttl                 : 63                Forwarded              : False
LastEgressId        : 00:00:00:21:05:db:eb:8f TerminalMep      : True
NextEgressId        : 00:00:00:23:3e:0d:4b:13 Relay            : rlyHit
ChassisIdSubType    : unknown value (0)
ChassisId:
   None
ManAddressDomain:
   None
ManAddress:
   None
IngressMac      : 00:00:00:00:00:00     Ingress Action    : ingNoTlv
IngrPortIdSubType : unknown value (0)
IngressPortId:
   None
EgressMac       : 00:23:3e:0d:4b:13     Egress Action     : egrOK
EgrPortIdSubType  : unknown value (0)
EgressPortId:
```

None
Org Specific TLV:
None

---

*A:uPE1# show eth-cfm mep 20 domain 1 association 1

Mep Information

Md-index : 1 Direction : Up
Ma-index : 1 Admin : Enabled
MepId : 20 CCM-Enable : Enabled
IfIndex : 37847040 PrimaryVid : 268369970
FngState : fngReset ControlMep : False
LowestDefectPri : macRemErrXcon HighestDefect : none
Defect Flags : None
Mac Address : 00:21:05:db:eb:8f CcmLtmPriority : 7
CcmTx : 84817 CcmSequenceErr : 0
Fault Propagation : disabled
Eth-1Dm Threshold : 3(sec)
Eth-Ais: : Disabled
Eth-Tst: : Disabled
CcmLastFailure Frame:
None
XconCcmFailure Frame:
None

UPE2 OUTPUTS

==========
*A:uPE2# show service sdp
==========
Services: Service Destination Points
==========
SdpId Adm MTU Opr MTU IP address Adm Opr Deliver Signal
---
30 9000 9000 10.1.1.12 Up Up LDP TLDP

Number of SDPs : 1

```
*A:uPE2# oam sdp-ping 30 resp-sdp 11
Err SDP-ID Info           Local          Remote
-------------------------------------------------
   SDP-ID:                30             11
   Administrative State:  Up             Up
   Operative State:       Up             Up
   Path MTU:              9000           N/A
   Response SDP Used:                Yes

   IP Interface State:    Up
   Actual IP Address:     10.1.1.50      10.1.1.12
   Expected Peer IP:      10.1.1.12      10.1.1.50

   Forwarding Class       be             be
   Profile                Out            Out

Request Result: Sent - Reply Received
RTT: 1.08(ms)
```

```
*A:uPE2# oam mac-trace service 50 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id        Rcvd-on              Path     Nexthop RTT
------------------------------------------------------------------------------
[Send request TTL: 1, Seq. 1, Size 186]
1     1   1  10.1.1.50       sap:1/2/3:50.*       Self     Flood   1.52ms

2     1   1  10.1.1.12       cpm-bvpls            In-Band  Flood   2.15ms
   Upstream Spoke-sdp 11:100 To: n/a, Ing-label: 131071, Sig: LDP
   Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
   Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 186]
3     2   1  10.1.1.15       cpm-bvpls            In-Band  Flood   2.28ms
   Upstream Mesh-sdp 15:100 To: n/a, Ing-label: 131066, Sig: LDP
   Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
```

```
   Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 186]
4    3   1   10.1.1.20       cpm                  In-Band  Flood   2.58ms
   Upstream Spoke-sdp 20:100 To: n/a, Ing-label: 131067, Sig: LDP
   Downstream Spoke-sdp 20:100 To: 10.1.1.15, Egr-label: 131065, Sig: LDP

[Send request TTL: 4, Seq. 1, Size 186]
5    4   1   10.1.1.20       sap:1/2/3:50.*       In-Band  Flood   1.08ms
```

```
*A:uPE2# oam mac-trace service 30 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id        Rcvd-on              Path     Nexthop RTT
------------------------------------------------------------------------------
[Send request TTL: 1, Seq. 1, Size 186]
1    1   1   10.1.1.50       sap:1/2/3:30.*       Self     Flood   1.47ms

2    1   1   10.1.1.12       cpm-bvpls            In-Band  Flood   2.17ms
   Upstream Spoke-sdp 11:100 To: n/a, Ing-label: 131071, Sig: LDP
   Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
   Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 186]
3    2   1   10.1.1.15       cpm-bvpls            In-Band  Flood   2.27ms
   Upstream Mesh-sdp 15:100 To: n/a, Ing-label: 131066, Sig: LDP
   Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
   Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 186]
4    3   1   10.1.1.20       cpm                  In-Band  Flood   3.19ms
   Upstream Spoke-sdp 20:100 To: n/a, Ing-label: 131067, Sig: LDP
   Downstream Spoke-sdp 20:100 To: 10.1.1.15, Egr-label: 131065, Sig: LDP

[Send request TTL: 4, Seq. 1, Size 186]
5    4   1   10.1.1.20       sap:1/2/3:30.*       In-Band  Flood   1.03ms
```

```
*A:uPE2# oam mac-ping service 30 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                  Path     RTT
------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.50:sap1/2/3:30.*          No FIB on Egress Self     3.52ms
```

```
1   10.1.1.20:sap1/2/3:30.*              No FIB on Egress In-Band  3.22ms
-------------------------------------------------------------------------------
*A:uPE2# oam mac-ping service 50 destination ff:ff:ff:ff:ff:ff

Seq Node-id                                    Path     RTT
-------------------------------------------------------------------------------
[Send request Seq. 1, Size 162]
1   10.1.1.50:sap1/2/3:50.*              No FIB on Egress Self     3.03ms
1   10.1.1.20:sap1/2/3:50.*              No FIB on Egress In-Band  3.25ms
```

```
*A:uPE2#  oam lsp-tr prefix 10.1.1.20/32
lsp-trace to 10.1.1.20/32: 0 hops min, 0 hops max, 104 byte packets
1  10.1.1.12  rtt=1.18ms rc=8(DSRtrMatchLabel)
2  10.1.1.3  rtt=11.2ms rc=8(DSRtrMatchLabel)
3  10.1.1.15  rtt=2.88ms rc=8(DSRtrMatchLabel)
4  10.1.1.20  rtt=1.27ms rc=3(EgressRtr)
*A:uPE2#
```

```
*A:uPE2# show eth-cfm mep 30 domain 1 association 1
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index            : 1                 Direction           : Up
Ma-index            : 1                 Admin               : Enabled
MepId               : 30                CCM-Enable          : Enabled
IfIndex             : 37847040          PrimaryVid          : 268369970
FngState            : fngReset          ControlMep          : False
LowestDefectPri     : macRemErrXcon     HighestDefect       : none
Defect Flags        : None
Mac Address         : 00:23:3e:0d:4b:13 CcmLtmPriority      : 7
CcmTx               : 83905             CcmSequenceErr      : 0
Fault Propagation   : disabled
Eth-1Dm Threshold   : 3(sec)
Eth-Ais:            : Disabled
Eth-Tst:            : Disabled
CcmLastFailure Frame:
   None
XconCcmFailure Frame:
   None
```

```
*A:uPE2# show eth-cfm cfm-stack-table
===============================================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================================
CFM SAP Stack Table
===============================================================================
Sap             Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
1/2/3:50.*        5   Up        1          1   30 00:23:3e:0d:4b:13 ------
1/2/3:50.*        7 Both        10         10  MIP 00:23:3e:0d:4b:13 ------
===============================================================================

===============================================================================
CFM Ethernet Tunnel Stack Table
===============================================================================
Eth-tunnel        Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================

===============================================================================
CFM SDP Stack Table
===============================================================================
Sdp             Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
===============================================================================

===============================================================================
CFM Virtual Stack Table
===============================================================================
Service         Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
No Matching Entries
```

```
*A:uPE2#  show eth-cfm mep 30 domain 1 association 1 loopback
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index          : 1                   Direction        : Up
Ma-index                : 1                     Admin            : Enabled
MepId                   : 30                    CCM-Enable       : Enabled
```

```
IfIndex                : 37847040              PrimaryVid       : 268369970
FngState               : fngReset              ControlMep       : False
LowestDefectPri    : macRemErrXcon          HighestDefect    : none
Defect Flags           : None
Mac Address        : 00:23:3e:0d:4b:13     CcmLtmPriority   : 7
CcmTx                  : 84363                 CcmSequenceErr   : 0
Fault Propagation      : disabled
Eth-1Dm Threshold  : 3(sec)
Eth-Ais:               : Disabled
Eth-Tst:           : Disabled
CcmLastFailure Frame:
   None
XconCcmFailure Frame:
   None
-------------------------------------------------------------------------------
Mep Loopback Information
-------------------------------------------------------------------------------
LbRxReply          : 5                 LbRxBadOrder     : 0
LbRxBadMsdu        : 0                 LbTxReply        : 10
LbSequence         : 1                 LbNextSequence   : 6
LbStatus           : False             LbResultOk       : True
DestIsMepId        : False             DestMepId        : 0
DestMac            : 00:00:00:00:00:00     SendCount        : 0
VlanDropEnable     : True              VlanPriority     : 7
Data TLV:
   None
*A:uPE2#
```

```
*A:uPE2#  oam eth-cfm loopback 00:21:05:db:eb:8f mep 30 domain  1 association  1 send-
count 5
Eth-Cfm Loopback Test Initiated: Mac-Address: 00:21:05:db:eb:8f, out sap: 1/2/3:50.*
Sent 5 packets, received 5 packets [0 out-of-order, 0 Bad Msdu]
```

```
*A:uPE2# show eth-cfm mep 30 domain 1 association 1 linktrace
-------------------------------------------------------------------------------
Mep Information
-------------------------------------------------------------------------------
Md-index           : 1                 Direction        : Up
Ma-index           : 1                 Admin            : Enabled
```

```
MepId             : 30                  CCM-Enable       : Enabled
IfIndex           : 37847040            PrimaryVid       : 268369970
FngState          : fngReset            ControlMep       : False
LowestDefectPri   : macRemErrXcon       HighestDefect    : none
Defect Flags      : None
Mac Address       : 00:23:3e:0d:4b:13   CcmLtmPriority   : 7
CcmTx             : 84573               CcmSequenceErr   : 0
Fault Propagation : disabled
Eth-1Dm Threshold : 3(sec)
Eth-Ais:          : Disabled
Eth-Tst:          : Disabled
CcmLastFailure Frame:
  None
XconCcmFailure Frame:
  None
--------------------------------------------------------------------------------
Mep Linktrace Message Information
--------------------------------------------------------------------------------
LtRxUnexplained   : 0                   LtNextSequence   : 2
LtStatus          : False               LtResult         : False
TargIsMepId       : False               TargMepId        : 0
TargMac           : 00:00:00:00:00:00   TTL              : 64
EgressId          : 00:00:00:23:3e:0d:4b:13  SequenceNum   : 1
LtFlags           : useFDBonly
--------------------------------------------------------------------------------
Mep Linktrace Replies
--------------------------------------------------------------------------------
SequenceNum       : 1                   ReceiveOrder     : 1
Ttl               : 63                  Forwarded        : False
LastEgressId      : 00:00:00:23:3e:0d:4b:13  TerminalMep   : True
NextEgressId      : 00:00:00:21:05:db:eb:8f  Relay         : rlyHit
ChassisIdSubType  : unknown value (0)
ChassisId:
  None
ManAddressDomain:
  None
ManAddress:
  None
IngressMac        : 00:00:00:00:00:00   Ingress Action   : ingNoTlv
IngrPortIdSubType : unknown value (0)
IngressPortId:
  None
EgressMac         : 00:21:05:db:eb:8f   Egress Action    : egrOK
EgrPortIdSubType  : unknown value (0)
EgressPortId:
  None
Org Specific TLV:
```

None

---

*A:uPE2# show eth-cfm mep 30 domain 1 association 1

Mep Information

Md-index : 1 Direction : Up
Ma-index : 1 Admin : Enabled
MepId : 30 CCM-Enable : Enabled
IfIndex : 37847040 PrimaryVid : 268369970
FngState : fngReset ControlMep : False
LowestDefectPri : macRemErrXcon HighestDefect : none
Defect Flags : None
Mac Address : 00:23:3e:0d:4b:13 CcmLtmPriority : 7
CcmTx : 84763 CcmSequenceErr : 0
Fault Propagation : disabled
Eth-1Dm Threshold : 3(sec)
Eth-Ais: : Disabled
Eth-Tst: : Disabled
CcmLastFailure Frame:
None
XconCcmFailure Frame:
None

PE1 and PE2 OUTPUTS

==========
*A:PE1# show service sdp
==========
Services: Service Destination Points
==========
SdpId Adm MTU Opr MTU IP address Adm Opr Deliver Signal
---
14 9000 9000 10.1.1.20 Up Up LDP TLDP
15 9000 9000 10.1.1.12 Up Up LDP TLDP

Number of SDPs : 2

==========
*A:PE2# show service sdp
==========
Services: Service Destination Points
==========
SdpId Adm MTU Opr MTU IP address Adm Opr Deliver Signal
---
11 9000 9000 10.1.1.50 Up Up LDP TLDP

```
12      9000    9000    10.1.1.15       Up   Up         LDP      TLDP
-------------------------------------------------------------------------------
Number of SDPs : 2
```

*A:PE1# show service id 100 fdb detail

```
===============================================================================
Forwarding Database, Service 100
===============================================================================
ServId    MAC               Source-Identifier       Type   Last Change
                                Age
-------------------------------------------------------------------------------
100       00:1a:f0:a3:6c:9d sdp:14:100              L/0    06/20/2012 21:32:50
100       00:1a:f0:a3:84:9d sdp:15:100              L/0    06/20/2012 21:32:51
-------------------------------------------------------------------------------
No. of MAC Entries: 2
-------------------------------------------------------------------------------
Legend: L=Learned; P=MAC is protected
```

*A:PE1# oam svc-ping 10.1.1.12 service 100 local-sdp remote-sdp
Service-ID: 100

```
Err Info              Local          Remote
------------------------------------------------------
   Type:                VPLS           VPLS
   Admin State:         Up             Up
   Oper State:          Up             Up
   Service-MTU:         1536           1536
   Customer ID:         1              1

   IP Interface State:  Up
   Actual IP Addr:      10.1.1.15      10.1.1.12
   Expected Peer IP:    10.1.1.12      10.1.1.15

   SDP Path Used:       Yes            Yes
   SDP-ID:              15             12
   Admin State:         Up             Up
   Operative State:     Up             Up
   Binding Admin State: Up             Up
   Binding Oper State:  Up             Up
   Binding VC ID:       100            100
   Binding Type:        Mesh           Mesh
   Binding Vc-type:     Ether          Ether
   Binding Vlan-vc-tag: N/A            N/A

   Egress Label:        131065         131066
   Ingress Label:       131066         131065
   Egress Label Type:   Signaled       Signaled
   Ingress Label Type:  Signaled       Signaled
```

Request Result: Sent - Reply Received

---

*A:PE2# oam svc-ping 10.1.1.15 service 100 local-sdp remote-sdp
Service-ID: 100

Err Info	Local	Remote
Type:	VPLS	VPLS
Admin State:	Up	Up
Oper State:	Up	Up
Service-MTU:	1536	1536
Customer ID:	1	1
IP Interface State: Up		
Actual IP Addr:	10.1.1.12	10.1.1.15
Expected Peer IP:	10.1.1.15	10.1.1.12
SDP Path Used:	Yes	Yes
SDP-ID:	12	15
Admin State:	Up	Up
Operative State:	Up	Up
Binding Admin State:	Up	Up
Binding Oper State:	Up	Up
Binding VC ID:	100	100
Binding Type:	Mesh	Mesh
Binding Vc-type:	Ether	Ether
Binding Vlan-vc-tag:	N/A	N/A
Egress Label:	131066	131065
Ingress Label:	131065	131066
Egress Label Type:	Signaled	Signaled
Ingress Label Type:	Signaled	Signaled

Request Result: Sent - Reply Received

---

*A:PE1# oam sdp-ping 15 resp-sdp 12

Err SDP-ID Info	Local	Remote
SDP-ID:	15	12
Administrative State:	Up	Up
Operative State:	Up	Up
Path MTU:	9000	N/A
Response SDP Used:		Yes
IP Interface State:	Up	
Actual IP Address:	10.1.1.15	10.1.1.12
Expected Peer IP:	10.1.1.12	10.1.1.15

```
   Forwarding Class       be            be
   Profile                Out           Out

Request Result: Sent - Reply Received
RTT: 1.06(ms)
```

```
*A:PE2# oam sdp-ping 12 resp-sdp 15
Err SDP-ID Info           Local         Remote
-------------------------------------------------
   SDP-ID:                12            15
   Administrative State:  Up            Up
   Operative State:       Up            Up
   Path MTU:              9000          N/A
   Response SDP Used:                   Yes

   IP Interface State:    Up
   Actual IP Address:     10.1.1.12     10.1.1.15
   Expected Peer IP:      10.1.1.15     10.1.1.12

   Forwarding Class       be            be
   Profile                Out           Out

Request Result: Sent - Reply Received
RTT: 1.11(ms)
```

```
*A:PE1# oam mac-trace service 100 destination ff:ff:ff:ff:ff:ff
Reply TTL Seq Node-id       Rcvd-on              Path     Nexthop RTT
-------------------------------------------------------------------------
[Send request TTL: 1, Seq. 1, Size 198]
1     1   1   10.1.1.20     cpm-bvpls            In-Band  Flood   0.100ms
   Upstream Spoke-sdp 20:100 To: n/a, Ing-label: 131067, Sig: LDP
   Downstream Spoke-sdp 20:100 To: 10.1.1.15, Egr-label: 131065, Sig: LDP

2     1   1   10.1.1.12     cpm-bvpls            In-Band  Flood   0.170ms
   Upstream Mesh-sdp 12:100 To: n/a, Ing-label: 131065, Sig: LDP
   Downstream Spoke-sdp 11:100 To: 10.1.1.50, Egr-label: 131066, Sig: LDP
   Downstream Mesh-sdp 12:100 To: 10.1.1.15, Egr-label: 131066, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 198]
3     2   1   10.1.1.50     cpm-bvpls            In-Band  Flood   0.230ms
   Upstream Spoke-sdp 30:100 To: n/a, Ing-label: 131066, Sig: LDP
   Downstream Spoke-sdp 30:100 To: 10.1.1.12, Egr-label: 131071, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 198]
[Send request TTL: 4, Seq. 1, Size 198]
Request TTL: 3, Seq. 1 timed out. Sending Size 198
Request TTL: 4, Seq. 1 timed out. Sending Size 198
```

```
*A:PE2# oam mac-trace service 100 destination ff:ff:ff:ff:ff:ff

Reply TTL Seq Node-id         Rcvd-on                Path     Nexthop RTT
------------------------------------------------------------------------------
[Send request TTL: 1, Seq. 1, Size 198]
1     1   1   10.1.1.15       cpm-bvpls              In-Band  Flood   0.180ms
    Upstream Mesh-sdp 15:100 To: n/a, Ing-label: 131066, Sig: LDP
    Downstream Spoke-sdp 14:100 To: 10.1.1.20, Egr-label: 131067, Sig: LDP
    Downstream Mesh-sdp 15:100 To: 10.1.1.12, Egr-label: 131065, Sig: LDP

2     1   1   10.1.1.50       cpm-bvpls              In-Band  Flood   0.100ms
    Upstream Spoke-sdp 30:100 To: n/a, Ing-label: 131066, Sig: LDP
    Downstream Spoke-sdp 30:100 To: 10.1.1.12, Egr-label: 131071, Sig: LDP

[Send request TTL: 2, Seq. 1, Size 198]
3     2   1   10.1.1.20       cpm-bvpls              In-Band  Flood   0.230ms
    Upstream Spoke-sdp 20:100 To: n/a, Ing-label: 131067, Sig: LDP
    Downstream Spoke-sdp 20:100 To: 10.1.1.15, Egr-label: 131065, Sig: LDP

[Send request TTL: 3, Seq. 1, Size 198]
[Send request TTL: 4, Seq. 1, Size 198]
Request TTL: 3, Seq. 1 timed out. Sending Size 198
Request TTL: 4, Seq. 1 timed out. Sending Size 198
------------------------------------------------------------------------------
```

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