# MPLS-VPN Impact on VOIP-QoS

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***Abstract*** — *Technologies are developing on a daily basis; thus it is also important to upgrade the communication networks based on those new technologies to be responsive to today's user requirements. One of these requirements, and a hot topic is Voice over Internet Protocol (VoIP), which is an essential and sensitive application that cannot tolerate too much delay, jitter, packet losses, etc. but which, at the same time, requires high throughput. So, to deal with such kind of problems, a form of service guarantee is needed, namely Quality of Services (QoS). In this thesis we focus on Multiprotocol Label Switching (MPLS) as a mechanism used for supporting QoS in networks for real time traffic VoIP. MPLS can provide enhanced QoS as compared to traditional IP.By using Virtual Private Network (VPN) and Traffic Engineering (TE), MPLS enables the network to provide QoS and to minimize the factors previously mentioned which have affects VoIP traffic. In this thesis, we first focus on theoretical aspects of MPLS, then we analyze its performance and affects compared with traditional IP while transmitting VoIP by using OPNET network simulation.*

***Keywords***: *MPLS, VoIP, MPLS-VPN, MPLS-QoS and OPNET*

## I. INTRODUCTION

Voice over Internet Protocol is the umbrella for the transition technology family that provide voice communication over IP network like the Internet. The initial steps of Internet calls is the conversion of voice signals to digital format that are further transmitted as internet protocol packets; on the receiving side this process is simply reversed. As [1]pointed out, recently VoIP has advanced to provide incredible opportunities to service providers, as one can use a single IP network for both voice and data communication in a cost effective and a reliable manner. Multiple label switching protocols are considered as the newest technology for supporting the quality of service; it is useful for multimedia applications, service reliability and also for the efficient use of network resources. Furthermore, MPLS is a protocol which can prioritize network traffic and optimize network Performance by usingpacket labels; so if there are QoS sensitive applications (VoIP, Video conferencing SAP and other real time applications) running on the network, then MPLS isconsidered as a very good candidate for supporting these.The best solution (scalability and easy management) for all types of companies to connect to remote users on public or private site is MPLS-based VPN. When we compare MPLS-based VPN with ATM/Frame relay, MPLS-based VPN offers different beneficial services such as better scalability, easy management and QoS; as indicated in [2], before the advent of MPLS-based VPN implementation, VPN used to be based on ATM and Frame relay and it served as point to point VPN in Layer2 of the OSI reference model. But later, when MPLS got integrated in Layer 3 of the OSI model, VPN mechanism got enhanced by using Generic Routing Protocol (GRE) or IPSec tunneling to make it stronger from security aspects [2].

Quality of Service (QoS) is a set of techniques to control delay, jitter, and packet loses in a network, as [3]wrote “It refers to a number of related features of telephony and computer networks that permits the transportation of traffic with the necessities”. Basically QoS refers to the ability of network to provide best services for selected network traffic over various technologies such as ATM, Frame relay and IP routed networks. According to [3]“The primary goal of QoS is to provide priority, dedicated bandwidth, controlled jitter, and latency required by some real-time and interactive traffic, and improved loss characteristics”.

The purpose of this thesis is to analyze the operation of VoIP over MPLS-based VPN for guaranteed quality of services which is influenced by a number of important factors such as delay, load, throughput, packet loss, jitter, security, etc.

## II. RELATED WORK

We have studied several research papers (both from journals and conference proceedings) to devise a plan for writing the background for this thesis; this plan leads us to have better understanding of the various topics studies in this thesis such as VoIP, MPLS, MPLS-VPN and QoS. So this section is divided according to those topics within the research area.

### *A. Voice over Internet Protocol (VoIP)*

As we know from the name “Voice over Internet Protocol”, the voice is transmitted over internet digitally; as [4] pointed out, VoIP is a kind of communication that allows the users to have a call over internet connection instead of analog traditional telephony as shown in figure 1 . This type of communication is possible when both sides (sender and receiver) of the communication are active at the same time. For activating this communication, both the protocols and the communicative devices are required; according to[5] “A protocol is a set of rules used to allow orderly communication”, so VoIP communications and voicedeliver are based on these protocols over the internet. According to [4], the communicative devices for VoIP services are computers or dedicated VoIP phones, but the communication way of VoIP phone and traditional analog phone call is a little different; as [6]pointed out, all phones which are used with home landlines are based on an analog system, but VoIP phone is based on a digital system, for VoIP communication first the voice is converted to digital packets and compressed for best transportation and then the voice packets are transferred over the connection, (and this process is reversed at the receiving site of the communication link).

About ten years ago when VoIP communication was getting a hot topic in network communication, the users stated using voice software enabled computers, internet connections and other software’s that made them communicate because VoIP has many advantage such as free of charge calls all over the world, if both sides have the same voice enabled services parameters; however, the main disadvantage at that time was that only computers could be used for VoIP call communications. As [7] pointed out, fortunately now this disadvantage has been solved by VoIP by fulfilling two requirements for scalable and having optimal VoIP communication, they are as follow:

- Widely adoption of internet broadband connection service;
- Manufacturers have developed a simple, inexpensive integration of IP network with the traditional telephonic system.


***Figure 1:*** **VoIP network infrastructure with both voice and data transition**

### *B. Multiprotocol Label Switching (MPLS)*

Multiprotocol label switching is a standard-based technology to forward the packets based on labels. Such labels may correspond to IP destination network, and MPLS is used for communication since many years in industries’ network such as[8]said, i.e.RFC 3031 discusses how MPLS is designed to replace or combine older frame relay and ATM technologies.

As [1]stressed, the MPLS technology for internet traffic provides efficient prioritization, quality of services, and traffic engineering to increase the performance of internet application such as voice and video used by service providers as well as enterprise networks.

According to [9], MPLS is a new technology used in network for providing better services and enhancement of voice traffic transmission. There are many reasons for using MPLS in a network which are as follows:

1. **Scalability:** one significant problem with ATM and frame relay was network scalability, but by using MPLS this problem can be solved.

2. **Compatibility:** as indicated by its name, MPLS is compatible with many other protocols such as IP and ATM in a network.

3. **IP QoS:** to ensure and enhance the QoS, MPLS uses various methods such as traffic engineering and load balancing.

As [10] described, “The different QoS requirements of voice traffic can be met by using MPLS in conjunction with DiffServ, proper traffic engineering, and other techniques”. Voice packet is a real time application and its main challenge is real time transmission delay, while delivering voice traffic; thus, by using MPLS these challenges can be solved [9].

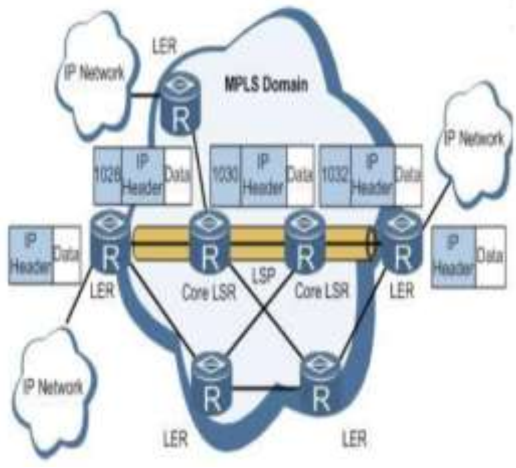


***Figure 2:*** **MPLS network Architecture adopted from*[11]***

### *C. Multiprotocol Label Switching (MPLS)*

As [12]pointed out, MPLS-VPN is a network which is created based on MPLS.For performing VPN task, there are used three kinds of routing devices, such as shown in Figure 28:

- Customer edge (CE): these devices provide routing tables from the MPLS network;
- Provider edge (PE): these devices are connected directly with CE and provide VPN routing tables;
- Provider (P): these devices are used in MPLS backbone network and provide essential information about VPN such as identification, and its routing globally.

According to [1]the whole network is divided into two parts by using MPLS Virtual Private Network. One part is customer-network which is controlled by customers and another one is provider-network which is controlled by providers. So in the customer network there can be manysites, and these sites are connected via VPN through the provider network and the provider edge devices that intervene into the customer edge devices routing for exchanging it with other customers' edge device and the rest of provider edge. Note that the backbone routes only transmit CE routing information but it is not participating into CE routing. PE devices maintain CE information in a separate routing tables called virtual routing and forwarding (VRF) for communications.

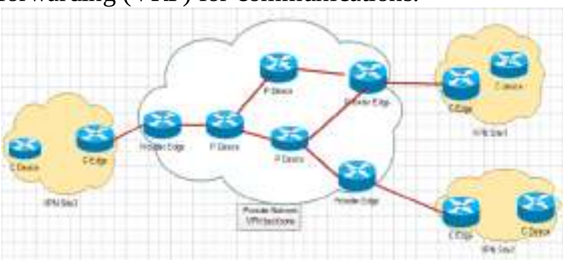

***Figure 3:* Customer and provider network Devices**

## III. METHODOLOGY

In this part we present the information about our research methodology (Simulation) and perform the analysis with respect to our research question.

Simulation is a term used for different proposes by different people; we can say here that simulation is the process that tests and analyzes proposed designed model with their characteristics and controlling factors of the system as in a real environment. Thus with simulation we can predict the behavior, strengths and weaknesses of the proposed model before its implementation in reality.

We are using OPNET simulation for doing the second part of my thesis. The main task is here to analyze the behavior of both traditional IP and MPLS networks with the respect to different performance parameters such as delay, jitter, packet send and receive, end to end delay and throughput. Thus for analyzing these parameters we must divide the simulation process into two tasks:

1. **Task one:** in this first part, our simulation performs the task of sending VoIP traffic from one endpoint to another endpoint based on my network diagram in both (MPLS and traditional IP networks). Our main goal here to compare and analyze VoIP traffic performance for both (MPLS and traditional IP) network in terms of delay, jitter, and packet losses and throughput. We also present the efficient technology for transmission of VoIP traffic.

2. **Task two:** in this second part of the simulation, we estimate the minimum calls which are hold by two (MPLS and traditionalIP) Networks.

### *A. Assumption*

It is rather difficult to fully simulate and predict the characteristics of MPLS VPN because they depend onthe network design and its implementation factors are numerous such as VoIP model, VoIP Codecs, type of services, call per time, etc.

To deal with these numerous factor, here in this simulation we have defined two scenarios (MPLS and Traditional IP, see below) for analysis of VoIP traffic; for each scenario the duration of the simulation is 450 seconds and starts fromthe 100th second and ends at 450s of simulation time.

For network design we should perform two scenario in OPNET network simulation;

- **Scenario 1:** this scenario will be consisted MPLS-VPN network with it is related requirements, as we defined below in section.
- **Scenario 2:** this scenario will be consisted IP traditional VPN network with traditional IP requirements, as we defined below in sections.

Scenario1:

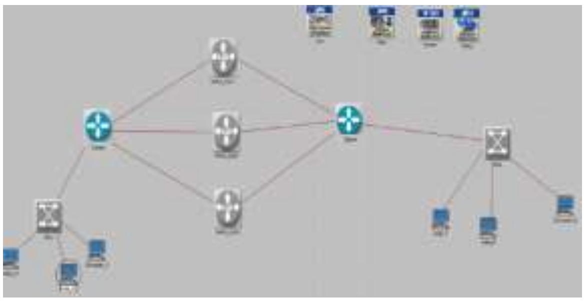

***Figure 4:Screenshot of the MPLS OPNET Network Model***

Scenario 2:

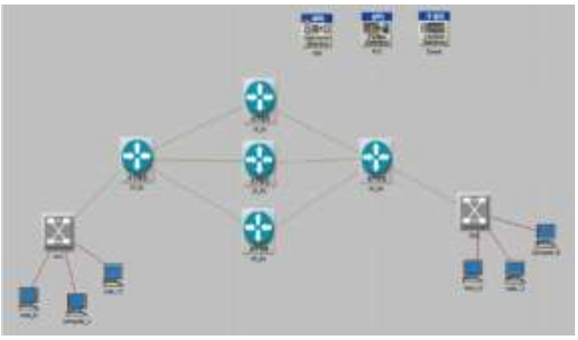

***Figure 5:Screenshot of the Traditional IP network model***

We configured both network scenarios with the same configuration as described in the following:

The VPN is implemented in the above network simulation models by using RSVP signaling protocol; this protocol sets up the CR-LSP for direct route. Here it is configured between the ingress and egress routers and when the network traffic jam is accrued in a network, the traffic is directed along this path and the traffic is distributed in the MPLS network. This CR-LSP controls the jams in a network and use network resources efficiently.

In this scenario, the voice traffic is sent by Computer_A to Computer_B as we established in the Application definition and Profile definitionobject attributes for the above model and via VPN that we configured as shown in Figure 39.We then simulated both scenarios for obtaining packet jitter, delay, as well as packet sentand received.

## IV. RESULT AND ANALYSIS

For the analysis of these network simulations and scenarios we want to analyzeand compare the following performance matrix of both scenarios also we only order our requirement in simulation for getting the result, there are no the configuration of routers, switches…etc. as we do in real network.

- VPN send and receive;
- VPN load (packet/sec);
- VPN throughput (packet/sec);
- VPN end to end delay;
- VPN latency ;
- VPN jitter;

The results of the simulations are illustrated in following figures and are used for analyzing the performance metrics of both networks (MPLS and traditional IP).We have designed the networks for both scenarios and we show their performance metrics separately, but in order to compare them in this part of my thesis, the simulation time is the same for both (450 seconds and the start time of the simulation is 100th second).Moreover, the VoIP call is added in a regular fixed time, i.e. once the first call starts from the 100th second and ends after 450seconds, another call is added after a 2 seconds, and it will again start from the 100thsecond up to 450 seconds. This will be repeated up to the end of the simulation. From the graphs shown in Figures 44 and 45, it can be seen that VoIP packet performance is increased when the MPLS technology is used for its transmission as compared to traditional IP.

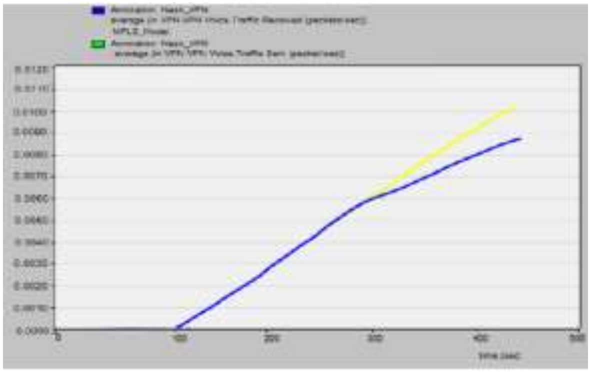

***Figure 6: Screenshot of the simulated MPLS VPN voice traffic sent and received (packets/sec)***

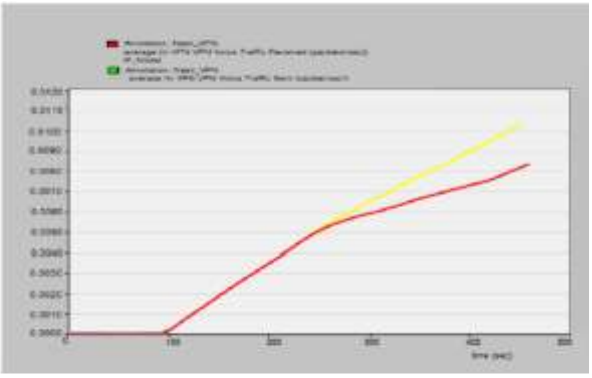

***Figure 7: Screenshot of the simulated IP Conventional VPN voice traffic sent and received (packets/sec)***

Figures 6 and 7 show the average VPN voice traffic sent and received for both scenario (MPLS and Traditional IP) and that towards the end of simulation it is clearly visible that the MPLS technology gives more throughput than the TraditionalIP technology.

In this comparison, as we see in Figure 44, the voice traffic started from the 100th second and dropped in the 300th second of the simulation, but for TraditionalIP shown in Figure 45, the voice packet started from the 100thsecond and dropped in the 220$^{th}$second. Thus in Traditional IP network model, after the 220$^{th}$secondpackets cannot be established with acceptable quality so the call will lose some information or packets and this is the cause of voice traffic skip and breaks during transmission. But in the comparison with MPLS, voice packet are dropped after the 300th second. Thus in fact MPLS technology deliver packets with high transmission speed with low delay.

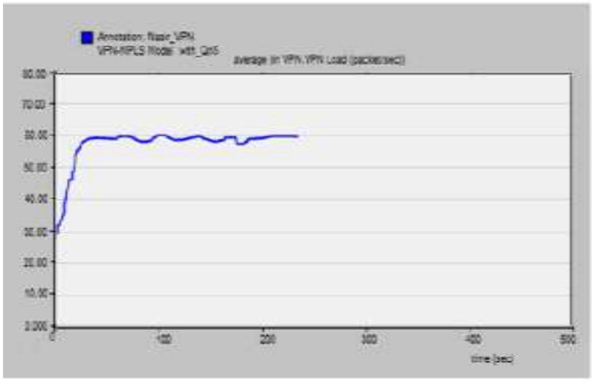

***Figure 8: Screenshot of the simulated MPLS VPN load (packets/sec) in OPNET***

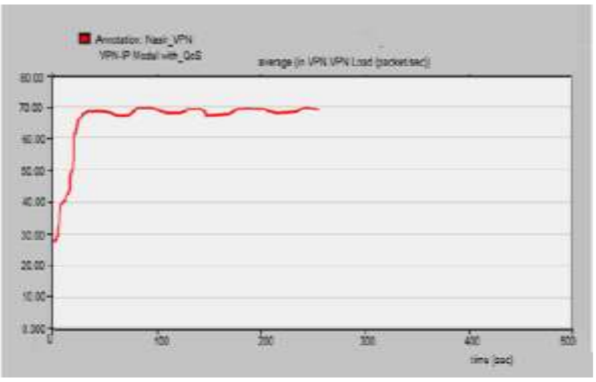

***Figure 9: Screenshot of the simulated IP Conventional VPN load (packets/sec) in OPNET***

In Figures 8 and 9 we can see the respective VPN loads for both network models (MPLS and Traditional IP).The Traditional IP has a higher VPN load thanthe MPLS VPN, i.e. VPN load for traditional IP is 70.00 packets/sec and for MPLS VPN 60.00 packets/sec.

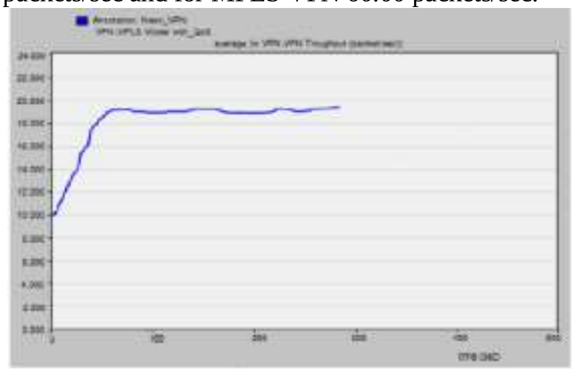

***Figure 10: Screenshot of the MPLS VPN model throughput (packets/sec) in OPNET***

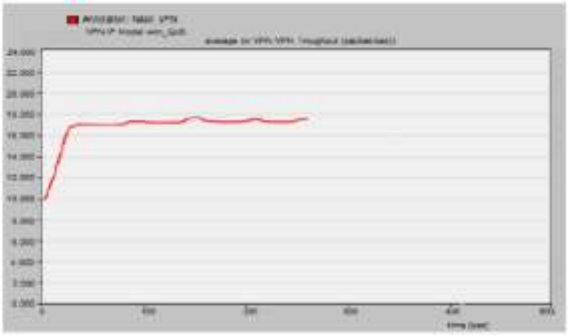

***Figure 11: Screenshot of the simulated conventional IP VPN throughput (packets/sec) in OPNET***

The VPN throughput for both (MPLS and Traditional IP) network models are shown in Figures 48 and 49. The MPLS VPN has a higher throughput than Traditional IP VPN, i.e. Traditional IP VPN has 17.00 packets/sec, but MPLS-VPN has 19.00 packet/sec.

So in the comparison, the MPLS-VPN has the greatest throughput based on its load because, as we mentioned previously, MPLS-VPN forwarding the packets based on LSP.However, Traditional IP forward the packets based on destination IP Address instead of LSP in MPLS, and there will be delays for searching and finding the targeted destination address into the routing table at the router and this will consume network bandwidth and resources; thus MPLS is the best technology over traditional IP for forwarding of the real time traffic such as VoIP with higher throughput and less traffic load.

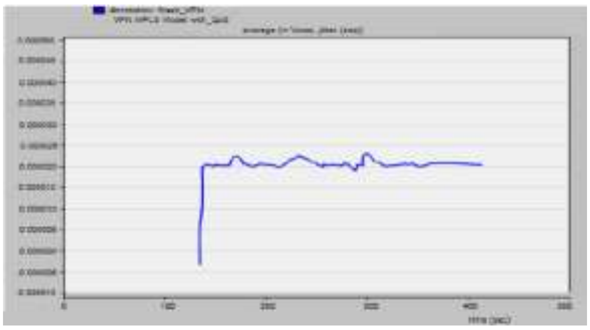

***Figure 12: Screenshot of the simulated MPLS VPN voice jitter (sec) in OPNET***

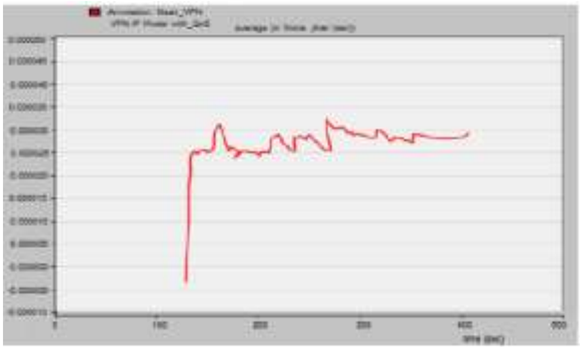

***Figure 13: Screenshot of the simulated IP VPN voice jitter (sec) in OPNET***

Figures 12 and 13 show the jitter for both network models implementation.It is very low as compared to the acceptable jitter (less than 50ms).It can also be noted that MPLS VPN has a more stable and slightly lower jitter thanthe traditional IP VPN.

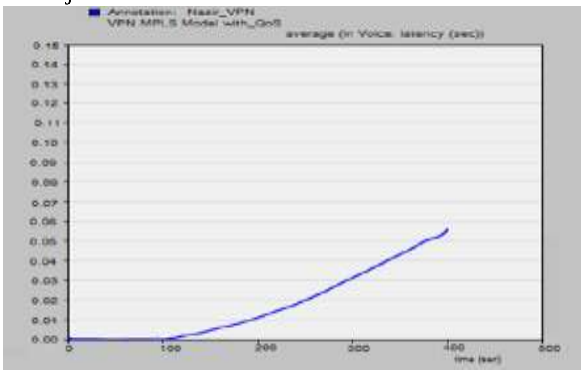

***Figure 14: Screenshot of the simulated MPLS VPN latency (sec) in OPNET***

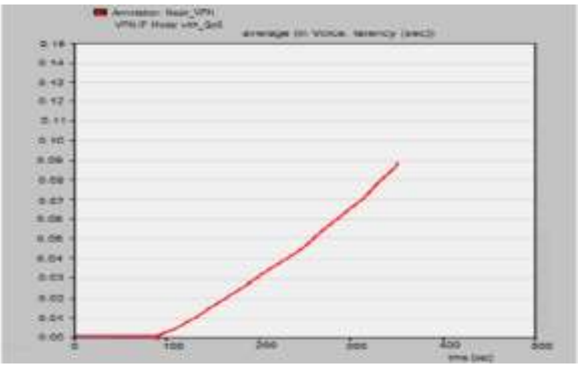

***Figure 15: Screenshot of the simulated IP VPN latency (sec) in OPNET***

Figures 14 and 15 show the latency for both network models implementation. It is very low as compared to the acceptable latency (less than 150ms or 0.15s).It can also be noted that MPLS VPN has more stable and slightly lower latency than the traditional IP VPN.

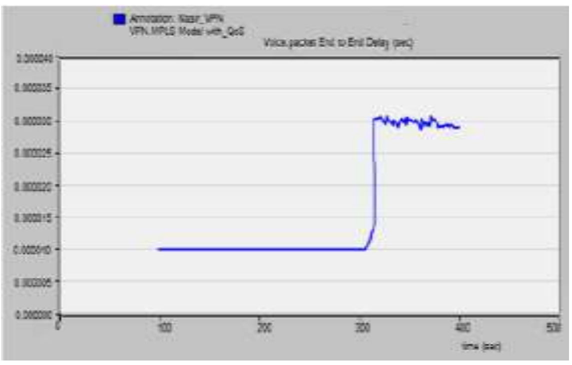

***Figure 16: Screenshot of the simulated MPLS VPN end to end delay (sec) in OPNET***

***Figure 17: Screenshot of the simulated IP VPN end to end delay (sec) in OPNET***

Figures 16 and 17 show the end to end VPN delay for both network model implementations. It can be seen that the MPLS VPN reaches end to end delay threshold at 310 seconds and that the traditional IP VPN reaches at 230 seconds. Thus traditional IP VPN reaches it earlier than MPLS VPN and MPLS VPN uses the network resources more efficiently as compared to IP VPN.

### *A. Call Calculation*

Here we want to estimate the maintained number of VoIP calls with acceptable quality by means of simulations. So these maintained VoIP calls in both (MPLS and traditional IP) scenarios are estimated based on end to end delay traffic graphs. Figure 6 shows the end to end delay in MPLS network and Figure 7 shows end to end delay in traditional IP network.

From Figure 6 it can be seen that the end to end delay in MPLS network reaches the threshold value at 310 second whereas in traditional network end to end delay threshold is reached at 230 second. As we also discussed previously after the configuration of Application definition and Profile definition the VoIP call is added every 2 seconds and VoIP call addition will start from 100th second, repeatedlyuntil the end of the simulation.

For calculating total numbers of VoIP calls in each scenario are gotten by calculating total simulation time (from 100th second up to end of simulation 450th second), the calls added regularly after 2 seconds, so here we can calculate the total VoIP calls (450-100)/2 =175 VoIP calls, (recall that these calls are established in each scenario).

Now we want to determine the numbers of VoIP calls separately in each scenario.

For the calculation of VoIP calls in traditional IP network model we implement the above formula based on Figure 7:

(230-100)/2=65 VoIP Calls with acceptable qualitythe calculation of VoIP Calls in MPLS network model is based on Figure 6:

(310-100)/2=105 VoIP Calls in MPLS network with acceptable quality.

As we are seeing, there are much difference between VoIP calls calculation in both network scenarios, and MPLS VPN has delivered more calls with best quality whereas traditional IP VPN has delivered less calls with acceptable quality at the same time. So MPLS provides better quality over traditional IP for VoIP traffic.

## V. CONCLUSION

The main goal of this thesis was to describe the theory and analyze the performance of both IP traditional and MPLS networks for VoIP traffic transmission. The performance analysis has been conducted by means of OPNET network simulations by considering two separate network approaches (MPLS and Traditional IP) with minimum VoIP call quality which can be maintained in both mentioned networks.

The performance analysis considered performance metrics such as VPN voice jitter, VPN voice sent and receive, VPN voice load and VPN voice throughput.

For achieving the research questions as I mentioned at the beginning of the thesis, this research started with literature review about VOIP, MPLS, MPLS-VPN and MPLS-QoS, and these literature review helped me to answer my research questions as I mentioned in the beginning of my thesis. Furthermore, based on the conducted OPNET simulations, it is concluded that MPLS is the best choice for transmitting VoIP traffic as compared to traditional IP technology because:

- ✓ MPLS routers takes less time for traffic processing, thus this is the best choice for delivering real time traffic (VoIP) which tolerate less delay in a network;
- ✓ MPLS routers use LSP for traffic forwarding over network, this LSP will be forwarded based on RSVP and RC-LDP signaling protocols, which improves the performance;
- ✓ MPLS provides more throughput and less delay as compared to traditional IP.
- ✓ MPLS VPN decreases performance matrix (delay, Jitter...etc.) During VoIP traffic forwarding as previously mention limited time for delay, jitter and packet loses, as compared to traditional IP VPN; also these are confirmed by network simulation.

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