PERFORMANCE ANALYSIS OF VIDEO TRAFFIC OVER MPLS-TE WITH DIFFSERV

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Abstract— **At present, Service Providers (SP) are in the midst of evaluating and evolving their various networks to a single converged Internet Protocol (IP) -based network infrastructure which able to use the existing and future services. Despite of having many options proposed, it is still a challenging task to implement Quality of Service (QoS) in IP based network. Differentiated Services (DiffServ) as one of the QoS mechanism, has become the mainstream of QoS solution. With DiffServ mechanism, traffic can be classified based on the priority to provide quality of service in order to meet the Service Level Agreement (SLA). Multi-Protocol Label Switching (MPLS) with Traffic Engineering (TE) complements DiffServ mechanisms to perform better in providing QoS architecture. This paper discussed and analyzed performance of video traffic over MPLS Traffic Engineering (TE) with DiffServ using a set of traffic model for video and data. Four different network scenarios were chosen which include different type of scheduling mechanism in QoS application. Performance parameters such as end to end delay, throughput, and Packet Delay Variation (PDV) were compared and analyzed. The comparative study showed that Priority Queuing (PQ) has generally improved the performance of video traffic compared to MPLS-TE only network and other type of scheduling mechanism.**

Index Terms— **MPLS, DiffServ, Traffic Engineering, Quality of Service (QoS), end to end delay, throughput, Packet Delay Variation (PDV)**

I. INTRODUCTION

With the aggressive internet market nowadays, service providers and IT companies need to increase their data speed, a better way to enhance the network performance. Furthermore, high speed network is able to adapt various type of traffic with a minimum congestion.

One of the common value added services users seek from the service provider is the Quality of Service (QoS). Quality of Service (QoS) is not only a value added services but is a must to any corporate or enterprise customers which require high reliability network to connect to their branches. In another hand, Quality of Service (QoS) also is very crucial to companies which require high reliability, prioritization and security of their traffic across the internet cloud.

In particular, end to end Quality of Service (QoS) is very demanding which concern the bandwidth throughput, delay, jitter and packet loss rate. In recent years, the multimedia traffic application such as Internet Protocol television (IPTV) and video conferencing are very popular. The service mechanism in IP network is on best-effort basis and will no longer able to meet the emerging business needs. Plus, with the current demand for High Definition (HD) IPTV which require a lot of bandwidth consumption. A detail and excellent network planning is necessary for a service provider to ensure minimum packet drop, delay for multimedia traffic such as video, voice and data. Therefore, Multiprotocol Labels Switching (MPLS), the next technology is on demand with its features that can benefit users with Quality of Service (QoS) and Traffic Engineering (TE).Currently, this new technology is the most preferable choice among the Telecommunication companies and Internet Service Provider.

Commonly, bottleneck happens at the routers. In conventional routing, each packet is forwarded hop by hop using routing table based on algorithm in each router. Each packet is forwarded independently in every router. This approach is unreasonable and inefficient for multimedia traffic [2]. Thus, MPLS architecture has been introduced to use the label to forward packets. The implementation of MPLS-TE with DiffServ architecture is able to support traffic engineering as well as the implementation of traffic classification, marking, policing and scheduling.

In this paper, the network performance was evaluated based on the throughput, end to end delay and Packet Delay Variation (PDV). The results were compared with acceptable range from International Telecommunication Union (ITU) and previous works related. By using OPNET, simulations were performed over a congested network by transmitting high load traffic such as video, FTP and HTTP to see the effect of implementing MPLS-TE in DiffServ domain.

II. OVERVIEW

A. Multiprotocol-Label Switching (MPLS) with Traffic Engineering (TE)

Multi – protocol Label Switching (MPLS) is a high performance switching used for packet to be transmitted over the network. This technology provides a mechanism that can forward packets regardless of any network protocol. The capabilities of MPLS have massively expanded, for example to support Traffic Engineering (TE), Virtual Private Network (VPN), network convergence and the increase of network reliability.

In MPLS mechanism, packet is tagged with an identifier label to differentiate Label Switch Protocol (LSPs). When packets received at the router, this label is used to identify the LSP. From the forwarding table information, the router then determines the best route to forward the packet and the next label to use at the next hop. Each hop uses a different label. The label choosing and forwarding tasks are performed by routers or switches.

MPLS node or router represents either a Label Edge Router (LER) or Label Switching Router (LSR). In principle, LER functions at the edge of MPLS network.

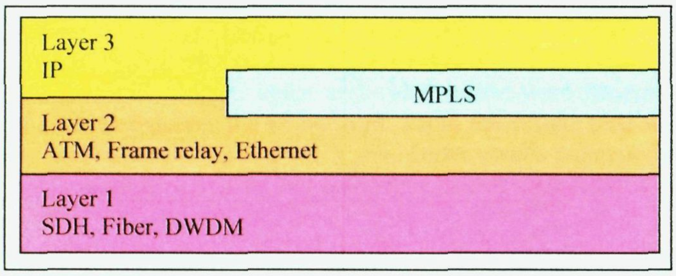

Fig. 1. MPLS Layer

Figure 1 shows the MPLS layer is in between Layer 2 (data link) and Layer 3 (network). One of the MPLS characteristic is protocol-independent that is compatible with any layer 2 or layer 3 protocols including routing protocols such as Open Shortest Path First (OSPF) and Resource Reservation Protocol (RSVP).

Traffic Engineering (TE) is a mechanism that controls the traffic flows in the networks and provides the performance optimization by optimally utilizing the network resources [1]. Some of the key features of TE are resource reservation, fault-tolerance and optimum resource utilization [1].The important factors needed for Traffic Engineering (TE) are distribution of topology information, the path selection, traffic directed along the computed paths, and traffic management [1].MPLS main purpose is to efficiently optimize the available network resources and improve service quality of applications on the internet.

Signaling protocol developed by Internet Engineering Task Force (IETF) to implement Traffic Engineering (TE) in MPLS are Resource Reservation Protocol (RSVP) and Constraint Based Distribution protocol (CR-LDP). These protocols are used to establish LSPs from Ingress to Egress router and implementing TE in MPLS network.

B. Quality of Service (QoS) Implementation in MPLS

During network congestion, Quality of Service (QoS) is beneficial to help traffic being prioritized based on the class of service and ensure there is no packet drop, jitter or latency especially to the highly sensitive traffic such as video and voice.

In IP-based network, there are two types of QoS mechanisms known as Integrated Service (IntServ) and Differentiated Service (DiffServ). However, in MPLS –based network, the QoS implementation is only compatible with DiffServ mechanism.

DiffServ is an easier model in service quality applications in terms of usage and application when compared to the difficulty of IntServ and RSVP applications [1]. The main objective to have DiffServ model implemented in the network is to meet customer's desire of a quality network performance. Service provider can offer customer different type of services based on priority. With DiffServ Quality of Service (QoS) mechanism, traffic is marked with different features and delivers it to different class. At each of the router, Per Hop Behavior (PHB) will take effect.

In PHB at each router, packet classification and packet conditioning according to the traffic are defined and assigned in DiffServ architecture. On the entrance point of the backbone, PHB are assigned to the previously-specified path in accordance with their criteria. Expedited Forwarding (EF) and Assured Forwarding (AF) are the common used PHB which currently applied.

The QoS mechanisms used for the simulations are DiffServ approach using standard network parameters such as throughput, end to end delay and Packet Delay Variation (PDV). The simulation's results were compared with the standard Service Level Agreement (SLA) which has been agreed by International Telecommunication Union (ITU). Four main steps are required to implement QoS in MPLS architecture. The steps are described as follows;

i- Traffic classification and marking
ii- Policing
iii- Scheduling
iv- Congestion Avoidance Mechanism

In summary, traffic policing, conditioning, dropping or shaping the traffic based on the class of service are performed at the ingress node. Scheduling mechanism such as First in First out (FIFO), Weighted Fair Queuing (WFQ) and Priority Queuing (PQ) are commonly implemented. Traffic policing and marking are performed once traffic classification completed. The bandwidth limit to the traffic is specified by the policer configuration. There is only one policer can be applied to a packet per direction.

III. LITERATURE REVIEW

In recent years, several projects have been done to study, test and analyze the effect of QoS in MPLS network. The various studies include the implementation of Traffic Engineering (TE) in MPLS and DiffServ. The previous works related to QoS in MPLS have benefit the network engineers in order to have better planning, implementation and managing network while maintaining the quality of service to meet the Service Level Agreement (SLA).

Previous works by Jasrina Jafar [5], discussed the video performance when applied DiffServ- Aware in MPLS network. The term DiffServ-Aware is also known as Traffic Engineering (TE). This paper focused the effect of video performance between conventional IP network, with and without DiffServ and MPLS-TE network with and without DiffServ. In this paper, the implementation of QoS was only focused on using Priority Queuing (PQ) and Weighted Fair Queuing (WFQ) as the scheduling mechanism. From the results obtained, the end to end delay of video traffic has improved when applied DiffServ in MPLS-TE network as well as the throughput. Even though video traffic has less delay, the other data traffic such as FTP and HTTP have been impacted with fewer throughputs.

Another works related to this was done by Mohammad Mirza Golam Rashed and Mamun Kabir [13], which discussed the effect of scheduling or queuing mechanism in IP network. Simulations were done using OPNET and three scheduling mechanisms have been tested which are First in First out (FIFO), Weighted Fair Queuing (WFQ) and Priority Queuing (PQ). In this project, voice and video traffic were generated and simulated over the IP network. From the results obtained, we can conclude PQ and WFQ gave better results compared to FIFO in term of end to end delay and Packet Delay Variation (PDV).

Other than using OPNET as the simulation's tools, there were also project that use J-Sim coding to produce a network topology and simulate scenario based on the parameters chosen. This has been proved by Muhammad Romdzi Ahamed Rahimi [3], which discussed on the implementation of Quality of Service (QoS) in MPLS network. This paper focused on a comparative study of Expedited Forwarding (EF) and Assured Forwarding (AF) packet classification in term of throughput and the packet loss. As a conclusion, the EF packet have better throughput and less packet loss compared to AF packet.

Beside from research on video traffic performance, there are also related works on QoS implementation with highly sensitive application such as Voice over IP (VoIP). Thesis by Jeevan Kharel [9], discussed on how scheduling mechanism such as FIFO, WFQ and PQ affect the voice traffic over MPLS-TE performance. Based from the results, it was concluded that the network performed better when DiffServ was applied in MPLS-TE compared to MPLS-TE only. In term of scheduling method, PQ has contributed for lower end to end delay and Packet Delay Variation (PDV).

Thesis by Saad M. AlQahtani [10], introduced the general comparison between MPLS and MPLS with DiffServ with transmitting voice, video and FTP traffic over the network. Several queuing mechanism have been configured such as Deficit Weighted Round Robin (DWRR), Modified Deficit Round Robin Queue (MDRR), Priority Queuing (PQ) and Weighted Fair Queuing (WFQ). From the graphs obtained, it can be concluded that WFQ gave the best result in term of end to end delay, throughput and Packet Delay Variation (PDV), while PQ gave the best result for video for both delay and delay variation. Nevertheless, In MPLS network, video traffic was facing much higher delay compared to MPLS with DiffServ-aware. This has met the expected result as video was given the highest priority among other traffics.

IV. SIMULATION MODEL

Figure 2 shows the flow chart of research methodology, this project was divided in three phases, literature review, design and simulation and data analysis and discussion.

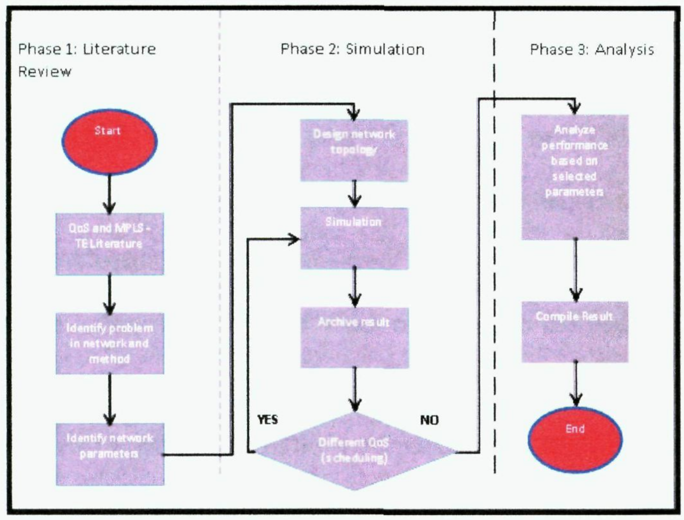

Fig. 2. Research Methodology

A. Phase 1: Literature Review

In the first phase, a comprehensive study was done for MPLS-TE technology, QoS mechanism in MPLS and also the OPNET network simulator. At the same time, during this phase, network issues and method to overcome it has been identified.

B. Phase 2: Design and Simulation

The second phase of this project focused on the design of MPLS network architecture using OPNET. This includes implementing all the appropriate attributes to the network element in order to achieve network design which almost similar to the real-live network. Once design completed, simulations were started with the traffic variation and scenarios. All simulation's results were archived for analysis.

C. Phase 3: Analysis and Discussion

The third phase is when all data collected were analyzed and discussed based on network parameter chosen.

In this project, all simulations were performed using OPNET network simulator tools. The network topology is designed according to standard service provider requirement. Below are the bandwidth assignment;

- 75% for Video (EF)
- 25 % for FTP (AF21) and HTTP (AF11)

The bandwidth segregation was taken from local service provider network configuration. OPNET was chosen as the simulation tools as its features are able to support most of the protocols and network elements. It is also capable to have a close to real life network simulation and configurations. In this paper, there are four scenarios chosen.

I. MPLS-TE Only
II. MPLS-TE with DiffServ (FIFO)
III. MPLS-TE with DiffServ (WFQ)
IV. MPLS-TE with DiffServ(PQ)

The simulations were performed by sending a high load video traffic flow as shown in Table 1 and observed the performance of traffic based on throughput, end to end delay and Packet Delay Variation (PDV). Aside from video traffic, FTP and HTTP applications were also simulated. FTP and HTTP application details were obtained from OPNET and heavy data transmission has been chosen. FTP application transmit a 5MB file capacity while HTTP use the heavy browsing application characteristic.This is to ensure the network was congested in order to observe the network performance with Traffic Engineering and DiffServ implementation.

TABLE I. VIDEO TRAFFIC DEFINITION

Video Traffic	Frame Interval (frames/sec)	Frame Size (pixels)
High Resolution	15	128 x 240

A 5MB FTP traffic was set as a high load and best effort type of service. The inter-repetition time was constantly set at 30 seconds. To ensure the network was fully congested, a heavy browsing HTTP traffic also has been simulated. The page inter-arrival time selected was exponentially distributed with mean of 60 seconds and each page has 5 medium images with 1000 bytes size.

In these network simulations, services have been classified in two class of service which are Expedited Forwarded (EF) and Assured Forwarded (AF). EF traffic has low end-to end-delay, low jitter and low PDV. Video traffic has been classified in EF class in the simulation. Nevertheless, due to video traffic nature which sometimes burst, packet loss can happen. 75% of the bandwidth were dedicated and guaranteed for EF traffic and the rest were for AF traffic classes including the Best Effort traffic. For this project AF class chosen were AF11 and AF21. AF11 was set for HTTP application while AF21 was for FTP application.

In order to provide assurance of packet delivery, Assured Forwarding (AF) ensures packets reach the destination as long as it did not exceed the subscribed rate. In the core network, all backbone links which connected to the core routers were configured with DS3 link capacity that carried 45MBps.

The core network was designed using 4 LSR routers and 2 LER routers. From the network topology shown in Figure 3 and Figure 4, LER1 and LER 2 were the ingress router while Router A, Router B, Router C and Router D were the LSR routers. The core bandwidth and the access links between edge router and the client/server were configured with 45MB for each link. This is to simulate the same scenario as the Service Provider core network. For this network , OSPF has been configured as the routing protocol as its compatibality with MPLS implementation. In OSPF mechanism, the lowest cost path was chosen to route the traffic. Hence, for this case, path from Router A to Router C was be the best path to route traffic for basic IP routing mechanism. However, In MPLS implementation, packets were forwarded to LSR using the LSP path. In this simulation, to impelement MPLS Traffic Engineering (TE), a static LSP path was developed from LER 1 to LER 2 using route from Router A –B –C. This to avoid congestion to happen when all of the traffics were routed to the same path (Router A – Router C). This is when we can control the traffic forwarding to have a better load balancing between paths. MPLS-TE can establish bandwidth-guaranteed paths for traffic flows [4]. The Video traffic which has been classified in EF class has been assigned to its own Forwarding Equivalent Class (FEC) that binds to the static LSP. This FEC had a high priority treatment at each hop with a specific trunk profile. AF11 and AF21 traffic were routed to follow path using the existing OSPF routing protocol algorithm which has been configured across the network. Hence, this setup avoids the link between LER 1 and Router A to be congested and all traffics were segregated to their dedicated pre-configured path.

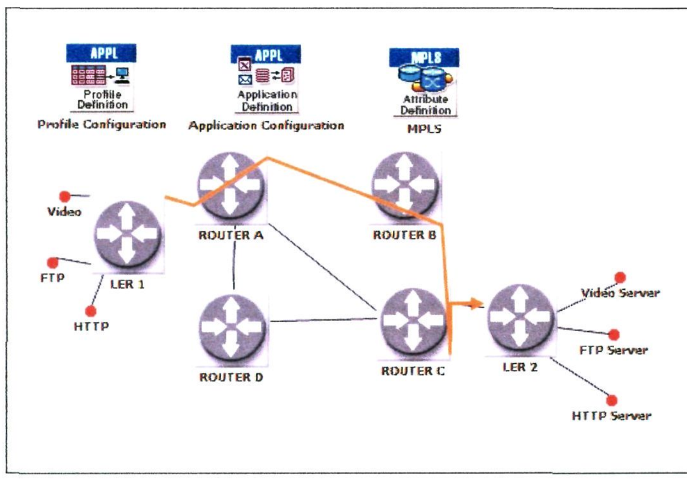

Fig. 3. MPLS Network Topology

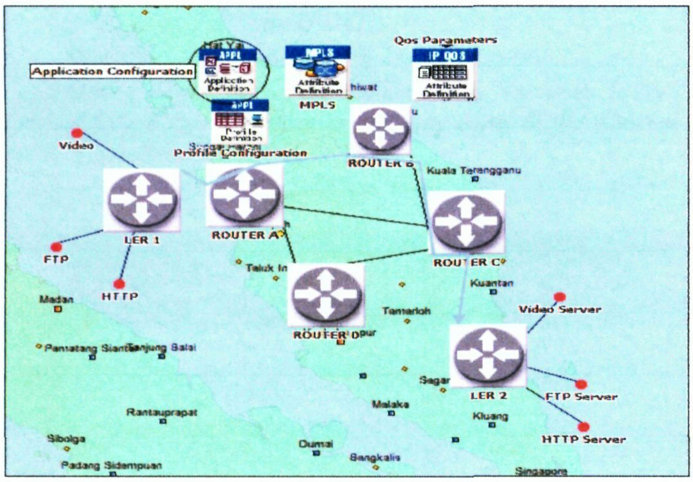

Fig. 4. MPLS TE with DiffServ Network Topology

In MPLS with DiffServ domain, three scenarios were simulated using different type of scheduling mechanism, which are the conventional queuing method, First in First out (FIFO), Weighted Fair Queuing (WFQ) and Priority Queuing (PQ). At the Ingress router, Traffic policing Committed Access Rate (CAR) was used in order to police the packets' flow before being transmitted going into MPLS-TE DiffServ domain. CAR is a policing algorithm that enables the service provider to control the flow rate from one link to another link that has different bit-rates requirement [5].

To have a better congestion control in the network, Random Early Drop (RED) was configured as the congestion avoidance algorithm. Probabilistically discards arriving packets when a core node's buffer occupancy reaches a certain threshold [6]. Discarding arriving packets forces the corresponding TCP sources to reduce their congestion windows, which effectively slows down their transmission rates and reduces the probability of congestion [6]. The advantage of employing DiffServ-MPLS in the IP network is the capability of the service provider to make full use of Forward Equivalent Class (FEC) by DiffServ traffic classification via PHB [5].

The QoS configurations are shown in Table II to define the traffic classification, policing, scheduling and congestion avoidance configured in the network.

TABLE II. QOS PARAMETERS

Scenario/ Topology	Traffic Scheduler	Traffic Classification	Traffic Policer	Congestion Avoidance Mechanism
MPLS TE (FIFO)	FIFO	Video – EF FTP – AF21 HTTP – AF11	CAR	RED
MPLS TE (WFQ)	WFQ	Video – EF FTP – AF21 HTTP – AF11	CAR	RED
MPLS TE (PQ)	PQ	Video – EF FTP – AF21 HTTP – AF11	CAR	RED

V. RESULTS AND ANALYSIS

The simualtion results were obtained for each application under the four scenarios. Scenario 1 (MPLS TE only) was the reference for the comparative study where no DiffServ applied to the network. The overall performance proved that for highly sensitive data such as video conferencing, DiffServ application using Priority Queuing (PQ) with CAR and RED algorithm gave lower end to end delay, PDV and better throughput.

A. Video End to End Delay

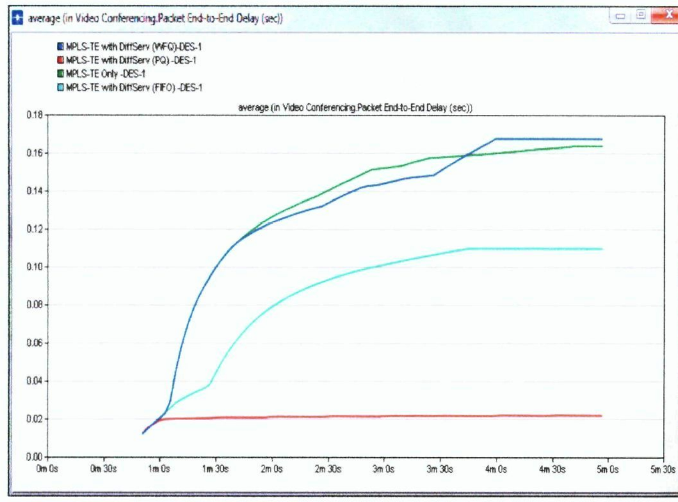

Fig. 5. Average end to end delay for video traffic

Figure 5 demonstrates how Video traffic marked with EF class of service has a better end-to-end delay when Priority Queuing (PQ) was being implemented as the traffic scheduler. PQ gave high prority for EF packet to be in queue before other packets. This ensure the video traffic to have less latency or lower end-to end delay in order to maintain the video performance at the receiver end. In average, MPLS TE with DiffServ using PQ has given 0.02 sec (20ms) of packet delay as compared to others and this has met the standard video conferencing acceptable range for delay which is 100ms. As shown in Figure 5, FIFO implementation in MPLS-TE did not have a big impact in terms of the delay as compared to the PQ since FIFO is a conventional queuing mechanism and there is no priority to the marked packet. For WFQ implementation, based from the graph in Figure 5, the effect is slightly lower than MPLS-TE Only scenario, since this queuing mechanism gave priority based on the weight configured for each queuing.Thus, fair queuing method was provided to all application not only for video traffic. Aside from that, the implementation of CAR and RED also contribute to reduce video end-to-end delay for all scenarios.

B. Packet Delay Variation (PDV)

Figure 6 below shows the Packet Delay Variation (PDV) graph. PDV is the difference in one way delay of the selected packets as defined by the IETF [8]

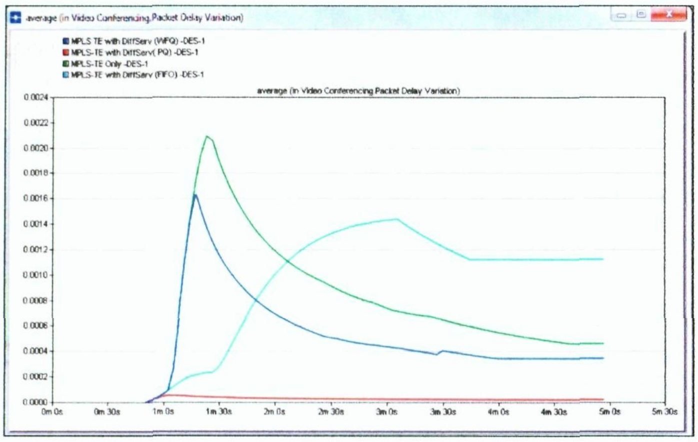

Fig. 6. Average Packet Delay Variation (PDV) for video traffic

The graph in figure 6 shows that Priority queuing (PQ) when used as the scheduling scheme for MPLS-TE with DiffServ network shows better performance which was lower PDV.

C. Video Throughput

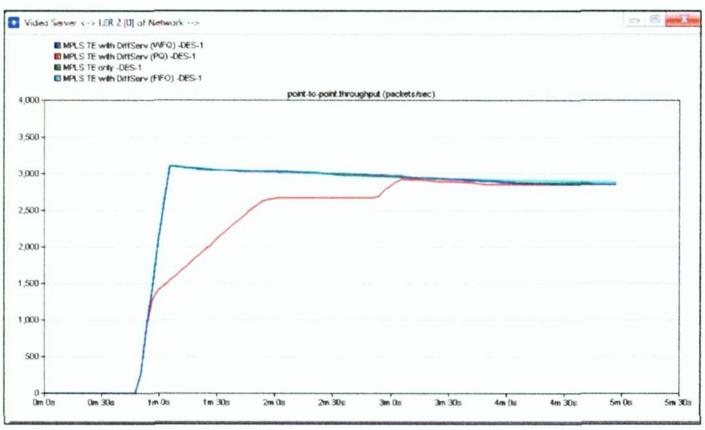

Fig. 7. Video Throughput

Figure 7 demonstrates the throughput performance at Video server and it shows that eventhough end-to-end delay was higher with the implementation of FIFO, WFQ and MPLS-TE only in the network configurations, at the receiving end, the throughputs were still improved. However, for PQ implementation, at the beginning of simulations, the throughput a bit lower but it has increased after 3 minutes of simulation and maintain the performance until the simulation end.

D. Other Traffic Throughput

Figure 8 and Figure 9 explain how the QoS implementation can affect Assured Forwarded (AF) traffic in the network when using the three scheduling schemes. From both graphs, it is reminded that in DiffServ network, FTP was given higher priority than Http traffic.

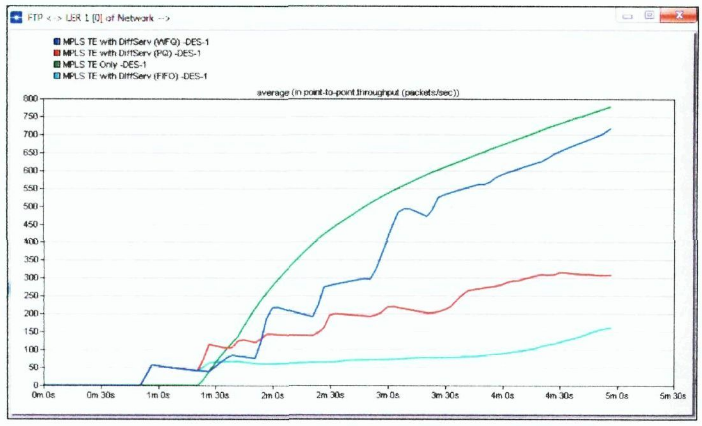

Fig. 8. FTP throughput

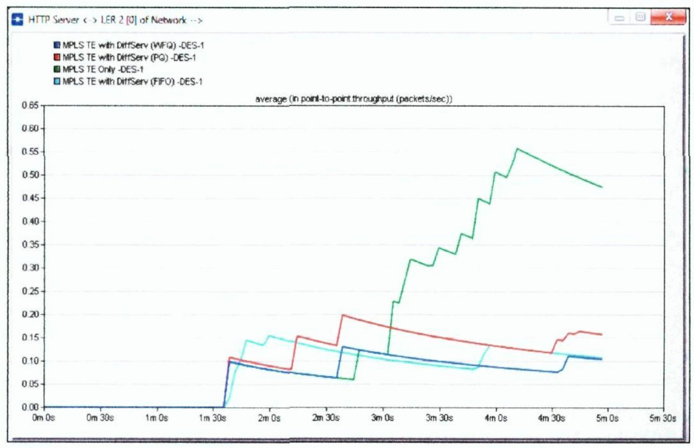

Fig. 9. HTTP throughput

As discussed, during scenario 1 , MPLS-TE simulation, there were no traffic marked, hence FTP and HTTP make use the available bandwidth in the network. This results the throughput to become higher compared to other scenario. WFQ uses multiple queues to separate and provide equal amounts of bandwidth to each of the flows, while FIFO placed all packets into one queue and then transmitted those packets as bandwidth becomes available [7]. As illustrated in Figure 8, traffic received under the WFQ scenario was higher than FIFO.For FTP application, it can be concluded that PQ and FIFO gave the worst throughput.

For HTTP throughput result which demonstrates in Figure 9, the performance using DiffServ in the MPLS-TE network has been reduced compared to MPLS-TE only since HTTP traffic was not given high priority compared to video and FTP traffic.

VI. CONCLUSION

The implementation of Traffic Engineering (TE) and DiffServ in MPLS network in overall has improved the video traffic end to end delay, Packet Delay Variation (PDV) and maintained the throughput. Priority Queuing (PQ) was proven to be the best scheduling mechanism for high sensitive application such as video conferencing. The mechanism that provides low, medium and high queuing priority enable EF marked traffic to differentiate the traffic treatment at each hop. Besides, traffic policer and congestion avoidance mechanism also contributed to a better performance.For low sensitivity application such as FTP and HTTP, WFQ scheduling mechanism is suitable to balance the queuing priority hence it did not jeopardize the throughput and end to end delay performance.

However, more studies need to be done further in QoS mechanism such as Weighted Random Early Detection (WRED), Custom Queuing (CQ), other traffic policing, queuing and congestion avoidance. For example, the implementation of other queuing mechanism can be combined with a different congestion avoidance or traffic policer. A comprehensive study will determine which the best QoS configuration's setup that benefits highly sensitive traffic and at the same time maintain the other traffic performance.

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