Mitigating Network Congestion through MPLS-TE Based Load Balancing Using Alternate Optimal Path

Saeed A.Magsi, Riaz Ul Amin, Abdul S. Malik, Bakhtiar K. Kasi and Mumraiz K.Kasi

***Abstract* – In this paper the alternate optimal path AOP is presented to mitigate network congestion particularly in MPLS networks. One way to measure network congestion is to measuring parameters such as end to end delay and packet loss. These parameters show direct proportion to the network congestion. On the other hand, larger values of these parameters show poor performance of the network. It is therefore important to address the issue of network congestion. There are several algorithms and techniques used for congestion control and load balancing. However, these algorithms fail to provide an optimal and reliable congestion control mechanism that not only reduce the congestion but also provide the load balancing so as to increase the optimal usage of network.**

***Index Terms* – Multiprotocol label switching (MPLS), Alternate Optimal Path (AOP), Congestion Control, Load Balancing, optimal network usage.**

I. INTRODUCTION

Growth of bandwidth demanding applications limits the network performance in terms of response time. Thus, to improve network performance, it has become essential to implement new methods and techniques such as network traffic engineering to maximize the utilization of resources and to meet QoS requirements of each application.

Traffic Engineering (TE) offers methods and techniques to allow maximum amount of traffic that may pass through a network while ensuring priority of applications linked to available resources.

Conventional networks i.e. IP based networks faces delay because of IP based translations of network. This limitation increases the end to end delay thus, decreases the network performance. Multiprotocol label switching (MPLS) overcomes such issues by attaching a label to the packet for traversing through core network. In telecommunication, MPLS works as core network. The protocol which is defined and standardized by the IETF (Internet Engineering Task Force) is a set of specifications to improve the routing of MPLS. In MPLS, labels are inserted in the headers of packets, transmitted in the network, not the destination address of the network, as can be seen in the Fig 1.

As its name suggests, MPLS is multi-protocol, so it is not restricted to level Layer 2 of the OSI model. It works on all types of protocol for routing packets at layer 3 of the ISO. Often the MPLS label is placed between the header level 2 and level 3 that is why MPLS is level 2.5 [1].

The core concept behind the development of MPLS technology is to combine the forwarding label switching with the network routing layer.

The key concept of label switching is to achieve the address issues and overheads which are linked with Internet protocol over ATM networks [2]. It also enables the transmitting to occur in terabits with the help of working in the core of the system. There are some important MPLS factors which are as under.

Header: The MPLS has fixed length of 32bits (4octets) and is present in between the Data Link Layer (Layer 2 header) and the Network Layer header (IP header).

LSP: Label switching path is the path which is being followed for the flow of packets.

FEC: The Forward Equivalence Class (FEC) symbolize a group of packages, all of which are transmitted by the same transmission criteria

LSR and LER: There are two types of hops which are used in MPLS based network. They are Label Switch routers (LSR) also known as core routers and Label edge routers (LER). The core hops make MPLS network while edge routers are positioned at the edge of MPLS based network. The edge routers are called label edge routers (LER's) and core routers are called Label switch routers (LSR's) [3]. Unlike IP that uses the destination address to route packets, MPLS uses the labels for routing packets on the given paths also known as LSP (Label Switched Paths). Each LSP is made up of interconnections of LSRs from source to a destination, allowing the packets to follow the same route to reach their destination. To determine the LSP, MPLS must borrow a package to find optimized path to its destination. This function is done by using labels. Each identified label on any LSP is associated with package group (or FEC Forwarding Equivalence Class) which is transmitted simultaneously on the MPLS network. Thus, upon receiving a packet by an input edge router LER (Label Edge Router), LER deducts the FEC associated with the package from information contained in its header (such as destination address) and checks its LFIB table labels (Label Forwarding Information Base) to deduct the label and the output interface for routing the packet. Then, the input LER adds the label to the packet (operation push) before sending to the output interface.

When many LSR's use the same LSP for their transmission of data then Congestion occurs. It affects quality of service (Qos) adversely. Congestion is created when many LSRs start to send the packets across the

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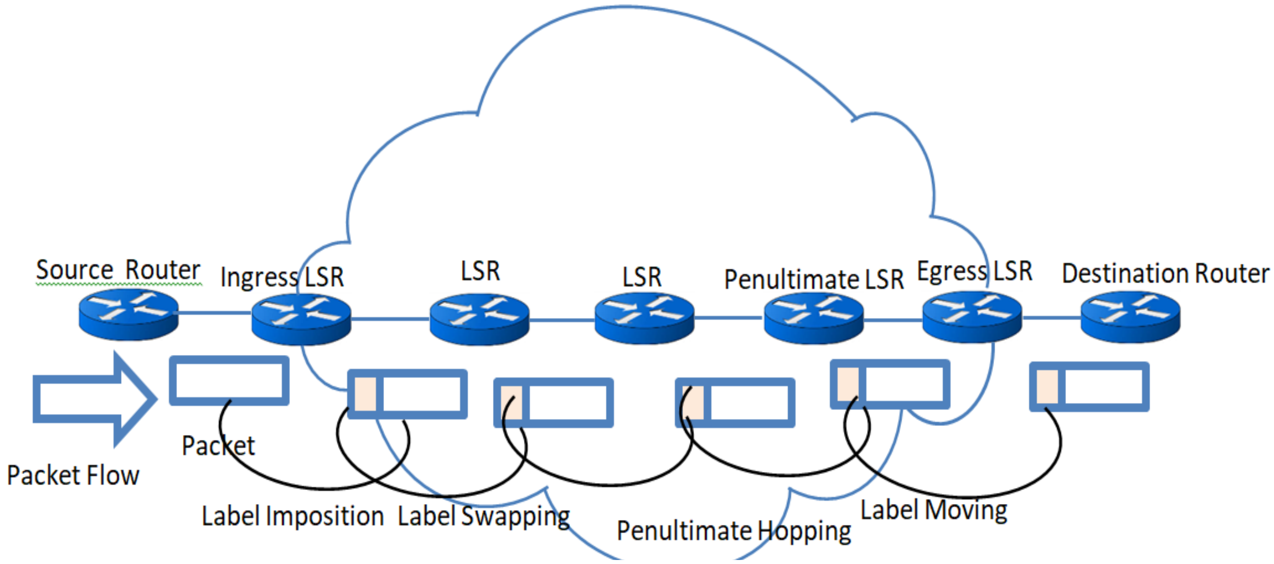

Fig. 1 MPLS Network

common path. This creates the bottleneck and as a result either packets sending speed decrease dramatically or the packet loss.

II. LITERATURE REVIEW

The purpose of Traffic engineering (TE) is to maximize the efficiency of network with the limited resources. The main theme behind Traffic engineering is to extend the limits of network to make it capable of successfully overcoming different situations in the network [4]. Generally, T.E is achieved by equal distribution of data over all the links. By this method no specific link is overloaded. If in a case some data is sent through a link which already is transmitting another data then link congestion may occur [5]. Many models and techniques have been presented to overcome such situation.

In IP, based routing algorithm like Intermediate System-Intermediate System (IS-IS), Routing Information Protocol (RIP) and Open Shortest Path First (OSPF), they are unable to solve network congestion. In these methods link is selected on the criteria of final hop address [6]. Final hop act as destination node. In those mentioned methods selection of path does not consider bandwidth available and traffic characteristics. So, a link selected based on above algorithms can guarantee the least transmission time. The dark aspects of these are that they become completely silent for insuring the minimum packet loss. As the concept of minimum packet loss is totally related to successful transmission of data. Successful transmission is achieved when desired bandwidth is available [7].

To avoid the above problems and to get better results Multi-Protocol Label Switching (MPLS) is developed. It is bendable and elastic technology which can work with many existing technologies [8]. In MPLS explicit routing is much used. The reason for using is that it provides large amount of controlling over traffic. By using explicit routing in MPLS based network, congestion is avoided successfully. *Technically it provides effective load balancing criteria.*

In MPLS load balancing is one of the important parameter which is achieved by successful link utilization. The concept of load balancing is achieved by choosing the alternate path through many factors other than only number of hops [8]. Many models and algorithm are also presented in MPLS based network for the said purpose.

Shortest Path First (SPF) is among the starting algorithm which are presented to avoiding congestion and traffic delay. IN this method, shortest path is selected based on number of hops only. SPF calculates the path based on hops only so it does not check many other parameters such as bandwidth, throughput, and jitter [9].

In Disjoint Path Algorithm (DPA) adaptive adjustment becomes essential. Because of adaptive adjustment one can address the extremely unpredictable characteristics of traffic. In this method modification of network traffic is made by keeping in view flow request [10]. Flow request is generated based on traffic. In DPA alternate path is selected for rerouting the data based on uncommon combinational nodes. Two links will not share two link resources if and only if they have only one common node. DPA take the advantage of it. DPA has also its limitations as it is completely silent for bandwidth and throughput.

Effective Delay-controlled load distribution over multipath networks can be applied to limit the end to end delay. This model minimizes the end to end delay, there by reduces packet delay variation and risk of packet reordering [11]. This model emphasizes on end to end delay while sidelining the throughput and packet loss. Network congestion control with Markovian multipath routing is another model or technique to reduce congestion in IP networks.

This technique works on maximizing the network utilization by minimizing the queuing delays [12]. This model proposes the solution for IP network but it is not guaranteed to work on MPLS network.

In [14] a heuristic BE-schedulers were implemented in

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BE-internet routers and MPLS. This algorithm implemented congestion controlling. To avoid congestion, it used heuristic BE-scheduler. It used queuing method therefore end to end delay increased using this algorithm which was a bottleneck. Fast Acting Traffic Engineering (FATE) mechanism can be applied on preemptive congestion as well as post-emptive congestion. In this technique, the programming is done on the service scheduler. The purpose of it is to check every class based buffer. This process is performed at the rate proportionate to the loading of the said buffer as well as its QoS constraints. To avoid loss due to congestion scheduling template is planned. Its planning is based on the loss probability for every buffer within a LSP. The FATE has very large transmission time [5].

In FATE + technique, the LSR which lies on the congested path take the decision. The corresponding LSR at which congestion occur will start the calculation to find new path by bypassing the congested path. If a condition occurs in which the respective LSR is unable to find the optimized alternate path then LSR send a CIN (Congestion Indication Notification) message to the upcoming LSR. In this method packet loss and transmission delay is much improved as compared to FATE model [13].

In Deviation Path algorithm, there are mainly three steps that the Label switch router has to perform to balance the network traffic.

1. Create Spanning Tree and get Isolines.
2. Monitoring and Flow Selection.
3. Path Searching.

As the LSR has to perform all the three processes to compute the next path which is congestion free therefore the overhead increases in every LSR, which results in greater End to End Delay.

Alternate Optimal Path (AOP)

AOP helps to minimize congestion in such a way that it minimizes the traffic flow in congested nodes. It also helps to provide load balancing w hich helps to improve the network utilization. As the traffic flow decreases the congestion in that node decreases significantly. For congestion control in a network either the sender should stop sending the packets to the receiver or change the path of the flow. Stopping the traffic flow is not a solution therefore changing the path of the flow can be considered to overcome congestion. But for the selection of the network there are some parameters which need to be considered like bandwidth, number of hops, end to end delay, packet losses and throughput. The proposed technique makes decision of alternate path in such a way that it first sees some network parameters like its bandwidth, number of hop counts etc. It makes decision in such a way that if it is the shortest path and it has enough bandwidth, it selects that path which is known as alternate optimal path. In this way, it decides the next path which is not only free for traffic but is efficient.

As shown in Fig 2, this algorithm first selects any traffic flow. It then calculates the parameters like number of hop counts, bandwidth etc. If that path is uncongested and is best path according to its parameters then the traffic is transmitted to that optimal path. If that path also gets congested it again repeats the whole procedure and then diverts the traffic to the next optimal path. The proposed solution is verified by comparing the network with congestion and the network without congestion using AOP. The end to end delay, packet loss and throughput increases significantly with that proposed algorithm. As all the routing is done with Explicit routing using Resource Based Static Balancing Algorithm therefore the overhead in each router decreases significantly resulting in minimum End-To-End Delay and Packet Loss while increasing Throughput. The whole procedure can be understood by a flow diagram in Fig 2.

III. SIMULATION AND RESULTS

Network simulator (version 2) is a discrete event network simulator. It is a power simulator to simulate different network scenarios. It is an important simulator for the researchers to research about the network behaviors.

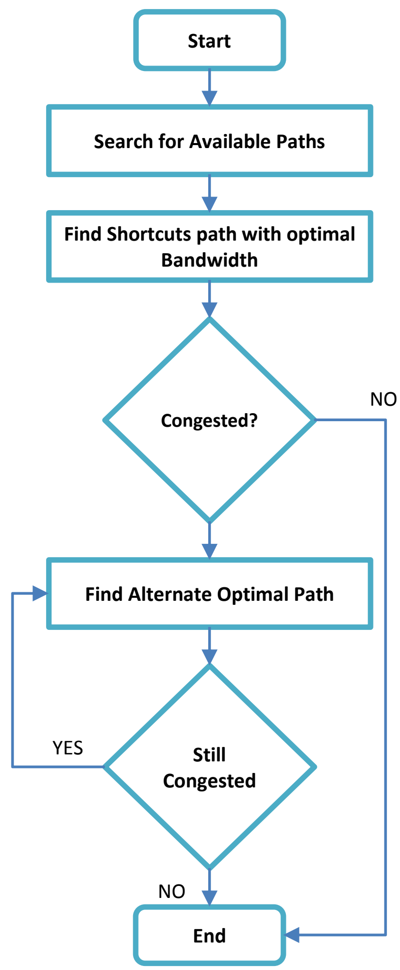

Fig. 2 AOP Flow Chart

NS2 uses C++ and OTCL to simulate different network topologies. It uses two different languages to fulfill the requirement of different tasks. It uses C++ where run time speed is important like manipulation of bytes and packet

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headers. It can simulate bunch of protocols like UDP, TCP, FTP, HTTP and DSR. NS2 can be used to simulate wired and wireless networks. It can be used for performance evaluation for both wired and wireless networks. The simulation results are taken to prove the Alternate optimal path (AOP) efficiency. Three different scenarios are taken. The congestion of those scenarios is minimized using the AOP technique. It can be clearly seen that the End to End Delay, Average Packet loss is considerably minimized while improving the throughput.

Scenario 1: In the network of Fig 3 there are total of 17 nodes. Nodes 0,1,15 and 16 are IP nodes whereas nodes 2 to 14 are MPLS nodes. Node 0 and 1 are designed in such a way that they are the sources while IP node 15 and 16 are the destination nodes. Nodes 0 and 1 start sending packets to node 15 and 16 respectively. If the AOP technique is not applied the congestion occurs which results in maximizing the end to end delay and packet loss and minimizing the throughput which can be seen in the Fig 4, Fig 13 and Fig 14. If the AOP technique is applied, the end to end delay and packet loss decrease while throughput increases. It can be seen in Fig 4, Fig 13 and Fig 14.

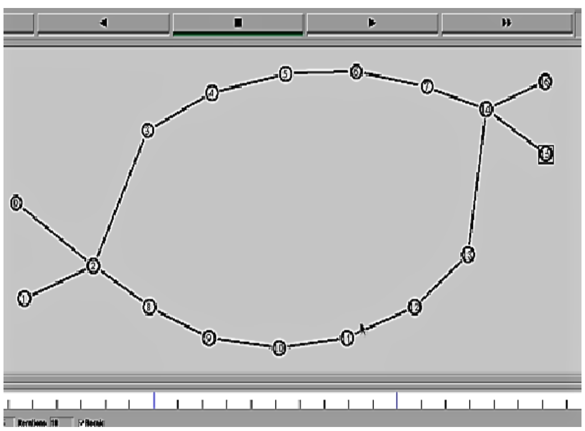

Fig. 3 Scenario 1 configuration

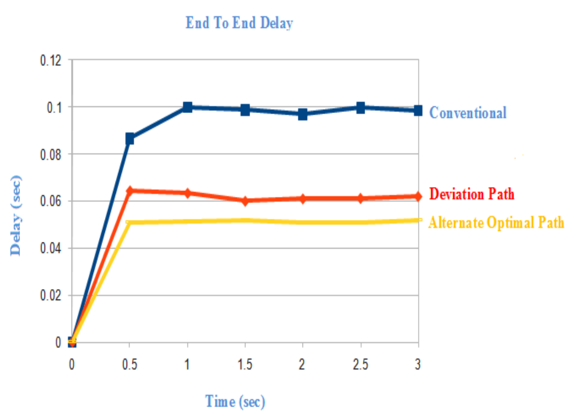

Fig. 4 Scenario 1 End to End Delays

End to End Delay

End to End delay for the topology can be seen from the Fig 4. It shows the End to End delay with congestion and without congestion using AOP. It can be seen in Fig 4 that AOP outclasses all the conventional routing techniques as well as Deviation path technique in minimizing End to End Delays.

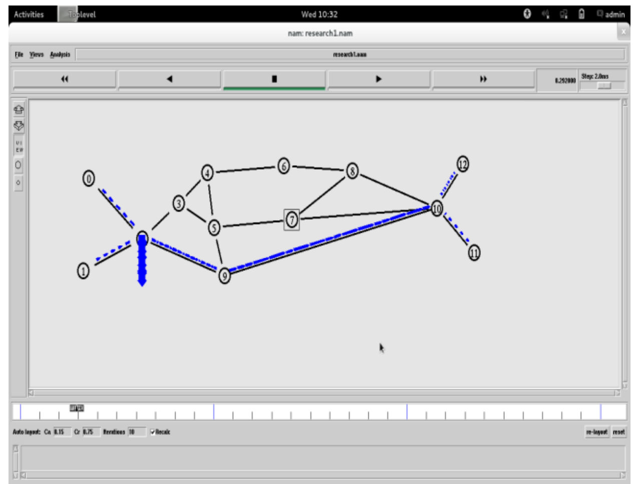

Fig. 5 Scenario 2 configuration

Scenario 2: In the network of Fig 5 there are 13 nodes. Node 0,1,11 and 12 are IP nodes while 2 to 10 nodes are MPLS nodes. Node 0 and 1 are designed to act as a source while 11 and 12 are destination nodes. As can be seen in Fig 5 there are many paths that a packet can to from source to destination. The AOP intelligently route the traffic in such a way that minimum congestion occurs which can be seen in the Fig 6, Fig 13 and Fig 14.

End to End Delay

End to End delay for the network can be seen in Fig 6.

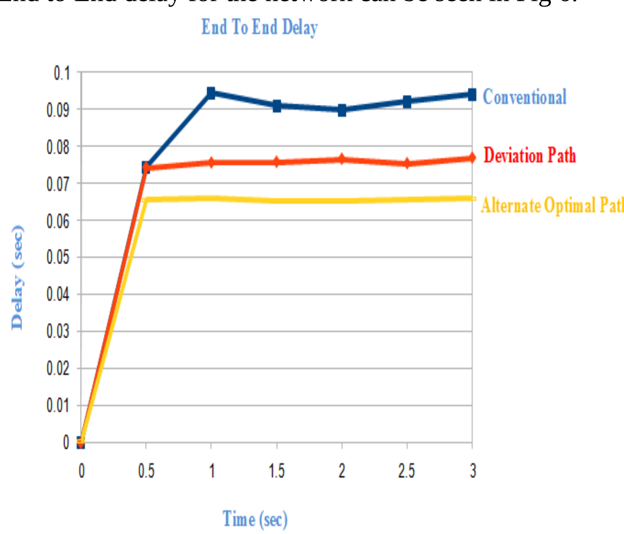

Fig. 6 Scenario 2 End to End Delays

Scenario 3: In the network of Fig 7 the congestion is improved significantly using AOP protocol which can be verified in the Fig 8, Fig 13 and Fig 14 as well.

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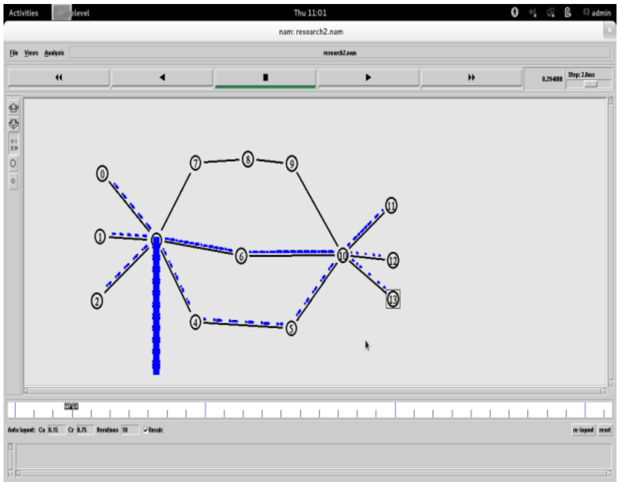

Fig. 7 Scenario 3 configuration

End to End Delay

End to End delay for the network can be seen in Fig 8. There are three different algorithms which are compared. 1. Conventional Routing algorithms like Shortest Path First. 2. Deviation Path Algorithm. 3. Alternate Optimal Path.

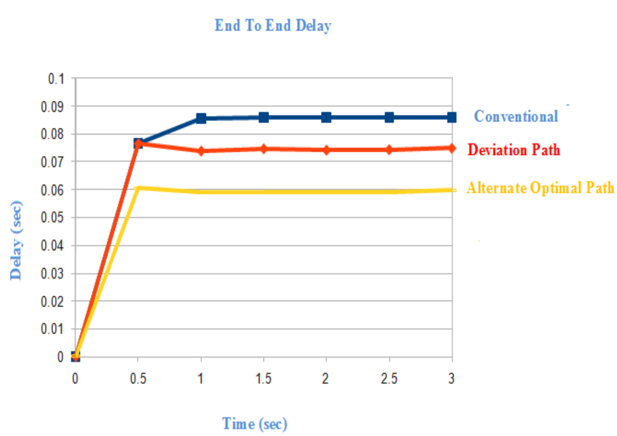

Fig. 8 Scenario 3 End to End Delays

Scenario 4: The network in Fig 9, the congestion is improved significantly using AOP protocol which can be verified in the Fig 10, Fig 13 and Fig 14 as well.

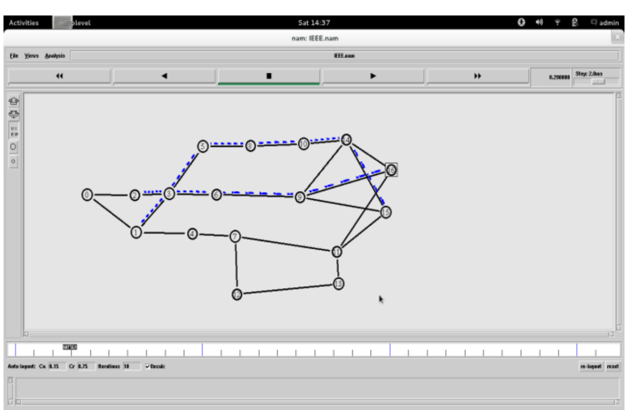

Fig. 9 Scenario 4 configuration

End to End Delay

End to End delay for the network of Fig 9 can be seen in Fig 10.

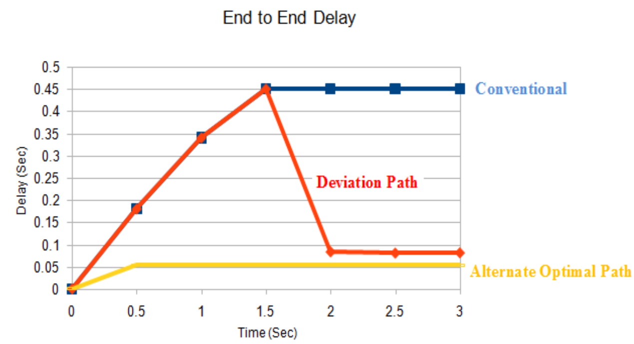

Fig. 10 Scenario 4 End to End Delays

Scenario 5: The scenario 5 is given less nodes deliberately to see the behavior of traffic in lesser nodes. The network in Fig 11 has 9 nodes. The node 0, 1, 7 and 8 are IP nodes while nodes 2 to 6 are MPLS nodes. The congestion is improved significantly using AOP protocol which can be verified in the Fig 12, Fig 13 and Fig 14.

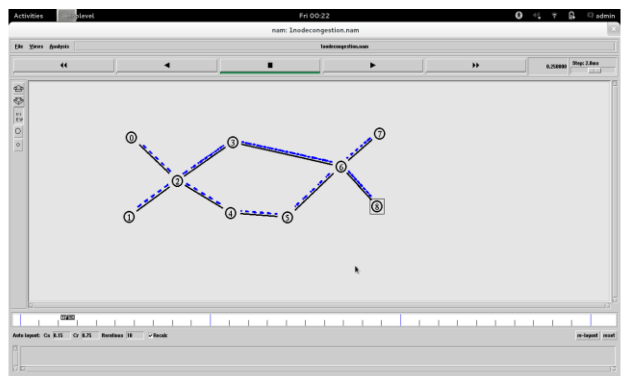

Fig. 11 Scenario 5 configuration

End to End Delay

End to End delay for the network can be seen in Fig 12

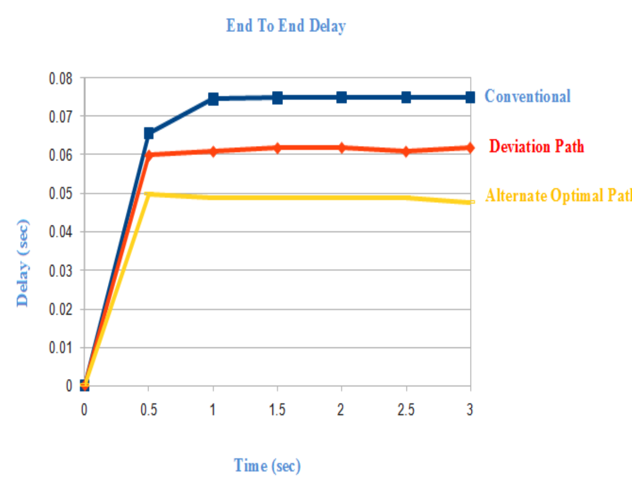

Fig. 12 Scenario 5 End to End Delays

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Average Packet Loss

In Fig 13, it can be seen that the packet loss is significantly reduced to 0 packets loss for all the scenarios by applying AOP protocol. The blue line shows the packet loss for the network with conventional routing protocol while there is no packet loss in both Deviation Path Algorithm and Alternate Optimal Path.

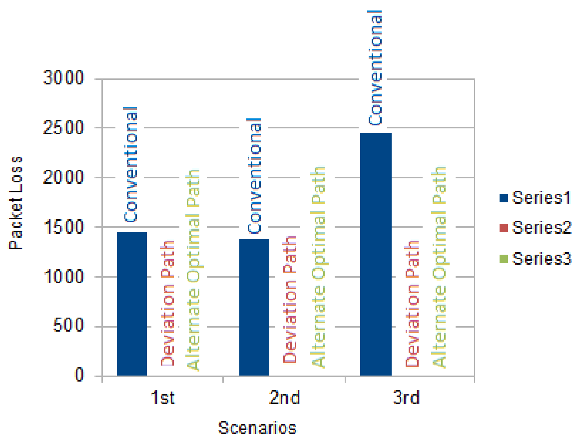

Fig. 13 Average Packet Losses

Throughput

In Fig 14 it can be seen that the throughput increases significantly while the AOP protocol is applied. The blue line shows the results after application of AOP protocol while the red line shows the network with Deviation Path Algorithm applied and the yellow bar showing the conventional routing protocols.

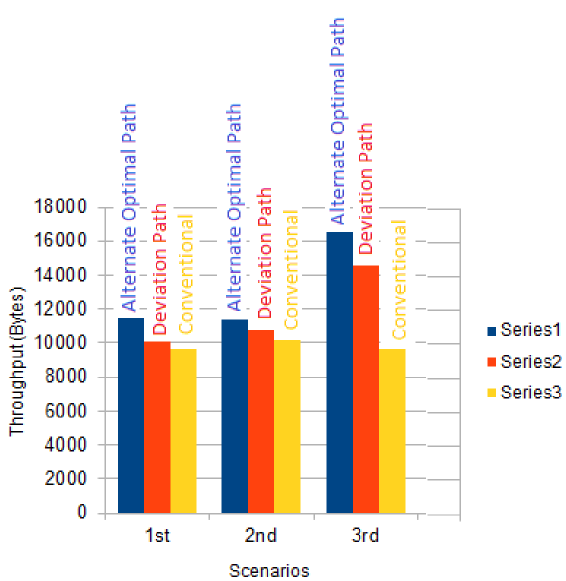

Fig. 14 Throughput

IV. CONCLUSION & FUTURE WORK

This paper concluded the effectiveness of MPLS-TE to improve network performance. This research contributes in mitigating network congestion in a reliable way by proposing an alternate optimal path algorithm. Our algorithm AOP is found to be effective in minimizing congestion on an MPLS network. Furthermore, this algorithm is proved to be effective in an MPLS network in a way that overall end to end delay and packet loss are significantly decreased while the throughput was significantly improved. The results also show that implementation of AOP helps to improve resource utilization in a reliable way and thus improve the overall network performance.

There are several directions where the future work can be extended to improve the way to address the network congestion effectively.

The AOP algorithm is applied to a limited number of nodes. There are limited network topologies which were used to get the results. In the future, the number of nodes as well as topologies can be increased and changed to get the results. Different models can be meshed with AOP to see if it gives better results. Pre-Congestion notification states can be added to the MPLS header to get more efficiency in the AOP protocol. Similarly, Qos safety protocol can be analyzed in the AOP protocol.

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