Analysis of traffic engineering parameters while using multi-protocol label switching (MPLS) and traditional IP networks

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Abstract— **Traffic Engineering is a subject which ensures the utilization of your resources at their optimum level. In order to uplift the traffic engineering in our today networks, Multiprotocol Label Switching (MPLS) is being used which is very helpful for reliable packets delivery in recent internet services. It ensures high transmission speed, efficient utilization of bandwidth and lower delays during delivery of packets from one location to another. The purpose of MPLS in traffic engineering is to employ the networks as well as network resources efficiently. Based on lower network delay, capable forwarding means, scalability and expected performance of the services given by MPLS technology indicates its significance for implementing real-time applications i.e Voice & video. The salient of the thesis is to indicate the shortcomings of traditional IP networks vis-à-vis benefits of MPLS networks. The comparison analysis is based on the traffic engineering parameters such as delay variation, effective utilization of bandwidth, Jitter, Quality of Service (QoS), data loss and congestion etc. The results of the comparison revealed that traffic engineering through MPLS networks has enhanced reliability, scalability and other parameters as compared to traditional IP networks. In this thesis, Graphic Network Simulator (GNS3) has been used for simulation purpose to ascertain the results of both networks.**

Keywords- MPLS, Traffic Engineering and Graphic Network Simulator (GNS3).

I. INTRODUCTION

Considering enormous demand of multimedia services, traffic engineering is an essential concern at the design level as well as handling of operations through big public Internet backbone networks. In telecommunication, traffic engineering is based on certain performance parameters. It provides an opportunity to select the best path for forwarding data packets while utilizing the network resources efficiently. Therefore, In order to address the flaws in the traditional IP networks, IETF (Internet Engineering Task Force) has developed the MPLS (Multiprotocol Label Switching). Traditional IP forwarding depends on the destination address in IP header of each packet whereas routers are using Multi-Protocol Label Switching (MPLS) which uses the technique of labels while forwarding the packets based on the label which is available in the MPLS header. It is however, worth mentioned that MPLS improve traffic engineering over IP-based networks while using the layers of the Open System Interconnection Model (OSI), especially between the Link Layer (Layer 2) and the Network Layer (layer 3). This support for an integrated layer 2 & 3 routing model is termed as label-switching. The Layer 3 protocols would be the present network layer protocols like IP, IPX, Apple Talk, CLNP etc. Based on these protocols, label-switching scheme is therefore named as 'multi-protocol'. It is to be noted that traffic engineering through MPLS is very helpful in existing forwarding platforms i.e IP & ATM networks.

II. PURPOSE

The purpose of the paper is to give analysis among different traffic engineering parameters like bandwidth, throughput, delays, Quality of service (QoS), congestion, data loss etc while considering the traffic through both networks (i.e traditional IP & MPLS).

A. Defining Multiprotocol Label Switching

Multi Protocol Label Switching (MPLS) is an ultimate solution in order to resolve the traffic engineering problems (like speed, scalability, and quality of service (QoS) etc) encountered by today networks. MPLS allows routers at the edge of the provider network to incorporate labels into the incoming packets from the customer side and then forward traffic to the core routers based on labels rather than performing complex resource consuming routing lookups. While the labels exchanged at the core are generally based on destination IP subnets, the labels are also dynamic enough including more forwarding criteria like Quality of Service (QoS) and traffic engineering.

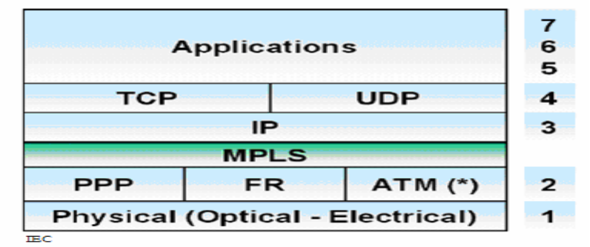


Fig 1: OSI Reference Model for MPLS

The efficient label switching/ traffic engineering at the core and IP routing at the Edge, MPLS networks are the most viable solutions for service providers. While looking at the above figure, it is evident that MPLS is not a Link Layer because it works over various Link Layer technologies (e.g. Ethernet and ATM). Taking OSI (Open System Interconnection) reference model into consideration; MPLS works between the Data-Link and Network layers (layer 2 & layer 3) resulting in layer 2.5 as shown in Figure 1.

B. *MPLS Network Infrasture*

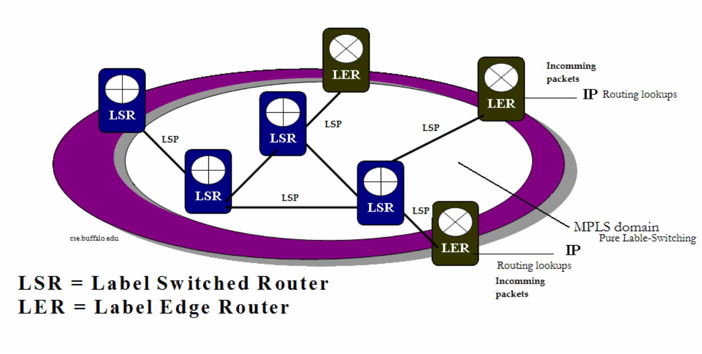


Fig 2: MPLS Network Infrastructure

MPLS is a forwarding mechanism which developed from Cisco's Tag Switching. It uses a fixed-length label in order to decide the packet handling. MPLS label format uses a 32-bit label field, which is comprising of the under mentioned fields.

Field	Description
20-bit label	The actual label.
3-bit experimental field	Used to define a class of service (CoS) (IP precedence).
Bottom-of-stack bit	MPLS allows multiple labels to be inserted; this bit determines if this label is the last label in the packet. If this bit is set (1), it indicates that this is the last label.
8-bit time-to-live (TTL) field	A timer field that has the same purpose as the TTL field in the IP header which is to track the lifetime of the datagram*.

Cisco Systems

The MPLS header is encapsulated between the link layer header & the network layer header while considering Point to Point and LANP protocols. The main idea behind MPLS is based on forwarding the packets according to a short, fixed length labels which are checked by each Label Switching Router (LSR) on the Label Switching Path (LSP). The conventional IP routing look-ups problems are resolved through this technique. Instead, the Label Edge Router (LER) takes the responsibility of recognizing the traffic and the associated conditions for its routing via the LSP. Fig 2.2 indicates the main MPLS network infrastructure. The LER is responsible for incorporating and taking off the labels for packets coming in and out the MPLS domain respectively at ingress (entrance) and egress (exit) of MPLS network. Simply, the operation is based on routing at the edges and simple label switching in the core.

III. Challenges for Traffic Engineering in IP Networks

The provision of traffic engineering through conventional IP networks is really a challenging task. In this type of networks, IP packets are forwarded while considering the Open shortest path first (OSPF) protocol which chooses the shortest path from source to destination. Although the selection of the shortest paths may save network resources, however they may lead to the following problems:-

(a) There is the possibility that shortest paths from various sources may overlap at some positions in the Internet. Resultantly, congestion would be the final outcome for those links.
(b) It is however noted that the longest path between the two nodes is under utilized although the capacity of traffic exceeds the capability of shortest path between the nodes.
(c) Load balancing and equal-cost multipath of the links are the other concerns which pose difficulty to implement the TE in IP networks.
(d) Equal-cost multipath of links is achieved whenever a source needs to forward traffic to the destination while utilizing the paths which have equal-costs.
(e) Load sharing is another important factor which could not be obtained in IP networks among multiple paths of different costs.
(f) Finally, the routing lookups are being performed on every hop.

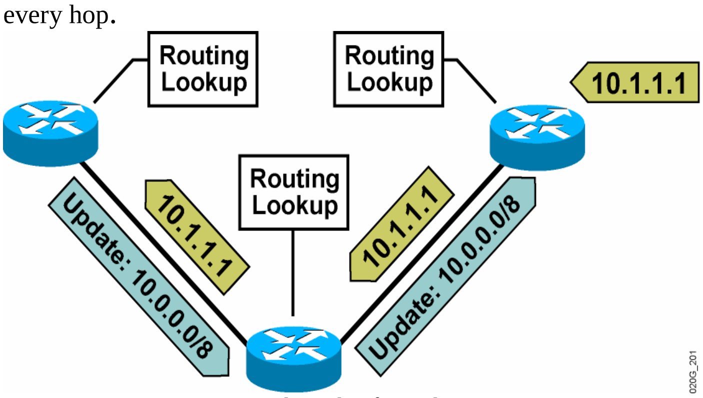


Fig 3. Traditional IP forwarding

(Fig 3) indicates that destination based lookup is required at each router. Resultantly, each router will maintain complete internet information. Therefore, lot of information is required to be maintained in large networks (may be 150,000 routers).

Therefore, in order to address the above mentioned problem, architectural principle of MPLS is a clear segregation of control and forwarding the data packets. MPLS is the viable solution to address above highlighted concerns. Following example would explain the forwarding mechanism in MPLS network

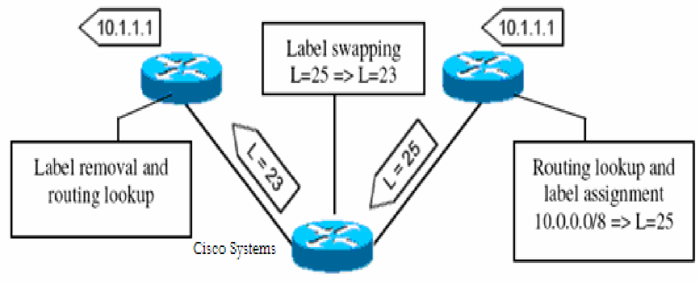


Fig 4. Example on MPLS forwarding

(Fig 4) illustrates a situation where the intermediate router does not have to perform a time-consuming routing lookup.

IV. Traffic Engineering in MPLS Networks

The under mentioned figure illustrates the effect of TE with MPLS over the traditional IP routing. The first figure indicates a topology with unequal links in which the traffic goes between sites-A & B and uses only the primary link. It is pertinent to mention that traditional IP forwarding has not a scalable mechanism in order to allow the usage of backup link. Resultantly, the scenario would cause in an uneven load balancing.

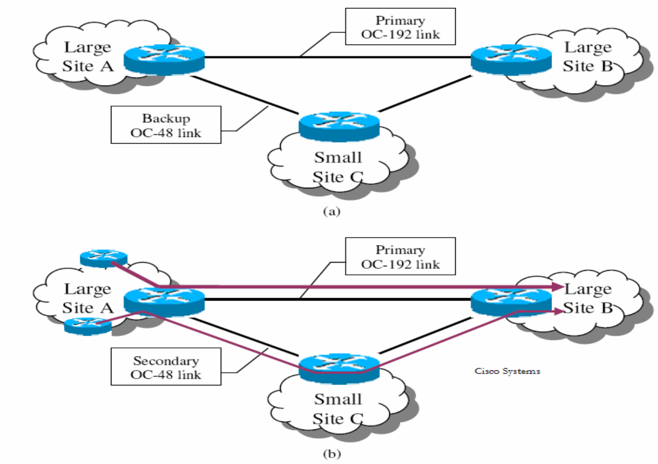


Fig 5: TE with MPLS over the traditional IP routing mechanisms

Whereas, 2nd figure (b) shows, how MPLS supports Traffic Engineering. Traffic tunnels can be created based on traffic analysis to share load balancing on unequal paths instead of compel all traffic to utilize the same path as what is being done in traditional IP forwarding. MPLS TE purposes include the following:-Fig 4-1. TE with MPLS over the traditional IP routing mechanisms

- Maximize usage of links as well as nodes in whole network.
- Reduce the effect of a single failure.
- Arrange/ ensure provisioning of spare link capacity for traffic re-route in case of failure.

MPLS TE implementation has special requirements:-

- Every LSR should consider complete topology of the network (only OSPF and IS-IS hold the entire topology).
- Every LER should be able to make an LSP tunnel on demand.

It is however noticed that the motivation behind MPLS TE is because of Constraint Based Routing (CBR). This type of routing protocol takes bandwidth, policies and network topology into consideration for establishing a path (path refers to LSPs) in MPLS network in order to forward the packets from one location to other. Constraint Based Routing (CBR) is basically the extension of shortest path algorithms. The CBR compute the path in MPLS which is based on the limitations like minimum possible requirement of bandwidth needed in a link, end-to-end delay and administrative policy. Constraint Based Routing (CBR) is extensively usage in the MPLS Traffic Engg for directing the traffic evenly and increasing the network performance.

A. Signaling Protocols used in MPLS Traffic Engineering

The LSPs are established in MPLS networks. Subsequently, the labels are assigned on each hop along the LSPs before the packets are forwarded. In MPLS network, LSPs are established in two ways i.e control driven LSP and the other is explicitly routed LSP. Control driven is set using LDP protocol and are also called hop-by-hop LSP. The process for setting up of control driven LSPs include the process of each LSR determining the next hop for the LSP as per its IP forwarding table. Accordingly, it sends the label request to the next hop in order to establish LSP. Then this process remains continued till the LSP reaches to the edge router (i.e egress router) in MPLS domain. The routed LSPs are also called as constraint based routed LSPs (CR-LSPs). CR-LSPs are set by mentioning the route for LSP in the setup message. This setup message travels all the hops along the assigned route. Following two protocols are used to set CR-LSPs in MPLS which are as follows: -

(a) Constraint based routed LDP (CR-LDP)
(b) Resource Reservation Protocol (RSVP)

V. Simulation and Results Analysis

The simulation of both IP and MPLS networks has been done while using Graphic Network Simulator (GNS3). Both scenarios have been implemented while considering the same network topology. The purpose is to compare the performance of traffic engineering parameters like bandwidth, delay variation, throughput and data loss etc in both IP and MPLS networks. The following network topology is used to simulate the results

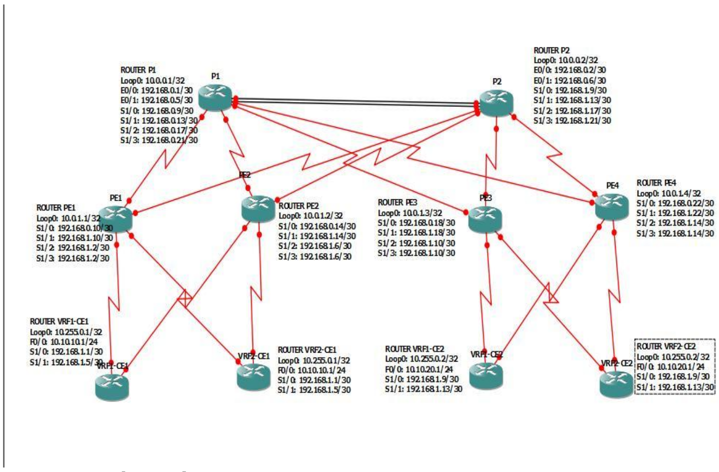


Fig 6: Network Topology

The simulation results indicate that the input packets forwarded to the network are similar to that of output packets. This represent that the data loss in negligible in the MPLS network.

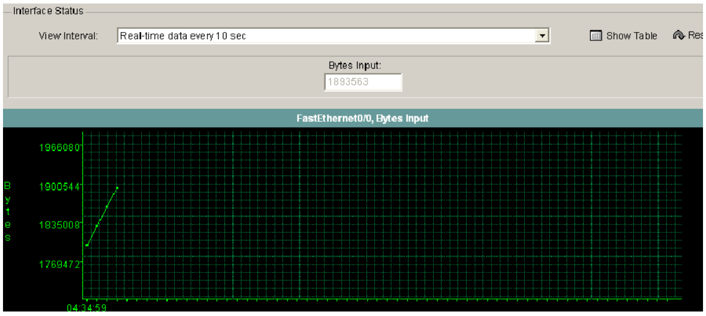


Fig 7 Simulation of Input and output packets and representation of data loss

This figure is the representation of the input bytes of the network topology. Whereas, the output bytes are indicated on the next figure. If we compare both, the input/ output bytes are almost similar which shows that there is a negligible data loss while using the MPLS network.

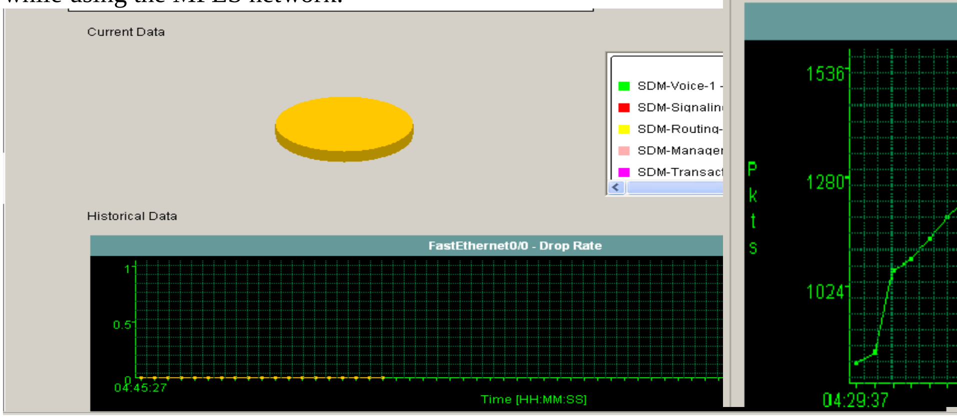


Fig 8 Drop rate representation

It is evident from the simulation that the drop rate is around minimum as indicated with yellow line. The following figure depicts that the loss rate of high level voice traffic is very less. With the protection, the voice traffic can have the lower loss rate which is nearly zero.

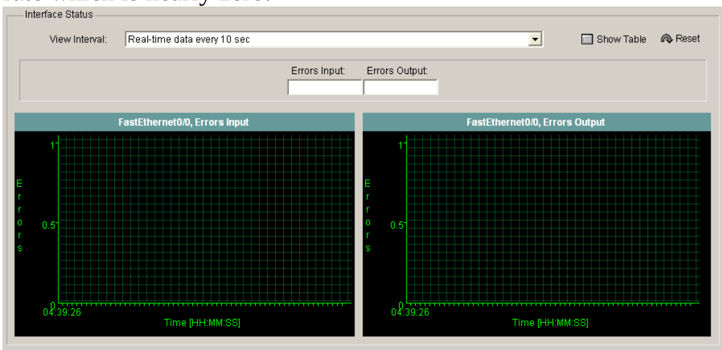
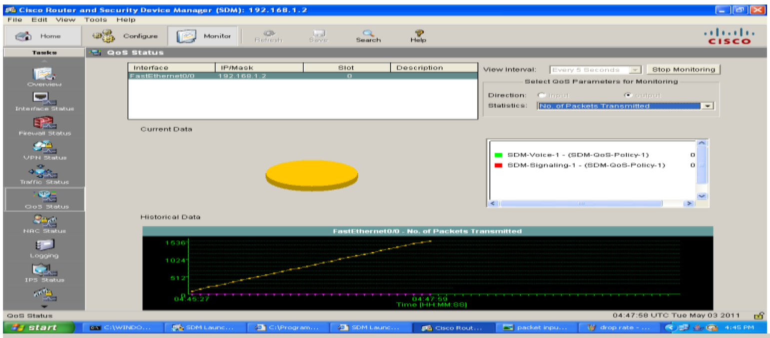
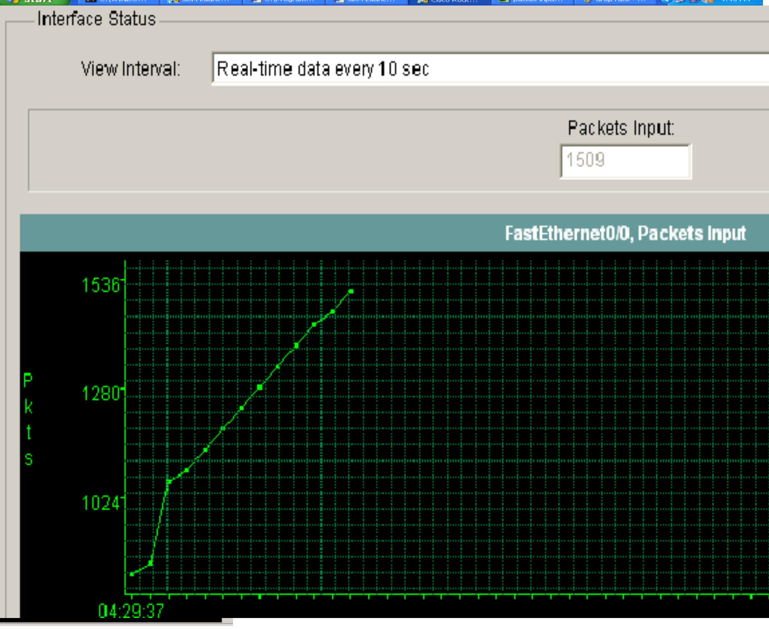


Fig 9: Demonstration of error rate

This figure indicates that the error rate is minimum in MPLS while utilizing the same network topology. It is evident from the figure that the error rate at input and output approaches to zero





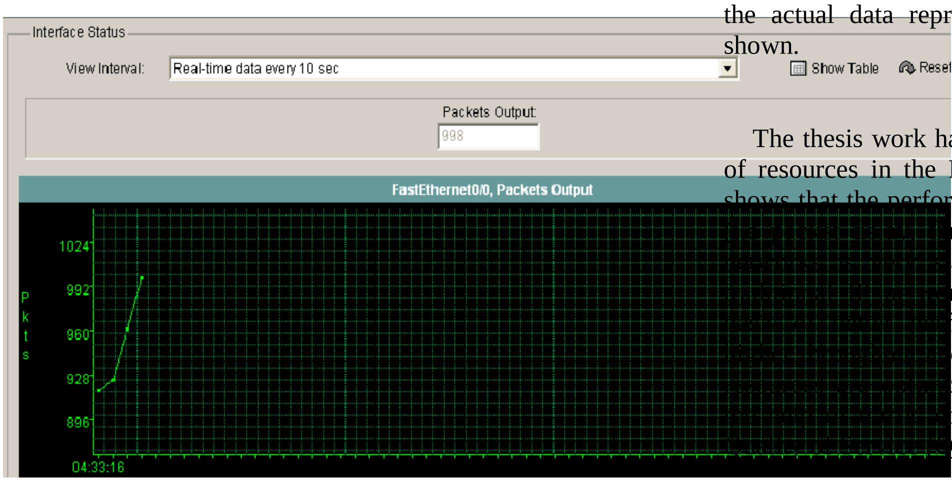
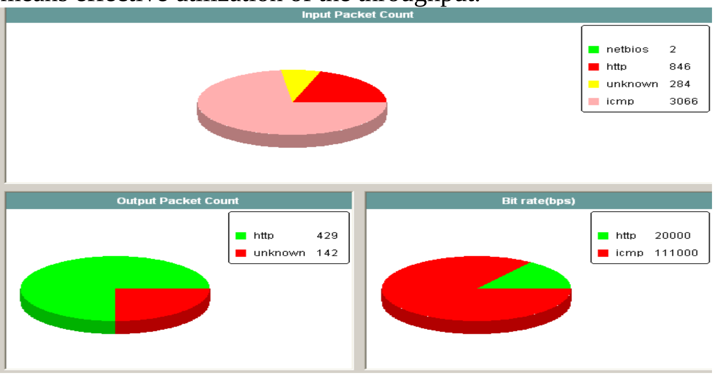


Fig 10:Simulation of throughput results

The simulation results indicates that throughput is maximum while utilizing the above mentioned network topology. The output packets are forwarded to the end users efficiently which means effective utilization of the throughput.



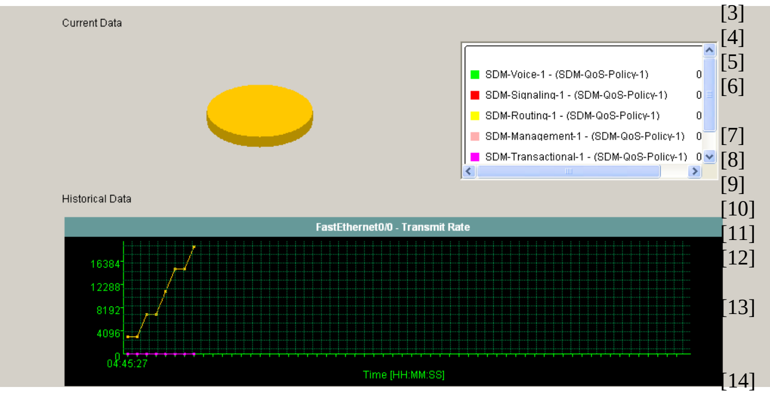


Fig 11 Implementation of quality of service and display of data

The result demonstrates that the packet quality of service is applied and found that all the data packets are transmitted and no packet drop is being observed. Whereas in above figure, the actual data representation is MPLS network has been shown.

VI. Conclusion

The thesis work has indicated the effective implementation of resources in the MPLS networks. The simulation results shows that the performances of traffic engineering parameters [illegible]roughput, loss rate, Jitter etc) in MPLS [illegible]able and much better as compared to [illegible]rks. The results further validate on the [illegible]formance to higher-priority flows with [illegible]d lower transmission delay. The network [illegible]zed at their optimum performance with [illegible]gineering. Additionally, the end to end [illegible]oS) is also being ensured.

VII. Future Work and Recommandations

The further work related to this discussion is the practical demonstration of the idea being presented throughout the thesis. It is however worth mentioning that the theoretical discussion is useless unless there is a real time investigation as well as the testing is performed. The further work is to create the prototype for the testing purpose. The result should be further analyzed and investigated in order to implement the MPLS networks in the specified context based scenario. As the analysis indicates that MPLS is the viable solution for today networks, and then there should be no delay for the practical implementation of the same in our departments especially the PTCL, Banking, Defence forces etc. The advantage of the approach is the provision of Quality of Service (QoS) through Traffic Engineering and the efficient design and gradual deployment of the system accordingly.

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