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PERFORMANCE ANALYSIS OF MPLS AND MPLS-DiffServ FOR REAL-TIME APPLICATIONS

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ABSTRACT

The increasing demand for QoS in real-time applications such as VoIP has led to the development of advanced networking techniques. This study focuses on analyzing the performance of MPLS networks with and without the use of DiffServ. Using OPNET simulation software to evaluate key performance metrics, a network was created and implemented. The metrics include end-to-end delay, packet delay variation, jitter, queuing delay, throughput, and utilization. Results demonstrate that MPLS-DiffServ performs better by minimizing jitter, reducing end-to-end delay, and enhancing throughput. The integration of MPLS as a forwarding mechanism, with DiffServ, as a QoS mechanism, guarantees effective prioritization of voice traffic and better network resource utilization, making it ideal for real-time applications. The study concludes that MPLS-DiffServ achieves superior performance than MPLS-only configurations, providing lower delays and enhanced network reliability. It is, therefore, recommended to adopt MPLS with DiffServ for critical services, leverage MPLS-VPN for improved traffic management, and transition to IPv6 to address future network demands. This study demonstrates the importance of combining MPLS and DiffServ to meet the requirements of modern networking environments.

Keywords: Multiprotocol Label Switching; Quality of Service; Differentiated Services; Voice over IP (VoIP); OPNET Simulation

1.0 INTRODUCTION

With the increasing demand for high-quality network services, particularly in real-time applications like Voice over IP (VoIP) and video conferencing, the need for better network traffic management has grown substantially [1]. Multiprotocol Label Switching (MPLS) is generally regarded as a robust forwarding mechanism which ensures more efficient utilization of network resources by its ability to manage traffic engineering efficiently [2]. However, the integration of MPLS with Differentiated Services (DiffServ) improves its ability to deliver Quality of Service (QoS) [3]through prioritizing critical traffic flows [4].

MPLS is a routing technique designed to enhance the speed and efficiency of data packet transmission across networks [5]. In contrast to traditional internet protocol (IP) routing, MPLS uses labels rather than network addresses to determine the path of data packets, in so doing, reducing the processing time at each router. MPLS is particularly suitable for real-time applications due to its ability to manage traffic effectively, ensuring low latency and reduced jitter. On the other hand, DiffServ is a model used to manage QoS in IP networks. By determining and prioritizing network traffic into different service levels, DiffServ ensures that high-priority applications, such as VoIP and video conferencing, receive the necessary bandwidth and low latency. When integrated with MPLS, DiffServ provides a robust solution for optimizing real-time data transmission through efficient traffic engineering and QoS management [6].

This study focuses on analyzing the performance of MPLS and MPLS-DiffServ in handling voice traffic under different circumstances. The Open Network Engineering Simulator (OPNET) [7]is used for simulating network environments to enable the evaluation of parameters such as end-to-end delay, jitter, packet delay variation, queuing delay, throughput, and utilization [8] The findings of this study will provide valuable insights into how DiffServ integration enhances MPLS performance and provides significant benefits to service providers seeking to provide real-time applications. The results will also highlight the practical implications of using MPLS-DiffServ for improved traffic differentiation and prioritization, particularly in areas having high reliability and low latency.

2.0 METHODOLOGY

To analyse the performance of MPLS and MPLS-DiffServ for real-time applications, this study employed a simulation-based approach using OPNET network simulation tool [8]. The methodology comprised a number of key stages, as explained in the ensuing subsections.

2.1 Network Design

The simulated network includes 8 PCs and 3 Core Router. The PCs are divided into two groups, each connecting to Label Edge Routers (LERs) for ingress and egress. The routers are used as Label Switch Routers (LSRs) to manage packet forwarding across the network. Figure 1 shows the network architecture employed for both MPLS and MPLS-DiffServ scenarios. The network is structured in a way that it simulates both MPLS with DiffServ and MPLS without DiffServ scenarios. LERs identify traffic, while LSRs manage label-based packet forwarding.

1. Simulation Environment Setup

A simulation model was developed to emulate real-real-time network situations. The network topology comprises routers, switches, and end devices, with configurations designed to mimic real-world applications. Traffic sources were configured to generate data packets imitating voice, video, and other latency-sensitive applications.

The simulation parameters were configured identically for both scenarios to ensure fair comparison, as summarized in Table 1.

Table 1: Simulation Parameters for MPLS and MPLS-DiffServ

Metric	**MPLS with DiffServ**	**MPLS configuration**
Delay	Low	High
Jitter	Low	High
Packet Variation	Better	Bad
End to end delay	Low	High
Queuing delay	Better	Bad
Throughput	High	Low
Utilization	Better	Bad

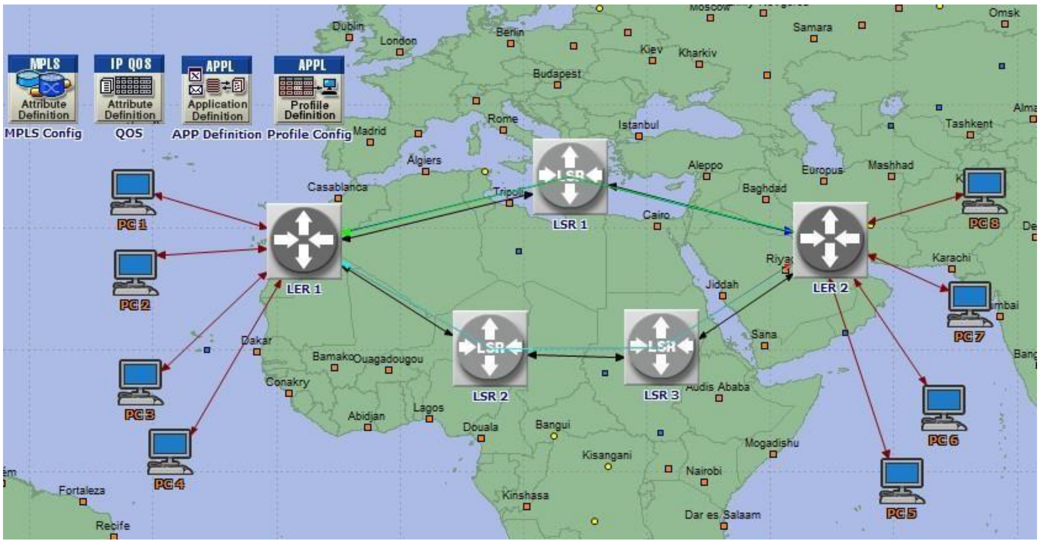

Figure 1: Network Design with MPLS and MPLS-DiffServ

2.2 Traffic Flow and Mapping

The traffic in the network is categorized and prioritized based on Differentiated Services Code Point (DSCP) settings. In the MPLS-DiffServ configuration, the Traffic enters the network via the LER. The packets are then classified into specific queues based on their priority (e.g., Expedited Forwarding (EF) for voice traffic). Then FEC mappings are applied to establish LSPs. Figure 2 shows the mapping of FEC to LSP.

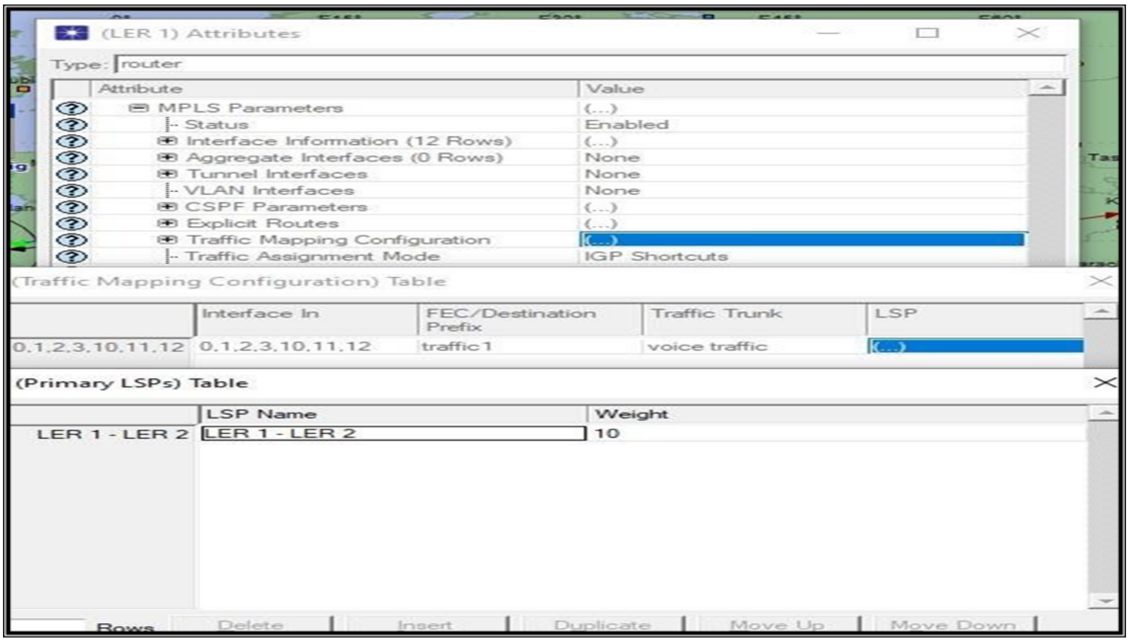

Figure 2: Mapping of FEC to LSP

FEC mapping ensures that traffic flows are connected to specific LSPs to enhance efficiency and prioritization in the MPLS-DiffServ networks.

2.3 Implementing MPLS and MPLS-DiffServ

Two setups were implemented and analyzed in this study. Figure 3 depicts the configuration menu for MPLS with DiffServ.

1. MPLS Configuration: The MPLS framework was implemented to route data packets using labels. The forwarding tables were configured to ensure efficient packet delivery. In this situation, the traffic was assigned a standard Type of Service (ToS) configuration, without prioritization.
2. MPLS-DiffServ Integration: The DiffServ model was applied over the MPLS setup. Traffic was classified into different QoS classes, and priority was assigned based on application requirements. In this setup, the DSCP value for voice traffic is set to Expedited Forwarding (EF) with a decimal value of 184, ensuring prioritized delivery. And the applications include voice, video, and database services.

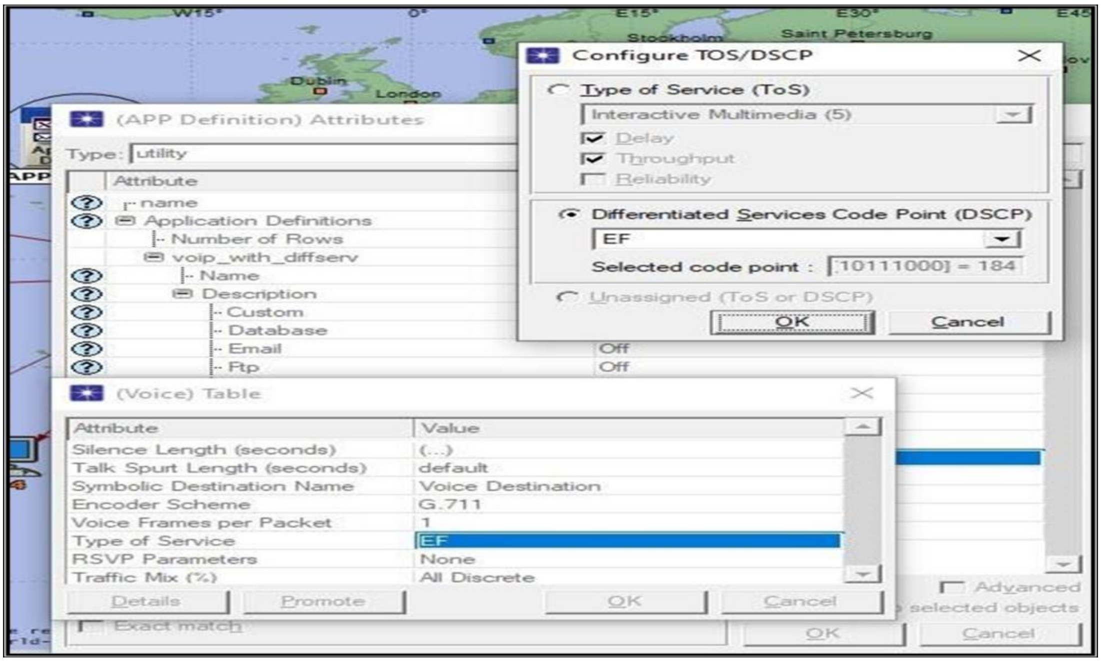

Figure 3: MPLS with DiffServ Application Configuration

The DiffServ are enabled in the MPLS network by configuring DSCP values to ensure high-priority traffic handling.

Figure 4 shows the implementation of MPLS without DiffServ by using the type of service option from the APP definition menu to be standard.

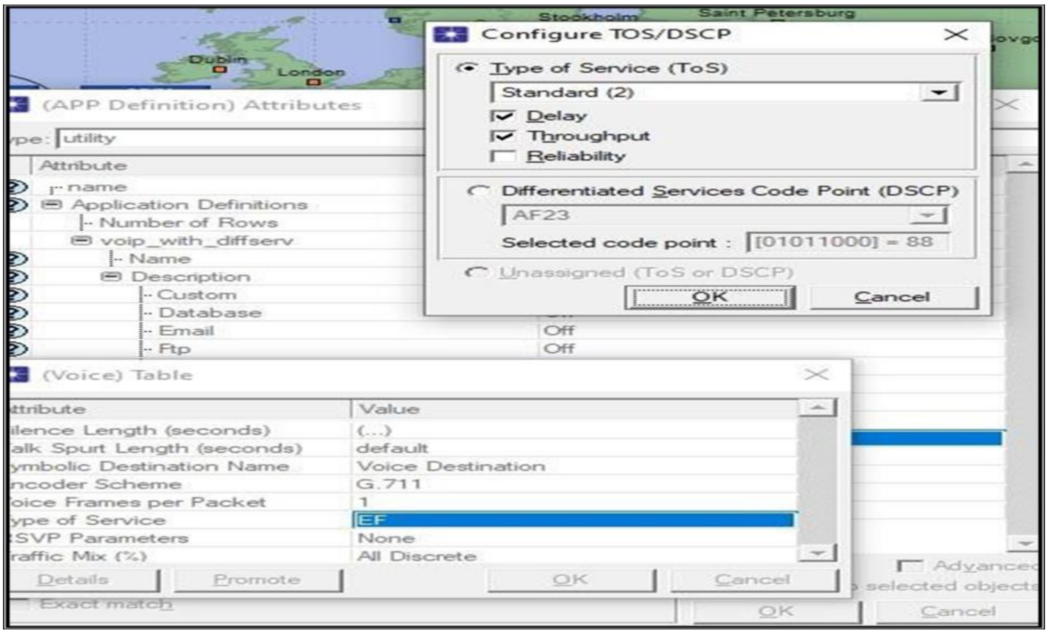

Figure 4: MPLS without DiffServ

2.4 Performance Evaluation

The following metrics were used to evaluate the performance of MPLS and MPLS-DiffServ:

- Delay: Average packet delay across the network.
- Jitter: Variations in packet arrival times.
- Queuing Delay: Time packets spent in transmission queues.
- Throughput: Volume of successfully transmitted data packets.
- Utilization: Percentage of available bandwidth consumed during the simulation.

3.0 RESULTS AND ANALYSIS

This section presents a comparative analysis of the MPLS and MPLS-DiffServ models using the performance metrics, including delay, jitter, packet delay variation, queuing delay, throughput, and utilization. The results highlight the improvements achieved by integrating DiffServ with MPLS for handling real-time voice traffic.

3.1 Delay Analysis

End-to-end delay measures the time taken for packets to navigate the network from the source to the destination. The results as depicted in Figure 5 show that the MPLS-DiffServ model consistently achieves lower delay in comparison to the MPLS-only model.

- Observation: MPLS-DiffServ ensures prioritized handling of real-time voice traffic through effective traffic classification and label switching.
- Impact: Reduced delays improve the QoS for time-sensitive applications like VoIP and video conferencing.

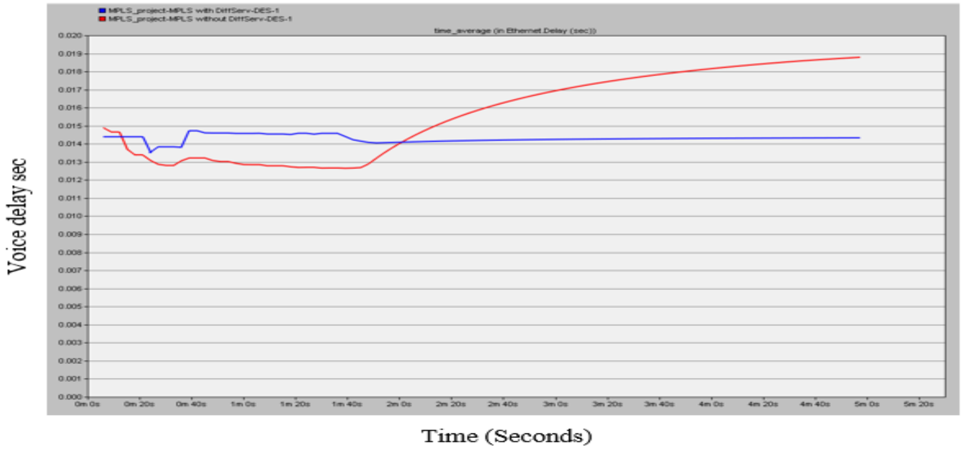

Figure 5: Comparison of Delay for MPLS and MPLS-DiffServ

The delay is significantly lower in MPLS-DiffServ due to better traffic prioritization.

3.2 Jitter Analysis

Jitter represents the variation in packet delay and is critical for maintaining the quality of real-time services. The comparison, illustrated in Figure 6, shows that:

- MPLS-DiffServ displays minimal jitters because of its strong handling of time-sensitive traffic.
- MPLS-only networks suffer higher jitters which leads to potential packet loss at the receiver end.

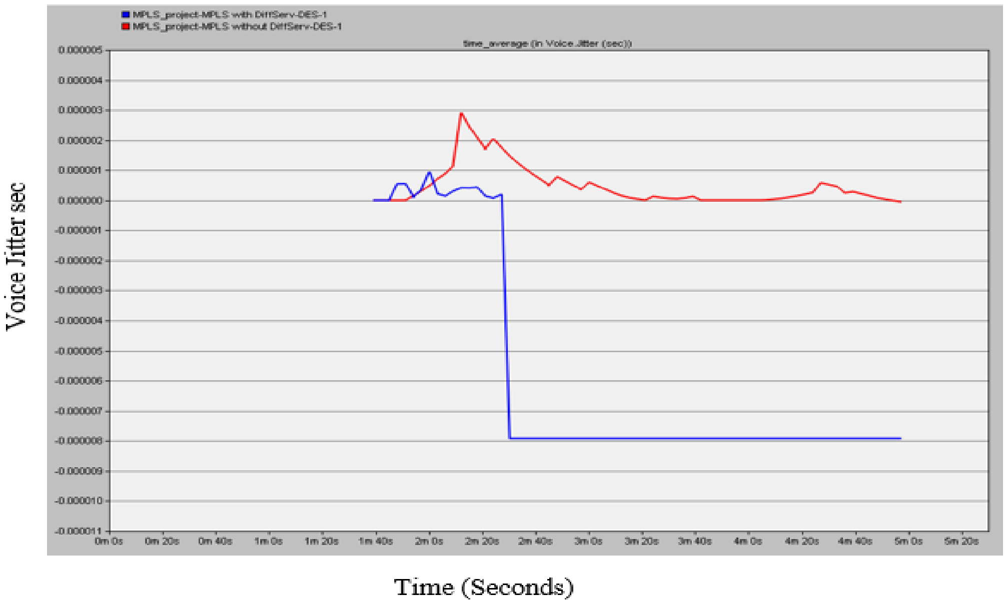

Figure 6: Comparison of Jitter for MPLS and MPLS-DiffServ

MPLS-DiffServ demonstrates superior jitter management, ensuring stable delivery of voice packets.

3.3 Packet Delay Variation

Packet delay variation (PDV) is the delay difference between selected packets. As shown in Figure 7, MPLS-DiffServ achieves significantly lower PDV values which indicate enhanced network consistency and reliability.

The total voice packet delay, called "analog-to-analog" or "mouth-to-ear" delay = network_delay + encoding_delay + decoding_delay + compression_delay + decompression_delay.

Network delay is the time when the receiver node gave the packet to RTP when the receiver received it from RTP.

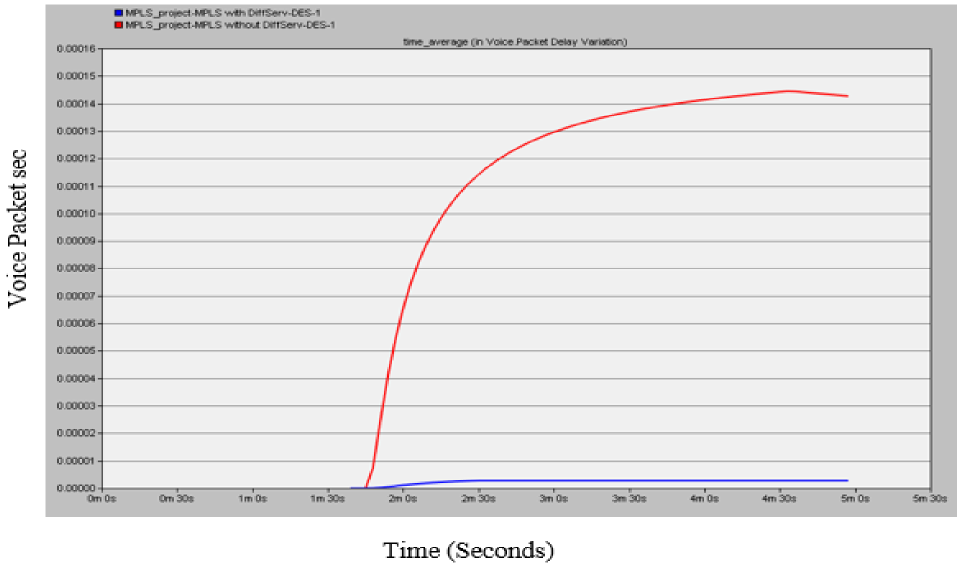

Figure 7: Packet Delay Variation for MPLS and MPLS-DiffServ

Lower PDV values in MPLS-DiffServ enhance the performance of streaming applications.

3.4 Queuing Delay

Queuing delay reflects the amount of time packets spend waiting in the router's queue. Figure 8 shows the queuing delay for both situations. MPLS-DiffServ reduces queuing delays by prioritizing high-priority traffic through DSCP settings. MPLS-only networks, which lack traffic prioritization, suffer from higher queuing delays during congestion.

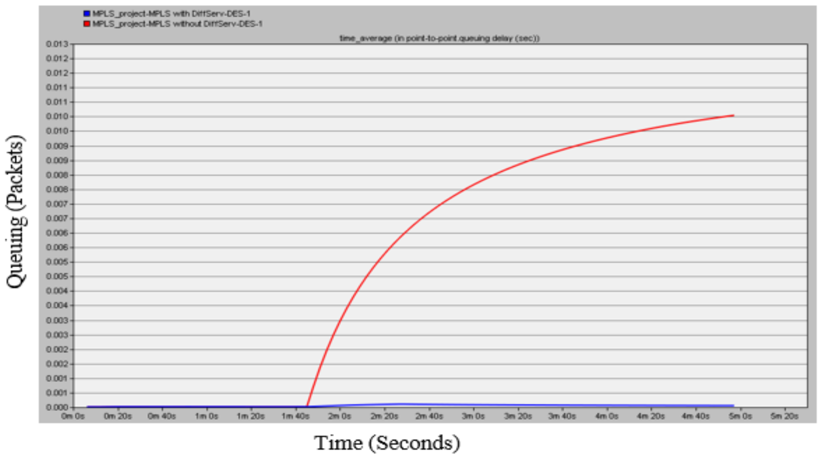

Figure 8: Comparison of Queuing Delay for MPLS and MPLS-DiffServ

MPLS-DiffServ exhibits reduced queuing delays, resulting in better QoS for voice traffic.

3.5 Throughput Analysis

Throughput is the measure of the amount of data successfully received by the destination node. Figure 9 shows the differences: MPLS-DiffServ achieves higher throughput due to optimized bandwidth utilization. MPLS-only networks encounter reduced throughput under extreme traffic conditions.

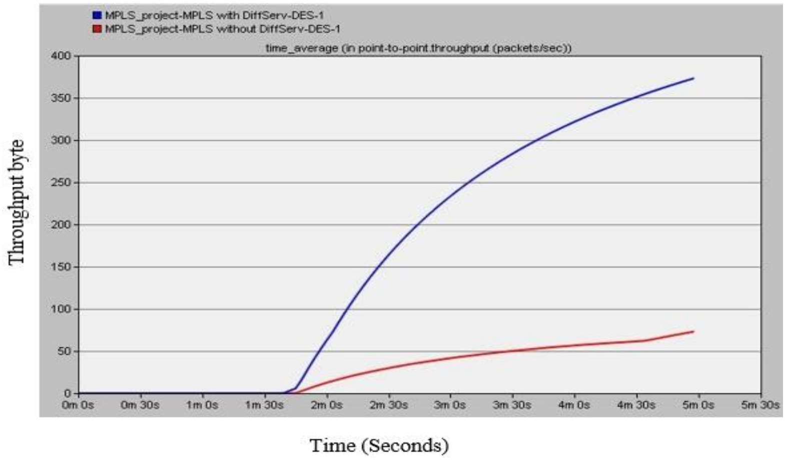

Figure 9: Throughput Comparison for MPLS and MPLS-DiffServ

Higher throughput in MPLS-DiffServ networks guarantees efficient delivery of large volumes of data.

3.6 Utilization Analysis

Utilization indicates the amount of available bandwidth consumed. As indicated in Figure 10, MPLS-DiffServ attains better utilization by ensuring efficient distribution of resources. It was observed that MPLS-DiffServ prevents overutilization of bandwidth, providing a superior service to high-priority traffic.

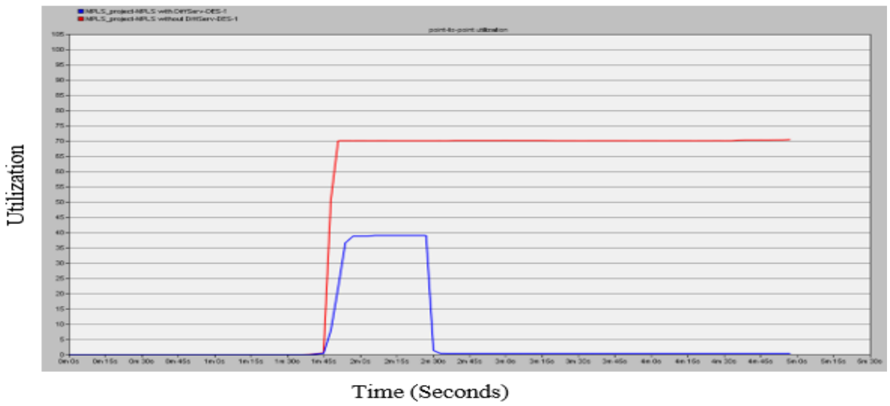

Figure 10: Bandwidth Utilization for MPLS and MPLS-DiffServ

To recap the results section, the simulation results demonstrated that MPLS-DiffServ outperformed standard MPLS in terms of managing real-time application traffic. It was observed that:

- Latency: MPLS-DiffServ consistently maintained a lower latency compared to MPLS, particularly during peak traffic conditions.
- Jitter: The integration of DiffServ significantly reduced jitter, ensuring smoother delivery of real-time data packets.
- Throughput: Both MPLS and MPLS-DiffServ achieved high throughput; however, MPLS-DiffServ provided more consistent performance under varying traffic loads.

Figure 6 illustrates the latency comparison between MPLS and MPLS-DiffServ, while Figure 10 shows the jitter variations over time. The observed jitter reduction at specific intervals highlights the effectiveness of DiffServ's traffic prioritization.

4.0 Conclusion and Recommendations

4.1 Conclusion

This study has established that integrating DiffServ with MPLS substantially enhances the performance of voice traffic compared to an MPLS-only network. Through enabling traffic engineering and QoS mechanisms, MPLS-DiffServ achieves the following listed key gains:

- Reduced End-to-End Delay: The combination of MPLS forwarding and DiffServ prioritization minimizes delay for real-time applications like VoIP and video conferencing.
- Minimized Jitter and Packet Delay Variation: Integration guarantees consistent packet delivery, reducing disruptions in voice communications.
- Improved Throughput and Bandwidth Utilization: Higher throughput and optimized utilization guarantee effective network operation, even under high traffic loads.
- Better Queuing Management: MPLS-DiffServ prioritizes critical traffic, reducing queuing delays and improving overall network reliability.

The simulation results confirmed that MPLS-DiffServ outperforms MPLS-only configurations across all evaluated metrics. These findings highlight the importance of adopting MPLS-DiffServ for applications requiring stringent QoS guarantees.

4.2 Recommendations

We propose the following recommendations: Service providers should implement MPLS-DiffServ to enhance QoS for time-sensitive applications in data centers and enterprise networks. Future study should explore the performance enhancements achievable through MPLS-VPN, which combines the benefits of VPN security with MPLS efficiency. As networks migrate to IPv6, future implementations of MPLS-DiffServ should consider this transition to guarantee scalability and compatibility. Further studies can further enhance the use of MPLS-DiffServ to other real-time applications, such as online gaming and remote healthcare services, to evaluate its impact across different domains. Continuing performance analysis with advanced tools such as OPNET and newer frameworks can provide more insights into network optimization strategies.

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