University of Alberta

MINT 709 Project Report

Topic:

Implementing Scalable 4G LTE Wireless Backhaul: Challenges and Solutions

Submitted by:

Syed A Tahir

Special thanks to Dr. Mike MacGregor for his continued support during this project.

Contents

ACRONYMS

ATM	Asynchronous Tranfer Mode
aGW	Access Gateway
BS	Base Station
CDMA	Code Division Mutiple Access
EDGE	Enhanced Data for GSM Evolution
EVC	Ethernet Virtual Connection
EV-DO	Evolution – Data Only
FDD	Frequency Division Duplexing
GIWF	Generic Interworking Functions
GPRS	General Packet Radio Service
GSM	Global Systems Mobile
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
LTE	Long Term Evolution
MBBI	MPLS Mobile Backhaul Initiative
MEF	Metro Ethernet Forum
MEN	Metro Ethernet Network
MPLS	Multi-Protocol Label Switching
RAN BS	Radio Access Network Base Station
RAN NC	Radio Access Network – Network Controller
RNC	Radio Access Network Controller
RPR	Resilient Packet Ring
SAP	Service Access Point
TDM	Time Division Multiplexing
UMTS	Universal Mobile Telecommunications System
UNI	User Network Interface
UPSR	Unidirectional Path Switched Ring
VoLTE	Voice over LTE
VPLS	Virtual Private LAN Service
VPWS	Virtual Private Wire Service

1. Introduction

With the advent of bandwidth-intensive applications and powerful wireless devices, service providers face a challenge to satisfy the needs of customers in a cost effective manner. Legacy wireless backhaul networks are limited in their flexibility to scale well with rapidly increasing backhaul bandwidth requirement. Service providers are beginning to deploy 4G LTE technology and are planning for widespread coverage in the near future.

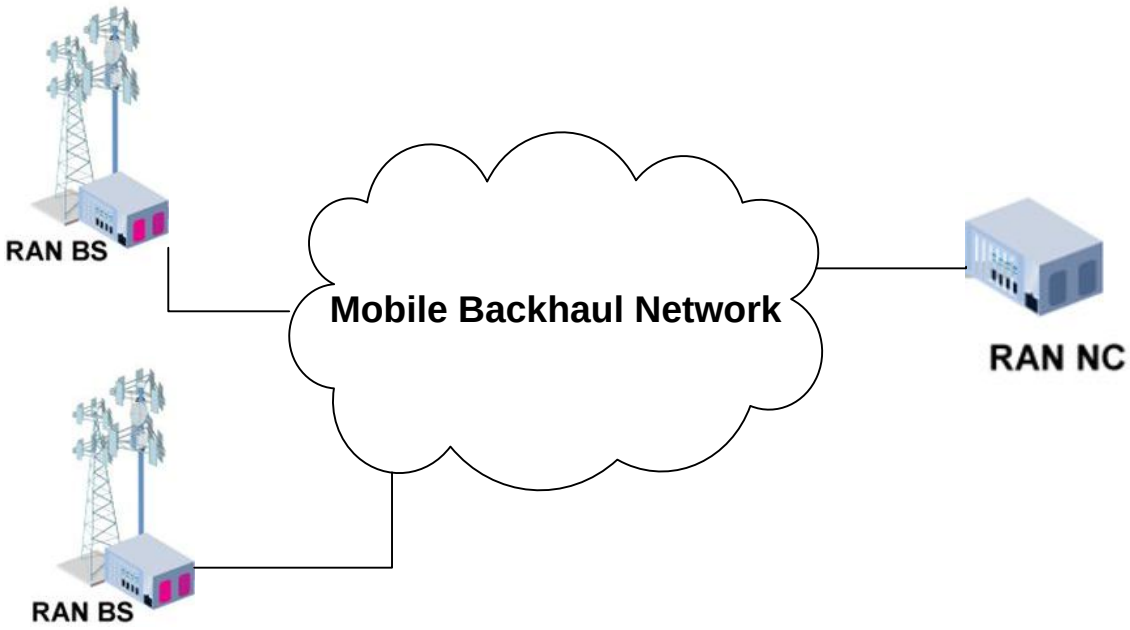
The challenges faced by service providers are twofold. Firstly the legacy backhaul transport networks are not cost-effective for increasing capacity for higher data rates and secondly there is a lot of investment in the current backhaul networks which cannot be overlooked, regardless of whether or not they backhaul themselves or outsource to another service provider. Hence there is a need for a proper migration strategy where service providers can maximize the use of their current network deployments in a cost-effective manner while migrating towards packet-switched 4G backhauls to serve applications with demanding throughput requirements. This strategy ensures that the backhaul network does not become a potential traffic bottleneck for 4G applications.

To overcome these challenges, service providers and equipment manufacturers are working together towards a unified approach to deal with this difficult problem. Metro Ethernet Forum and Broadband Forum (MPLS Forum) have been working for implementation options for backhaul networks focusing on migration paths towards all IP packet-switched backhaul network. Their goal is to cost-effectively maximize the use of Ethernet and MPLS technologies since the 4G networks are strictly IP based.

In this project an attempt has been made to explore the solutions proposed by the two forums. Also, a network setup is also configured at the end as an example of one possible solution employing part of the recommendations made, with the use of Carrier Ethernet and MPLS.

2 Mobile Backhaul Traffic

A mobile backhaul network is the network between Radio Access Network Controllers (RAN NC or RNC) and Radio Access Network Base Stations (RAN BSs). The following diagram shows a simplified view of the mobile backhaul network.



2.1 Current and Legacy Networks

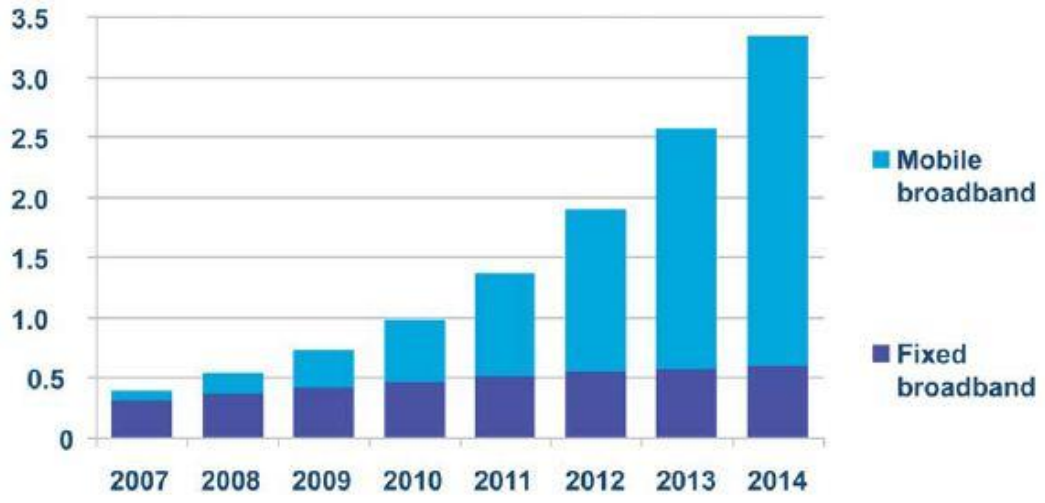
Current and legacy backhauls use variety of transport networks with different data rates depending on the technology used. GSM/GPRS/EDGE networks use TDM transport layers whereas UMTS/HSDPA/HSUPA networks employ either ATM or IP as their transport layers. CDMA 1x-RTT can have either HDLC or TDM transport whereas CDMA 1x EV-DO uses IP as its transport mechanism. Among these 2G and 3G technologies data rates can be somewhere from approximately 56Kbps to 3 Mbps. As most of the legacy backhauls were primarily designed for circuit-switched services and later evolved and provided packet-switched services, providing increasingly higher data rates for packet-switched services has not been cost effective. It is because of these challenges the new 4G LTE standards were developed by 3GPP. Since 4G networks are IP-only networks, different solutions were proposed to provide cost effective migration paths from legacy backhauls to 4G backhauls. As discussed later, Metro Ethernet Forum and Broadband Forum (formerly MPLS forum) have proposed solutions for migration strategies based on Ethernet and MPLS.

2.2 4G LTE Networks

The focus of 4G LTE is all IP, packet-switched network as standardized by 3GPP. It was introduced in Rel. 8. With increase in demand for mobile broadband services, 4G promises to solve the problem of providing cost effective high bandwidth packet switched services. It is forecasted that the demand for circuit switched voice services is going to decrease relative to the corresponding increase in demand for IP based services.

The lines between circuit switched voice and packet switched voice are already getting blurred. In wired networks, VoIP already has a firm foothold. In wireless networks, Voice over LTE (VoLTE) appears to the mode of choice for future as it provides a voice solution similar to VoIP with the option of simultaneous use of other internet services. With the recent successful test announcement (Feb. 10, 2011) of a VoLTE call by Verizon in US, it is clear that we are seeing a gradual transformation of mobile wireless networks into all IP packet based networks similar to what we already have in wireline networks. Nokia Siemens is also in testing phase of VoLTE implementations.

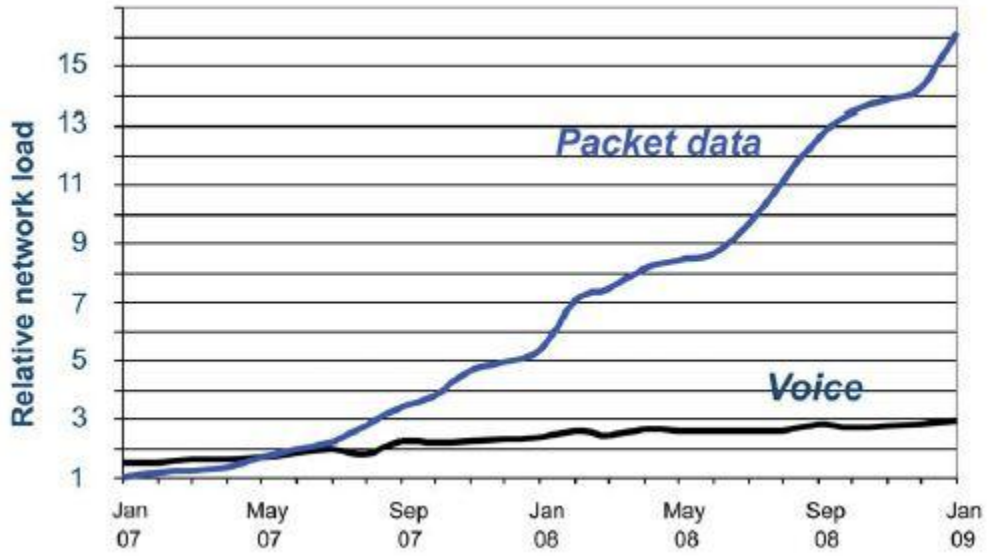
It is estimated that 3.4 billion people will have broadband access by 2014 and among them 80% are expected to be mobile broadband users [10]. In order to serve all these subscribers, LTE is going to be the technology of choice with the migration from current network technologies. The figure below shows the projected growth of fixed and mobile broadband subscribers. [10]



Source: [10]

Packet data has already overtaken voice traffic in terms of relative use. This happened after HSPA was introduced in 2007. Since then there is a continuous growth in packet data [10]. With the continuous growth of packet data with the use of applications like video blogging, interactive video and video streaming, LTE is the technology of choice

for mobile network implementations. The graph below shows the trend of packet data increase relative to voice traffic.



Source: [10]

The key features that make LTE beneficial are the capacity, performance, simplicity and support of wide range of terminal equipment. The downlink speeds of more than 300Mbps is allowed with the requirement of providing at least 100 Mbps of peak rate. Radio access network round-trip times of less than 10ms are already being met. Simplicity comes from the flexibility in choosing carrier bandwidth. The bandwidth can be from 1.4MHz to 20MHz with the choice of FDD or TDD multiplexing. This gives wireless carriers the flexibility in LTE deployments matching customer requirements and business goals. LTE also support wide range of terminal equipment and meets requirements of handover and roaming to existing networks.

It is clear from above that LTE puts significant demand on mobile backhaul network. Since LTE is all IP network, it gives the tools and flexibility of using Ethernet and IP related protocols, standards and technology for cost-effective mobile backhaul deployments, in contrast with the legacy backhauls which have been in use and evolved from voice and circuit-centric approach.

3 Proposed Solutions

Metro Ethernet Forum (MEF) and Broadband Forum (formerly MPLS forum) have been working for the promotion, equipment interoperability and widespread deployment of Carrier Ethernet and MPLS technologies. Whereas MEF develops standards for defining UNI interfaces and services for Carrier Ethernet networks, Broadband Forum works on the translation and implementation of these services by using MPLS as a transport mechanism.

3.1 Metro Ethernet Forum (MEF)

MEF is a non-profit organization formed in 2001 to promote and accelerate worldwide adoption of Carrier Ethernet technologies, solutions and services. With membership of over 150 organizations it creates interoperability standards and specifications for Carrier Ethernet deployments. [2]

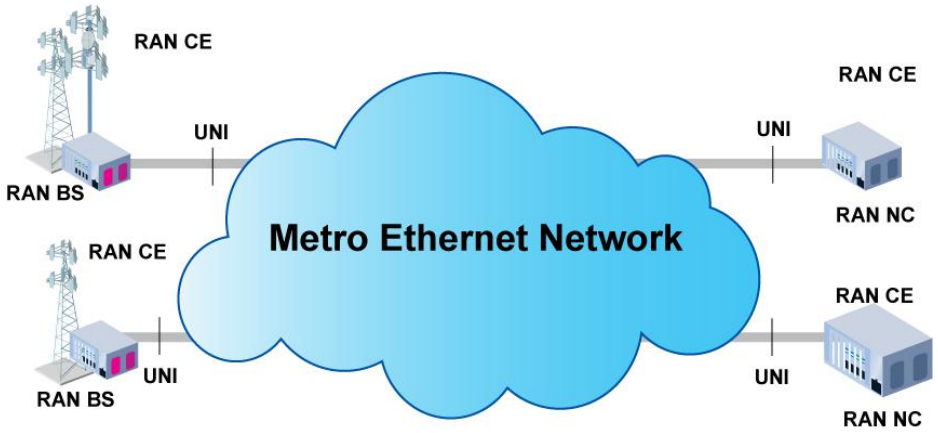
Carrier Ethernet is characterized by its ability to provide standard services like E-Line and E-LAN, scalability and granularity of bandwidth offerings, reliability with QoS guarantees and OAM support.

The Ethernet connectivity can be offered to a customer that could span across the globe providing standard Ethernet interfaces at customer sites. The Ethernet connections are termed as Ethernet Virtual Connections (EVC) and are transparently transported across a variety of transport media. The services offered could be point-to- point (E-Line), multipoint-to-multipoint (E-LAN) or point-to-multipoint (E-Tree) [2].

For a typical mobile backhaul application a typical setup would be point-to-multipoint where different mobile cell sites are backhauled to a common point. In this scenario an E-Tree type of service is most appropriate. Since the traffic in a 4G environment is IP centric, a scalable packet-switched Ethernet solution is ideal.

3.3.1 MEF 22 – Mobile Backhaul Implementation Agreement Specification

MEF 22 specifications provide guidelines on migration strategies and use cases pertaining to mobile backhaul network Ethernet solutions. The reference model used for the specification is shown below [5]:



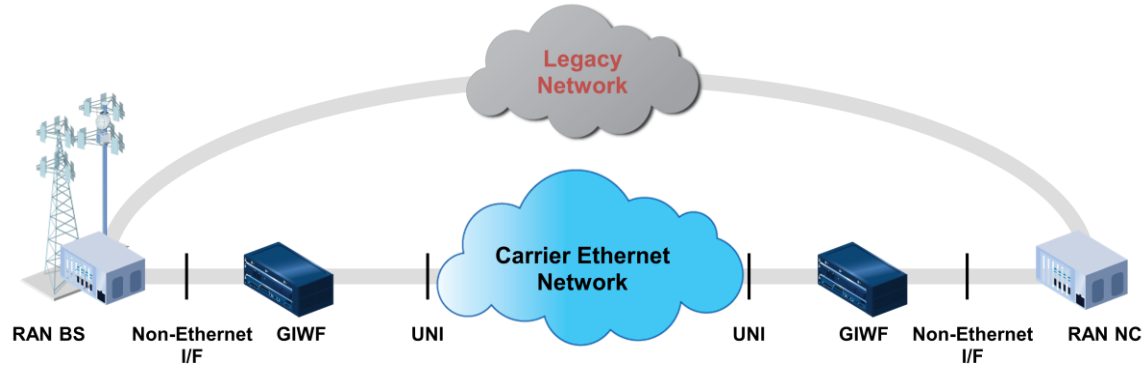
Reference Model for MEF specifications. Source: [5]

RAN CE is a general term used for a Radio Access Network Customer Edge which could be a RAN BS or a RAN NC. The specification use the terms Metro Ethernet Network and Carrier Ethernet Network interchangeably. Scenarios where multiple MEN domains are involved are not studied in MEF 22 specifications.

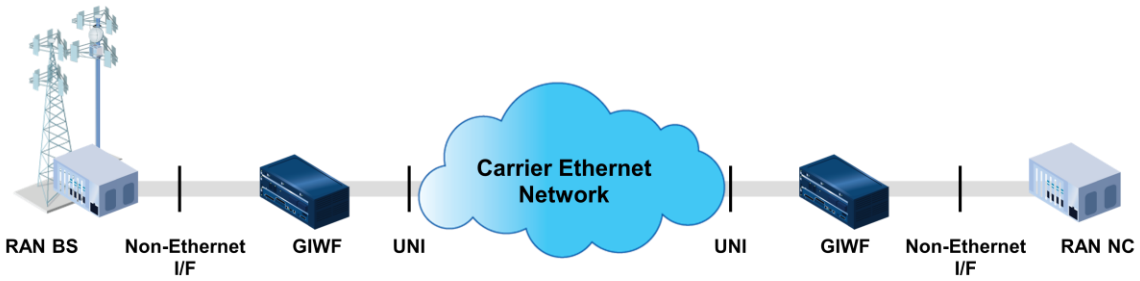
Specifically the specification deals with service types, traffic classes, migration strategies, use cases, Generic Interworking Functions (GIWF), synchronization and clock recovery.

The deployment of Ethernet services between RAN BSs and RAN NCs may fall in one of the use cases discussed below.

In a scenario where both RAN BS and RAN NC are not equipped with Ethernet interfaces and utilize only legacy interfaces like TDM or ATM an additional function needs to be added between legacy interfaces and MEN UNI. The Specification calls this function as Generic Interworking Function (GIWF). Depending upon the migration strategy used, the operator might not want to transfer all traffic through GIWF. In this case the legacy network is maintained while offloading some traffic to MEN. The two diagrams below show the two variations mentioned above. [5]

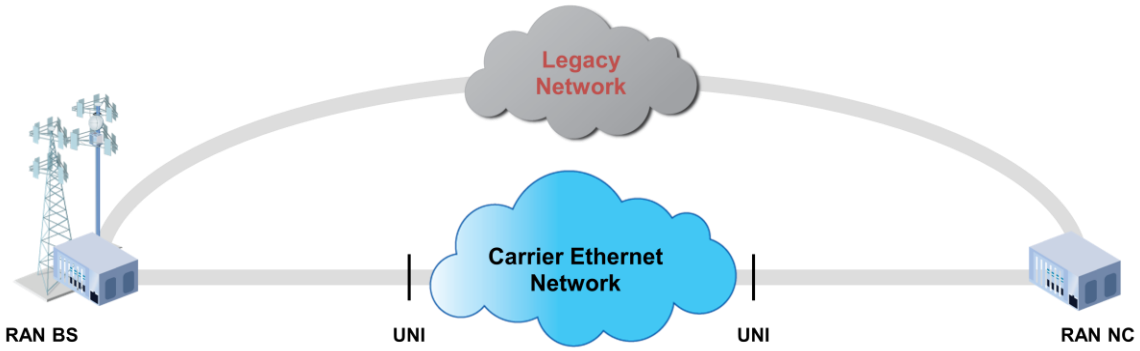


Co-existence of Carrier Ethernet and Legacy Network. Source: [5]

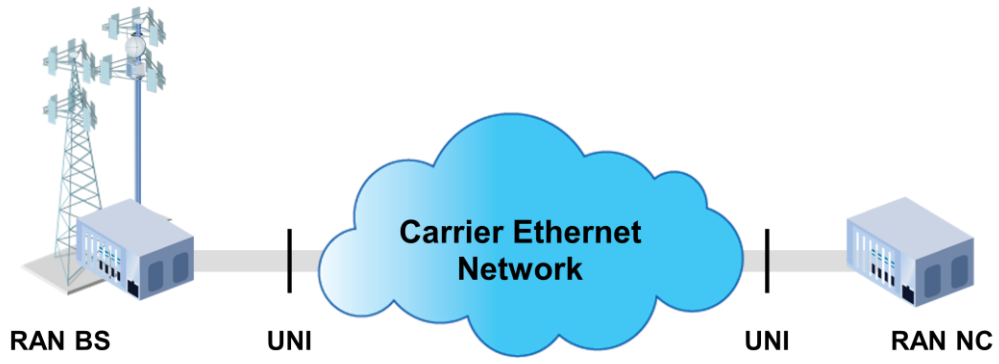


All Traffic Through Carrier Ethernet Network [5].

In contrast with the above scenarios, RAN BS and RAN NC might be able to interface directly with the MEN UNI interface eliminating the need of GIWF as above. In this case as well, the operator might still want to keep the legacy backhaul network for high priority traffic while offloading bandwidth intensive traffic to the MEN. The following two diagrams depict the two variations depending whether or not legacy backhaul is kept in the setup. [5]



Direct interfacing of RAN BS with Carrier Ethernet Network without GIWF [5].



Ethernet-only network with no parallel legacy network [5].

As mentioned above, mobile backhaul Ethernet service can be deployed as E-Line, E-LAN or E-Tree service. Since the Ethernet service can be either port-based or VLAN-based, there are six possible types of services which could be utilized in a mobile backhaul Ethernet network. The services are,

- Ethernet Private Line Service
- Ethernet Virtual Private Line Service
- Ethernet Private LAN Service
- Ethernet Virtual Private LAN service
- Ethernet Private Tree Service
- Ethernet Virtual Private Tree Service

The specifications gives a CoS model that can be used for mobile backhaul traffic. Based on this model traffic can be classified into 4, 3 or 2 classes. The table below shows the different CoS classification.[5]

	Example of Generic Traffic Classes mapping into CoS		
Service Class Name	**4 CoS Model**	**3 CoS Model**	**2 CoS Model**
Very High (H$^+$)	Synchronization	-	-
High (H)	Conversational, Signaling and Control	Conversational and Synchronization, Signaling and Control	Conversational and Synchronization, Signaling and Control, Streaming
Medium (M)	Streaming	Streaming	-
Low (L)	Interactive and Background	Interactive and Background	Interactive and Background

The specification mandates the use of at least 2 CoS model where the traffic is classified into High and Low classes.

Another functionality that the Carrier Ethernet Network needs to have is synchronization. Different mobile technologies have different synchronization requirements. The timing distribution in a mobile network can be achieved using one of the following three methods and are mentioned for reference purpose only.

- Using GPS or via a legacy TDM network. In this case the synchronization is achieved outside of the packet based Ethernet network.

- Distribution of timing using the packet based Ethernet network.

- Using synchronous Ethernet.

3.2 Broadband Forum (MPLS Forum)

While MEF provide specifications for different types of Ethernet services and SLAs for external interfaces of the packet network, the Broadband Forum's work and specifications pertains to the underlying transport network to provide satisfactory Ethernet services specified by MEF.

The Broadband Forum, which merged with IP/MPLS forum in 2009 focuses on the evolution of next generation IP networks. The forum's work spans different areas of interest related to next generation IP networks. The area of work which pertains to this project is the forum's MPLS Mobile Backhaul Initiative (MMBI).

3.2.1 MPLS Mobile Backhaul Initiative (MMBI).

MPLS is considered the key technology that provides a smooth transition path from legacy backhaul to a packet based backhaul network. Therefore MPLS is considered evolution friendly where service providers can maximize the use of their existing investment while gradually migrating to a completely packet-based backhaul network. With the ability of traffic engineering, QoS requirement enforcement, OAM and resiliency, MPLS technology is a perfect fit for mobile backhaul implementations. For LTE deployments, 3GPP specifications make an IP based backhaul mandatory. Broadband Forum's MMBI is an industry wide initiative with the goal to use MPLS technology in mobile backhaul network. The aim is to reduce the risk of interoperability issues by providing guidelines for backhaul network deployments. With the use of MPLS, backhaul aggregation can be implemented with Virtual Private LAN Service (VPLS), Virtual Private Wire Service (VPWS) or L3 VPN. VPLS implementation blends well with the recommendations of Metro Ethernet Forum especially in LTE scenario where any-to-any connectivity is desired.

The use of MPLS in a mobile network can be separated into two general categories corresponding to types of mobile networks. A mobile backhaul network is considered either centralized or flat depending upon how BS Sites/Gateways are connected to Radio Controllers/Access Gateways and whether or not BS-BS direct links exist. The two categories are briefly described below.

Centralized Mobile Network:

A centralized mobile network is implemented for current and legacy technologies. In order to use MPLS is such networks, different Transport Network Layers need to be carried over the MPLS network. The following table shows transport network layer requirements for different mobile technologies. [8]

Network Technology	**Transport Network**
GSM/GPRS/EDGE (2G/2.5G)	TDM
UMTS	ATM, IP
CDMA 1x-RTT	HDLC or TDM
CDMA 1x EV-DO	IP

As mentioned above, there are four different Transport Network Layers that need to be carried over an MPLS network, i.e., TDM, ATM, HDLC and IP. Emulation of these transport layers over MPLS network is required for smooth migration from these legacy and current technologies to an all IP and Ethernet 4G network.

Different use cases may arise depending on the extent of MPLS use along the path from a Cell Site Gateway to Radio Controller. These use cases may become part of a migration strategy for gradual transformation from legacy transport networks to Ethernet and MPLS transport network.

Flat Mobile Network:

Flat Mobile Network architecture is used for LTE, Mobile WiMAX, HSPA and UMB. The transport network layer used is strictly IP. With the transport network layer being IP, MPLS implementations between BS and aGW (Access Gateway) as well as between BS and BS can be characterized into two different use cases. The implementation can either be a L2VPN or L3VPN service.

L3VPN is implemented in access, aggregation and core parts of mobile backhaul network. The same L3VPN solution must be used for BS-aGW and BS-BS links in the network.

As in L3VPN solution, L2VPN can also be implemented in access, aggregation and core parts of mobile backhaul network. Also, the same L2VPN solution must be used for both BS-aGW and BS-BS links in the network.

Later in the example lab setup, we'll implement a L2VPN MPLS solution in the form of VPLS.

4 Vendor Support

Metro Ethernet Forum and Broadband Forum have certification programs to certify vendor equipment. Most major equipment vendors have certified network equipment to be used for mobile backhaul applications. The manufacturers include Alcatel-Lucent, Fujitsu, Cisco, Ceragon, Ciena, Ericsson, Juniper, Nokia Siemens, RAD and others. Since we have access to Alcatel-Lucent routers and Fujitsu Flashwave 4500 platforms for our lab setup, we'll focus on these two.

4.1 Alcatel Service Router series

Alcatel-Lucent Service Router series is well-suited for implementation of mobile backhaul and transport of Ethernet services over an MPLS enabled routed network. With the service distribution model and Service Access Point (SAP) configuration options for service end points, Ethernet services can be easily transported. Service end points can take the form point-to-point, point-to-multipoint and any-to-any topologies. It provides the flexibility needed for a flat network requirement of 4G backhaul. In our example setup we are implementing VPLS network to simulate a topology between RNC and BSC sites. Alcatel 7710 and 7750 routers are being used in addition to Fujitsu Flashwave 4500 provisioning platforms. The Alcatel routers are certified by MEF for Ethernet Private Line (EPL), Ethernet Virtual Private Line (EVPL) and Ethernet LAN (ELAN) services standardized in MEF 9 and MEF 14 standards.

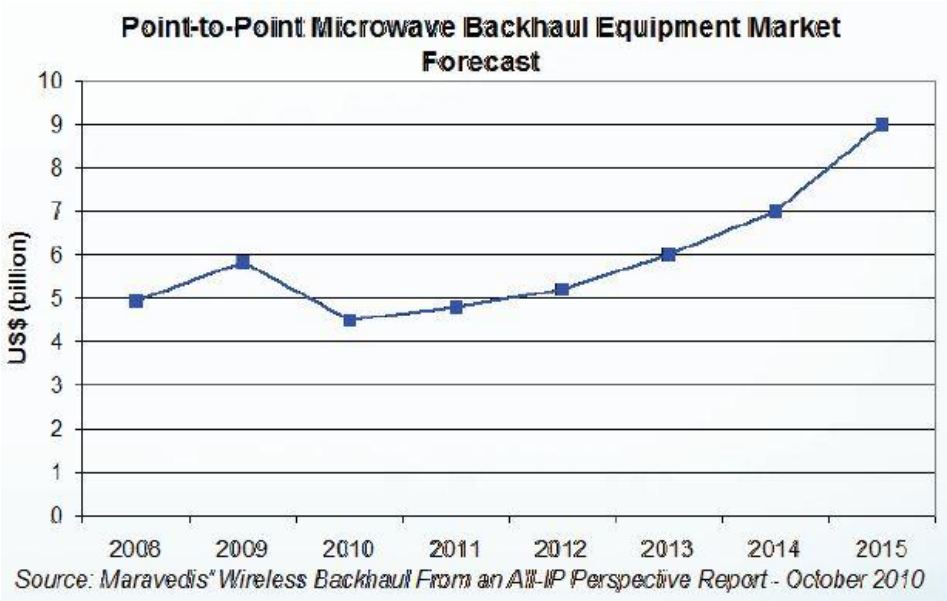
4.2 Fujitsu Flashwave 4500 Provisioning Platform

In order to add fibre core into our example setup we are implementing a UPSR SONET fibre ring using four Flashwave 4500s available in our lab. The 4500 Platform provide provisioning options suitable for carrying packet-based Ethernet services across an optical fibre ring. Possible provisioning options include EPORT (Ethernet Port), TPORT (Ethernet Trunk Port) and (RPR) Resilient Packet Ring. These services can be provisioned on specific plug-in units designed for these services. Since we have access to EPORT plug-in units only, we'll be using EPORT service for the fibre core network.

4.3 Microwave Wireless Backhaul Option

In addition to the wireline backhaul solutions involving copper and fibre connections, there is a competing backhaul solution using point-to-point microwave links. At certain sites, especially at remote locations, wired backhaul is either not possible or too expensive compared to RF solution. With 4G backhaul being totally IP based, the difference in physical medium only puts limitations on maximum available data rates. Both licensed and unlicensed bands can be used for microwave links. There is a range of products available from a number of vendors, including Motorola, GE MDS, Bridgewave and others, for point-to-point microwave backhaul implementations. These microwave

links can be flexibly deployed forming backhaul topologies of hub-spoke, tree, mesh, ring or daisy chain as needed. Wireless backhaul market tends to increase in the coming years to provide universal coverage for 4G services. The following graph shows the trend in this direction based on study done by Maravedis [11].

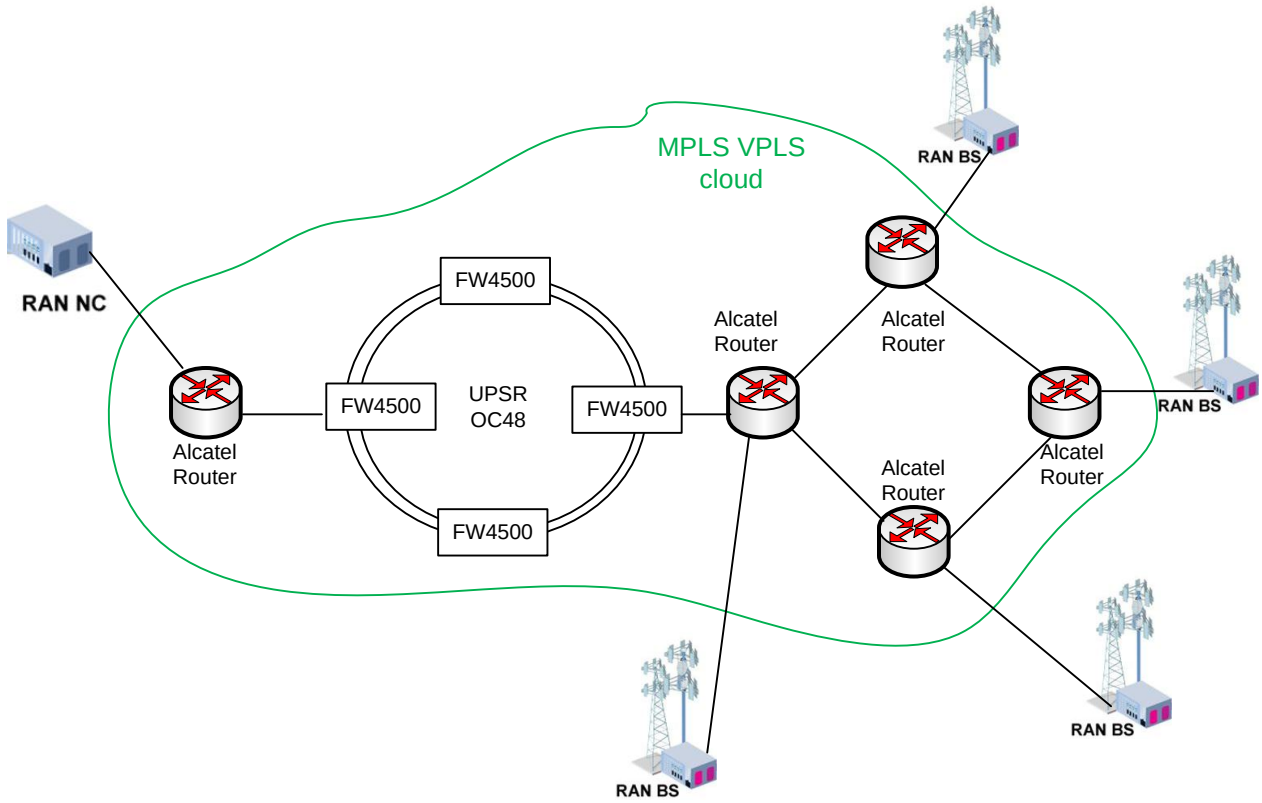


As mentioned above, wireless backhaul currently plays and expected to play an increasingly important role in mobile backhaul solutions. This aspect is not part of the example configuration setup of this project.

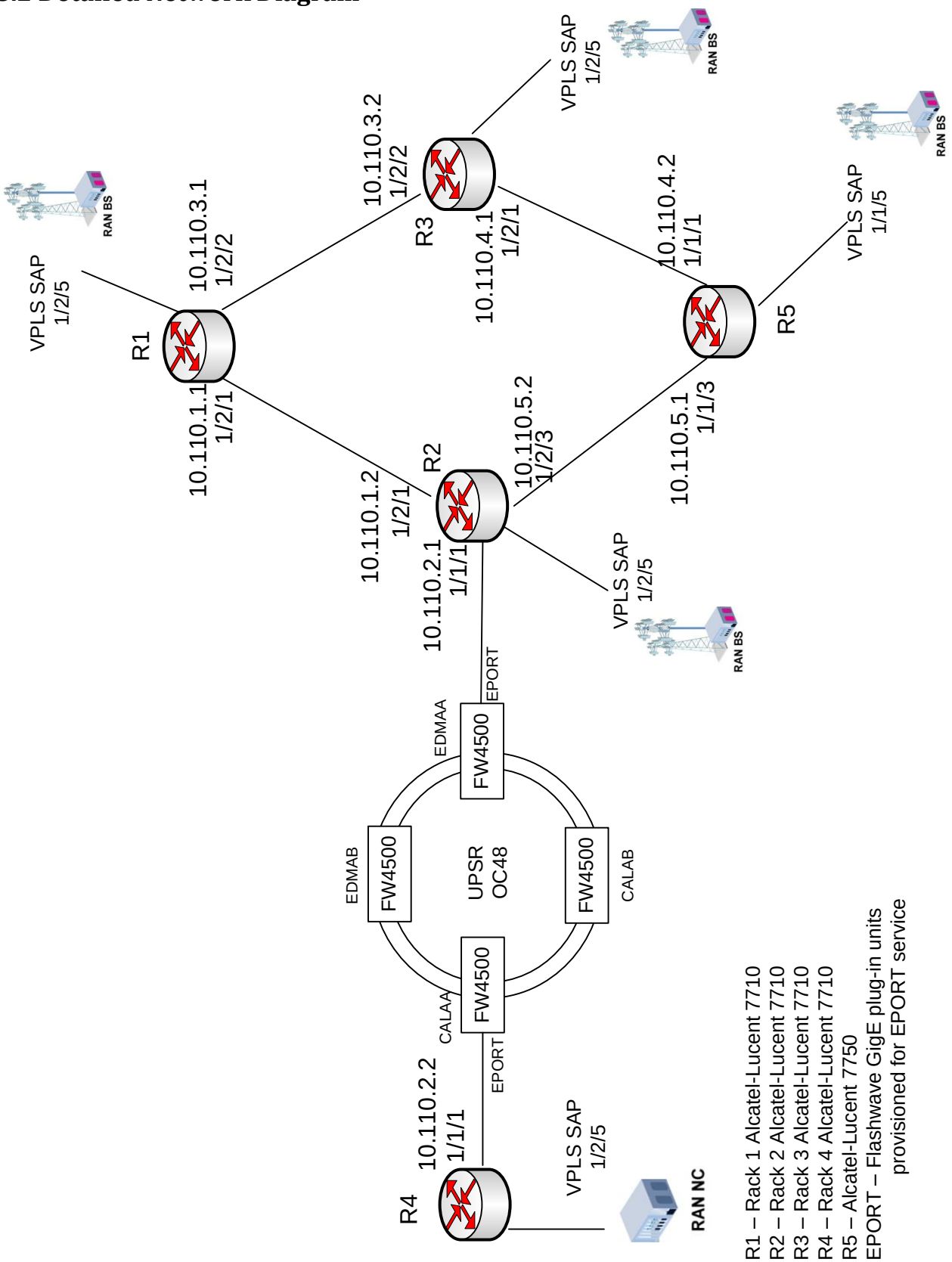
5 Example Lab Setup

5.1 Configuration Overview

In the lab setup four Alcatel Lucent 7710, one Alcatel Lucent 7750 and four Fujitsu Flashwave 4500 are used. One Alcatel 7710 is used to simulate connection to an RNC site and the remaining Alcatel routers are used for BS or aggregation sites. MPLS VPLS service is configured across the whole network with Ethernet Service Access Points (SAPs) provided at all sites. A UPSR SONET ring is implemented which separates the simulated RNC site from all BS sites. EPORT service is provisioned at two sites which have Alcatel 7710 routers connected with Flashwave 4500 through the corresponding GigE fibre ports. Appropriate cross-connects are provisioned at all four Flashwave 4500 sites. Following is a conceptual diagram illustrating the network setup.



5.2 Detailed Network Diagram



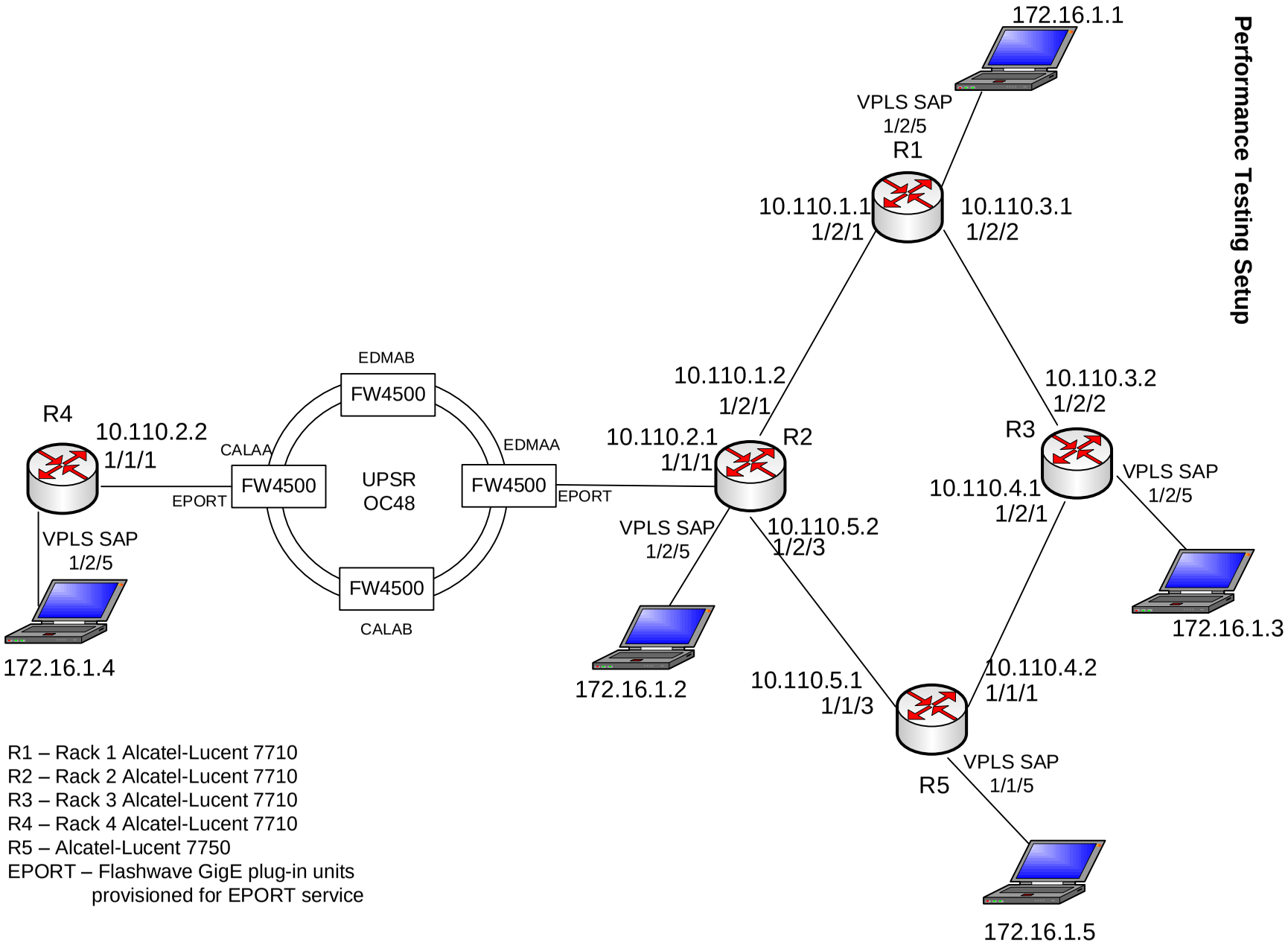
6. Testing

6.1 Performance Testing

The following tests are conducted to determine latency, throughput and jitter in between various VPLS service points.

1. Traceroute and Ping tests between two laptops placed at various VPLS service endpoints to verify layer-2 connectivity and to determine latency/delay.
2. Jperf test run between two laptops placed at various VPLS service points to determine jitter and throughput.

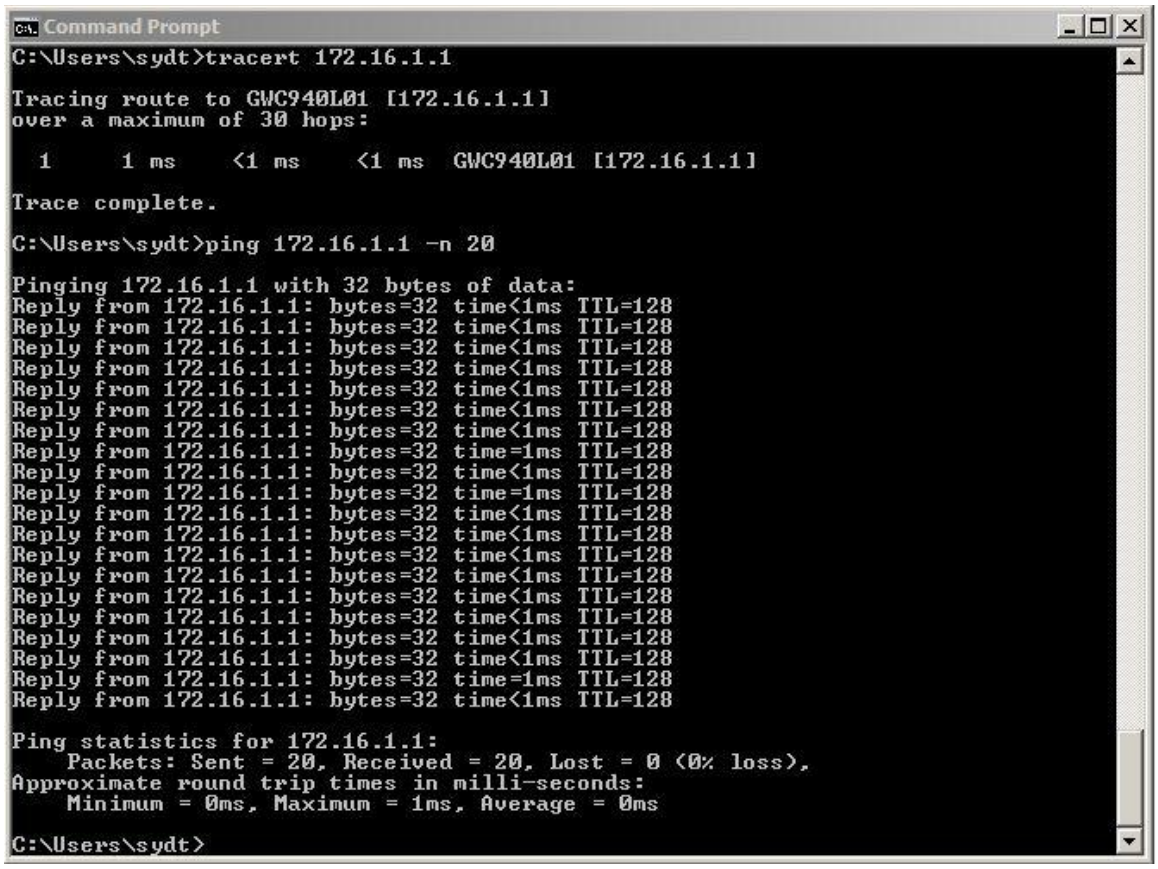
All laptops are part of the same subnet (172.16.1.0/24) as they are connected through a layer-2 VPLS service. The test setup for performance testing is illustrated in the following diagram.



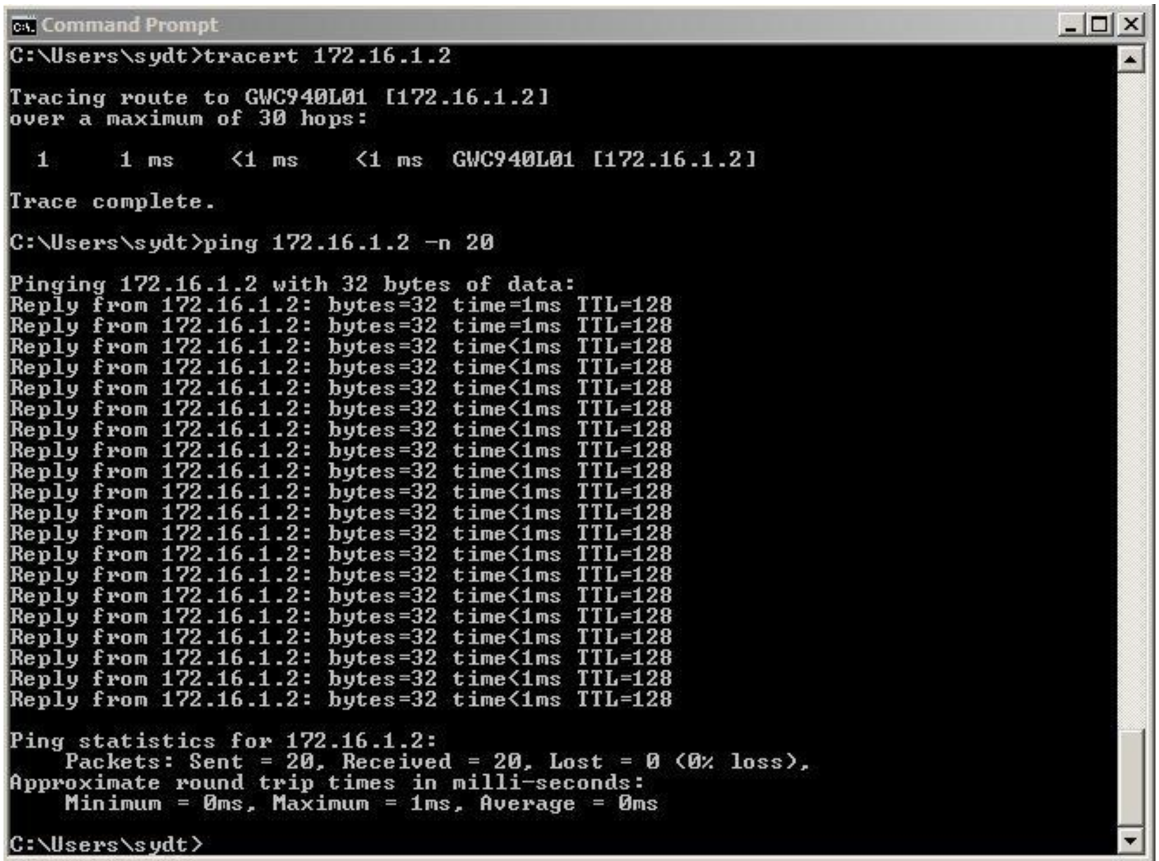
R1 – Rack 1 Alcatel-Lucent 7710
R2 – Rack 2 Alcatel-Lucent 7710
R3 – Rack 3 Alcatel-Lucent 7710
R4 – Rack 4 Alcatel-Lucent 7710
R5 – Alcatel-Lucent 7750
EPORT – Flashwave GigE plug-in units
provisioned for EPORT service

Test Results – Trace route and Ping

1. Trace route and Ping from R4 to R1.

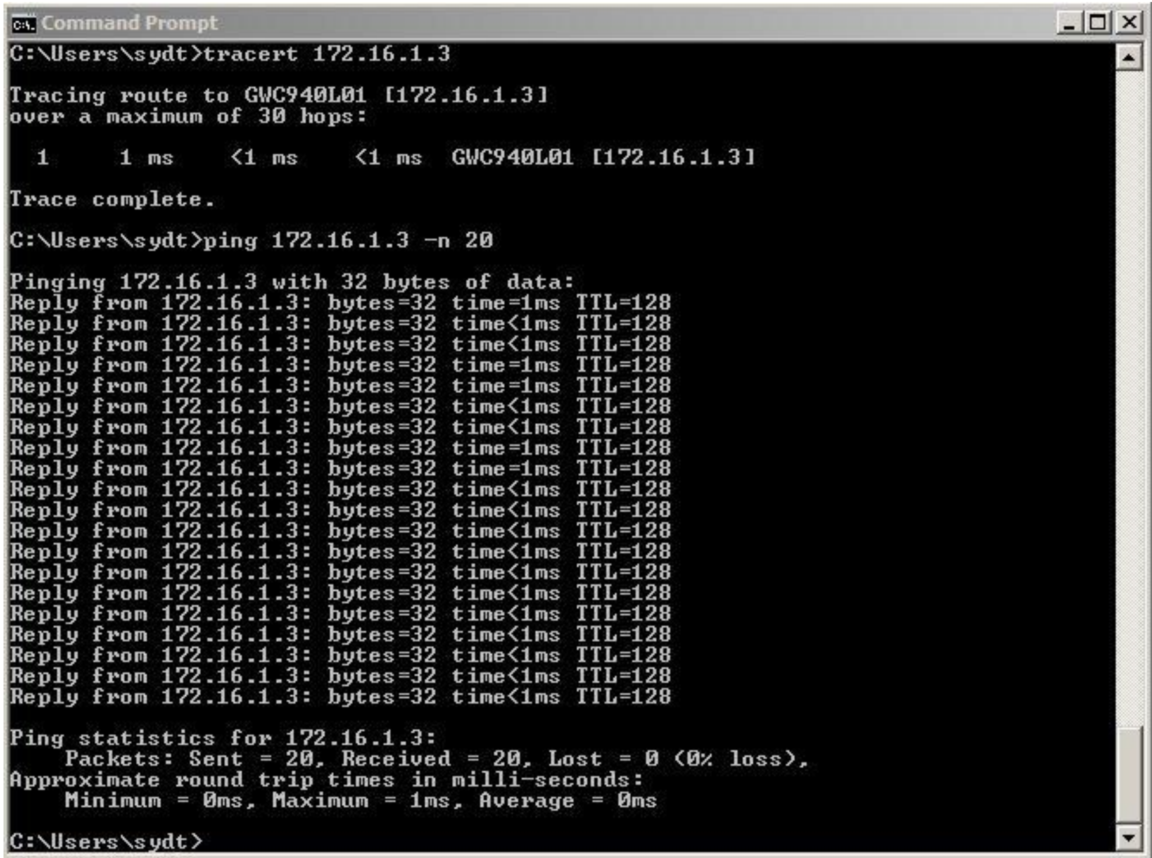


2. Trace route and Ping from R4 to R2.



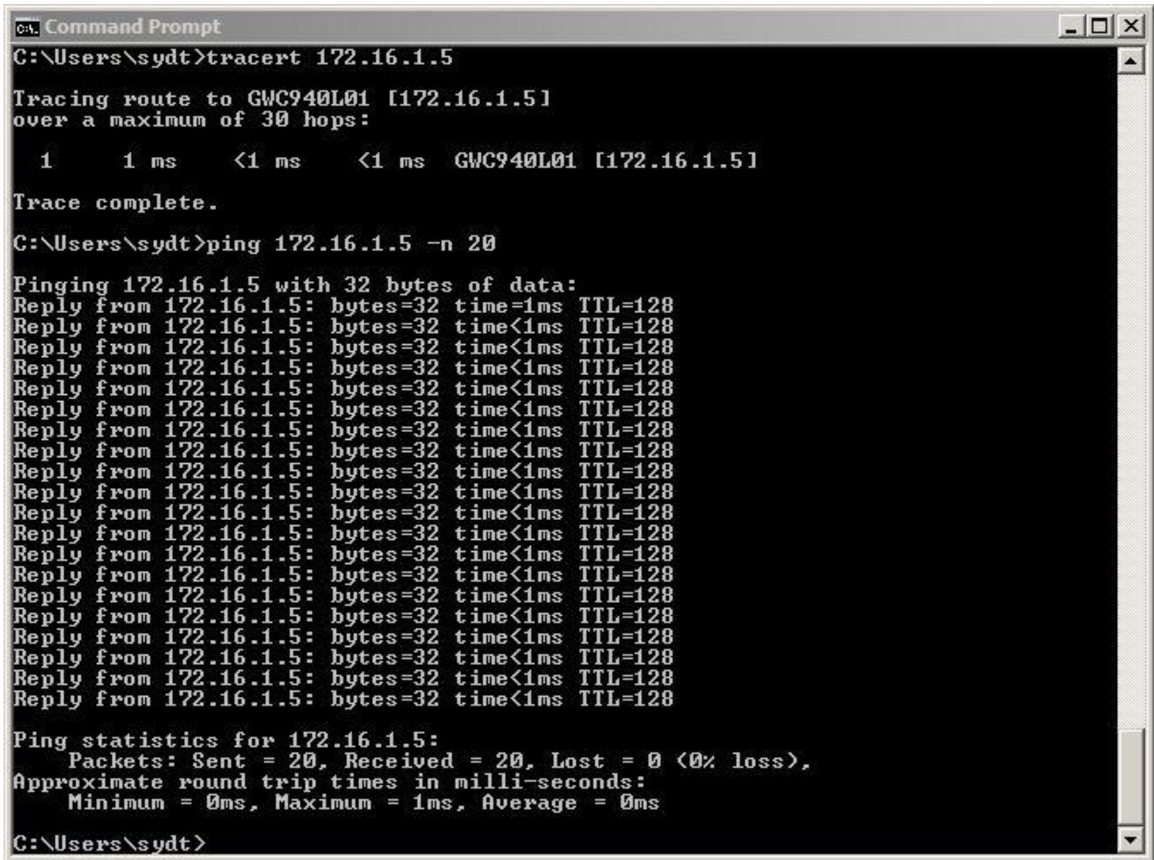
```
Command Prompt
C:\Users\sydt>tracert 172.16.1.2

Tracing route to GWC940L01 [172.16.1.2]
over a maximum of 30 hops:

  1     1 ms    <1 ms    <1 ms  GWC940L01 [172.16.1.2]

Trace complete.

C:\Users\sydt>ping 172.16.1.2 -n 20

Pinging 172.16.1.2 with 32 bytes of data:
Reply from 172.16.1.2: bytes=32 time=1ms TTL=128
Reply from 172.16.1.2: bytes=32 time=1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128
Reply from 172.16.1.2: bytes=32 time<1ms TTL=128

Ping statistics for 172.16.1.2:
    Packets: Sent = 20, Received = 20, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\sydt>
```

3. Trace route and Ping from R4 to R3.



```
Command Prompt
C:\Users\sydt>tracert 172.16.1.3

Tracing route to GWC940L01 [172.16.1.3]
over a maximum of 30 hops:

  1     1 ms    <1 ms    <1 ms  GWC940L01 [172.16.1.3]

Trace complete.

C:\Users\sydt>ping 172.16.1.3 -n 20

Pinging 172.16.1.3 with 32 bytes of data:
Reply from 172.16.1.3: bytes=32 time=1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time=1ms TTL=128
Reply from 172.16.1.3: bytes=32 time=1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time=1ms TTL=128
Reply from 172.16.1.3: bytes=32 time=1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128
Reply from 172.16.1.3: bytes=32 time<1ms TTL=128

Ping statistics for 172.16.1.3:
    Packets: Sent = 20, Received = 20, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\sydt>
```

4. Trace route and Ping from R4 to R5



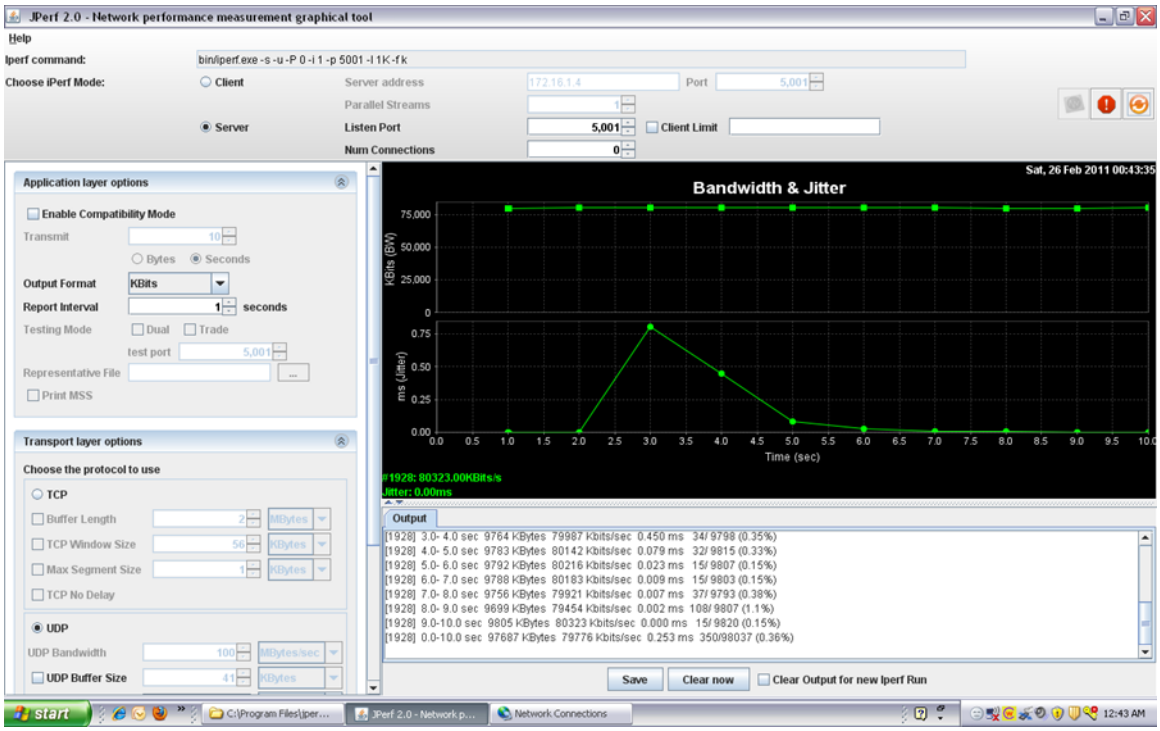
```
C:\Users\sydt>tracert 172.16.1.5

Tracing route to GWC940L01 [172.16.1.5]
over a maximum of 30 hops:

  1     1 ms    <1 ms    <1 ms  GWC940L01 [172.16.1.5]

Trace complete.

C:\Users\sydt>ping 172.16.1.5 -n 20

Pinging 172.16.1.5 with 32 bytes of data:
Reply from 172.16.1.5: bytes=32 time=1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128
Reply from 172.16.1.5: bytes=32 time<1ms TTL=128

Ping statistics for 172.16.1.5:
    Packets: Sent = 20, Received = 20, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\sydt>
```

As can be seen from the above 4 results, all end-devices (laptops) are only 1 hop away from each other. The ICMP round-trip times are less than or equal to 1ms.

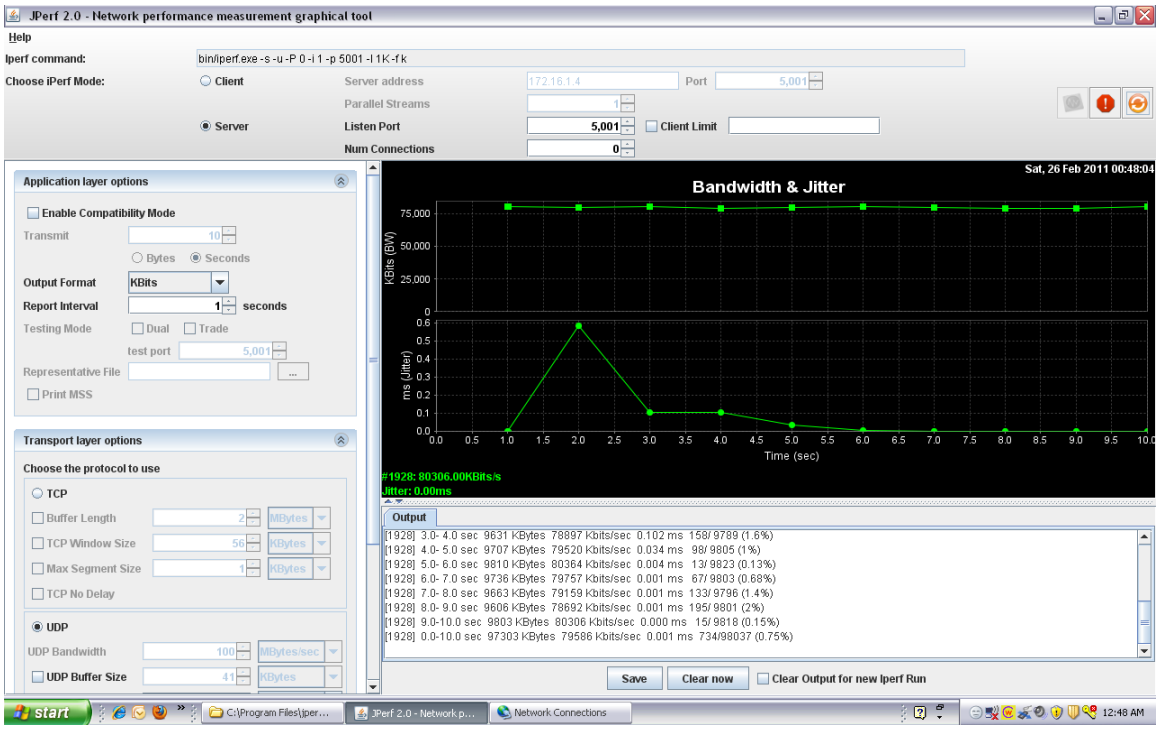
Test Results – Jitter and Throughput

Jperf is used for Jitter and Throughput measurements with client and server laptops connected in the same combinations as before.

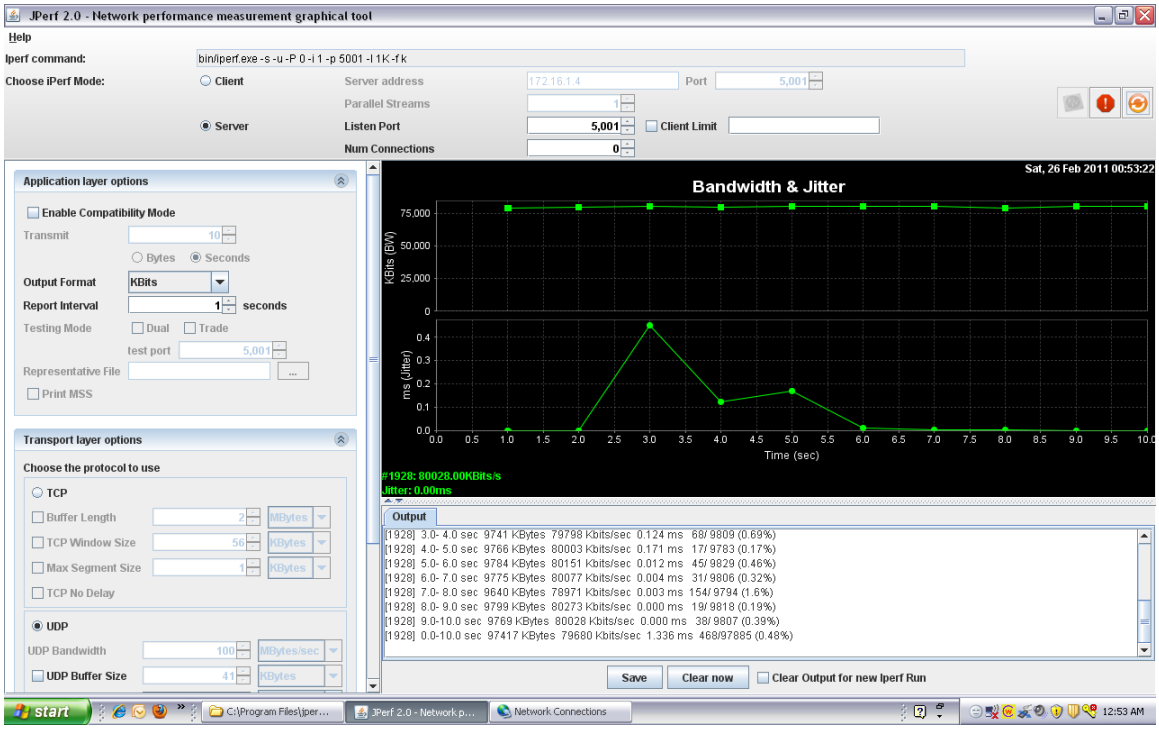
1. Jperf test between R4 and R1



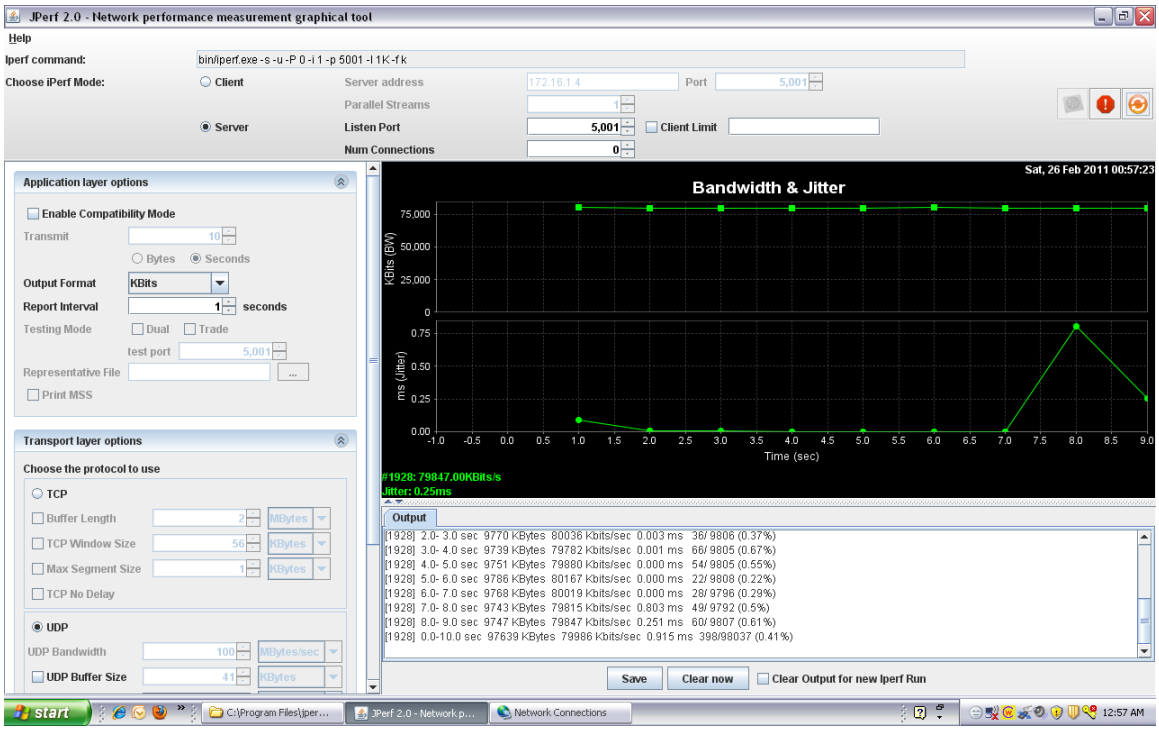
2. Jperf test between R4 and R2



3. Jperf test between R4 and R3



4. Jperf test between R4 and R5.

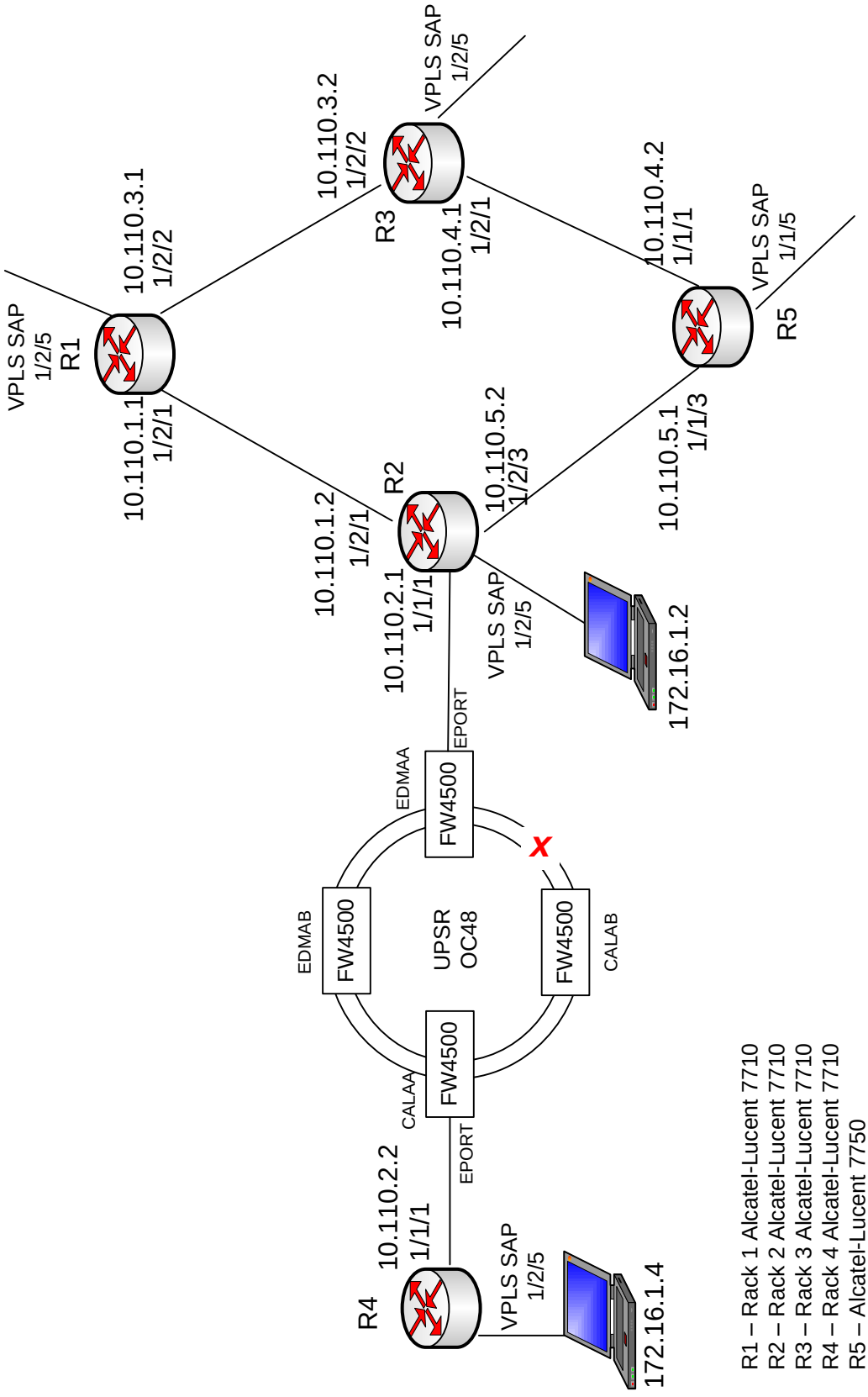


As can be seen from the above results, we are seeing approx. 80Mbps of throughput. The laptops are connected to 100Mbps ports of Alcatel routers. Jitter value is minimum (0.001ms) between R4 and R2. Both of these routers are directly connected to the fibre ring through the EPORT service of Flashwave 4500s. The maximum value of jitter (1.33ms) is between R4 and R3.

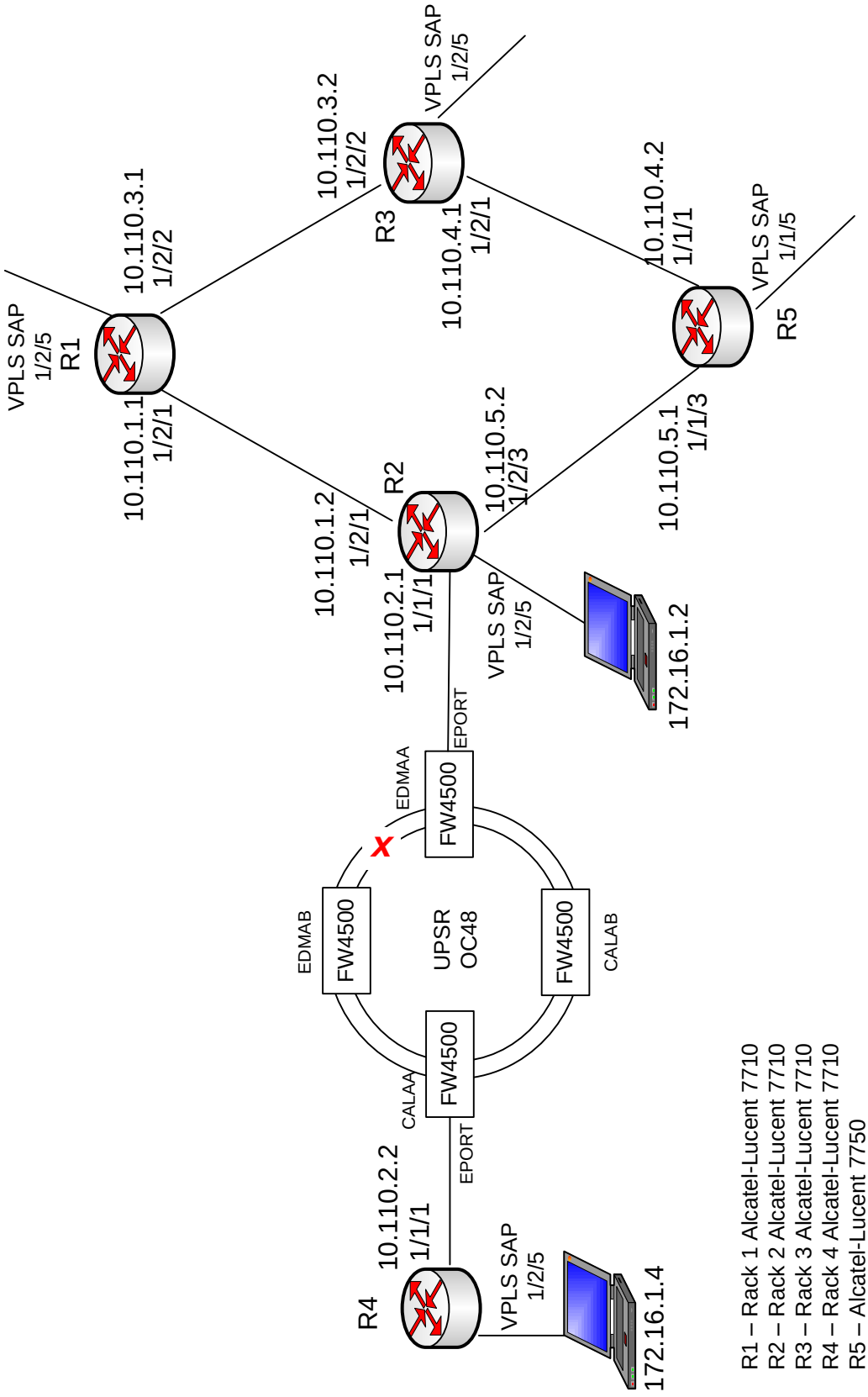
6.2 Fibre Ring Failure Testing

The following two scenarios of fibre link failure are tested by unplugging the fibres.

Fiber Link Failure Test 1

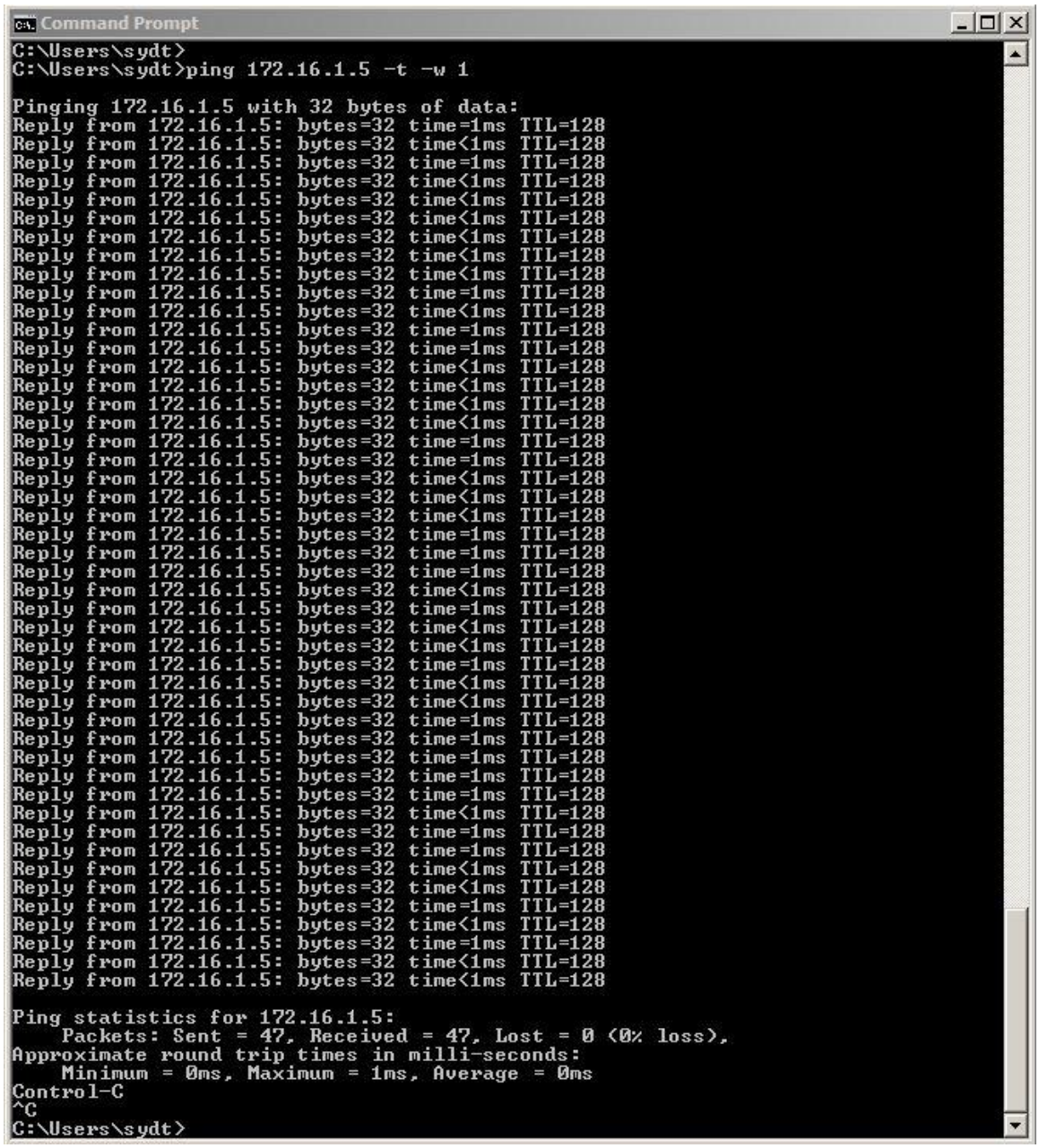


Fiber Link Failure Test 2



R1 – Rack 1 Alcatel-Lucent 7710
R2 – Rack 2 Alcatel-Lucent 7710
R3 – Rack 3 Alcatel-Lucent 7710
R4 – Rack 4 Alcatel-Lucent 7710
R5 – Alcatel-Lucent 7750
EPORT – Flashwave GigE plug-in units
provisioned for EPORT service

Before unplugging the fibres, continuous ICMP Ping messages are started from the laptop at R2 with the timeout set at 1ms. In both scenarios the ring recovered from failure before the timeout. A more precise method is needed to determine the actual recovery times. The screen shot is shown below.



7. Conclusion

The solution to 4G LTE wireless backhaul problem is complex especially considering the fact that there are a variety of backhaul transport networks already in place which cannot decommissioned overnight. The solutions proposed by MEF and Broadband Forum provide guidelines for migration strategies which can be put in place depending upon a particular scenario. The example network setup, which is configured, illustrates one such common scenario, among many, which can be used as a mobile backhaul solution.

8. References

1. MMBI White Paper on Use of MPLS in LTE.
2. Metro Ethernet Forum – An overview of the work of MEF.
3. Metro Ethernet Forum - Carrier Ethernet for Mobile Backhaul.
4. Introducing the specifications of MEF - Mobile Backhaul Implementation Agreement.
5. MEF 22 Technical Specifications.
6. MEF Technical Specifications 6.1 – Ethernet Services Definitions.
7. MEF Technical Specifications 10.2 – Ethernet Services Attributes.
8. MPLS Forum – MPLS in backhaul framework and requirements technical specifications.
9. Broadband Forum – Use of MPLS in mobile backhaul networks.
10 Ericsson White Paper – LTE An Introduction.
11. A Practical Look at LTE Backhaul Capacity Requirements by Maravedis Wireless Market Research and Analysis.
12.IP/MPLS Forum – "MPLS in Mobile Backhaul" Certification program

9. Appendix – Router Configurations

9.1 R1

```
# TiMOS-B-6.1.R4 both/hops ALCATEL SR 7710 Copyright (c) 2000-2008 Alcatel-
Lucent.
# All rights reserved. All use subject to applicable license agreements.
# Built on Thu Oct 30 15:49:21 PDT 2008 by builder in /rel6.1/b1/R4/panos/main

# Generated MON FEB 21 08:12:21 2011 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "RACK-1"
        ccm 1
        exit
        power-supply 1 ac single
        power-supply 2 ac single
        snmp
            shutdown
            packet-size 9216
        exit
        login-control
            telnet
                inbound-max-sessions 1
            exit
        exit
        time
            sntp
                shutdown
            exit
            zone MST
        exit
        thresholds
            rmon
            exit
        exit
    exit
#--------------------------------------------------
echo "System Security Configuration"
#--------------------------------------------------
```

```
    system
        security
            telnet-server
            ftp-server
            user "admin"
                password ".wwBSCf55BeJQsICA8BrJ." hash2
                access console ftp snmp
                console
                    member "administrative"
                exit
            exit
            snmp
                community "uTdc9j48PBRkxn5DcSjchk" hash2 rwa version both
            exit
            per-peer-queuing
        exit
    exit
#--------------------------------------------------
echo "Log Configuration"
#--------------------------------------------------
    log
        snmp-trap-group 98
            description "5620sam"
            trap-target "10.3.31.166:162" address 10.3.31.166 snmpv2c notify-community
"privatetrap98"
        exit
        log-id 98
            from main security
            to snmp 1024
        exit
    exit
#--------------------------------------------------
echo "System Security Cpm Hw Filters Configuration"
#--------------------------------------------------
    system
        security
        exit
    exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
    exit
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
```

```
    card 1
        card-type iom-9g
        mda 1
            mda-type c1-1gb-sfp
            ingress
            exit
        exit
        mda 2
            mda-type c8-10/100eth-tx
            ingress
            exit
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/1/1
        shutdown
        ethernet
        exit
    exit
    port 1/2/1
        ethernet
        exit
        no shutdown
    exit
    port 1/2/2
        ethernet
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
        exit
        no shutdown
    exit
    port 1/2/5
        ethernet
            mode access
        exit
        no shutdown
```

```
    exit
    port 1/2/6
        shutdown
        ethernet
        exit
    exit
    port 1/2/7
        shutdown
        ethernet
        exit
    exit
    port 1/2/8
        ethernet
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "System Sync-If-Timing Configuration"
#--------------------------------------------------
    system
        sync-if-timing
            begin
            ref1
                shutdown
            exit
            ref2
                shutdown
            exit
            commit
        exit
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
    router management
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.1.1.1/32
        exit
        interface "toR2"
            address 10.110.1.1/24
```

```
            port 1/2/1
        exit
        interface "toR3"
            address 10.110.3.1/24
            port 1/2/2
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            area 0.0.0.0
                interface "system"
                exit
                interface "toR2"
                exit
                interface "toR3"
                exit
            exit
        exit
#--------------------------------------------------
echo "IGMP Configuration"
#--------------------------------------------------
        igmp
        exit
#--------------------------------------------------
echo "PIM Configuration"
#--------------------------------------------------
        pim
            shutdown
            rp
                static
                    address 192.168.2.1
                    exit
                exit
                bsr-candidate
                    shutdown
                exit
                rp-candidate
                    shutdown
                exit
            exit
        exit
#--------------------------------------------------
echo "MPLS Configuration"
#--------------------------------------------------
        mpls
```

```
            interface "system"
            exit
            no shutdown
        exit
#------------------------------------------------
echo "RSVP Configuration"
#------------------------------------------------
        rsvp
            interface "system"
            exit
            no shutdown
        exit
#------------------------------------------------
echo "LDP Configuration"
#------------------------------------------------
        ldp
            interface-parameters
                interface "toR2"
                exit
                interface "toR3"
                exit
            exit
            targeted-session
                hello 5000 255
                keepalive 5000 255
                peer 10.33.133.2
                    hello 2500 104
                    keepalive 15 3
                exit
            exit
        exit
    exit

#------------------------------------------------
echo "Service Configuration"
#------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        sdp 14 mpls create
            far-end 10.4.4.4
            ldp
            path-mtu 9190
            keep-alive
                shutdown
```

```
            exit
            no shutdown
        exit
        vpls 34 customer 1 create
            stp
                shutdown
            exit
            sap 1/2/5 create
            exit
            mesh-sdp 14:34 create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
        exit
#--------------------------------------------------
echo "IGMP Configuration"
#--------------------------------------------------
        igmp
        exit
#--------------------------------------------------
echo "PIM Configuration"
#--------------------------------------------------
        pim
        exit
#--------------------------------------------------
echo "Policy Configuration"
#--------------------------------------------------
        policy-options
            begin
            policy-statement "test"
                entry 1
                    from
                        protocol direct
                    exit
                    action accept
                    exit
                exit
```

```
            default-action reject
        exit
        commit
    exit
exit

exit all

# Finished MON FEB 21 08:12:36 2011 UTC
```

9.2 R2

```
# TiMOS-B-6.1.R4 both/hops ALCATEL SR 7710 Copyright (c) 2000-2008 Alcatel-
Lucent.
# All rights reserved. All use subject to applicable license agreements.
# Built on Thu Oct 30 15:49:21 PDT 2008 by builder in /rel6.1/b1/R4/panos/main

# Generated MON FEB 21 07:22:15 2011 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "RACK-2"
        ccm 1
        exit
        power-supply 1 ac single
        power-supply 2 none
        snmp
            shutdown
            packet-size 9216
        exit
        login-control
            telnet
                inbound-max-sessions 1
            exit
        exit
        time
            sntp
                shutdown
            exit
            zone MST
        exit
        thresholds
            rmon
            exit
        exit
    exit
#--------------------------------------------------
echo "System Security Configuration"
#--------------------------------------------------
    system
        security
            telnet-server
```

```
            ftp-server
            user "admin"
                password ".wwBSCf55BeJQsICA8BrJ." hash2
                access console ftp snmp
                console
                    member "administrative"
                exit
            exit
            snmp
                community "uTdc9j48PBRkxn5DcSjchk" hash2 rwa version both
            exit
            per-peer-queuing
        exit
    exit
#--------------------------------------------------
echo "Log Configuration"
#--------------------------------------------------
    log
        snmp-trap-group 98
            description "5620sam"
            trap-target "10.3.31.166:162" address 10.3.31.166 snmpv2c notify-community
"privatetrap98"
        exit
        log-id 98
            from main security
            to snmp 1024
        exit
    exit
#--------------------------------------------------
echo "System Security Cpm Hw Filters Configuration"
#--------------------------------------------------
    system
        security
        exit
    exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
    exit
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 1
```

```
            mda-type c1-1gb-sfp
            ingress
            exit
         exit
         mda 2
            mda-type c8-10/100eth-tx
            ingress
            exit
         exit
         mda 4
            mda-type c2-oc12/3-sfp
            ingress
            exit
         exit
      exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
      port 1/1/1
         ethernet
            speed 100
         exit
         no shutdown
      exit
      port 1/2/1
         ethernet
         exit
         no shutdown
      exit
      port 1/2/2
         ethernet
         exit
         no shutdown
      exit
      port 1/2/3
         ethernet
         exit
         no shutdown
      exit
      port 1/2/4
         ethernet
         exit
         no shutdown
      exit
      port 1/2/5
         ethernet
```

```
            mode access
        exit
        no shutdown
    exit
    port 1/2/6
        shutdown
        ethernet
        exit
    exit
    port 1/2/7
        ethernet
        exit
        no shutdown
    exit
    port 1/2/8
        ethernet
        exit
        no shutdown
    exit
    port 1/4/1
        sonet-sdh
            path
                no shutdown
            exit
        exit
        no shutdown
    exit
    port 1/4/2
        shutdown
        sonet-sdh
        exit
    exit
#--------------------------------------------------
echo "System Sync-If-Timing Configuration"
#--------------------------------------------------
    system
        sync-if-timing
            begin
            ref1
                shutdown
            exit
            ref2
                shutdown
            exit
            commit
        exit
```

```
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
    router management
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.2.2.2/32
        exit
        interface "test2"
            address 2.2.2.2/24
        exit
        interface "toR1"
            address 10.110.1.2/24
            port 1/2/1
        exit
        interface "toR4"
            address 10.110.2.1/24
            port 1/1/1
        exit
        interface "toR5"
            address 10.110.5.2/24
            port 1/2/3
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            area 0.0.0.0
                interface "system"
                exit
                interface "toR1"
                exit
                interface "toR4"
                exit
                interface "toR5"
                exit
            exit
        exit
#--------------------------------------------------
echo "MPLS Configuration"
```

```
#--------------------------------------------------
        mpls
            interface "system"
            exit
            interface "toR1"
            exit
            static-lsp "static-lsp-1"
                shutdown
            exit
            no shutdown
        exit
#--------------------------------------------------
echo "RSVP Configuration"
#--------------------------------------------------
        rsvp
            interface "system"
            exit
            interface "toR1"
            exit
            no shutdown
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "toR1"
                exit
                interface "toR4"
                exit
                interface "toR5"
                exit
            exit
            targeted-session
            exit
        exit
    exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        customer 2 create
```

```
            description "Customer requiring epipe services"
        exit
        sdp 24 mpls create
            far-end 10.4.4.4
            ldp
            path-mtu 9190
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 34 customer 1 create
            stp
                shutdown
            exit
            sap 1/2/5 create
            exit
            mesh-sdp 24:34 create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
        exit
#--------------------------------------------------
echo "Policy Configuration"
#--------------------------------------------------
        policy-options
            begin
            policy-statement "1"
                entry 2
                    to
                        protocol bgp
                        neighbor 192.168.3.1
                    exit
                    action accept
                    exit
                exit
                entry 3
```

```
                to
                    protocol bgp
                    neighbor 172.3.7.249
                exit
                action accept
                exit
            exit
            entry 4
                to
                    protocol bgp
                    neighbor 172.3.7.246
                exit
                action accept
                exit
            exit
        exit
        policy-statement "2"
            entry 2
                from
                    protocol direct
                exit
                action accept
                exit
            exit
        exit
        policy-statement "isis"
            entry 1
                from
                    protocol isis
                exit
                action accept
                exit
            exit
            default-action accept
            exit
        exit
        commit
    exit
exit


exit all

# Finished MON FEB 21 07:22:20 2011 UTC
```

9.3 R3

```
# TiMOS-B-6.1.R4 both/hops ALCATEL SR 7710 Copyright (c) 2000-2008 Alcatel-
Lucent.
# All rights reserved. All use subject to applicable license agreements.
# Built on Thu Oct 30 15:49:21 PDT 2008 by builder in /rel6.1/b1/R4/panos/main

# Generated MON FEB 21 08:16:33 2011 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "Rack-3"
        ccm 1
        exit
        power-supply 1 ac single
        power-supply 2 ac single
        snmp
            shutdown
            packet-size 9216
        exit
        login-control
            telnet
                inbound-max-sessions 1
            exit
        exit
        time
            ntp
                server 129.128.5.210
                no shutdown
            exit
            sntp
                shutdown
            exit
            zone MST
        exit
        thresholds
            rmon
            exit
        exit
    exit
#--------------------------------------------------
echo "System Security Configuration"
```

```
#--------------------------------------------------
    system
        security
            telnet-server
            ftp-server
            user "admin"
                password ".wwBSCf55BeJQsICA8BrJ." hash2
                access console ftp snmp
                console
                    member "administrative"
                exit
            exit
            snmp
                community "uTdc9j48PBRkxn5DcSjchk" hash2 rwa version both
            exit
            per-peer-queuing
        exit
    exit
#--------------------------------------------------
echo "Log Configuration"
#--------------------------------------------------
    log
        snmp-trap-group 98
            description "5620sam"
            trap-target "10.3.31.166:162" address 10.3.31.166 snmpv2c notify-community
"privatetrap98"
        exit
        log-id 98
            from main security
            to snmp 1024
        exit
    exit
#--------------------------------------------------
echo "System Security Cpm Hw Filters Configuration"
#--------------------------------------------------
    system
        security
        exit
    exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
    qos
    exit
#--------------------------------------------------
echo "Card Configuration"
```

```
#--------------------------------------------------
    card 1
        card-type iom-9g
        mda 1
            mda-type c1-1gb-sfp
            ingress
            exit
        exit
        mda 2
            mda-type c8-10/100eth-tx
            ingress
            exit
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/1/1
        shutdown
        ethernet
        exit
    exit
    port 1/2/1
        ethernet
        exit
        no shutdown
    exit
    port 1/2/2
        ethernet
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
        exit
        no shutdown
    exit
    port 1/2/5
        ethernet
            mode access
        exit
```

```
        no shutdown
    exit
    port 1/2/6
        shutdown
        ethernet
        exit
    exit
    port 1/2/7
        shutdown
        ethernet
        exit
    exit
    port 1/2/8
        ethernet
        exit
        no shutdown
    exit
#--------------------------------------------------
echo "System Sync-If-Timing Configuration"
#--------------------------------------------------
    system
        sync-if-timing
            begin
            ref1
                shutdown
            exit
            ref2
                shutdown
            exit
            commit
        exit
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
    router management
    exit

#--------------------------------------------------
echo "Router (Network Side) Configuration"
#--------------------------------------------------
    router
        interface "system"
            address 10.3.3.3/32
        exit
        interface "toR1"
```

```
            address 10.110.3.2/24
            port 1/2/2
        exit
        interface "toR5"
            address 10.110.4.1/24
            port 1/2/1
        exit
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
            area 0.0.0.0
                interface "system"
                exit
                interface "toR1"
                exit
                interface "toR5"
                exit
            exit
        exit
#--------------------------------------------------
echo "LDP Configuration"
#--------------------------------------------------
        ldp
            interface-parameters
                interface "toR1"
                exit
                interface "toR5"
                exit
            exit
            targeted-session
            exit
        exit
    exit

#--------------------------------------------------
echo "Service Configuration"
#--------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        sdp 34 mpls create
            far-end 10.4.4.4
            ldp
            path-mtu 9190
```

```
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 34 customer 1 create
            stp
                shutdown
            exit
            sap 1/2/5 create
            exit
            mesh-sdp 34:34 create
            exit
            no shutdown
        exit
    exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
    router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
        ospf
        exit
    exit

#--------------------------------------------------
echo "System Time NTP Configuration"
#--------------------------------------------------
    system
        time
            ntp
            exit
        exit
    exit

exit all

# Finished MON FEB 21 08:16:35 2011 UTC
```

9.4 R4

```
# TiMOS-B-6.1.R4 both/hops ALCATEL SR 7710 Copyright (c) 2000-2008 Alcatel-
Lucent.
# All rights reserved. All use subject to applicable license agreements.
# Built on Thu Oct 30 15:49:21 PDT 2008 by builder in /rel6.1/b1/R4/panos/main

# Generated MON FEB 21 08:17:55 2011 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "RACK-4"
        ccm 1
        exit
        power-supply 1 ac single
        power-supply 2 ac single
        snmp
            shutdown
            packet-size 9216
        exit
        login-control
            telnet
                inbound-max-sessions 1
            exit
        exit
        time
            sntp
                shutdown
            exit
            zone MST
        exit
        thresholds
            rmon
            exit
        exit
    exit
#--------------------------------------------------
echo "System Security Configuration"
#--------------------------------------------------
    system
        security
            telnet-server
```

```
            ftp-server
            password
               admin-password "fc1BTOnQOn6" hash2
            exit
            user "admin"
               password ".wwBSCf55BeJQsICA8BrJ." hash2
               access console ftp snmp
               console
                  member "administrative"
               exit
            exit
            snmp
               community "uTdc9j48PBRkxn5DcSjchk" hash2 rwa version both
            exit
            per-peer-queuing
         exit
      exit
#--------------------------------------------------
echo "Log Configuration"
#--------------------------------------------------
      log
         snmp-trap-group 98
            description "5620sam"
            trap-target "10.3.31.166:162" address 10.3.31.166 snmpv2c notify-community
"privatetrap98"
         exit
         log-id 98
            from main security
            to snmp 1024
         exit
      exit
#--------------------------------------------------
echo "System Security Cpm Hw Filters Configuration"
#--------------------------------------------------
      system
         security
         exit
      exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
      qos
      exit
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
```

```
    card 1
        card-type iom-9g
        mda 1
            mda-type c1-1gb-sfp
            ingress
            exit
        exit
        mda 2
            mda-type c8-10/100eth-tx
            ingress
            exit
        exit
        mda 4
            mda-type c2-oc12/3-sfp
            ingress
            exit
        exit
    exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port 1/1/1
        ethernet
            speed 100
        exit
        no shutdown
    exit
    port 1/2/1
        ethernet
        exit
        no shutdown
    exit
    port 1/2/2
        ethernet
        exit
        no shutdown
    exit
    port 1/2/3
        ethernet
        exit
        no shutdown
    exit
    port 1/2/4
        ethernet
        exit
        no shutdown
```

```
    exit
    port 1/2/5
        ethernet
            mode access
        exit
        no shutdown
    exit
    port 1/2/6
        shutdown
        ethernet
        exit
    exit
    port 1/2/7
        shutdown
        ethernet
        exit
    exit
    port 1/2/8
        ethernet
        exit
        no shutdown
    exit
    port 1/4/1
        sonet-sdh
            path
                no shutdown
            exit
        exit
        no shutdown
    exit
    port 1/4/2
        shutdown
        sonet-sdh
        exit
    exit
#--------------------------------------------------
echo "System Sync-If-Timing Configuration"
#--------------------------------------------------
    system
        sync-if-timing
            begin
            ref1
                shutdown
            exit
            ref2
                shutdown
```

```
            exit
            commit
        exit
    exit
#------------------------------------------------
echo "Management Router Configuration"
#------------------------------------------------
    router management
    exit

#------------------------------------------------
echo "Router (Network Side) Configuration"
#------------------------------------------------
    router
        interface "system"
            address 10.4.4.4/32
        exit
        interface "test"
            address 10.200.1.1/24
            port 1/2/8
        exit
        interface "test2"
            address 1.2.3.4/24
            port 1/4/1
        exit
        interface "toR2"
            address 10.110.2.2/24
            port 1/1/1
        exit
#------------------------------------------------
echo "OSPFv2 Configuration"
#------------------------------------------------
        ospf
            area 0.0.0.0
                interface "system"
                exit
                interface "test"
                exit
                interface "toR2"
                exit
            exit
        exit
#------------------------------------------------
echo "LDP Configuration"
#------------------------------------------------
        ldp
```

```
            interface-parameters
               interface "toR2"
               exit
            exit
            targeted-session
            exit
         exit
      exit

#------------------------------------------------
echo "Service Configuration"
#------------------------------------------------
      service
         customer 1 create
            description "Default customer"
         exit
         sdp 41 mpls create
            far-end 10.1.1.1
            ldp
            path-mtu 9190
            keep-alive
               shutdown
            exit
            no shutdown
         exit
         sdp 42 mpls create
            far-end 10.2.2.2
            ldp
            path-mtu 9190
            keep-alive
               shutdown
            exit
            no shutdown
         exit
         sdp 43 mpls create
            far-end 10.3.3.3
            ldp
            path-mtu 9190
            keep-alive
               shutdown
            exit
            no shutdown
         exit
         sdp 45 mpls create
            far-end 10.5.5.5
            ldp
```

```
            path-mtu 9190
            keep-alive
               shutdown
            exit
            no shutdown
         exit
         vpls 34 customer 1 create
            stp
               shutdown
            exit
            sap 1/2/5 create
            exit
            mesh-sdp 41:34 create
            exit
            mesh-sdp 42:34 create
            exit
            mesh-sdp 43:34 create
            exit
            mesh-sdp 45:34 create
            exit
            no shutdown
         exit
      exit
#--------------------------------------------------
echo "Router (Service Side) Configuration"
#--------------------------------------------------
      router
#--------------------------------------------------
echo "OSPFv2 Configuration"
#--------------------------------------------------
         ospf
         exit
      exit


exit all

# Finished MON FEB 21 08:18:04 2011 UTC
```

9.5 R5

```
# TiMOS-C-6.1.R6 cpm/hops ALCATEL SR 7750 Copyright (c) 2000-2009 Alcatel-
Lucent.
# All rights reserved. All use subject to applicable license agreements.
# Built on Tue Jan 20 13:16:25 PST 2009 by builder in /rel6.1/b1/R6/panos/main

# Generated SAT JAN 01 01:52:11 2000 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "R5 Alcatel-7750"
        chassis-mode c
        snmp
            packet-size 9216
        exit
        login-control
            telnet
                inbound-max-sessions 1
            exit
        exit
        time
            sntp
                shutdown
            exit
            zone MST
        exit
        thresholds
            rmon
            exit
        exit
    exit
#--------------------------------------------------
echo "System Security Configuration"
#--------------------------------------------------
    system
        security
            telnet-server
            ftp-server
            user "admin"
                password "hOSZWd7FTGchc/uUtbrxRk" hash2
                access console ftp snmp
```

```
            console
               member "administrative"
            exit
         exit
         snmp
            community "uTdc9j48PBRkxn5DcSjchk" hash2 rwa version both
         exit
         per-peer-queuing
         cpu-protection
            policy 1 create
            exit
         exit
      exit
   exit
#--------------------------------------------------
echo "Log Configuration"
#--------------------------------------------------
   log
      snmp-trap-group 98
         description "5620sam"
         trap-target "10.3.31.166:162" address 10.3.31.166 snmpv2c notify-community
"privatetrap98"
      exit
      log-id 98
         from main security
         to snmp 1024
      exit
   exit
#--------------------------------------------------
echo "System Security Cpm Hw Filters Configuration"
#--------------------------------------------------
   system
      security
      exit
   exit
#--------------------------------------------------
echo "QoS Policy Configuration"
#--------------------------------------------------
   qos
   exit
#--------------------------------------------------
echo "Card Configuration"
#--------------------------------------------------
   card 1
      card-type iom2-20g
      mda 1
```

```
            mda-type m20-1gb-tx
            ingress
               mcast-path-management
                  shutdown
               exit
            exit
         exit
      exit
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
      port 1/1/1
         ethernet
            mtu 1514
            speed 100
         exit
         no shutdown
      exit
      port 1/1/2
         ethernet
         exit
         no shutdown
      exit
      port 1/1/3
         ethernet
            mtu 1514
            speed 100
         exit
         no shutdown
      exit
      port 1/1/4
         ethernet
         exit
         no shutdown
      exit
      port 1/1/5
         ethernet
            mode access
         exit
         no shutdown
      exit
      port 1/1/6
         shutdown
         ethernet
         exit
      exit
```

```
port 1/1/7
   shutdown
   ethernet
   exit
exit
port 1/1/8
   shutdown
   ethernet
   exit
exit
port 1/1/9
   shutdown
   ethernet
   exit
exit
port 1/1/10
   shutdown
   ethernet
   exit
exit
port 1/1/11
   shutdown
   ethernet
   exit
exit
port 1/1/12
   shutdown
   ethernet
   exit
exit
port 1/1/13
   shutdown
   ethernet
   exit
exit
port 1/1/14
   shutdown
   ethernet
   exit
exit
port 1/1/15
   shutdown
   ethernet
   exit
exit
port 1/1/16
```

```
        shutdown
        ethernet
        exit
    exit
    port 1/1/17
        shutdown
        ethernet
        exit
    exit
    port 1/1/18
        shutdown
        ethernet
        exit
    exit
    port 1/1/19
        shutdown
        ethernet
        exit
    exit
    port 1/1/20
        shutdown
        ethernet
        exit
    exit
#--------------------------------------------------
echo "System Sync-If-Timing Configuration"
#--------------------------------------------------
    system
        sync-if-timing
            begin
            ref1
                shutdown
            exit
            ref2
                shutdown
            exit
            bits
                shutdown
            exit
            revert
            commit
        exit
    exit
#--------------------------------------------------
echo "Management Router Configuration"
#--------------------------------------------------
```

```
    router management
    exit

#------------------------------------------------
echo "Router (Network Side) Configuration"
#------------------------------------------------
    router
        interface "system"
            address 10.5.5.5/32
        exit
        interface "toR2"
            address 10.110.5.1/24
            port 1/1/3
        exit
        interface "toR3"
            address 10.110.4.2/24
            port 1/1/1
        exit
#------------------------------------------------
echo "OSPFv2 Configuration"
#------------------------------------------------
        ospf
            area 0.0.0.0
                interface "system"
                exit
                interface "toR3"
                exit
                interface "toR2"
                exit
            exit
        exit
#------------------------------------------------
echo "LDP Configuration"
#------------------------------------------------
        ldp
            interface-parameters
                interface "toR3"
                exit
                interface "toR2"
                exit
            exit
            targeted-session
            exit
        exit
    exit
```

```
#------------------------------------------------
echo "Service Configuration"
#------------------------------------------------
    service
        customer 1 create
            description "Default customer"
        exit
        sdp 54 mpls create
            far-end 10.4.4.4
            ldp
            keep-alive
                shutdown
            exit
            no shutdown
        exit
        vpls 34 customer 1 create
            stp
                shutdown
            exit
            sap 1/1/5 create
            exit
            mesh-sdp 54:34 create
            exit
            no shutdown
        exit
    exit
#------------------------------------------------
echo "Router (Service Side) Configuration"
#------------------------------------------------
    router
#------------------------------------------------
echo "OSPFv2 Configuration"
#------------------------------------------------
        ospf
        exit
#------------------------------------------------
echo "Policy Configuration"
#------------------------------------------------
        policy-options
            begin
            policy-statement "direct"
                entry 1
                    from
                        protocol direct
                    exit
                    action accept
```

```
            exit
          exit
        exit
        commit
      exit
    exit

exit all

# Finished SAT JAN 01 01:52:14 2000 UTC
```