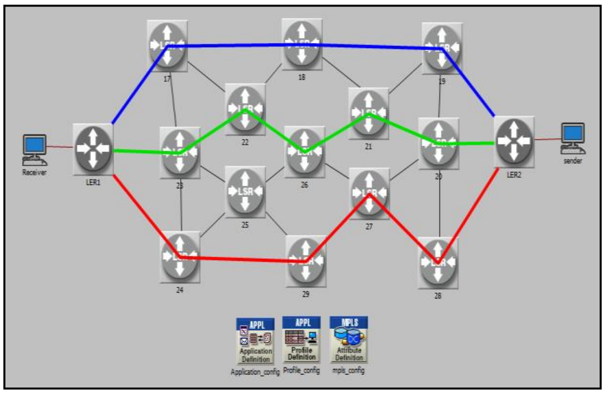

Figure 3 Scenario for Network Topology MPLS over IPv4 and IPv6

Scenario 5, 6: These scenarios illustrated in figure 4 were created to implement MPLS where the link between the routers node_17 and node_18 fails at 50 seconds and recovers at 200 seconds in both IPv4 and IPv6 network.

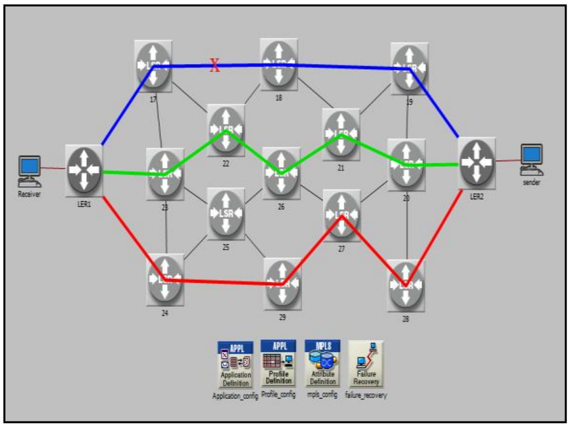

Figure 4 Scenario for Network Topology Link Failure

Scenario 7, 8: These scenarios illustrated in figure 5 were created to implement MPLS where the node_17 fails at 50 seconds and recovers at 200 seconds in both IPv4 and IPv6 network.

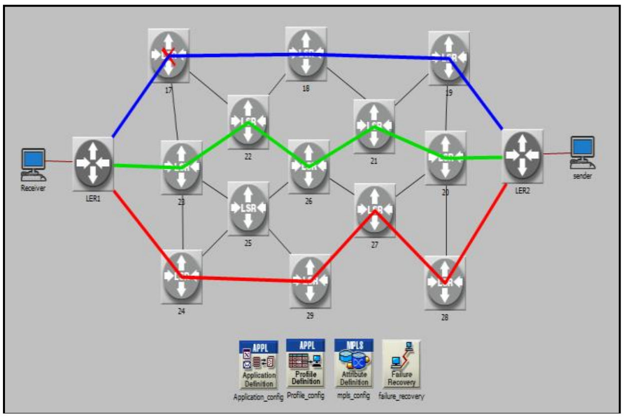

Figure 5 Scenario for Network Topology Node Failure

Scenario 9, 10: These scenarios illustrated in figure 6 were created to implement both MPLS and Traffic Engineering over IPv4 and IPv6 network. This scenario was used to overcome the problem of under-utilization and over utilization along the shortest path links in the network that were seen in scenario 1,2 and scenario 3,4. In order to fix this problem, one forwarding equivalence classes (FECs) for each data was created. A traffic trunk was also created for each traffic, one for UDP traffic and another for TCP traffic.

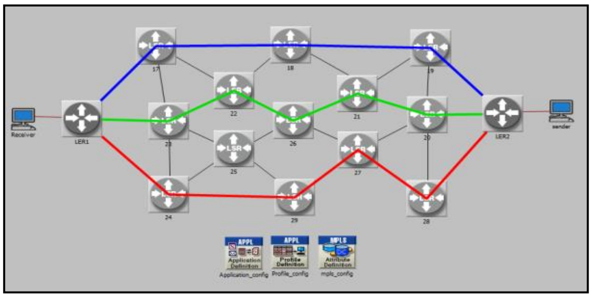

Figure 6 Scenario for Network Topology MPLS-TE

5. Results

After the simulation, the following parameters were evaluated to calculate the network's output under various scenarios.

i) Throughput
ii) Jitter
iii) Queuing Delay
iv) Link Utilization

5.1 Throughput

The throughput of a channel is a measure of amount of data that actually move through the channel while as bandwidth is the maximum number of data that can pass through a 'channel'. Both throughput and bandwidth are measured in bits per second (bps).[24]

5.1.1 Throughput along the Shortest Path

Throughput depends on the network infrastructure and the bandwidth of the links. As we can see from Figure 7 the throughput has shown improvement for IPv6 over MPLS as compared to simple IPv6 for Voice protocol. In Figure 8 we can see throughput is better in IPv4 over MPLS as compared to IPv4. In the case of IPv4, each packet must be initially processed and then a checksum generated. The route which manages the packet handles the optional field as well. However, in IPv6, the optional fields are put next to the IPv6 header along with other non-essential fields to the extension headers. The simulated results of "throughput" for 17 to 18 link in first four scenarios and scenario 9, 10 are obtained and compared in figure **9**. It is clear from the simulated results that in IP and MPLS based scenarios for both IPv4 and IPv6 the throughput over 17 to 18 link stays almost same. This is because all the traffic generated by clients follows the shortest path (LER1 to node 17 to node 18 to node 19 to LER2) from source to destination. But for “IPv4 MPLS-TE” and “IPv6 MPLS-TE” scenarios the throughput of same link goes down. This is due voice traffic generated by the voice clients had been forwarded through alternate path which was not being at all utilized before. Figure 10 illustrates the simulated results same scenarios for “link 18 to link 19” and the same explanation is also valid for this link because this link is also a part of shortest route.

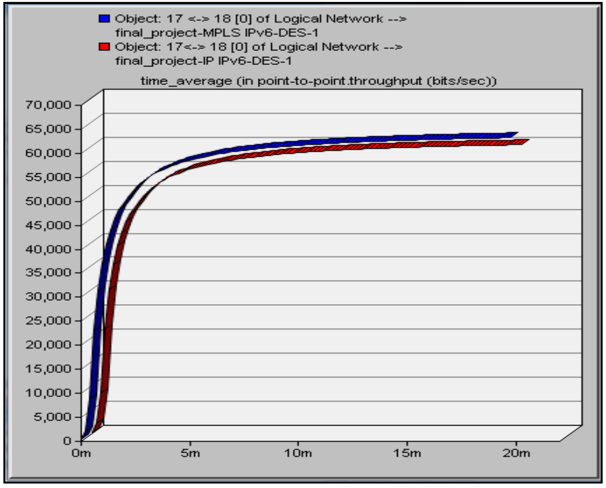

Figure 7 Average Throughput Comparison of IPv6 and MPLS IPv6 along 17 to 18 Link

5.1.2 Throughput along the Alternative Path

The simulated results of throughput for “24 to 29” link in first four scenarios and scenario 9, 10 are obtained and compared in figure 11. It is clear from the simulated results that in IP and MPLS based scenarios for both IPv4 and IPv6, the throughput over 24 to 29 link stays at zero. It is because the alternate paths available from source to destination in IP and MPLS were not utilized at all. But for “IPv4 MPLS-TE” and “IPv6 MPLS-TE” scenarios half of the traffic was passed through this alternate path by establishing a separate LSP for voice traffic and thus the throughput for those links in the alternate path had gone up. The same traffic then flows from 27 to 28 link and the same explanation is valid for this link. The figure 12 illustrates the throughput of the link 27 to 28 link for all these mentioned six scenarios. Thus, by MPLS-Traffic Engineering, over utilized links were offloaded by diverting some of the traffic through underutilized links in a network. This is achieved by making the use of RSVP protocol for MPLS-TE that establishes label switch paths (LSPs) or separate tunnels from ingress router to the egress router. In this way, the problems like congestion and under-utilization were efficiently addressed in an underlying network.

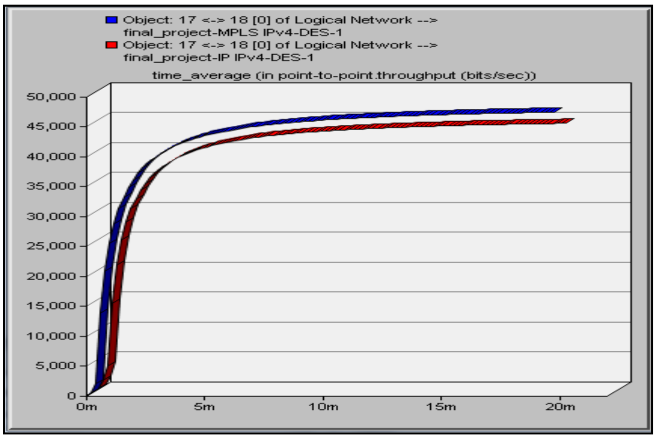

Figure 8 Average Throughput Comparison of IPv4 and MPLS IPv4 along 17 to 18 Link

5.1.3 Throughput Comparison for Link Failure in IPv4-MPLS and IPv6-MPLS Scenario

It is clear from the simulated results illustrated in Figure 13 that the throughput in IPv6 is higher than Ipv4. The link between node 17 and node 18 fails at 450 seconds and recovers at 750 seconds. The throughput performance in IPv6 is still better than IPv4 even if no repair techniques are used.

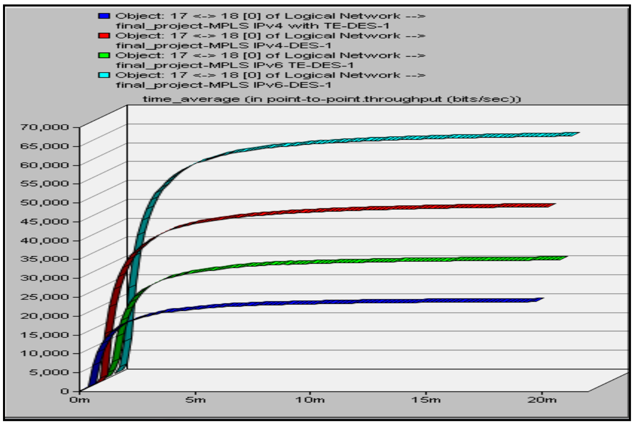

Figure 9 Throughput Comparison of IPv4 and IPv6 over MPLS and MPLS-TE along 17 to 18 Link

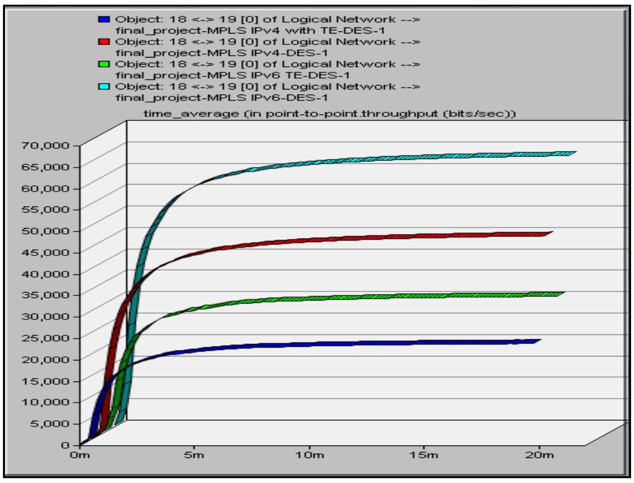

Figure 10 Throughput Comparison of IPv4 and IPv6 over MPLS and MPLS-TE along 18 to 19 link

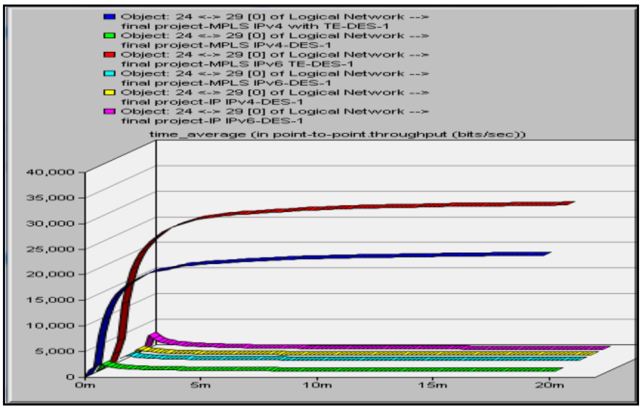

Figure 11 Average Throughput along 24 to 29 Link

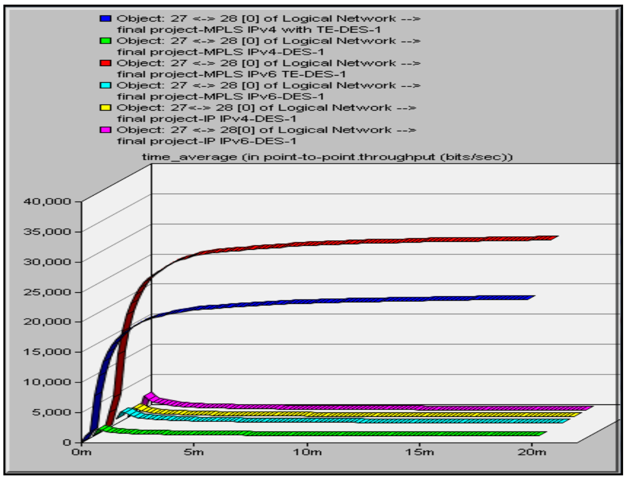

Figure 12 Average Throughput along 27 to 28 Link

5.1.4 Throughput Comparison for Node Failure in IPv4-MPLS and IPv6-MPLS Scenario

From the simulation results, as illustrated in Figure 14 it can be concluded if any node, say node 17 in our scenario fails at 450 seconds and recovers at 750 seconds, the throughput performance shown by IPv6 is better than IPv4. With regard to performance, the IPv6 Protocol offers better transmission efficiency and high output with the highest utilization per line.

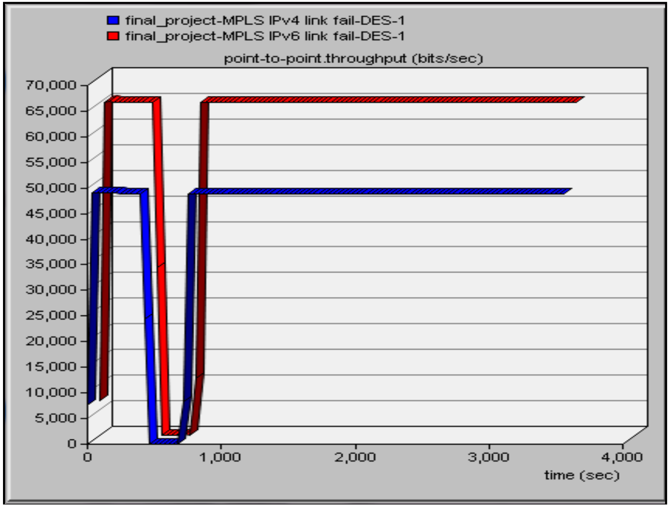

Figure 13 Link failure

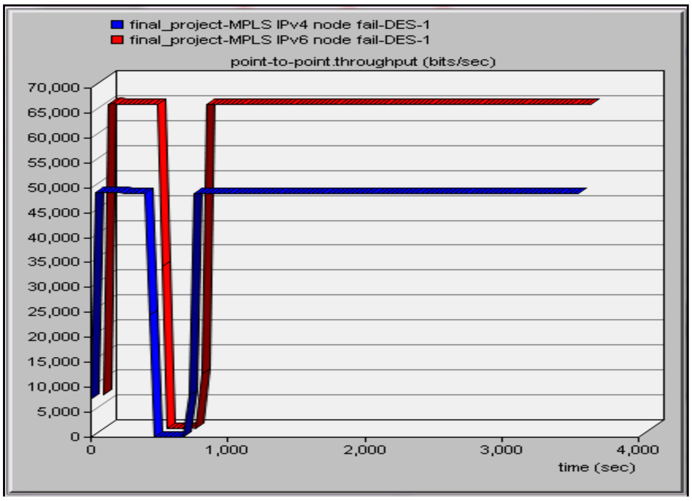

Figure 14 Node failure

5.2 Jitter

Electromagnetic interference can cause jitter in the network and crosstalk with other signal carriers. This causes undesirable effects in audio signal and data loss between network devices. Jitter is the rate of change of delay. As illustrated in Figure 15, Figure 16 and Figure 17, latency is more extensive in IPv6 over the MPLS network than in

IPv4 over the MPLS network, therefore Jitter is more extreme in IPv6 over MPLS.

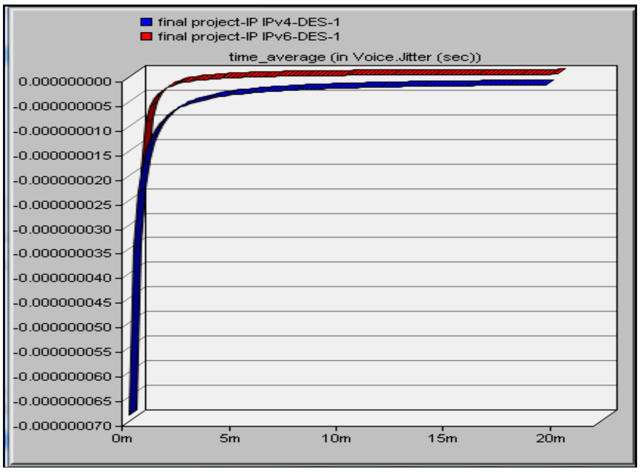

Figure 15 Jitter comparison of IPv4 and IPv6 network

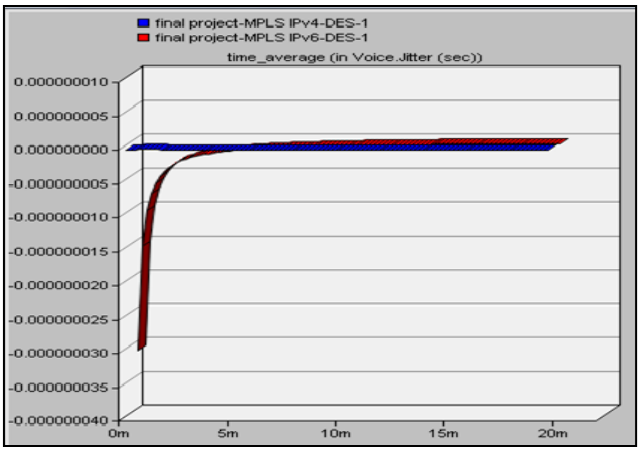

Figure 16 Jitter Comparison of IPv4 and IPv6 over MPLS

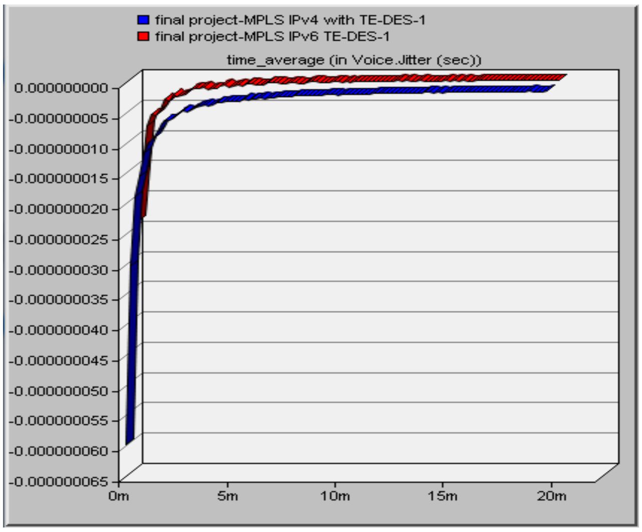

Figure 17 Jitter comparison of IPv4 and IPv6 over MPLS-TE

5.3 Queuing Delay

The time that a packet is waiting in a queue is an important feature of a network design and its performance and it is measured as the time it takes for a job to take place. The amount of delays that a packet faces between entry to a network and transmission time to addresses is summarized in the packet switched network. Queues are generally formed by the delays produced at the originating devices like switches, routers etc.

5.3.1 Queuing Delay of Shortest Path (LER1 to 17 to 18 to 19 to LER2 Link)

The simulated results of queuing delay over 17 to 18 link under six scenarios are obtained and compared in figure 18 and figure 19. It is clear from the graph that the average queuing delay for IP and MPLS based scenarios are high while as the queuing delay for Traffic Engineering based scenarios is almost zero seconds for both IPv4 and IPv6. The main reason behind it is that in IP and MPLS based scenarios all the packets follow the shortest path route from source to destination. This shortest path route becomes jammed and packets need to wait at each and every router which results the higher queuing delay along the shortest path. While as in MPLS based scenarios for both IPv4 and IPv6 half of the traffic (i.e. the traffic from voice client) was steered through the alternate route. This results the free flow of the packets through the shortest route and thus not a single packet needs to wait at any router. Thus, the queuing delay for the packets that follow the shortest route from source to destination in Traffic Engineering is zero.

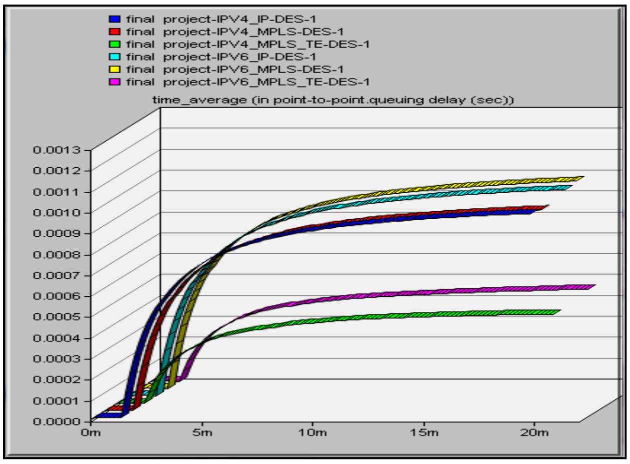

Figure 18 Average Queuing Delay Comparison along shortest path

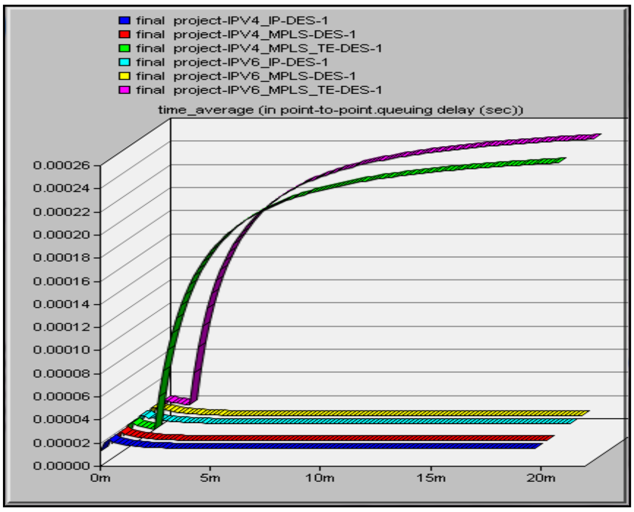

Figure 19 Average Queuing Delay Comparison along alternate path

5.4 Utilization

The utilization of a link is the percentage of the bandwidth currently used by network traffic and the constant high use that is more than 50 percent which suggests network congestion or failure points in the network and the need for network infrastructure enhancements.

In order to exploit the limitations of the routing protocol like OSPF, each traffic generating client (voice client and video client) generates 386 packets per second (each packet of 2000 bits) destined for voice server and video server respectively. Once these packets reach to the core of the network, all the packets from these traffic generating clients were forwarded through the shortest path of the network towards their destinations. Even though there were multiple paths available in the network for the traffic flow but only a specific route were utilized for forwarding the traffic. This is due to because all the IP routing protocols works on the least cost principle. Due to this reason the shortest path links were utilized by more than 90% while as the other paths were not utilized at all (i.e. underutilized).

5.4.1 Utilization of 17 to 18 Link

The simulated results of the point to point link utilization (17 to 18 link) in first four scenarios and scenario 9, 10 are illustrated in Figure 20, Figure 21, Figure 22. It is clear from the graph that link utilization stays at high for both IPv4 and IPv6 MPLS and without MPLS based scenarios. This is due to because "without MPLS scenarios" follows the least cost principle of the routing protocol like OSPF and in MPLS based scenarios an MPLS core is actually being made in which the packets are being forwarded on the basis of labels rather than destination address but the traffic generated by the traffic generating clients follows the same route from source to destination. It is to be noted here that in IP networks, routing look ups are performed by each and every router as packets get forwarded from source to destination.

While as in MPLS based scenarios, these routing look ups are not performed as the packets get forwarded on the basis of labels and thus save a lot of time while forwarding the packets. But in Traffic Engineering based scenarios for both IPv4 and IPv6, the utilization of 17 to 18 link had come down from 90% to 45% (i.e. the over utilization problem of 17 to 18 link got resolved). This is due to half of the traffic from the traffic generating clients was steered through the other links that were not used before in the network. Earlier in MPLS and without MPLS based scenarios entire traffic from the traffic generating clients was forwarded through shortest path in the network and thus the utilization of 17 to 18 link was about 90% but in traffic engineering based scenarios, voice traffic has been steered through other path and video traffic flows the same shortest path. Steering of traffic via alternate paths in the network is achieved by making the use of RSVP protocol which actually establishes the tunnels (called LSPs) for each traffic flow. Thus, implementation of Traffic Engineering in the network addresses the problem of congestion that was seen in IP and MPLS based scenarios for both IPv4 and IPv6.

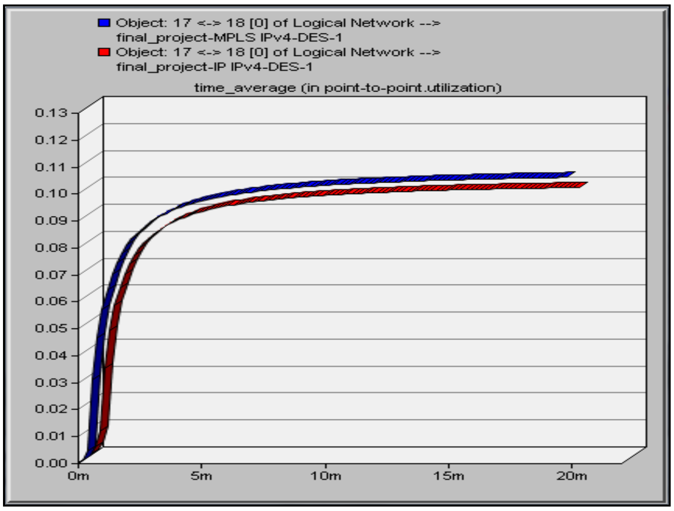

Figure 20 Link Utilization Comparison of IPv4 and MPLS IPv4 along 17 to 18 Link

5.4.2 Utilization of 18 to 19 Link

The simulated results of the point to point link utilization (18 to 19 link) under six scenarios are illustrated in Figure 23, Figure 24 and Figure 25. It is clear from the graph that link utilization stays at 90% for both IPv4 and IPv6 MPLS and without MPLS based scenarios. But for Traffic Engineering based scenarios for both IPv4 and IPv6 the utilization of the same link (i.e. 18 to 19 link) had come down from 90% to 45%. The explanation is given in above section. Thus, it is clear the shortest path route that was earlier congested in IP and MPLS based scenarios had become congestion free in Traffic Engineering case.

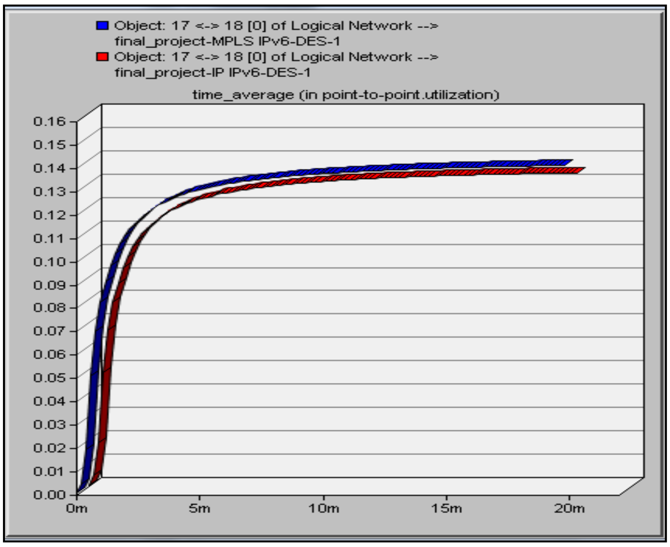

Figure 21 Link Utilization Comparison of IPv6 and MPLS IPv6 along 18 to 19 Link

5.4.3 Utilization of 24 to 29 Link

The simulated results of the point to point utilization of 24 to 29 link under six scenarios are obtained and compared in Figure 26. It is clear from the graph that link utilization stays at 0% for both IPv4 and IPv6 MPLS and without MPLS based scenarios. This is due to because entire traffic from traffic generating clients was forwarded through the shortest path and not a single packet got forwarded through the available alternate path in the network. Thus, the utilization of this link during IP and MPLS based scenarios for both IPv4 and IPv6 stays at 0%. But simulated results from the Traffic Engineering based scenarios for both IPv4 and IPv6 shows that utilization of this link has gone up from 0% to 45%. This is due to because the voice traffic gets forwarded through this link. This is achieved by using the RSVP protocol for Traffic Engineering that establishes a separate tunnel for each application.

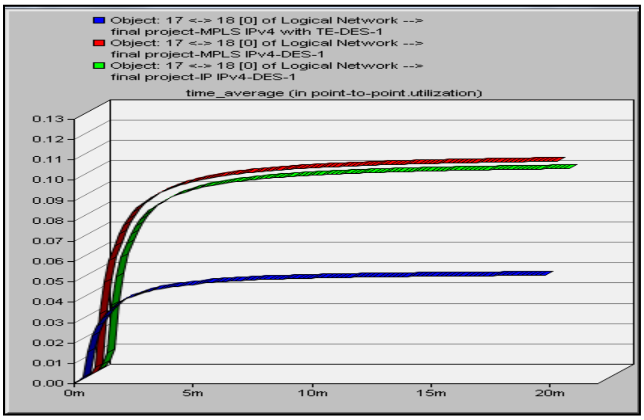

Figure22 Link Utilization Comparison of IPv4,IPv4 over MPLS and IPv4 over MPLS-TE along 18 to 19 Link

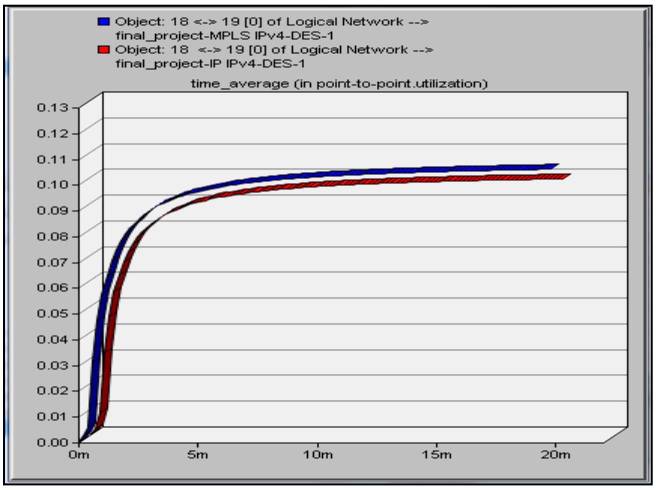

Figure 23 Link Utilization Comparison of IPv4 and MPLS IPv4 along 18 to 19 Link

5.4.4 Utilization of 27 to 28 Link

The simulated results of the point to point utilization of 27 to 28 link in all six scenarios are obtained and compared in figure 27. It is clear from the graph that link utilization stays at 0% for both IPv4 and IPv6 MPLS and without MPLS based scenarios. But simulated results from the Traffic Engineering based scenarios for both IPv4 and IPv6 shows that utilization of this link has gone up from 0% to 45%. The reason is already explained in above section.

It is clear that the shortest path links which were over utilized (90% utilization) in the IP and MPLS based scenarios have become congestion free (only 45% utilization) in Traffic Engineering scenarios and the alternate paths that were not used at all (0% utilization) in IP and MPLS scenarios had now been utilized (45% utilization).

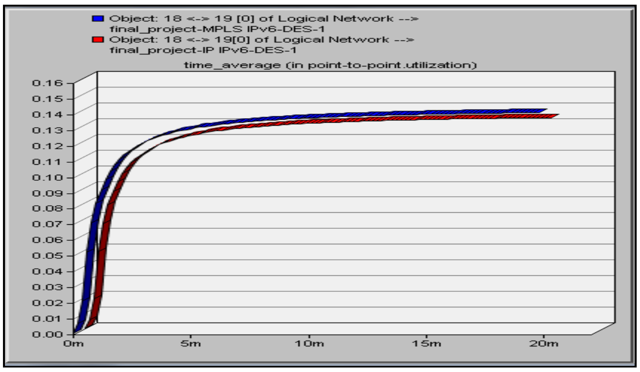

Figure 24 Link Utilization Comparison of IPv6 and MPLS IPv6 along 18 to19 Link

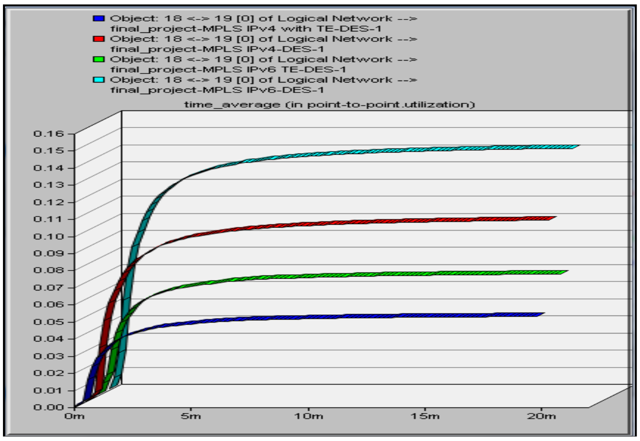

Figure 25 Link Utilization Comparison of IPv4,IPv4 over MPLS and IPv4 over MPLS-TE along 18 to 19 Link

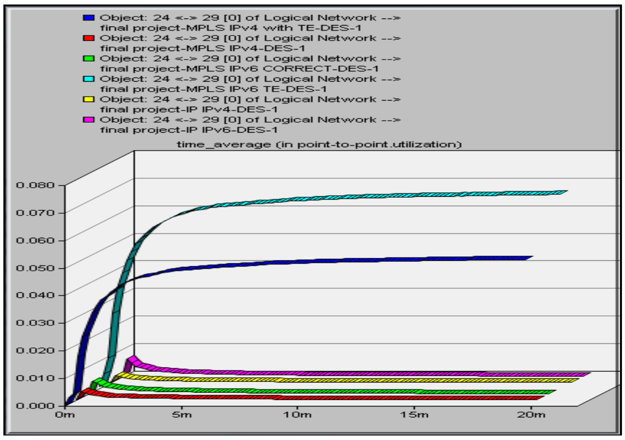

Figure 26 Link Utilization Comparison of 24 to 29 Link

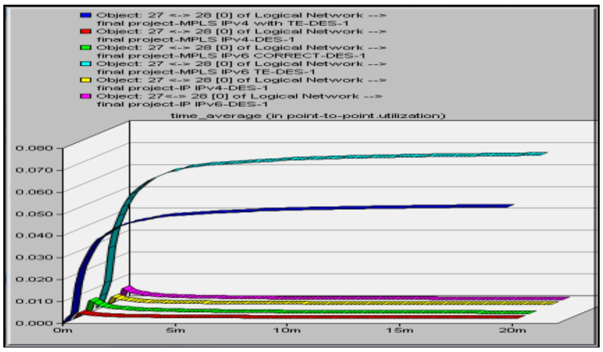

Figure 27 Link Utilization Comparison of 27 to 28 link

6. Conclusion

All Business organizations are constantly being flooded with an enormous amount of data [25]. Due to the huge Internet traffic due to increased demand for heavy audio / video content and other real-time services, it is now necessary to integrate bandwidth-optimized technologies such as MPLS with Traffic Engineering. In this study, traffic engineering performance evaluation with MPLS was conducted in various scenarios involving IPv4 and IPv6 addressing protocols. Traffic engineering has made better use of the connections by reducing the use of overused links to zero, 90 to 45. It was found that network resources could be used well if most of the underutilized links were put to use. The reduction was almost the same for both IPv4 and IPv6 scenarios. With respect to Queuing latency, both the IPv4 and IPv6 MPLS situations involving Traffic Engineering were less. Because of the traffic engineering reduced traffic over LSPs, it was seen that packet drop in MPLS-TE scenarios was also reduced. Nevertheless, it has been observed that average packet drop in traffic engineered networks based on IPv6 MPLS is nearly double that of traffic engineered networks based on IPv4 MPLS. Finally, it was found that average LSP delays in both IPv4 and IPv6 traffic-engineered scenarios were lower than those in which traffic-engineering was not used. Therefore, the simulations carried out demonstrated the applicability of the traffic engineering carried on IPv6 over MPLS.

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