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MPLS Performance Enhancement for Video Applications

Ahmed F. Jasim[1], Ammar D. Jasim[2]

[12]Al Nahrain University, College of Information Engineering, Baghdad, Iraq
[1]Department of Network Engineering
[2]Information and Communication Engineering Department

Abstract: MPLS uses the idea of virtual paths to build the network topology and provides traffic engineering feature balances network load by distributing traffic on all available paths in the network. The user's perceived quality is an important indicator of how much the system can deliver the expected quality to the user. This paper presents an MPLS load balancing that distributes the traffic based on the maximum quality state of virtual paths in MPLS network. Network path quality is estimated using a fuzzy system that depends on the packet loss and delay variations as QoS measures. The system was simulated using NS-2 simulator. The simulation results has shown that the proposed system can improve the network throughput by detecting congestion in the network and shifting traffic to another path in the network.

Keywords: MPLS, QoE, QoS.

I. INTRODUCTION

MPLS (RFC 3031) is a packet label switching mechanism, originally proposed to reduce the processing at the network layer. At the edge router of an MPLS network a label is appended on top of the IP datagram header [1]. The intermediate nodes only look at the label to determine the destination of the next hop, no need to access the entire packet to lookup the destination address.

MPLS uses the idea of virtual paths to build the network topology. Virtual paths are established between edge nodes. For each virtual path there is a set of dedicated labels that is assigned to packet following that path. The edge ingress router is responsible for classifying packets and determining the next destination of the packet. Intermediate nodes are no longer responsible for determining the destination of each packet (this is done only by the ingress node) the only action is taken by the intermediate nodes is forwarding to the next hop. These mechanisms simplify the QoS implementation by assigning each path a certain type of service level of packet treatment [1] [2]. MPLS uses a Traffic Engineering (TE RFC 2702) mechanism to avoid congestion [3]. TE means shifting a portion of traffic to another path when a certain path becomes congested [3]. For MPLS, TE is applied to virtual paths, and can be used with QoS mechanisms to improve network performance and network resources utilizations.

QoS can capture the application quality from the network point of view. However, QoS do not reflect the actual application's perceived quality from the user perspective. QoS metrics also fails to capture user's reception for the service quality [4].The International Telecommunications Union (ITU-T) gave a definition to the video perceived quality: *"the overall acceptability of an application or service as perceived subjectively by the end-user"* [5]. Video QoE is depending on many factors: end devices, network states, service infrastructure, user's expectations, and the environment in which the user is communicating [5] [6].

The main goals of this paper is to design a mechanism that enables MPLS load balancing to take into the account the user QoE in distributing the traffic among network paths. The modification introduced in MPLS includes a video quality estimation mechanism. The video QoE estimation system is based on fuzzy-QoE estimation system proposed by [7]. The fuzzy QoE estimation system is based on results obtained from a subjective test experiment, and the experiment results is modeled using a fuzzy system accepts network QoS as an input and output the Mean Opinion Score (MOS). The MOS is the metric that express the user's quality [8]. The fuzzy QoE estimation system proposed in this paper differs from one proposed in [7], that it takes into the account the performance of MPEG-2 video codec, where this paper also presents a subjective performance evaluation for MPEG-2 video codec. The results of MPEG-2 evaluation were modeled by using fuzzy system.

II. MPLS LOAD BALANCE

The design of the enhancements is based on Elwalid et al. [9] and Krishnadas and Roy [10] proposals. The implementation is performed is based on the following assumptions:

1. The existence of multi paths to the destination in the core network.
2. Incoming traffic are distributed based on the estimated MOS for each LSP, where it assigned to the LSP with highest MOS.
3. MOS state is estimated periodically to keep track of MOS state for each path. Traffic is shifted to another path if the MOS of the current path is low.
4. MOS Estimation occurs between the ingress node and the egress node path for each LSP and only in one direction.
5. The MOS calculation is performed at the egress node and the results are sent to the ingress node.
6. Since the packet loss and packet delay variation are QoS parameters that can affect directly video streams, the estimation mechanism is designed to estimate these two metrics.

A. *Enhancements Functional Model*

The enhancements are implemented as an agent protocol in MPLS control plane, the arrangement is shown in Figure 1. The estimator agent consists of: fuzzy function and packet loss and packet delay variation estimation mechanism. Figure 2 shows the functional model the estimator agent. The dotted arrows in Figure 2 represent feedback information for each LSP. The feedback information is passed to the fuzzy estimation function. The fuzzy estimation function returns the MOS value of the estimated LSP to the MPLS data plane.

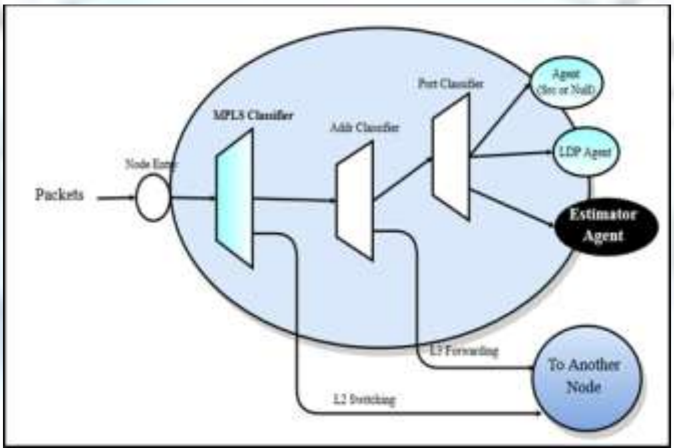

Figure 1: Enhancement placement in the control plane

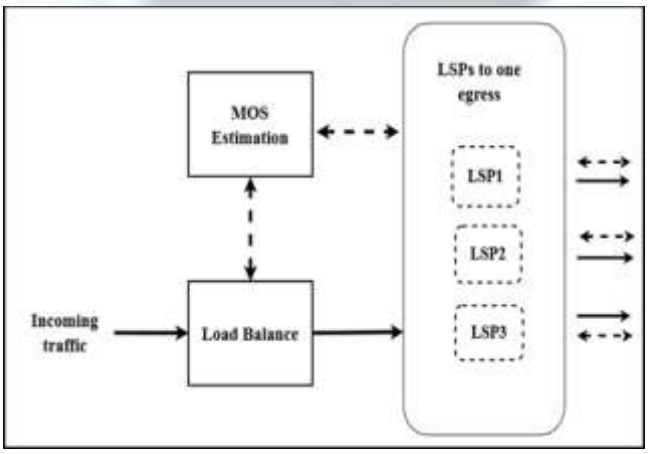

Figure 2: Estimator functional model in the ingress LSR.

The load balance model shown in Figure 2 is where the LSP assignment occurs. The LSP assignment is performed in a dynamic way according to the MOS value returned from the feedback shown in Figure 2. Traffic flow is assigned to the LSP with the highest MOS.

B. *MOS Estimation*

The estimation model is responsible for MOS estimation. The existing methods for QoE estimation are either subjective or objective, and depending on the approach the source signal may be required for estimating the video quality. For online estimation of QoE, the estimation process should be performed without requiring the source signal, and must be placed at the core network. In order to meet this requirement to estimate the MOS objectively based on a subjective test results approach is used. The approach was originally proposed by Pokhrel et al [7]. The MPEG-2 codec was evaluated subjectively by asking the user for their experience. The details for the subjective test results are presented in the next section.

C. *LSP Assignment*

When the estimation process is finished the MOS value for each LSP is stored in a table shown in figure 3. This is used to bind the MOS values to LSPs and bind the FEC to LSPID-MOS pairs. The table has four entries; the index field for search operations in the table, the FEC field used to hold the flow FEC which is assigned to a particular LSP, the LSPID for holding the LSP id, and finally the MOS field which holds the MOS state value. The table is used by the fuzzy model to bind MOS to LSPs, and used by the load balance model to bind the FEC to LSPID-MOS pair. When the ingress LSR tries to assign flow to a particular LSP the MOS-LSP table is searched for LSP with the highest MOS.

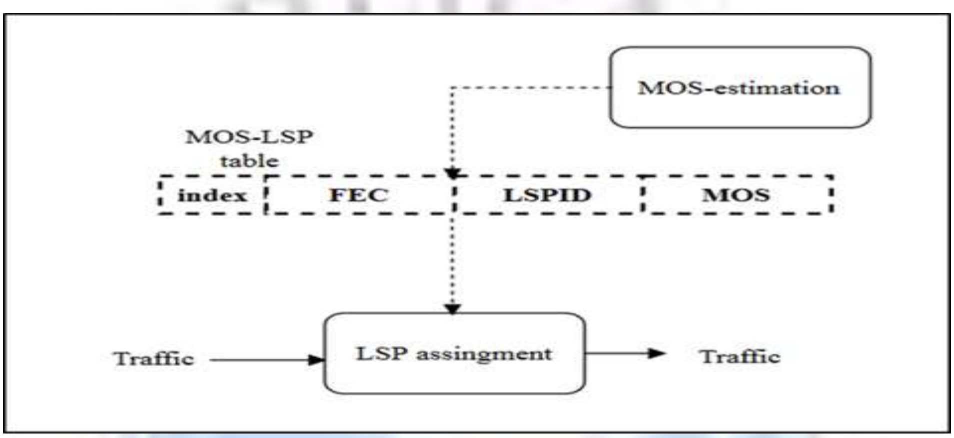

Figure 3: Traffic assignment to the LSP

III. MPEG-2 SUBJECTIVE EVALUATION

The purpose of the subjective experiment is to obtain realistic performance results of MPEG-2 video codec. The experiment was performed in Alnahrain University. The participants were fourth grade students from network engineering department, where they possess knowledge of video processing.

A. *Subjective Experimnet Tools and Cnfigurations*

Studying video applications requires a video application for generating video streams, displaying and storing video files. It is also required a WAN network for introducing network perturbations to video streams. The following tools are used for producing the fore mentioned technology, which are used in this experiment:

1. Video LAN player (VLC): which is configured to be MPEG-2 codec and it is used to act as a server that stream videos to a client. It is also used to store MPEG-2 video files.
2. Network Emulator (NetEm): This is gateway which can introduce network impairments to the streamed video data.

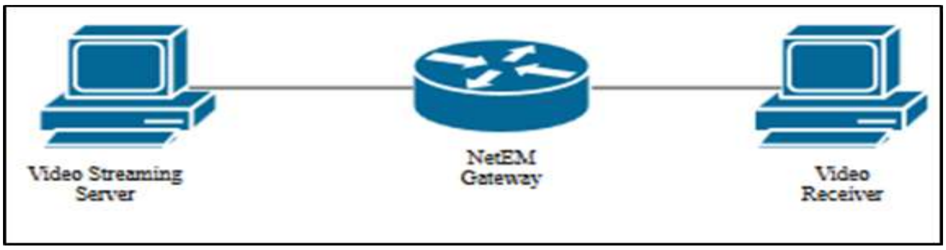

Figure 4: Streaming topology.

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Using network emulator and VLC player the network topology shown in figure 4 is configured. The VLC player is configured to stream video packet to the client through the NeEm gateway. The video stream is played and stored at the client side. The server device is a laptop with windows 7 environment. In the same device a virtual machine is installed (Ubunto 12.3). All packets travelled from the server to the client are passed through the virtual machine. The client device is another laptop connected to the server with a wireless connection. All streamed video files are stored as MPEG-2 version type of files.

The network emulator (virtual machine) is configured to introduce three network impairments: delay, delay variation and packet loss. During the experiment it was noticed that the delay impairment does not affect the quality of the video, while the delay variation and the packet loss ratio can significantly affect the video quality. As a result the network packet loss and delay variation are impairments and their values were chosen. The settings for packet loss and packet delay variations chosen for this experiment were:

1. for packet loss [{0.5,1,2.5,5,7.5,10,12.5,15,17.5,20}%].
2. for packet delay variations [100±{50,100,150,200,250,300,350,400,450}ms].

B. *Video Test samples and Viewing Condition*

Twenty five viewers are participated in the experiment test. They are non-experienced assessors in video picture quality with age varying between 22 and 25 years old. All users viewed the sixty video sequences divided into six groups. 15 of participants were students from the University of Alnahrain Information Engineering college, which they have a prior knowledge about video processing. The test sequence was viewed in a low light classroom on a data show with a high definition resolution. Other users were engineers from other college. The participants are given a feedback form shown in appendix C, and asked to fill the form with information regarding their names, gender, and occupation and there opinion on the depicted test sequence. The viewers should watch and assess in total sixty video samples. The video sequence was given random names to hide the perturbation effects. The test took around 35 to 40 minute approximately. The test starts by viewing the original video sample with no perturbations followed by the test samples. After watching each test sample, the users will rate it on five grade scale shown in the table 3-1.

TABLE I. **: MOS GRADING SCALE**

MOS	Quality	Perception
5	Excellent	Imperceptible
4	Good	Perceptible
3	Fair	Slightly Annoying
2	Poor	Annoying
1	Bad	Very annoying

C. *Subjective Test Results*

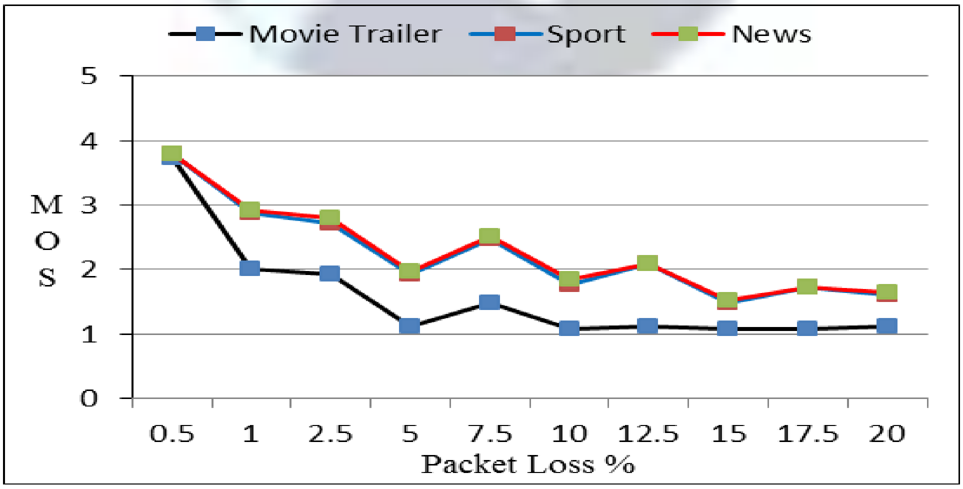

Figure 5: Packet loss Vs. MOS

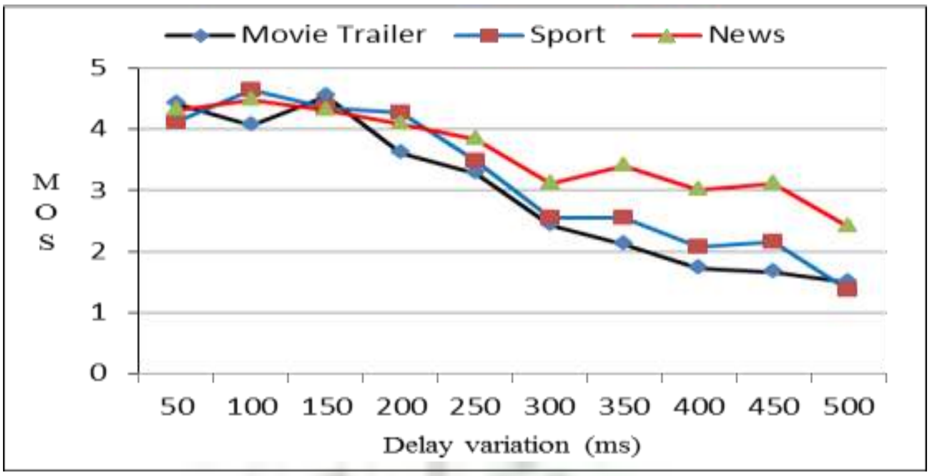

Figure 6: Packet delay variations Vs. MOS

Figure 5 shows the averaged score ratings for packet loss effect on video quality. The figure shows for 0.5 percent loss good quality were scored by the viewers. For 1 and 2.5 loss percent the viewers the average score was on a good quality level, while the trailer movie video is poor quality. The rest of packet loss values the quality is poor on a low level.

Figure 6 shows the average quality ratings for all users for all videos affected by delay variations. For delay variations between 50ms and 200ms the video quality was rated as excellent quality for all videos. The user's ratings drop good quality to a good quality for delay variations between 200ms and 300ms. For the news video the quality is rated with a lower good quality while the movie trailer and sport video are given poor quality, this due to the fact the video content can affect the video quality.

IV. DESIGN OF FUZZY ESTIMATOR

The purpose is to design a system that is able to produce an output similar to the output that was obtained from the subjective test experiment. The reason for choosing a fuzzy system to estimate the user's QoE is Fuzzy logic system decisions can mimic the logic of human thought, which is less rigid than the calculations that computers would perform. The system is designed to have two input variables: delay variations and packet loss, and is given one output variable the MOS. Figure 6 shows the designed fuzzy system.

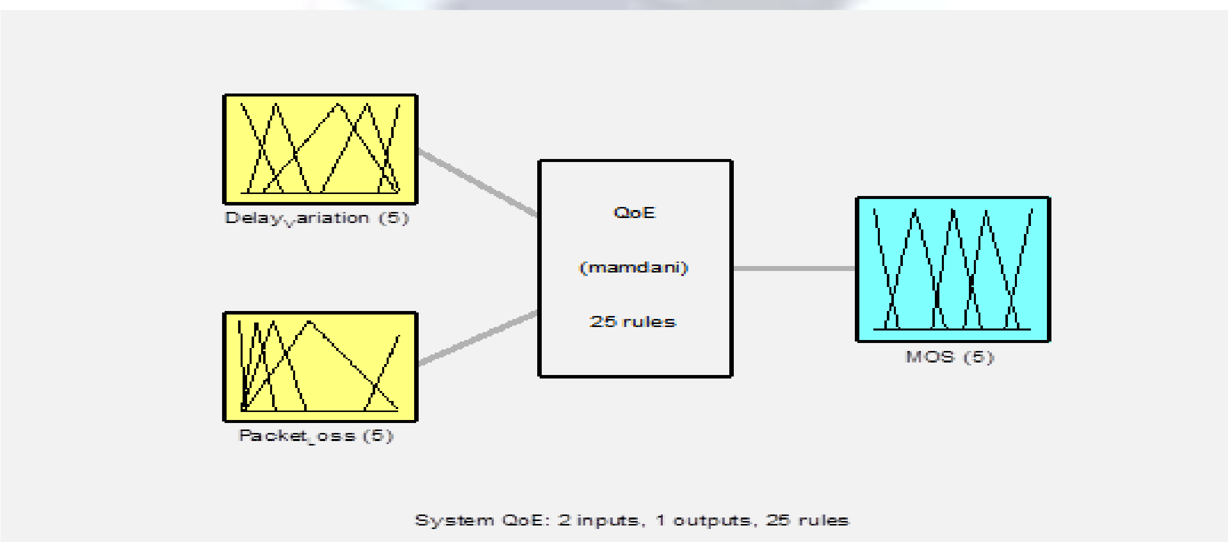

Figure 6: Fuzzy MOS estimator system

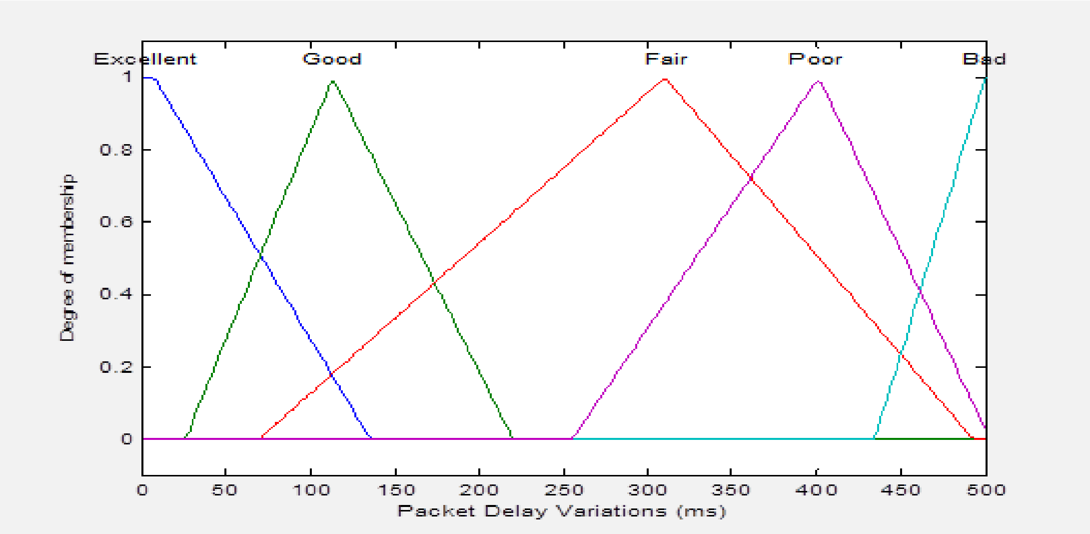

Figure 7: Packet delay variation member ship function

The defined input variables consist of five membership functions. The linguistic terms are taken from the ITU-T five grading scale. The shape of the defined membership functions is set to a triangular type and it was adjusted (based on the probability distribution of user's ratings) to produce output similar to the one obtained from the subjective test. One output variable is defined as the MOS, and it was represented by the five linguistic terms for the MOS scale. The output membership functions are shaped like triangular type. Figure 7, Figure 8 and Figure 9 shows the input and output membership functions. The inputs and output terms combination has resulted a total of 25 fuzzy inference rules.

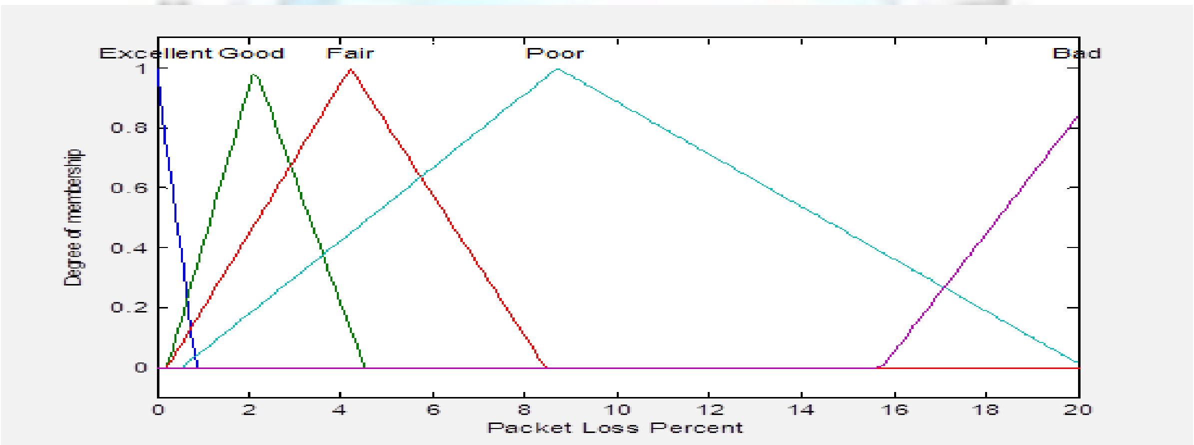

Figure 8: Packet loss member ship function

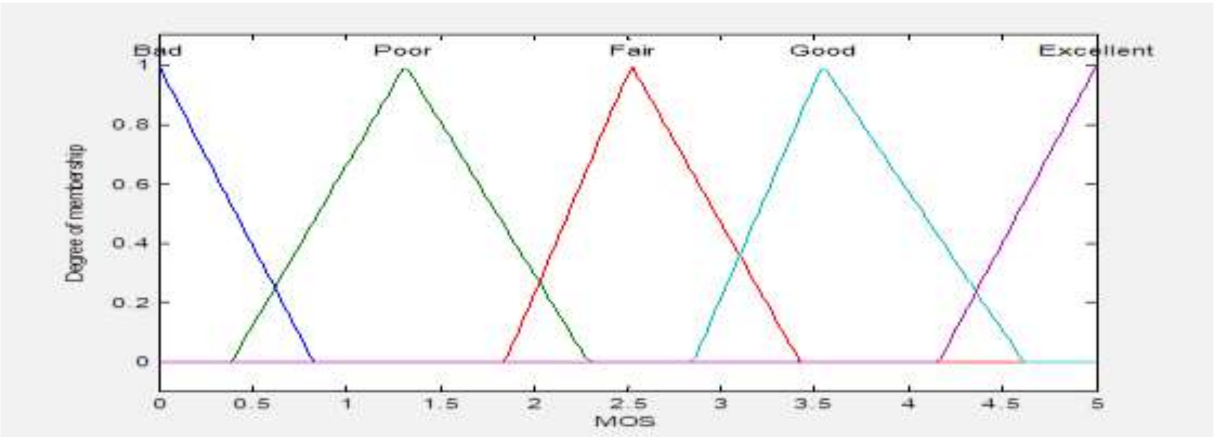

Figure 9: Output membership function

The designed fuzzy system performance is compared against the results of the subjective test experiment by applying the same packet losses and delay variations values to the system. The test results are plotted against the subjective test results in figure 10 and figure 11. The test results have showed the designed fuzzy system can produce an MOS that is close to the average results for the subjective test experiment. It is assumed that MOS values below 2.5 are considered bad quality for the video; this is why the fuzzy MOS lines tend to be more inaccurate with the subjective results. Otherwise the results are close to the original ones that were obtained from the subjective experiment tests.

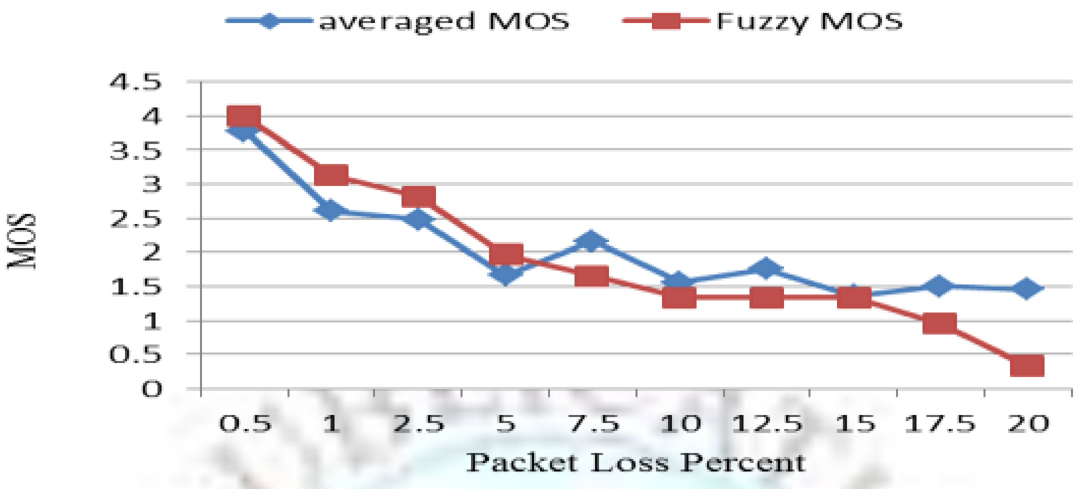

Figure 10: fuzzy MOS VS subjective MOS, packet loss test

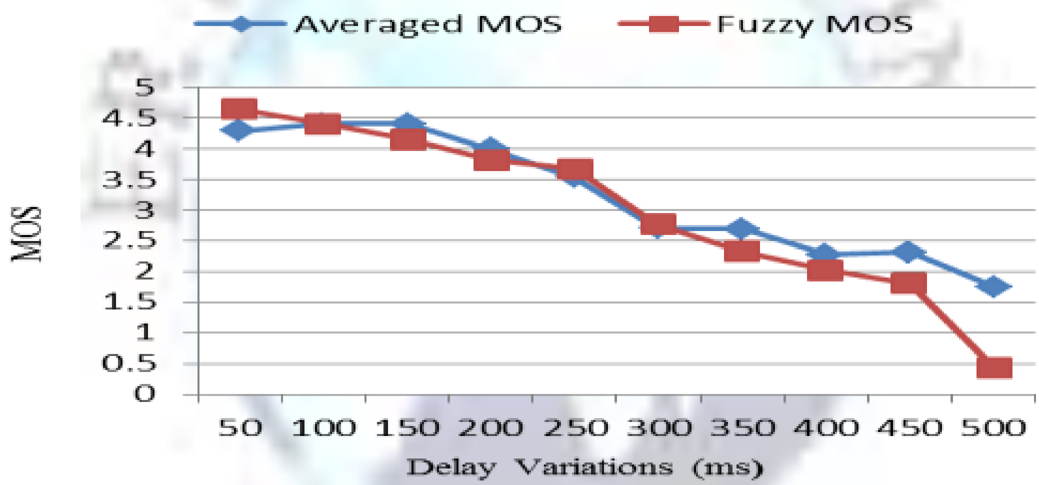

Figure 11: fuzzy MOS VS subjective MOS; delay variation test

V. SIMULATION SCENARIO USING NS-2 SIMULATOR

This section gives the details of simulation scenario for MPLS with the estimator agent. The comparison is based on packet loss ratio and end to end packet delay.

A. *Simulation Topology and settings*

The simulation topology is shown in figure 12. The general components in the topology are: end devices, access routers, and core network. In Figure 3-6 there are total of 15 nodes. Nodes 0-1-2-3-4 are end devices which are configured act as traffic sources; nodes 5-12-13-14 is are destination stations. Nodes 6-7-8-9-10 are routers that form the core network. The links attributes that is used to connect the end nodes to the access routers are configured with a rate of 100Mbytes/sec and a delay of 10ms delay, while links that connects the core routers has attributes of 44.73Mbytes/sec and 30ms delay. The queue size attribute for each link is configured to have capacity of 1000 packet for each link in all scenarios. For video applications simulation, CBR/UDP (Constant Bit Rate) application source traffic is used. Three traffic sources were configured to send traffic to destination at a rate of 11Mbytes/sec, and one high rate traffic source of 25Mbytes/sec. The simulation is configured to run for 60 seconds. Source-1 starts sending after passing 9 seconds from simulation period, source 2 will start after 10 seconds after source-1, source-3 will start after 10 seconds from source-2 and source-4 starts after 10 seconds from source-3.

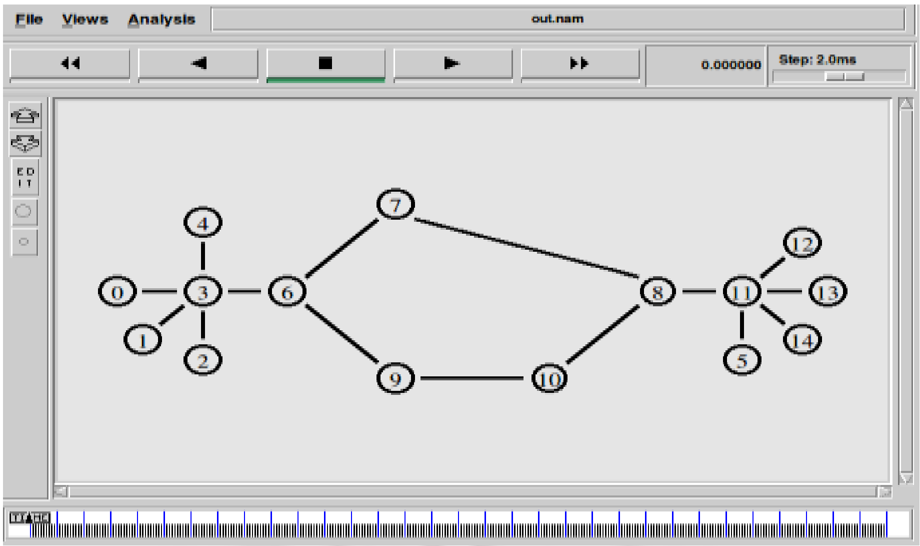

Figure 12: NS-2 Simulation topology.

In MPLS-MOS scenario, the estimator agent is configured to perform the MOS estimation sessions every 10 seconds during simulation time. Traffic is assigned to LSPs based on the MOS value of the LSP, where traffic is admitted to the LSP with the highest MOS. After assigning all four traffic flows to their LSP, the estimator agent will check the MOS state of the LSP, if other LSP has a better MOS state than the current LSP the traffic is shifted to that LSP.

VI. Simulation Results Analysis

This section presents the analysis results of simulation that was performed using NS-2 simulator. First an analysis for the protocol is presented using the Network Animation facility in NS-2 (NAM), which is a good tool to study the protocol behavior. Next, the mechanism is analyzed with QoS measures namely: throughput and packet end-to-end delay.

A. *Nam Trace Analysis for MOS-MPLS scenario and MOS states*

The NAM tool is useful for studying and verifying protocols behavior. Figure 13 shows a snapshot from the MOS-MPLS simulation scenario which is taken after passing 29 seconds from the simulation time. Data traffic is assigned with different colors for each source: source-0 has red color, source-1 traffic is colored with yellow and source-2 traffic is colored with blue color. Figure 14 shows the traffic distribution on LSPS, where the traffic of source-0 is sent on the lower path, and source-1, and source-2 traffic is sent to the upper path.

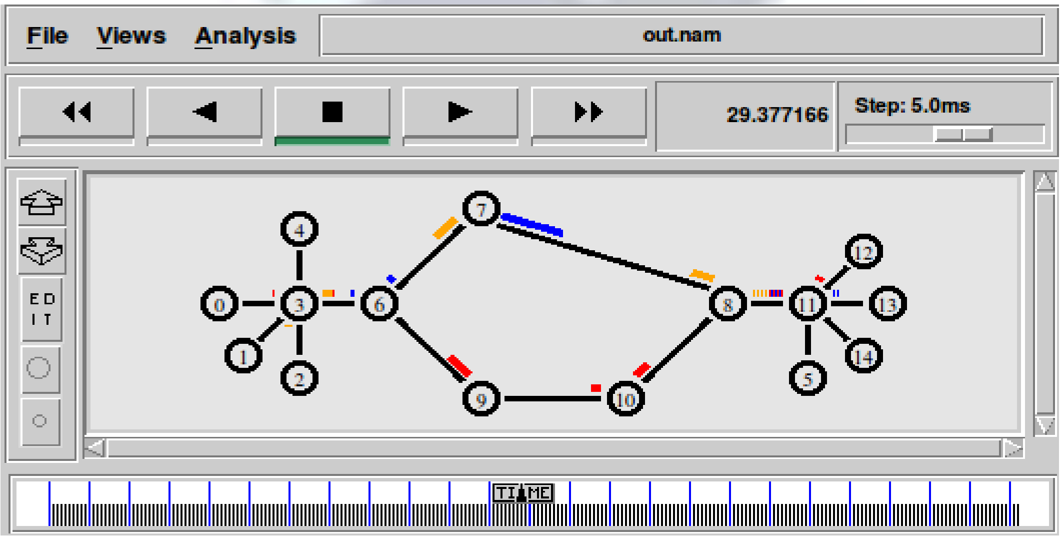

Figure 13: network animation snapshot-1.

Figure 14 shows another snapshot where source-4 (traffic is colored with a purple color) which is a high data rate source has started to transmit traffic into the network. Source-4 traffic has congested the upper path of the network.

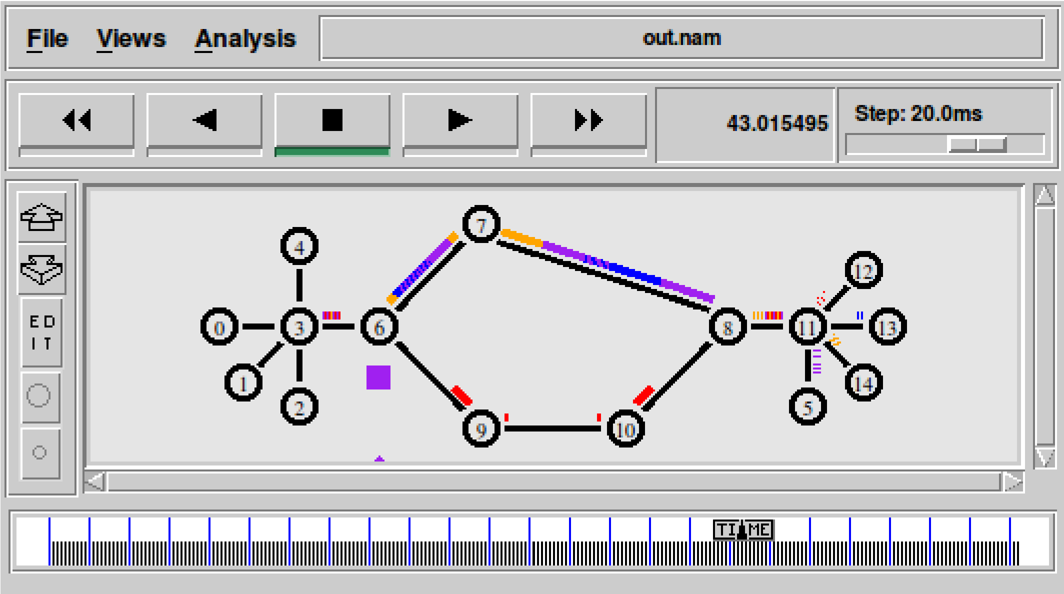

Figure 14: network animation snapshot-2

The congestion causes degradation in video quality. Figure 15 shows a snap shot after passing few seconds from the simulation time; the traffic is redistributed in the network. When the fuzzy estimator indicate a low MOS value in the upper path, the traffic of sources 0, 1, 2 are shifted to the lower path which has a higher MOS than the upper path, and thus a load balancing which is based on the MOS values is occurred in this scenario case study.

Table 2 shows the MOS states that are estimated by the fuzzy estimator. The first column shows the time which the MOS state is collected, the second column show the MOS value estimated for the upper path in the network, and last column is the estimated MOS for the lower path of the network.

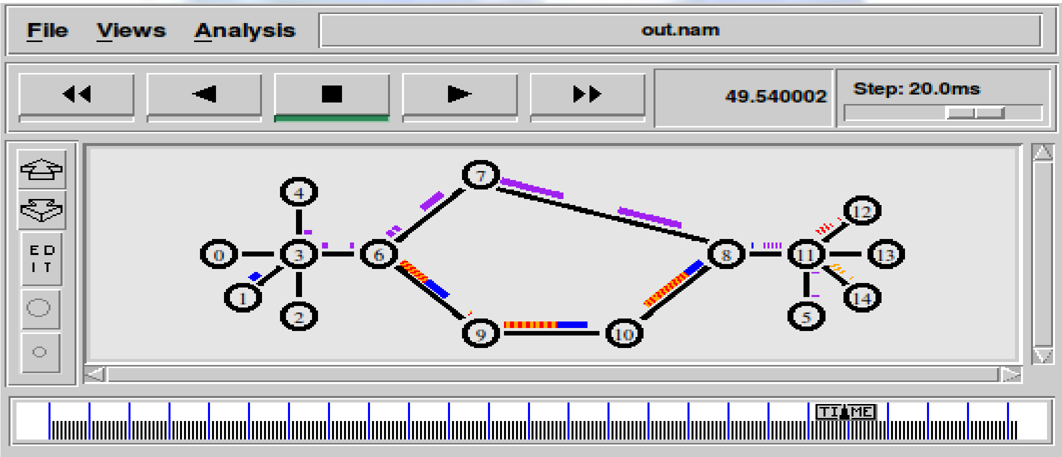

Figure 15: network animation snapshot-3

The first row is showing the initial MOS values for each path, both LSPs are assigned with the same initial value. The estimator then assigned source-0 flow to the lower path (see Figure 13). The second row showing the estimated MOS of the LSP-1 is higher than the MOS of LSP-2, so any traffic flow admitted to the network is assigned to LSP-1(see Figure 14). The same case in row 3 and 4 where LSP-1 has a higher MOS state than LSP-2, thus all traffic are assigned to LSP-1. The fourth row shows that the MOS state of LSP-1 is degraded; this indicates that there is congestion on the LSP1. The fifth column shows that the MOS state of LSP-1 has higher MOS value than LSP-2, this is because the estimator agent has shifted portion of the traffic to other LSP.

TABLE II. : MOS STATES IN MOS-MPLS SCENARIO

Time (sec)	LSP1-MOS state	LSP2-MOS state
6	4.52	4.52
19.4	4.62	4.52
28.9	4.61	4.52
39	4.61	4.52
47.5	0.45	4.52
59	4.61	4.42

B. *Throughput analysis*

The throughput is measured by counting the received bytes at the receiving nodes. Figure 16 shows the throughput performance for MOS-MPLS scenario. The figure shows that source-1, source-2 and source-3 have a throughput value of 11±2 MBits/sec for all simulation time. Source-4 starts after passing 39 seconds from the simulation time, which is started with a throughput value of 22.5±2 MBits/sec during the period 39-49 seconds from simulation time. After 50 seconds passed from the simulation time the throughput of source-4 is increased to values of 25±1 MBits/sec.

C. *End-to-End Delay performance*

The performance of end to end delay for all scenarios is presented in figure 17, respectively. It is clear from the figures that the MOS-MPLS scenario can deal with the congestion situations. Figure 4 26 shows that Source-1 traffic flow has delay of 130ms for all simulation time; this is because source-1 traffic flow is sent on the lower path of the network. Traffic flow from source 2 and 3 starts with fixed delay value of 100ms for period 0-39 seconds from the simulation time. After 40 seconds of the simulation time source-4 starts sending traffic on the network causing a rise in the delay values of source-2 and 3 to 270ms. After the period 50 seconds of the simulation time, source 2 and 3 traffic delay performance is fixed at 130ms, and source-4 traffic delay performance is fixed at 100ms.

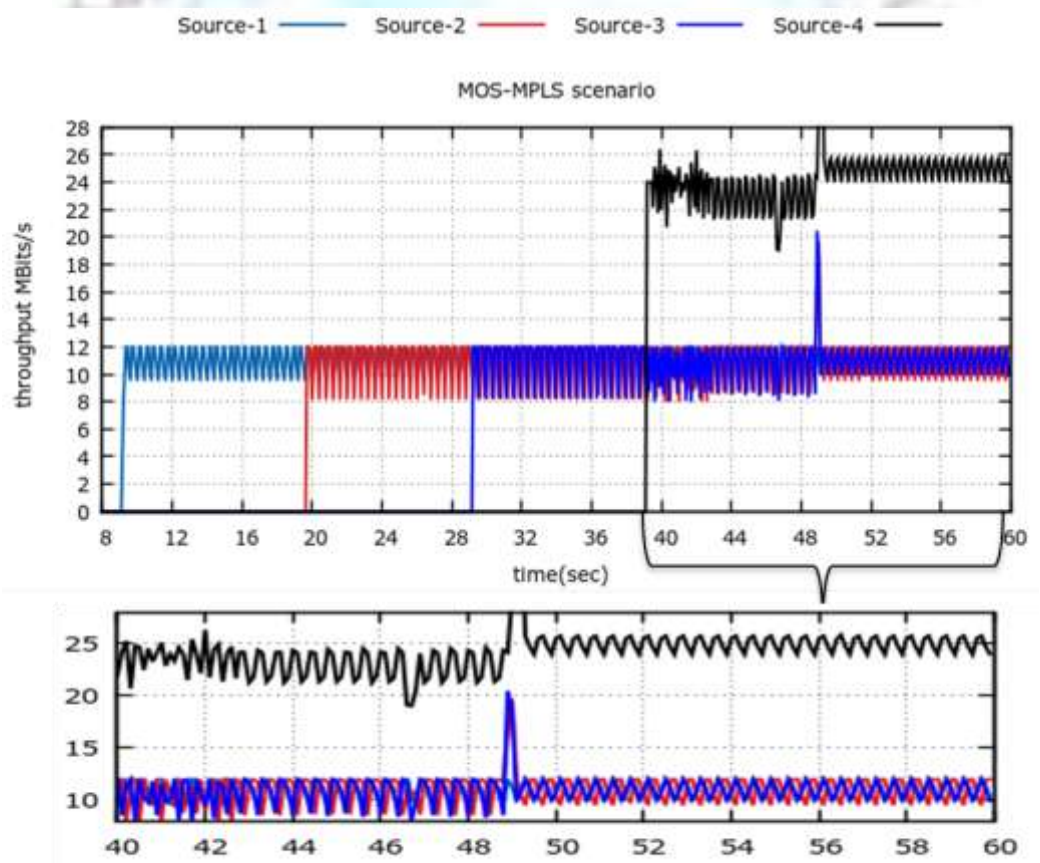

Figure 16: Throughput performance

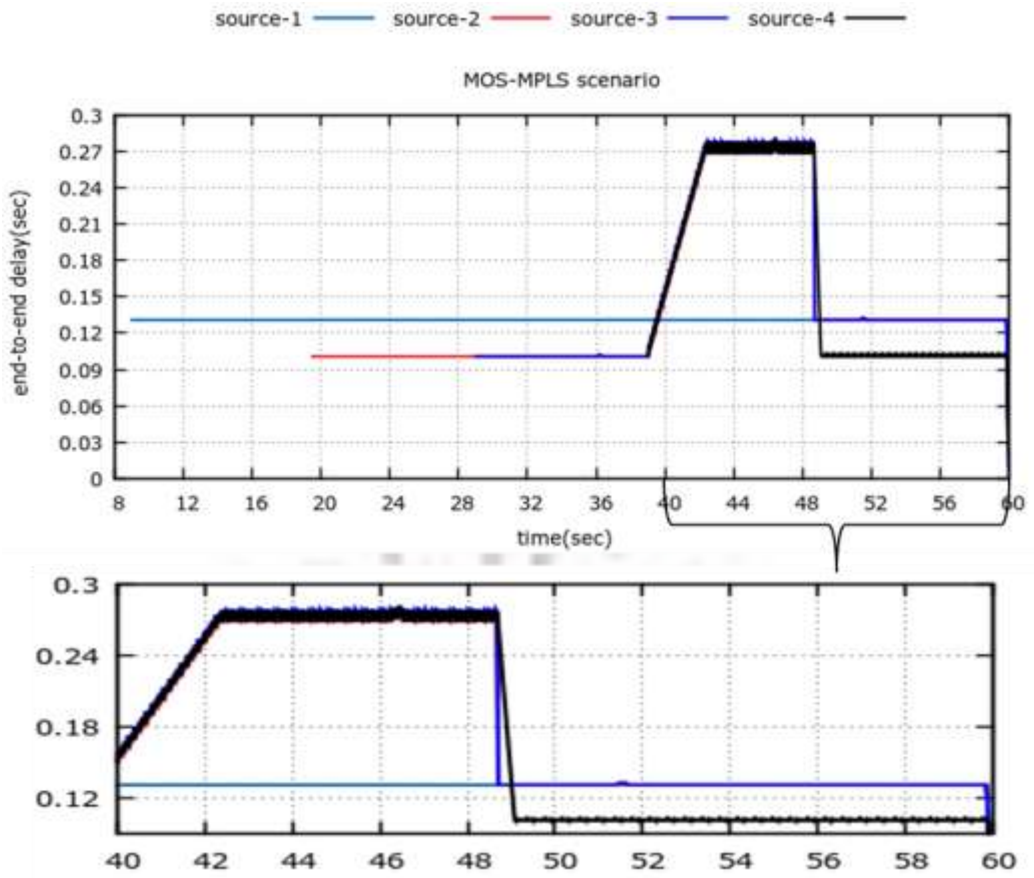

Figure 17: Delay performance

VII. CONCLUSIONS

The simulation analysis has shown that the proposed enhancements for MPLS add the congestion control mechanism in the MPLS network. Using the fuzzy-MOS estimation technique enabled the core network to detect congestion without requiring a feedback from the application. This can improve the performance of video application by utilizing network resources instead of changing the data rate of video applications as in the classic techniques of congestion control, also this congestion control technique is designed based on the application requirements.

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