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Quality of Service Comparison of Seamless Multi -Protocol Level Switching and Multi-Protocol Level Switching Networks

By

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DECLARATION

I, the undersigned, hereby declare that this thesis entitled: "**Quality of Service Comparison of Seamless Multi-Protocol Level Switching and Multi-Protocol Level Switching Networks**" is my original work and that all sources of materials used for this thesis have been duly acknowledged. This work has been submitted partially, or in full, by any other person for an award of a degree in any other University or Institution and carried out the study under the guidance and support of the research advisor of Dr. Asrat Mulatu. The Assistance and help received during the course of this investigation have been duly acknowledged.

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Researcher's Name	Signature	Date

The thesis has been submitted for examination with my approval as an Advisor

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THESIS APPROVAL FORM

This is to certify that the thesis prepared by (**Genet Daba)**, entitled "Quality of Service Comparison of Seamless Multi-Protocol Level Switching and Multi-Protocol Level Switching Networks" and submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Computer Science MSc complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

A seamless MPLS network is one in which Multi-Protocol Level Switching is used for all packet forwarding within the network, from the time a packet enters the network until it leaves it. Seamless Multi-Protocol Level Switching was created with the goal of providing an architecture that can handle a wide range of services on a single Multi-Protocol Level Switching. Access, aggregation, and the core network are all integrated into one platform.

The goal of traffic engineering is to make network operations more effective and dependable while also maximizing network resource consumption and traffic performance. Because of the high cost of network infrastructure and the commercial and competitive nature of the Internet, traffic engineering has become an essential function in many big Autonomous Systems. These issues highlight the need of maximizing operational efficiency.

Traffic oriented performance objectives include the aspects the Quality of Service of traffic streams. In a single class, best effort Internet service model, the key traffic-oriented performance objectives include: minimization of packet loss, minimization of delay, minimization of jitter and maximization of throughput.

The primary goals of Quality of Service are bandwidth management, controlled jitter, latency and improved packet loss characteristics to provide satisfactory services for users.

The goal of this thesis is to improve the quality of service on multi-protocol level switching that is seamless. Two scenarios are used to examine the influence on Quality of Service parameters: one with Seamless Multi-Protocol Level Switching and the other with Resource Reservation Protocol -Traffic Engineering Seamless Multi-Protocol Level Switching. To compare the performances of the two situations, simulation tools such as Graphical Network Simulator-3, Ostinato, Paessler Router Traffic Grapher, and excel are utilized. On various Quality of Service metrics, the result demonstrates that Resource reservation protocol Seamless Multi-Protocol Level Switching is superior than Seamless Multi-Protocol Level Switching.

Keywords: MPLS, Seamless MPLS, QoS, Traffic Engineering, RSVP, Network Analysis

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LIST OF ABBREVIATION

ARP	Address Resolution Protocol
ATM	Asynchronous transfer mode
BFD	Bidirectional Forwarding Detection
BGP	Border Gateway Protocol
BGP	Border Gateway Protocol
BSC	Base station controller
CPU	Central processing unit
DOD	Downstream-on-Demand
FEC	Forwarding Equivalence Class
DSL	Digital Subscriber Line
IGP	Interior Gateway Protocol
PC	Personal computer.
IP	Internet protocol
DSLAM	Digital Subscriber Line Access Multiplexer
ENSP	Enterprise Network Simulation Platform
FTTB	Fiber to the building
FTTC	Fiber to the Curb
FTTH	Fiber to the home
GNS3	Graphical Network Simulator-3
HTTP	Hypertext Transfer Protocol.
IBGP	Internal Border Gateway Protocol
ICMP	Internet Control Message Protocol
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IPV4	Internet Protocol Version 4
IPV6	Internet Protocol Version 6
ISIS	Intermediate System to Intermediate System

ISP	Internet service provider
LDP	Label distribution protocol
LER	Label Edge Router
LFA	Loop-free alternate
LFIB	Label Forwarding Information Base
LIB	Label Information Base
LSP	Label switching path
LSR	Label Switching Router
MPLS	Multiprotocol Label Switching
MTU	Maximum transmission unit
NLRI	Network Layer Reachability Information
NNTP	Network News Transfer Protocol
NSR	Nonstop active routing
OAM	Operations, administration and management
OLT	Optical line terminal
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
PRTG	Paessler Router Traffic Grapher
QoS	Quality of service
RFC	Request for Comments
RIP	Routing Information Protocol
RNC	Radio network controller
RR	Route Reflector
RSVP	Resource reservation protocol
RTSP	Real Time Streaming Protocol
SIP	Session Initiation Protocol
SLA	Service level agreement
TCP	Transmission Control Protocol

TCP/IP Transmission Control Protocol/Internet Protocol,

TDP Tag Distribution Protocol

TE Traffic engineering

UDP User Datagram Protocol

VM Virtual Machine

VPN Virtual private network

WAN Wide area network

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CHAPTER ONE

Introduction

1.1 Background of the Study

Multiprotocol Label Switching (MPLS) is displacing other WAN technologies due to its improved reliability and efficiency. It is preferable than traditional Internet Protocol (IP) routing, which bounces data all across the internet before sending it to its final destination. They are more dependable in terms of developing scalability, secure platforms, efficient platforms, and service level agreement verification [3]. Asynchronous transfer mode (ATM) is a switching technique used by telecommunication networks that uses asynchronous time-division multiplexing to encode data into small, fixed-sized cells. For WAN connectivity, various technologies such as Frame Relay, ATM, T1 or E1 dedicated links were used in the past. Layer2 VPNs were used in business networks that were not scalable to maintain security issues. The MPLS VPN offers scalability and can be used to separate larger organizations. Multiprotocol Label Switching (MPLS) is data forwarding technology that increases the speed and controls the flow of network traffic. With MPLS, data is directed through a path via labels instead of requiring complex lookups in a routing table at every stop. [2].

Label Switching protocols are increasingly used in packet-based computer networks for traffic engineering and other purposes. Label Switching routers (LSRs) create label switched paths in a label switching network using the MPLS signaling protocols. (LSPs). MPLS protocols are used by LSRs to accept MPLS label map pings from downstream LSRs and to advertise MPLS label map pings.

MPLS provides an established and reliable network foundation for core and aggregation networks. MPLS can also be used in access networks, such as telephone or Digital Subscriber Line (DSL) backhaul networks. MPLS has two layers: the Transport Layer and the Service Layer (for MPLS VPNs, for example). In both cases, the protocols and encapsulation are the same [47].

Although the encapsulation is identical, the application of MPLS varies, especially in terms of signaling, control plane, provisioning, scalability, and update frequency. At the service layer, only service-specific information is shared, and each service can theoretically use its own design and protocols. The services are operated using the transport layer. 5A seamless MPLS network uses MPLS for all packet forwarding within the network, from the time a packet enters to the time it leaves [40].

Seamless MPLS was created with the aim of supporting a broad range of services on a single MPLS platform that completely integrates connectivity, aggregation, and the core network. The design of the building Seamless MPLS enables network and service providers to install service creation points practically anywhere in the network, allowing for more flexible service and service creation. Without the need for dedicated service creation areas on fixed sites, service creation can be achieved based on existing requirements. The development of services is easier with Seamless MPLS' versatility [33].

The ability of a network to deliver better service to specified network traffic through multiple technologies is referred to as Quality of Service (QoS). The main purpose of QoS is to provide dedicated bandwidth, controlled jitter and latency (which is required by some real-time and interactive traffic), and improved loss characteristics. It's also crucial to ensure that giving one or more flows precedence does not cause other flows to fail. QoS technologies provide the fundamental building blocks for future business applications in campus, wide-area network, and service provider networks. Whether it's a small company network, an Internet service provider, or an enterprise network, almost every network can benefit from QoS for maximum efficiency [6].

Quality of service (QoS) is the use of mechanisms or technologies that work on a network to control traffic and ensure the performance of critical applications with limited network capacity. It enables organizations to adjust their overall network traffic by prioritizing specific high-performance applications [22]. When utilizing MPLS, however, you have an additional option for implementing QoS for labeled packets. A signaled channel through the network between two routers is known as an LSP. The label on top of the packet can be used to indicate a portion of the QoS for that packet.

1.2 Statement of the Problem

The use of real-time application like (multimedia) in Seamless MPLS are becoming increasingly significant However, most of the routing strategies used in seamless MPLS provide only best effort service.

MPLS routing protocol also provides best effort service without any guarantee of QoS requirements. The main problems or limitation of Seamless MPLS is no link optimization, it's difficult to arrange bandwidth utilization and maintain the traffic path during congestion. Due to this limitation delivering better QoS for user is difficult. Real-time applications need QoS, since they are, by nature, highly time sensitive to reach destination within minimal delay compared to other traffics.

To address these challenges and improve QoS, traffic engineering can be applied to the core, aggregation and access layers in seamless MPLS. In this thesis work, it is planned to improve the QoS of Seamless MPLS networks by applying resource oriented traffic engineering techniques.

This is due to the fact that BGP does not allow for the deployment of QoS across various domains (inter-domain or inter-AS). Another drawback is that, by its very nature, BGP has a delayed convergence time (about 30 seconds) when the network experiences a breakdown. Because the lack of QoS in the inter domain network has an impact on the overall QoS, implementing QoS in the intra-domain network alone does not guarantee end-to-end QoS throughout the entire network.

To deal with these issues, Seamless MPLS is one convergent inter-domain network design proposed to improve management, service provisioning, and scalability, but its impact on QoS parameters has not been validated or quantified to ensure end-to-end QoS assurances. Despite the fact that some academics have undertaken traffic analysis for a single MPLS domain, the author's understanding of the influence of Seamless MPLS on QoS is limited. This analysis is necessary to determine the benefits and drawbacks of replacing existing multi-domain MPLS with Seamless MPLS based on QoS criteria. Limitation of MPLS they require less powerful routers with limited capabilities, require the customer to control routing, they support only IP traffic and PE routers are underutilized

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis is to quality of service in seamless Multiprotocol Level Switching Networks by applying resource reservation protocol.

1.3.2 Specific Objectives

- Identify the Seamless MPLS limitations with influence on TE.
- To compare and Analysis the current seamless MPLS architecture with the traffic engineering applied seamless MPLS architecture by Throughput, Latency, Packet Loss and Jitter.
- Identify the current state of communication techniques through TE.
- Identify the features in seamless MPLS which promise improved QoS.
- To simulate and evaluate Seamless MPLS architecture.
- To assess the impact of Seamless MPLS on QoS parameters.

1.4 Methodology

Seamless MPLS architecture & implementation scenarios with its benefits compared to Traffic Engineering applied seamless MPLS architecture are explained. In the implementation part, a practical environment is developed using network simulation tool, Enterprise Network Simulation Platform (ENSP) or GNS3, and two scenarios are built in order to collect test results from the simulator.

In this thesis state-of-the-art, related works and statement of the problem are used as baseline to achieve the objectives. The methodology starts with investigating different technologies enabling Seamless MPLS architecture. Then the methods of simulating and evaluating the architecture with QoS perspective are followed. A theoretical study of seamless MPLS and QoS features are done thoroughly along with the evaluation of the limitations of the seamless MPLS architecture.

The two scenarios are built in such a way that first an ordinary network is built with a Seamless MPLS network. Then the same network topology is implemented with traffic engineering Seamless MPLS features and the test results are collected from the simulator using Network Quality Analyzer (NQA) technology for the two scenarios. To make the scenarios like the real network, a network traffic generator called Ostinato is used to generate traffic into the network.

1.5 Scope of the Study

The scope of this study is concerned to Quality of Service Seamless MPLS Networks by applied traffic engineering.

1.7. Limitation of the Study

Due to memory limitations of personal computers and the process intensiveness of the simulation tools used, it is not possible to power on more than 20 nodes (routers) simultaneously in simulation environments and additional routers for redundancy and load balancing purposes are used only in the core network domain. But it should be noted that increasing number of routers for testing and analysis will not alter the overall result. I could not see the real result because it was made by simulation.

1.8. Thesis Layout

There are four chapters in this thesis. The thesis is introduced in the first chapter. It contains background information, a statement of the topic, the study's aims, the methods used to attain the objectives, the thesis' scope and limitations, the thesis' contributions, and related works. Basic ideas in MPLS technology, Seamless MPLS, traffic engineering, RSVP-TE signaling, and QoS parameters are covered in Chapter 2. It emphasizes the benefits of MPLS over older technologies, and the most frequent MPLS terms are briefly introduced in this chapter. The network design is described in detail in Chapter 3. This comprises two scenarios: one is a standard seamless MPLS network, and the other is RSVP-TE. The two scenarios' QOS parameters were used to demonstrate and assess seamless MPLS. The simulation and result analysis section discusses the simulation tools utilized, the simulation scenarios, the network structure, and the analysis of the data collected.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction to MPLS

MPLS is a telecommunications network forwarding mechanism that sends packets from one node to the next based on short labels attached to packets rather than seeking up large IP addresses at each router. This speeds up core routers that don't require sophisticated routing table lookups. As a result, the data transfer speed is greatly increased [21].

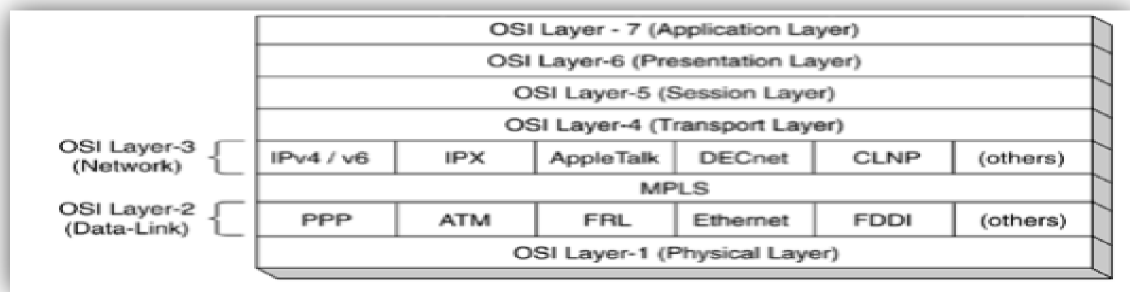

Figure 2.1: Position of MPLS in OSI model

2.1.1 Forwarding Equivalence Class (FEC)

MPLS is a rating-based technology. When transmitting equivalence classes, it groups the packets to be forwarded in the same way (FEC). Source address, destination address, source port, destination port, kind of protocol, and VPN are some of the classification criteria that can be used. The packets that belong to a specific FEC are then routed to the same symbol's Route (LSP). When a packet comes, the router analyzes it to determine if it belongs to an existing network. FEC is a logical object formed by the router, not a label or packet [35].

MPLs Label

A MPLS label is a short, fixed-length identifier pointing to a given FEC. A label may reprehensibly only send a single FEC, but multiple labels may correspond to an FEC. The label is part of the packet header and is only significant locally, as it carries no topology in formation [43].

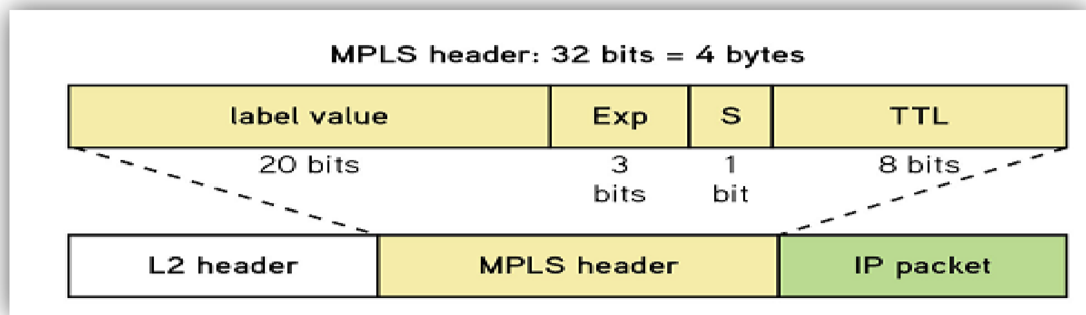

Figure 2.2: MPLS Packet Header (6)

2.1.2 Label Switching Router (LSR)

LSRs are the basic components of the MPLS network, and can be three different types depending on their network function:

Label Edge Router (LER)-located on the network's periphery and serves as a gateway between the MPLS network and the WAN or the Internet. Could be an LER:

Ingress router – it is the entry point of the MPLS network. When a packet arrives it decides whether the packet should be forwarded through the MPLS network, determines the FEC, the packet belongs to, and encapsulates it with an MPLS header, based on the information it carries.

Egress router – it is the exit point of the MPLS network. It performs a normal IP look-up and forwards the packet according to the appropriate IP routing protocol

Transit router – it is any router in the middle of the MPLS network and performs simple switching, based on the label value

Penultimate router-it's the router in the MPLS network before the last hop. The penultimate router eliminates the MPLS header before forwarding the packet to the egress router, as the packet will not be transferred to another transit router. The use of penultimate router configuration is optional, since the egress router can also delete the MPLS header. The penultimate router then operates

2.1.3 Label Switched Path (LSP)

From a particular FEC, the label switched path controls which direction packets will travel over the MPLS network. The LSP is a one-way virtual circuit that connects the input to the egress router. A signaling protocol, such as LDP or the Traffic Engineering Resource Reservation

Protocol, is used to create the LSP (RSVPTE). Figure 2.3 shows a simplified diagram of an MPLS network that demonstrates the LSP definition.

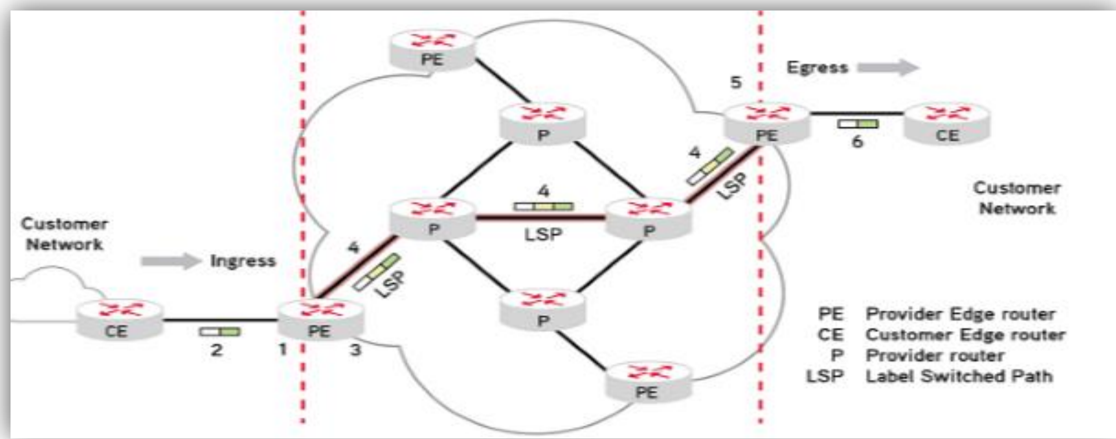

Figure 2.3: MPLS Network

2.1.4 Label Distribution Protocols (LDP)

The LDP protocol allows LSRs to request distribute and release binding information on the mark. The label distribution method is called hop-by - hop forwarding and is chosen by the underlying routing protocol of the Interior Gateway Protocol (IGP) along the normally routed paths. The resulting LSPs are then used to relay label traffic over the MPLS network.

2.2 Label Distributions

When the packet enters the topology of the MPLS, LSR receives the packet and imposes it on the packet via the Label Switch Path to the MPLS label and forward to the next hop. When the packet reaches the next LSR, i.e. the intermediate LSR, the incoming label is swapped with the outgoing label and the packet is transmitted. When the packet is received by the egress LSR it strips off the packet label and forwards it to the destination router.

All LSRs in the MPLS network have IGPs (e.g., EIGRP, RIP, OSPF, etc.) running over the network [7]. To order to accomplish the function of label delivery, neighboring LSRs need to decide on the label used by each IGP prefix. The swapping of incoming and outgoing labels should be visible for each LSR. Since the labels are local to neighboring routers and have no global significance across the network, we need a mechanism to tell the routers which label to be used when the packets are being forwarded. Two neighboring routers therefore need some kind of contact between them to decide on which mark to use for a given prefix. Otherwise the routers get no idea of the packets being exchanged. The Label Distribution Protocol is required for this purpose, or to complete the label distribution. Distribution of marks takes two separate ways [7]:

- Piggyback the labels on an existing IP routing protocol.
- Have a separate protocol distribute labels.

2.2.1 Piggyback the Labels on an Existing IP Routing Protocol

LSRs do not need new protocol in this method but they need to extend the existing routing protocol to carry labels. This method has a great advantage because the routing and label distribution are always synchronized which means that both labels and prefixes should be present. Implementation for the distance vector routing protocol, e.g. EIGRP, which originates the prefix from the routing table, is very simple.

2.2.2 Separate Protocol for Label Distribution

This label distribution method requires a separate protocol to distribute the labels and allows distribution of the prefixes by the routing protocol. This approach has the advantage of routing protocol independently and the downside is that each LSR needs a new protocol. There are several protocol varieties which distribute labels including:

- Tag Distribution Protocol (TDP)
- Resource Reservation Protocol (RSVP)
- Label Distribution Protocol (LDP)

TDP was the first protocol developed and implemented by Cisco for label distribution. LDP was later designed and developed by IETF. TDP and LDP operate in a similar way, but LDP has more functionality than TDP. Due to the easy availability of LDP, TDP was replaced by LDP in a very short time frame. RSVP is only used for MPLS traffic engineering.

2.3 Control Plane and Forwarding Plane

Control plane and forwarding plane are the part of router architecture. Control plane collects the information that is used to forward the incoming packets. While forwarding plane decides how to switch the incoming packets after being received at inbound interface [7].

2.3.1 Control Plane

With the adjacent routers, the control plane exchanges routing information and labels. It is made up of two types of protocols: routing protocols (e.g., RIP, EIGRP, OSPF, and BGP) and label exchange information protocols (e.g., RIP, EIGRP, OSPF, and BGP) (e.g., LDP, TDP, RSVP, etc.).

2.3.2 Data Plane

The forwarding plane of the data plane is based on the information connected to labels. Label Information Base (LIB) and Label Forwarding Information Base (LFIB) are the two sorts of tables (LFIB). The data plane uses LFIB to forward the tagged packets. The LIB table stores all of the local labels as well as the mapping of the labels received from neighboring routers.

2.6. Seamless MPLS

The demand for a single converged packet network that can provide both fixed and mobile networks, regardless of access type, grows on a regular basis. The performance of MPLS in core networks and the benefits it provides have paved the way for its use in aggregation and access networks as an alternative to ATM or traditional Ethernet-based aggregation. The widespread deployment of mobile backhaul infrastructure has necessitated the integration of mobile backhaul and core networks [9]. Deploying a service from one MPLS region to another necessitates provisioning in the end-to-end network at numerous intermediate points, making troubleshooting and fault recovery more difficult. A possible solution is deployment of Architecture of one end-to - end infrastructure and transport network [3].

2.6.1 Deterministic End-to-end Service Restoration

Seamless MPLS is a robust network that offers an end-to - end deterministic service restores (Sub-50ms), and there are two wide categories of functions that help to accomplish this. The first set of functions includes ways to allow fast detection of performance degradation events and fault location. The second set of functions consists of the required recovery activities necessary for rerouting and restoring services. Failure Detection Mechanisms: There are various failure detection mechanisms available. Layer2 failure detection relies on Ethernet Operation, Administration, and Maintenance (OAM) capabilities, as well as integration of Bidirectional Forwarding Detection (BFD) mechanisms with LSP and pseudo wires. For Layer3 fault detection and to test data plane consistency of pseudo wires, both single hop and multi-hop BFD specified in RFC 5883 and RFC 5884 are supported for BGP sessions and targeted LDP sessions.

2.6.2 Decoupled Network and Service Architectures

Other end-to - end MPLS options (e.g., end-to - end LDP in a flat network) do not contain IGP or MPLS signaling information within the region and are exchanged across regions. This increases the size of the routing/ forwarding tables within individual routers, as well as the MPLS state. Consequently, the Seamless MPLS architecture decouples the service and transport layer and integrates access, aggregation and core into a single platform that supports residential, wholesale, mobile, and business subscribers [3]. One of the major advantages is that problems on the transport layer can to be solved once (and all providers have the solutions available). With Seamless MPLS the use of service-specific configurations on intermediate nodes is not necessary; all services can be deployed end-to-end [2].

2.6.3 Service Flexibility with Simplified Provisioning and Operations

Seamless MPLS architecture suggests a systematic way to enable end-to - end MPLS between access nodes, with all MPLS-based forwarding labels. Using this method, packets are classified at the entry point of the access network and are distributed all over the network to the receiving end as classified packets. Therefore, service delivery and operations are significantly simplified, reducing the number of provisioning points of service, and making the topological location of service delivery points highly flexible.

2.6.4 Building Scalable Networks

Seamless MPLS helps to scale the end-to - end network to more than 100,000 MPLS devices, understanding that certain nodes (e.g., access) have limited functionality, and are usually designed for simplicity and lower cost. To deliver that scale, this clearly requires some new thinking and innovative techniques.

2.7. Seamless MPLS Architecture

The handling of the total size of the necessary routes and MPLS label in the formation control plane and forwarding plane state resulting from the specified scalability goals, in particular with regard to the total number of access nodes, is one of the main elements to consider when designing architecture for a Seamless MPLS network. The intra-domain routing within each of the MPLS domains (i.e. aggregation domains and core) utilize standard IGP protocols like OSPF or ISIS. A systemic way to enable end-to - end MPLS across a single domain. This architecture has limited provisioning flexibility since it is intimately tied with the topological arrangement of network nodes, and it requires dealing with several technologies for troubleshooting and fault recovery on the operational side.

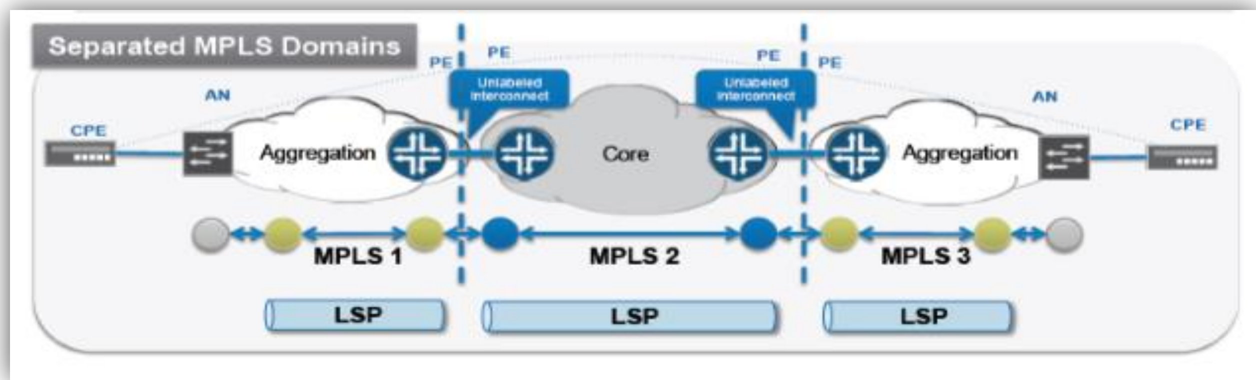

Figure 2.4: MPLS with multiple domains [4]

With Seamless MPLS, the idea is to provision the service end-to-end and minimize the number of provisioning points. The service provisioning is in-line with the network architecture, maintains simplicity in the access network, and relies on increased capabilities and intelligence on the service nodes. At the same time, it also simplifies operations and makes efficient use of network resources by reducing the number of provisioning points and relying on a single MPLS-based forwarding scheme in the data plane MPLS domains (regions) can be of different types: IGP area, IGP instance or BGP AS, all spanned by a single MPLS network, with any to any MPLS connectivity. Each area is in charge of connection (both IP and MPLS) within the region and can choose whether to use LDP, RSVP-TE, or even LDP-over-RSVP on its own. Inter-region connection is handled by region boundary nodes using an LSP hierarchy based on "labeled BGP."

Since the service is initiated as an MPLS pseudo wire from the origination point at the access node, any topological changes in the access can be easily made without having to completely re-provision the service layer. This can be a significant operational asset to mobile backhaul access, for example, where re-parenting of cell site routers to a different base station controller/radio network controller (BSC/RNC) is a common occurrence.

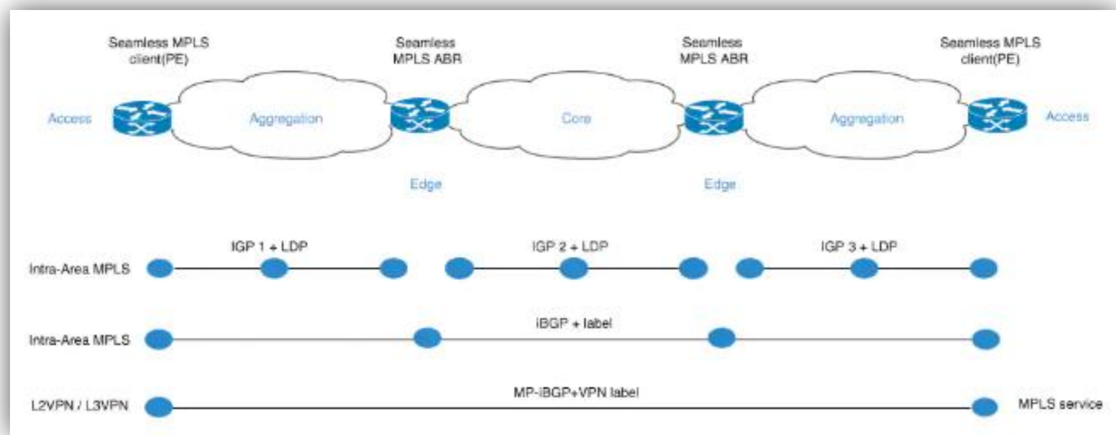

Figure 2.5: Inter-AS seamless MPLS architecture

2.8. Traffic Engineering

The goal of traffic engineering is to improve the performance of operating networks. In general, it refers to the use of technology and scientific principles to monitor, model, characterize, and regulate Internet traffic, as well as the application of that knowledge and method to meet specific performance goals. Measurement and control are two components of traffic engineering that are relevant to MPLS. One of the main goals of Internet Traffic Engineering is to make network operations more efficient and dependable while also maximizing network resource consumption and traffic throughput.

2.8.1 Refresh Reduction Techniques

The Bundle message defined in RFC 2961 [3] packs a number of RSVP messages sent to the same RSVP neighbor within a single larger RSVP message. To this purpose, a new RSVP bundle message is defined: this message has its own header and a body which is made up with a sequence of RSVP messages. Bundling is performed on a per-hop base.

2.8.2 RSVP with Traffic Engineering Extensions

Resource Reservation Protocol (RSVP) by its name we knows that it reserves the resource for the network. The main task of the RSVP is that it reserves the bandwidth between the source and destination along the defined path. In order to get the information in the network there is a router in the network which will send the message packets in the network in order to get the details regarding the bandwidth. There are four main messages which are used by the RSVP protocol and these are given below:

1) RSVP PATH message

2) RSVP error message
3) RSVP RESERVATION message
4) RSVP tear message

2.8.3 RSVP PATH Message

In this message the head ended router is responsible for the reserve path. The main function of the head ended router is that it sends the messages to the other routers and find out the path information and send it to the head ended router. After that head ended router will decide that which path is free from source to the destination?

2.8.4 RSVP RESERVATION Message

After the analysis of the Head ended router it will apply the resource reservation on the required path and then use it in an effective manner. In the above figure when head ended router send message to the inside router then it will send it to the next router and when it found that the resource is free then it will generate the reservation message and finally it will come back to the head ended router.

2.8.5 RSVP error Message

In this mechanism when head ended router send path message to the inside router there are basically two conditions first one is the suppose the inside router don't have any resources then it will send back the message that I don't have any resource right now with the identification of the PATHERR Message. At the start there is no handling of the resource. On the other hand, if there is a resource is available then it will send message to the other side most probably the destination and suppose at destination side there is no resource are available then it sends an error message then it will wait for some time according to the limitation when it gets any resource then it will be successful otherwise it generates an error.

2.8.6 RSVP Tear Message

In case of RSVP tear message it will generate two types of tear messages one is for the clear of the resources and the other one is for the clear of the path. When head ended router reserves any resources then it will send back message that is called tear message.

2.9. Quality of Service (QoS)

Quality of Service (QoS) is a broad word. It gives varying levels of treatment to various types of traffic or applications that pass across the network. Different network requirements apply to these applications. It must be the driving force behind various administrative policies that regulate applications according to their specific needs. QoS within a network is essential to guarantee the requirements of today's converged networks. QoS provides that different levels of service for business-critical application and delay-sensitive applications. QoS is to manage the following network elements [14] [15].

- Bandwidth /Throughput
- Jitter and
- Delay
- Packet loss.

2.9.1.Through put

Throughput is a measure of how much information units a system can process within a given amount of time. Given the dynamic nature of traffic flow across a network, differences in resources at different times can become bottlenecks.

Table 2.1: Quality standards for throughput

	Category	**Throughput/Bandwidth**
Throughput standard	Excellent	100%
	Good	75%
	Medium	50%
	Poor	<25%

2.9.2. Delay

RFC 7679 defines a metric for measuring one-way delay as the difference in the time at which the datagram crosses two reference points. The delay of a datagram experienced within a service provider network is defined as the difference in the time at which the datagram enters the network and the time at which it leaves the network. It is also commonly referred to as latency. Delay in TCP/IP networks can be classified as packetization delay, queuing delay, propagation delay, transmission delay and processing delay [13].

Table 2.1: Quality standards ITU-TG114 for delay

	Category	**Delay(MS)**
Delay standard	Good	0-150
	Medium	150-400
	Poor	>400

2.9.3. Jitter

A metric for quantifying one-way jitter was defined in RFC 3393. Jitter is the variance in network delay that datagrams undergo. Buffer space is made available in network nodes and datagrams are buffered to avoid losing datagrams when a resource is temporarily congested.

Table 2.3: Quality standards ITU-T G 114 for Jitter

	Category	**Jitter(ms)**
Jitter Standard	Good	0-20ms
	Medium	20-50ms
	Poor	50>ms

2.9.4. Packet Loss

Traffic loss characterizes the datagram drops that occur in the path of a one-way traffic flow between source and destination node. Having buffer space to temporarily queue datagrams in network nodes helps reduce datagram loss, but it cannot be completely eliminated. Some of the factors that contribute to datagram loss are [13] [14]:

- **Congestion -** Burstyn traffic can cause queue overflows resulting in datagram loss.
- **Traffic rate limiting** - In order to ensure customer traffic is conforming to a negotiated SLA, service providers may rate-limit incoming traffic and drop nonconforming datagrams.

Table 2.4: quality standard for packet lose

	Category	**Packet loss**
Packet loss standard	Excellent	0%
	Good	3%
	Medium	15%
	Poor	25%

2.10. Review of Related Works

The authors in [7] have described the MPLS is considered as a routing method, and it is not a facility or a service. MPLS can be encased with any prevailing infrastructures, namely digital subscriber line, asynchronous transfer mode, frame relay, and IP. MPLS is not platform dependent. It can work seamlessly without making any change in the current environment of these technologies.

Quality of Service and the Network performance for selected traffic can be improved using the MPLS. Different types of services bring in multiple classes of service. For example, an enterprise's mission-critical application can be placed in the top most section of service; the applications less important might be in the Second best level of service, recreational applications may be in the lower class services; separate class of service can be given to reduce the jitter for VoIP traffic [2].

The researchers in [4] present a term application layer protocol refers to a protocol that manages data and information exchanged between devices and the final software applications. A device can either be a single sensor; a gateway that integrates a larger number of sensors; or even actuating devices, such as motors, lighting equipment.

The Multiprotocol Label Switching (MPLS) network implemented at the AMIK Indonesia College. After the model design is carried out, the network implementation is continued, so that the MPLS network performance will be tested and compared to the performance without MPLS using the model the research team planned [5].

Through IP/MPLS technology, [8] the seamless MPLS connects the access layer, convergence layer, and backbone layer, and provides flexible and scalable networking architecture for operators. It is improper to directly inherit all technologies from the old IP network.

After the devices of each layer are seamlessly connected, the scale of the IP/MPLS domain improves by [9], orders of magnitude compared with the original networks. For example, in a network with 20,000,000 users, if each DSLAM connects 100 users in FTTC access mode, the number of nodes in the entire network is over 200,000. If each OLT connects 1000 users in FTTB/FTTH access mode, the number of nodes in the entire network is 20,000.

As shown in [6], QoS is mostly used for measuring various kinds of multimedia data. Sharing (uploading) on SC has become the daily activity of end-users. As a result of this activity, it provides an open challenge for service providers. As a service provider, the host delivers productive infrastructure, allowing end-users to upload and share their high-quality images.

As shown in [11], in addition, many access devices, such as DSLAMs and OLTs, are available in the network, taking up a high ratio of network investment. Hence, the introduction of the IP/MPLS should not obviously affect the cost of access devices. In Seamless MPLS, networking, the complexity of the access device control plane and performance specifications of the forwarding layer must be reduced.

The internet engineering task force (IETF) standard in RFC 8277 [13] and RFC 7032 [14] are aimed to address the drawbacks of traditional MPLS such as scalability and flexibility in service provisioning limitations. The scalability is achieved by using label distribution protocol (LDP) Downstream-on-Demand (DoD) label advertisements. MPLS traffic engineering, ATM, Layer 3 VPNs were configured, simulated and performance tested using the lab environment discussed in the next section.

Benchmarking and testing performance testing details were based from RFCs 2544 and 5695. As previously mentioned, pre-requisites such as dynamic routing protocols, network analysis, and other concepts can be explored by collapsing or expanding on the lab network discussed [15].

In the original networking mode, the order of magnitude of the number of nodes in the backbone and metro route domains is in the 1,000s. Hence, the scale of the route domain in Seamless MPLS networking increases by an order of magnitude of one or two. In a large-scale network, engineers must consider how to construct the route and MPLS tunnel, and how to guarantee the availability of the networks [10].

The problem of how to extend QoS capabilities across multiple provider domains has not been solved satisfactorily to date. The source of the problem lies mainly with the autonomous nature of Internet Service Providers (ISP) and their loose federation that forms the global Internet [1].

Similarly routers can also identify traffic on known servers but old routers cannot difference between traffic on higher level of protocols they are unable to differentiate between multiple http applications but new routers have solved this problem. QoS requirements for multimedia traffic have been covered by different standardization groups, like ITU, ETSI or 3GPP [18].

As in [3], the Segment Routing is a promising Traffic Engineering (TE) model that provides end-to-end communications SR can observably improve the network utilization and control the routing path flexibly by encoding route information into a list of segments, i.e., the Segment List (SL). The key feature of SR is that it adopts the source routing paradigm, which implies the routing path followed by a packet is determined and written to the packet header by the first switch of SR networks (called Ingress SR switch).

End points like video conferencing bridges can successfully mark the traffic but some time network managers try to avoid endpoint classification is cases where the user may be able to change the personal priority for online e-gaming [17].

The way to provide QoS in IP networks has been discussed for a long time [19]. The most accepted solutions are IETF's Internal Service and Difference Service both Internal Service and Difference Service endow the routers with QoS mechanisms, such as queuing, scheduling and shaping, as illustrated [20].

IP traffic can also manage voice and video data until less user traffic exists but as soon as the traffic increases through user request the packets travelling the same IP destination path become lost or slow due to OSPF congestion. So the quality of service guarantee voice and video data is no more accomplished. There is no standard way to provide QoS to voice and video data packets in IP packet transmission [16].

The internet engineering task force (IETF) standard in RFC 8277 [13] and RFC 7032 [14] are aimed to address the drawbacks of traditional MPLS such as scalability and flexibility in service provisioning limitations. The scalability is achieved by using label distribution protocol (LDP) Downstream-On-Demand (DoD) label advertisements. To enhance the flexibility in provisioning, label mapping information for a route is piggybacked in the same BGP update message that is used to distribute the route itself.

2.10.1 Review of Related Works Summary

Table 1.1: Summary of Review of Related Works

Author	Improved QoS Feature(s)	Technique/Approach Used	Tool(s) Used	Metrics Used	Gap(s) Identified
Asrat MB et al., [47]	End-to-end QoS parameters of MP-BGP MPLS VPN of EthioTelecom service level agreement (SLA) customers.	weighted fair queueing (WFQ) for congestion management and weighted random early detection (WRED) for congestion avoidance	Huawei's Enterprise Network Simulation Platform (eNSP) and Wireshark	delay, jitter, packet loss and traffic utilization	Chassis clustering of access & aggregation devices, using LDP to label MPLS down streaming.
Yalemzewd MB [24]	Impact of Segment Routing MPLS on end-to-end QoS parameter of SR-MPLS QoS.	Buffers packets in queues upon network congestion and use a scheduling algorithm to determine the forwarding order. Monitors network resource usage and drops packets to mitigate network overload if congestion worsens.	Emulated Virtual Environment -Next Generation (EVE-NG)	Delay, Jitter, Packet loss and Packet sequencing.	SR-domain with LDP only capable routers on endto-end QoS as most of the router especially in the access domain may not be SRMPLS capable.
Heng Luo [37]	Mobile ad hoc network (MANET), Best Effort QoS Support Routing in	Routing protocols DSDV, a typical proactive protocol and DSR, a typical reactive protocol and rank them accordingly.	GloMoSim, OPNET, QualNet and MATLAB	Delay, jitter and throughput.	Not multiple access techniques such as Bluetooth and MANETs.
Yalemzewd Negash [40]	end-to-end network QoS performance by classical MPLS.	Nonstop active routing (NSR)-enabled control plane protocols. loop-free alternate (LFA) support for ISIS, OSPF and LDP.	Enterprise Network Simulation Platform (eNSP), Network Quality Analyzer (NQA), Ostinato	Throughput, latency, packet loss and jitter	Border Gateway Protocol (BGP) does not support QoS implementation across multiple domains (inter-domain or inter-AS).
Omair Ahmad and Shakeel Ahmed[2]	MPLS over ATM method of media traffic routing.	Technique for traffic engineering and functioning of multiple services and it adds up the	Cisco Packet Tracer	Throughput, queuing delay and Bandwidth	Using MPLS that not helped to replace Frame Relay, dedicated leased lines and

		benefits like having greater scalability that can improve network operations.			offers a new option for WAN connectivity.
Fathurrahmad and Salman Yusuf [5]	MPLS VPN networks and providing a stable network bandwidth efficiency and is used at AMIK.	MPLS works on packages with MPLS headers, traffic engineering processes and implement a VPN network	GNS3, Microsoft Visio Network Design 2016 and Virtual Machines.	Bandwidth and throughput.	That may not produce realistic network performance related results
Nokia Ahmed [34]	Evolving to end-to-end MPLS architectures	LSPs, by using a technique such as the gradient method Internet traffic	MATLAB and CPLEX.	Maximum Link Utilization rate, Packet loss rate and Demand Rejection rate.	Information such as measured delay and residual bandwidth. It's high complexity
M. Tanvir and A. Said[45]	Decreasing Packet Loss for QoS Sensitive IP Traffic in DiffServ Enabled Network Using MPLS TE.	A Differentiated Service (DiffServ) based approach is proposed for QoS provisioning.	NS2 simulator	Packet loss, Packet delay.	MPLS QoS mechanism also cannot be considered to improve the performance of the traffic.
Cortese Gandr [26]	Creation and Deployment of End-User Services in Premium IP Networks.	QoS from end to end between network elements.	MATLAB	packet loss and throughput	These aggregate models is that they mostly capture steady state behavior because the averaging is typically done over large time scales
J.barakovic, H. Bajric and A.Husic [21]	Multimedia traffic analysis of MPLS and Non MPLS.	Traffic engineering and multi service functionality.	MATLAB and CPLEX.	Packet loss and Packet delay.	In this paper importance of MPLS and the need to implement it in order to overcome the limitations provided by ATM.

CHAPTER THREE

SIMULATION RESULTS AND ANALYSIS

The purpose of this chapter is to give a quick overview of the simulation approaches used to study service quality. The simulation scenarios and network topologies utilized in the analysis are listed below. At the conclusion, the simulation experiments and their interpretation are discussed.

3.1 Overview of Simulation Tools

3.1.1 Graphical Network Simulator-3 (GNS3)

GNS3 is an emulator for network software that was initially released in 2008. It enables the use of both virtual and physical devices to mimic complicated networks [20]. Cisco IOS is simulated using Dynamics emulation software. [20] Many significant corporations, like Exxon, Walmart, AT&T, and NASA, employ GNS3, which is also popular for network professional certification exam preparation. The software has been downloaded 11 million times as of 2015.+[26] In this paper, a network architecture with XRv routers as edge routers and IOSv routers as core routers is implemented in a GNS3 environment.

3.1.2 VMware Workstation

It allows you to run numerous operating systems on a single Windows or Linux computer. Create real Linux and Windows virtual machines as well as other desktop, server, and tablet environments, complete with configurable virtual networking and network condition simulation, for use in code development, solution architecture, application testing, and product demonstrations, among other things.

3.1.3 GNS3 VM

The GNS3 VM is a requirement if you want to run Qemu based devices on Windows or Mac OS. It is a virtual machine that you import into VMware Workstation (recommended) or Virtual Box on your local PC when running a local version of the GNS3 VM. It can also be used in a distributed environment where you run the client software (GNS3-all-in-one) on your local PC and the GNS3 VM on a Hypervisor such as ESXi or the cloud.

3.1.4 Cisco Internetworking Operating System (IOS) images

Cisco routers and modern Cisco Network Switches use the IOS operating system software. The image file for Cisco IOS (Internetwork Operating System) is usually stored in flash memory and has a naming convention.

3.1.5 Ostinato

Ostinato is a user-friendly packet maker, network traffic generator, and analyzer. Create and deliver packets using multiple protocols at varied rates for several streams. Ethernet/802.3/LLC SNAP; ARP, IPv4, IPv6, IP-in-IP, IP Tunneling (6over4, 4over6, 4 Client-server architecture is also supported. It has the ability to build and configure sequential and interleaved streams of various protocols at various rates. A user-defined script [18] also allows for the addition of any unimplemented protocol.

3.1.6 Paessler Router Traffic Grapher (PRTG)

PRTG is a network monitoring tool that helps you to ensure that your computer systems are running smoothly and that no outages occur.

3.2 Simulation Scenarios and Network Topology

In the implementation phase, the enterprise network simulation framework Graphical Network Simulator-3 is used to establish a realistic environment, and two scenarios with various parameters are built to assess the performance of the Seamless MPLS and RSVP-TE Seamless MPLS. Ostinato is utilized in both situations to generate network traffic and analyze network efficiency using four QoS indicators. Finally, using PRTG network monitoring tools, test results for the two scenarios are retrieved from the simulator. Seamless MPLS architecture (scenario 1) and RSVP-TE Seamless MPLS architecture (scenario 2) are depicted in Figures 3.1 and 3.2, respectively. In both scenarios three MPLS domains are used where access and aggregation regions are in one MPLS domain and the core network is in another MPLS domain

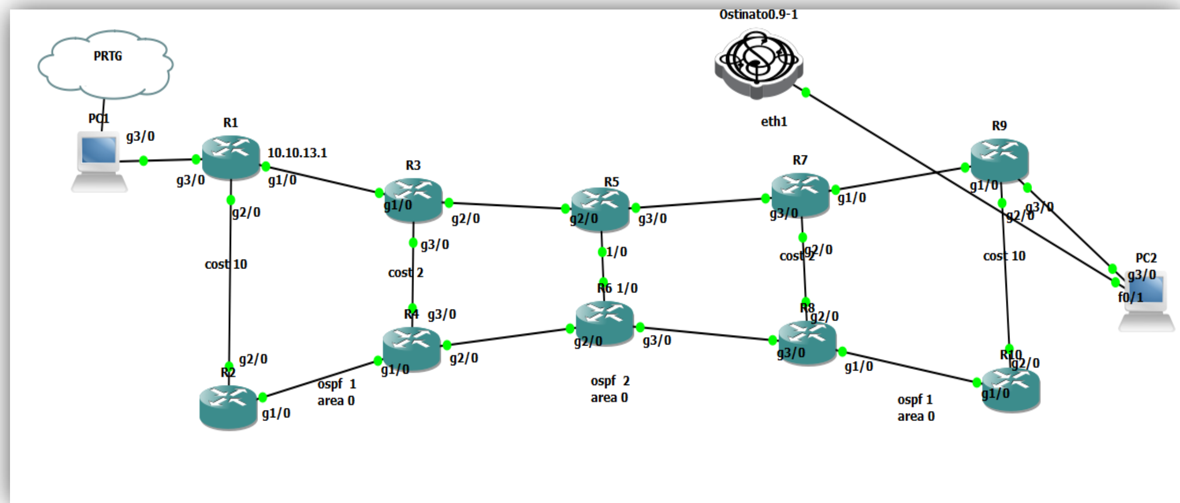

Figure 3.1: Seamless MPLS architecture

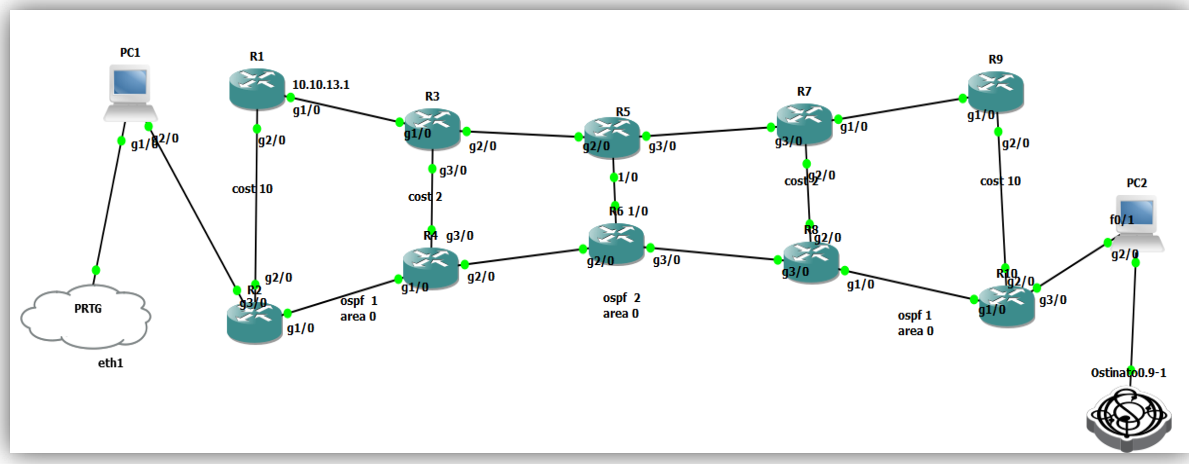

Figure 3.2: RSVP-TE Seamless MPLS architecture

3.3 Seamless MPLS Network topology details

Table 3.1: Topology details

Number of router	10
Number of links	14
Router model	7200
Router operating system	7200 Software (C7200-ADVENTERPRISEK9-M), Version 15.2(4)S3,
Cloud interface	Network monitoring (PRTG)
Ostinato	Traffic generator

3.4 Router interface configuration

Table 3.2: Router interface details

R1	10.10.10.1/32 is directly connected, Loopback0 10.10.10.9/32 is directly connected, Tunnel0 10.10.12.0/30 is directly connected, GigabitEthernet2/0 10.10.12.1/32 is directly connected, GigabitEthernet2/0 10.10.13.0/30 is directly connected, GigabitEthernet1/0
R2	10.10.10.2/32 is directly connected, Loopback0 10.10.12.0/30 is directly connected, GigabitEthernet2/0 10.10.12.2/32 is directly connected, GigabitEthernet2/0 10.10.24.0/30 is directly connected, GigabitEthernet1/0 10.10.24.1/32 is directly connected, GigabitEthernet1/0
R3	10.10.10.3/32 is directly connected, Loopback0 10.10.13.0/30 is directly connected, GigabitEthernet1/0 10.10.13.2/32 is directly connected, GigabitEthernet1/0 10.10.34.0/30 is directly connected, GigabitEthernet3/0 10.10.34.1/32 is directly connected, GigabitEthernet3/0 10.10.34.4/30 is directly connected, GigabitEthernet3/0.34 10.10.34.5/32 is directly connected, GigabitEthernet3/0.34 10.10.35.0/30 is directly connected, GigabitEthernet2/0 10.10.35.1/32 is directly connected, GigabitEthernet2/0
R4	10.10.10.4/32 is directly connected, Loopback0 10.10.24.0/30 is directly connected, GigabitEthernet1/0 10.10.24.2/32 is directly connected, GigabitEthernet1/0 10.10.34.0/30 is directly connected, GigabitEthernet3/0 10.10.34.2/32 is directly connected, GigabitEthernet3/0 10.10.34.4/30 is directly connected, GigabitEthernet3/0.34 10.10.34.6/32 is directly connected, GigabitEthernet3/0.34 10.10.46.0/30 is directly connected, GigabitEthernet2/0 10.10.46.1/32 is directly connected, GigabitEthernet2/0
R5	10.10.10.5/32 is directly connected, Loopback0 10.10.35.0/30 is directly connected, GigabitEthernet2/0 10.10.35.2/32 is directly connected, GigabitEthernet2/0 10.10.56.0/30 is directly connected, GigabitEthernet1/0 10.10.56.1/32 is directly connected, GigabitEthernet1/0 10.10.57.0/30 is directly connected, GigabitEthernet3/0 10.10.57.1/32 is directly connected, GigabitEthernet3/0
R6	10.10.10.6/32 is directly connected, Loopback0 10.10.46.0/30 is directly connected, GigabitEthernet2/0 10.10.46.2/32 is directly connected, GigabitEthernet2/0 10.10.56.0/30 is directly connected, GigabitEthernet1/0 10.10.56.2/32 is directly connected, GigabitEthernet1/0 10.10.68.0/30 is directly connected, GigabitEthernet3/0 10.10.68.1/32 is directly connected, GigabitEthernet3/0
	10.10.10.7/32 is directly connected, Loopback0 10.10.57.0/30 is directly connected, GigabitEthernet3/0 10.10.57.2/32 is directly connected, GigabitEthernet3/0 10.10.78.0/30 is directly connected, GigabitEthernet2/0

R7	10.10.78.1/32 is directly connected, GigabitEthernet2/0 10.10.78.4/30 is directly connected, GigabitEthernet2/0.78 10.10.78.5/32 is directly connected, GigabitEthernet2/0.78 10.10.79.0/30 is directly connected, GigabitEthernet1/0 10.10.79.1/32 is directly connected, GigabitEthernet1/0
R8	10.10.10.8/32 is directly connected, Loopback0 10.10.68.0/30 is directly connected, GigabitEthernet3/0 10.10.68.2/32 is directly connected, GigabitEthernet3/0 10.10.78.0/30 is directly connected, GigabitEthernet2/0 10.10.78.2/32 is directly connected, GigabitEthernet2/0 10.10.78.4/30 is directly connected, GigabitEthernet2/0.78 10.10.78.6/32 is directly connected, GigabitEthernet2/0.78 10.10.81.0/30 is directly connected, GigabitEthernet1/0 10.10.81.1/32 is directly connected, GigabitEthernet1/0
R9	10.10.10.9/32 is directly connected, Loopback0 10.10.79.0/30 is directly connected, GigabitEthernet1/0 10.10.79.2/32 is directly connected, GigabitEthernet1/0 10.10.91.0/30 is directly connected, GigabitEthernet2/0 10.10.91.1/32 is directly connected, GigabitEthernet2/0
R10	10.10.10.10/32 is directly connected, Loopback0 10.10.81.0/30 is directly connected, GigabitEthernet1/0 10.10.81.2/32 is directly connected, GigabitEthernet1/0 10.10.91.0/30 is directly connected, GigabitEthernet2/0 10.10.91.2/32 is directly connected, GigabitEthernet2/0

3.5 Router configuration for IP network

Each router in an IP network must be configured with routing protocols in order to advertise its network and to determine the path to the target address.

IP network configuration

Table 3.3: IP network details

Routing protocols	OSPF
Router	R1 up to R10

3.6 Router configuration for Seamless MPLS network

Tag switching must be enabled on all interfaces of a router that belongs to the MPLS domain in order to participate in an MPLS network. It's also a good idea to enable the protocol that publishes label numbers across the network (similar to how IP networks advertise subnets). RSVP makes advantage of the TE possibilities whereas LDP employs the MPLS forwarding technique. Tables 3.4 and 3.5 demonstrate the MPLS network configuration details.

MPLS network configuration

Table 3.4: MPLS network details

Routing protocols	Multi process number OSPF
Label distribution protocol	LDP

Table 3.5: Seamless MPLS-TE tunnel details

Tunnel number	Source	Destination
tunnel0	10.10.10.1	10.10.10.9
tunnel0	10.10.10.9	10.10.10.1
Label distribution protocol	RSVP-TE	

Table 3.6: Unified MPLS components

Routing protocol and label distribution	Three BGP domains
BGP 3107	R1 to R3 ,R3 to R7 and R7 to R9

3.7 Simulation Parameters Analysis

3.7.1 Throughput Analysis

The amount of data sent or received by a network or entity, or the amount of data processed in a certain time period, is referred to as throughput. Bits per second (bit/s or bps) are the basic units of measurement. Due to system losses and delays, the throughput may be lower than the input tax. Throughput is a good indicator of a communications link's channel capacity. To calculate the throughput, we must first determine how much data is being communicated and how long it takes to complete the data transmission. For both situations (Seamless MPLS (SMPLS) and RSVP TE-SMPLS), a traffic generator is employed to produce traffic at a rate of 1Mbps into the network. During the simulation, PRTG collects relevant information including traffic in, traffic out and total traffic. For different file sizes the test results for both scenarios are tabulated in the Table 3.7 shown below.

Table 3.7: Output of Throughput for Seamless MPLS and RSVP TE-Seamless MPLS at different file sizes

File size(bytes)	100	200	300	400	500	600	800	1100
Average RTT (Sec) for Seamless- MPLS	10.07	11.93	14.3	15.3	16.61	17.32	23.03	28.81
Average RTT (Sec) for RSVP-TE Seamless- MPLS	6.8	8.34	8.8	9.75	12.15	14.46	18.37	24.05
Throughput Seamless-MPLS (Kbps)	79.44	134.1	167.8	209.15	240.8	277.13	277.9	305.4
Throughput RSVP-TE Seamless-MPLS (Kbps)	117.6	191.8	272.7	328.2	329.2	331.95	348.4	365.9

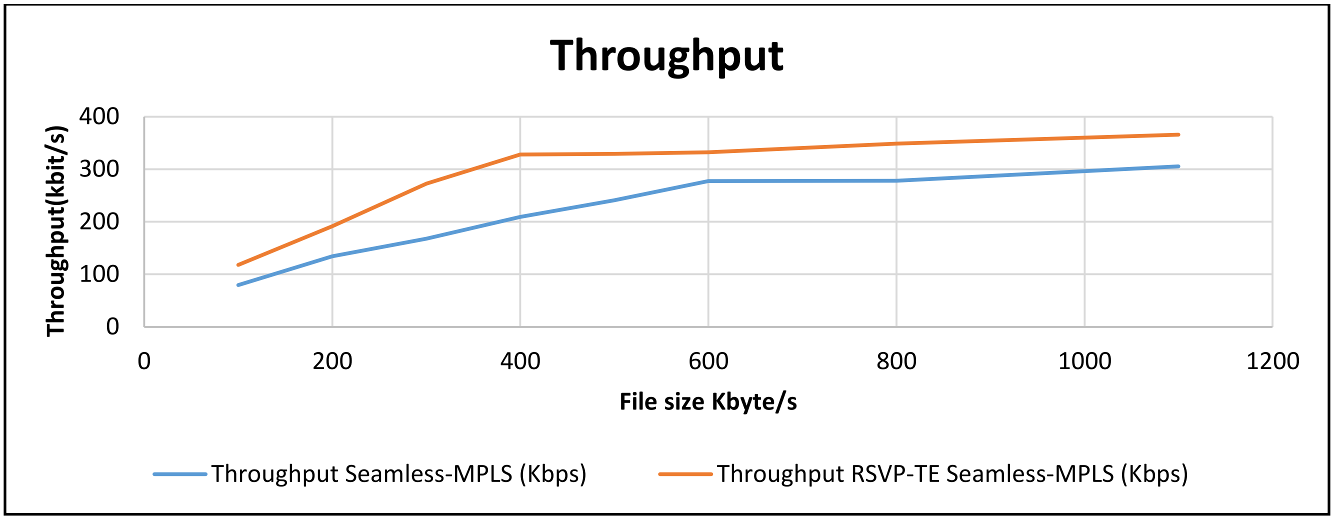

Figure 3.1: Graph of throughput for scenarios 1 and 2

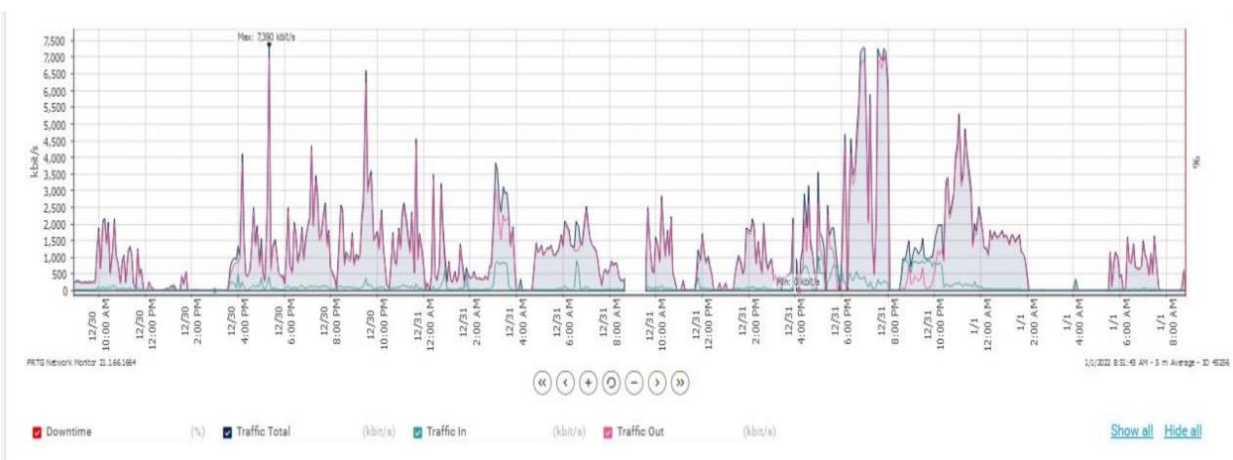

Figure 3.2: PRTG Graph of throughput for scenarios 1 and 2

Figure 3.3 displays a graph of simulation throughput results. At small file sizes, there is no notable difference in performance between the two scenarios, but as file sizes grow larger, RSVP-TE Seamless MPLS outperforms Seamless MPLS. For example, if we compare file sizes of 1100Kbytes, the throughput difference is approximately 104.9Kbps, or 19.8%. There are several reasons why RSVP-TE Seamless MPLS has a higher throughput than Seamless MPLS.

3.7.2 Latency Analysis

The ITU-T recommendation for maximum end-to-end latency is 150ms. Although the Same topology setup as in the throughput analysis is used for latency analysis, The ICMP (Internet Control Message Protocol) ping test type is used to send test probe. To collect the average completion time of each test probe at different data sizes as shown in Table 3.8. Network traffic is generated end-to-end traffic and PRTG collects the minimum, maximum and average delay of sending test message. For the simulation three congestion levels are considered: data rate less than link bandwidth, data rate equal to link bandwidth and data rate less than link bandwidth.

Table 3.8: Output of latency for Seamless MPLS and RSVP TE-Seamless MPLS at different file sizes

File size(bytes)	**100**	**200**	**300**	**400**	**500**	**600**	**800**	**1100**
Ave Completion Time(ms) for Seamless MPLS	58	64	75	85	94	106	117	127
Ave Completion Time(ms) for RSVP-TE Seamless MPLS	54	56	68	79	81	94	102	110
Latency different	2	8	7	6	13	12	15	17
Latency different in %	4	14	10.29	7.59	16.04	12.76	14.7	15.45

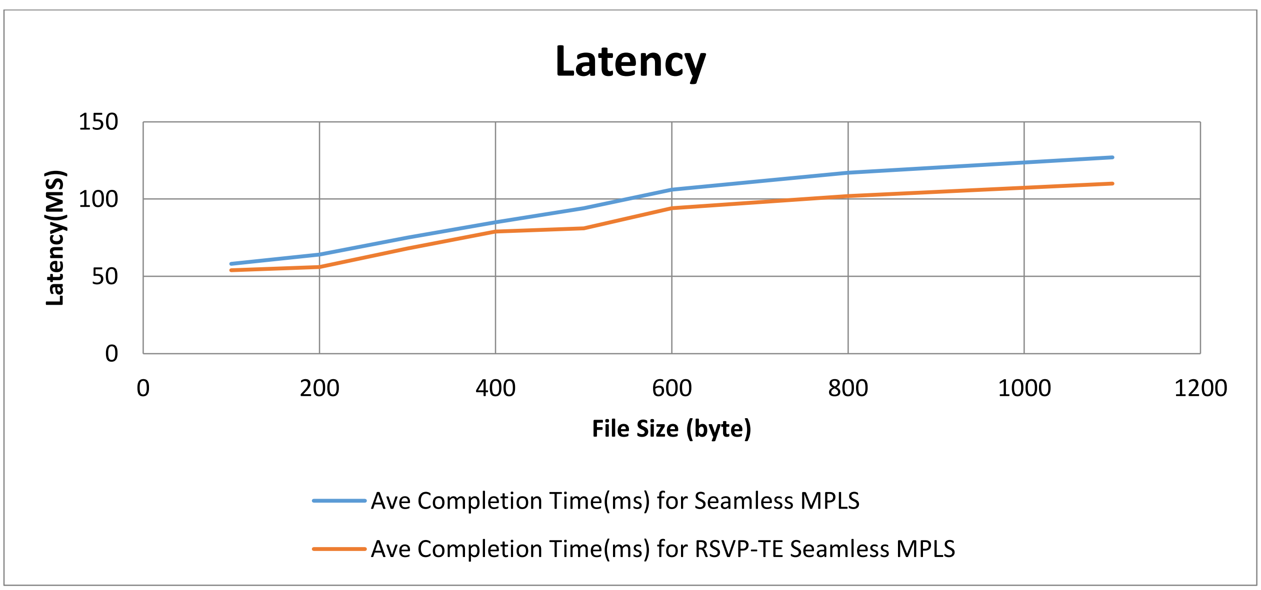

Figure 3.3: Graph of latency for scenarios 1 and 2

The latency versus file size graph in Figure 3.5 shows that the Seamless MPLS (Scenario 1) has higher latency than Seamless RSVP-TE MPLS (Scenario 2). On average the latency difference between the two scenarios is about 21.4%. That is the latency of Seamless RSVP-TE MPLS is improved on average by 10s (i.e. 21.45%) compared to the Seamless MPLS counterpart.

3.7.3 Packet Loss Analysis

When one or more packets of data being transmitted through the internet or a computer network fail to reach their destination, this is known as packet loss. Signal degradation, excessive loads on network lines, malformed packets being deleted, and network element defects can all cause packet loss. The recommended value for packet loss according to ITU standards is less than 3%. Congestion is chosen as a source of packet loss in this study, which means that the links in the network are purposely congested by utilizing network traffic generators to bring additional network traffic into the network. ICMP test type is used to send test probes at three conditions i.e data rate less than link bandwidth, data rate equal to link bandwidth and data rate greater than link bandwidth.

Table 3.9: Output of packet loss for Seamless MPLS and RSVP-TE Seamless MPLS at different file sizes

File size(bytes)	**20**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**8000**
Packet Loss for Seamless MPLS	0	0	0	0	1	4	12	22
Packet Loss for RSVP-TE Seamless MPLS	0	0	0	0	0	2	8	13
Packet Loss different	0	0	0	0	1	2	4	18
Packet Loss in %	0	0	0	0	1	1		

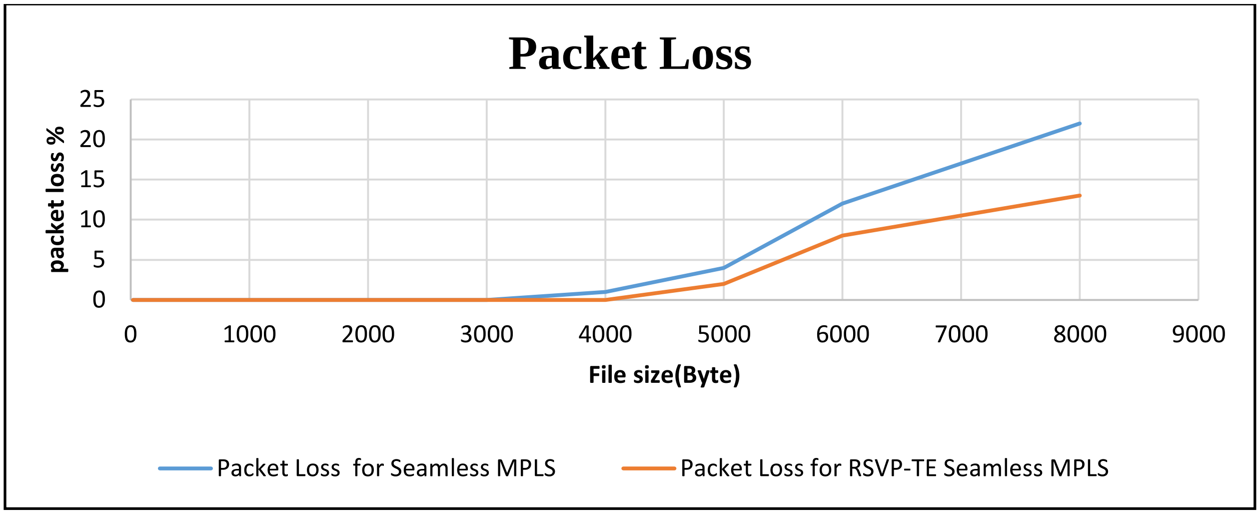

Figure 3.4: Graph of packet loss for scenarios 1 and 2

As shown in Table Figure 3.6 the other method by which RSVP-TE Seamless MPLS minimizes the effects of congestion and link failure is by using fast reroute and pre-computed alternative routes. These mechanisms help to use alternative paths and nodes in a sub-second to reduce packet loss. The performance of RSVP-TE Seamless MPLS is much better than Seamless MPLS

3.7.4 Jitter Analysis

Jitter is the delay variation and is introduced by the variable transmission of delay of the packets over the network. This can occur because of routers' internal queues behavior in certain circumstances (e.g. flow congestion), routing changes, etc. This parameter can seriously affect the quality of streaming audio and/or video. To handle jitter, it is needed to collect packets and hold them long enough until the slowest packets arrive in time, rearranging them to be played in the correct sequence. Jitter buffers can be observing when using video or audio streaming websites (e.g. YouTube) and are used to counter jitter introduced by the internet so that a continuous play out of the media transmitted over the network can be possible. When clicking in a link to play the video, buffering starts before the media stream actually does. This procedure causes additional delay, but is necessary in the case of jitter sensitive applications. We can simulate and calculate the jitter values using the same procedures and scenarios as for the other parameters. Network congestion is a common jitter factor and our simulation considered it primarily for jitter analysis.

Table 3.10: Output of jitter for Seamless MPLS and RSVP-TE Seamless MPLS at different file sizes

File size(bytes)	36	1000	2000	3000	4000
Jitter (ms) for Seamless MPLS	10	14	16	17	19
Jitter (ms) for RSVP-TE Seamless MPLS	7	10	12	14	16

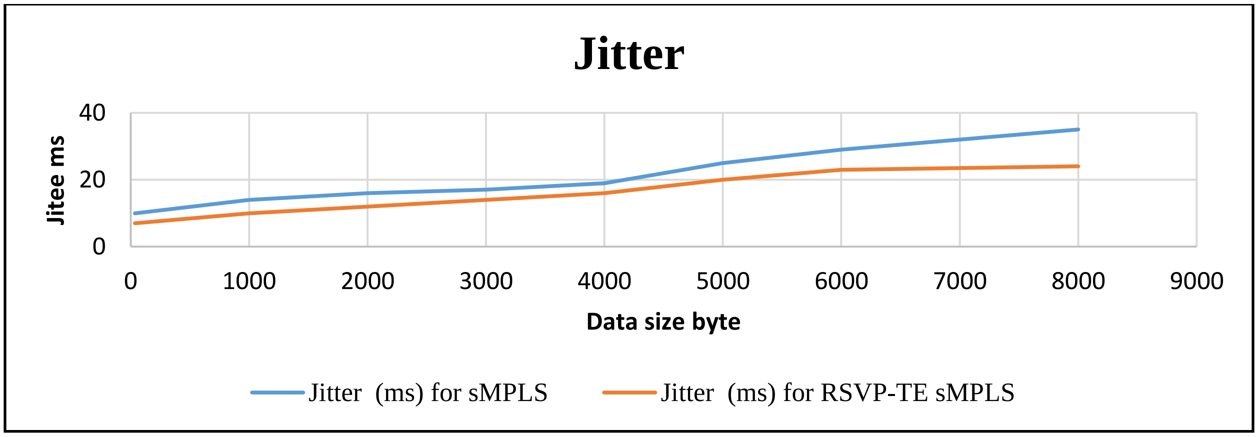

Figure 3.5: Graph of Jitter for scenarios 1 and 2

As shown in Figure 3.7, the simulation results of average jitter for RSVP-TE Seamless MPLS is smaller than that of Seamless MPLS. Take data size of 8000 bytes for example, the jitter difference is about 3ms (i.e. 12.5%). This performance difference between the two scenarios have significant impact on jitter sensitive real time traffic such as voice, video conference, live streaming, etc.

3.8. Comparative Analysis of Results

Author	Improved QoS Feature(s)	Technique/Approach Used	Tool(s) Used	Metrics Used	Gap(s) Identified	Compare
Yalemzewd MB [24]	Impact of Segment Routing MPLS on end-to-end QoS parameter of SR-MPLS QoS.	Buffers packets in queues upon network congestion and use a scheduling algorithm to determine the forwarding order. Monitors network resource usage and drops packets to mitigate network overload if congestion worsens.	Emulated Virtual Environment -Next Generation (EVE-NG)	Delay, Jitter, Packet loss and Packet sequencing.	SR-domain with LDP only capable routers on endto-end QoS as most of the router especially in the access domain may not be SRMPLS capable.	Quality of service of seamless MPLS by applying resource reservation protocol (RSVP) End-to-end users.
Heng Luo [37]	Mobile ad hoc network (MANET), Best Effort QoS Support Routing in	Routing protocols DSDV, a typical proactive protocol and DSR, a typical reactive protocol and rank them accordingly.	GloMoSim, OPNET, QualNet and MATLAB	Delay, jitter and throughput.	Not multiple access techniques such as Bluetooth and MANETs.	Techniques through TE, Seamless MPLS limitations with influence on TE
Yalemzewd Negash [40]	end-to-end network QoS performance by classical MPLS.	Nonstop active routing (NSR)-enabled control plane protocols. loop-free alternate (LFA) support for ISIS, OSPF and LDP.	Enterprise Network Simulation Platform (eNSP), Network Quality Analyzer (NQA), Ostinato	Throughput, latency, packet loss and jitter	Border Gateway Protocol (BGP) does not support QoS implementation across multiple domains (inter-domain or inter-AS).	Support QoS implementation with MPLS.
Omair Ahmad and Shakeel	MPLS over ATM method of media traffic	Technique for traffic engineering and functioning	Cisco Packet Tracer	Throughput, queuing delay and Bandwidth	Using MPLS that not helped to replace	Evolved through ATM and frame relay VAN networks;

Ahmed[2]	routing.	of multiple services and it adds up the benefits like having greater scalability that can improve network operations.			Frame Relay, dedicated leased lines and offers a new option for WAN connectivity.	MPLS uses labels to advertise between different routers by means of label mapping through label switching mechanism
Fathurrahmad and Salman Yusuf [5]	MPLS VPN networks and providing a stable network bandwidth efficiency and is used at AMIK.	MPLS works on packages with MPLS headers, traffic engineering processes and implement a VPN network	GNS3, Microsoft Visio Network Design 2016 and Virtual Machines.	Bandwidth and throughput.	That may not produce realistic network performance related results	The resulting LSPs are then used to relay label traffic over the MPLS network.
This Work	Improve the QoS of Seamless MPLS networks by applying resource oriented traffic engineering techniques.	QoS services in MPLS implementation and communication techniques through TE.	Graphical Network Simulator-3 (GNS3, Mware Workstation and GNS3 VM	Bandwidth, jitter, delay and packet loss.	Independent network traffic treatment for customer VPN and traffic classification.	MPLS by applying (RSVP) End-to-end users. Techniques through TE, Seamless MPLS.

CHAPTER FOUR

CONCULUSIONS AND FUTRURE WORKS

4.1 CONCLUSIONS

In this article, the quality of service seamless multiprotocol level switching is compared to two network scenarios, one with RSVP-TE seamless MPLS and the other without. We employed four KPIs of QOS characteristics to analyze and compare Seamless MPLS with RSVP-TE Seamless MPLS: throughput, latency, packet loss, and jitter. To analyze the lap report, we use GNS3 to establish the two topologies with the needed configuration files, Ostinato to produce network traffic, PRTG network monitoring tools to collect data, and PRTG and Excel to present the results. RSVP-TE allows user packets to be tunneled inside an RSVP LSP to an LDP far-end destination (with the benefits of RSVP LSPs, fast-reroute (FRR), and traffic engineering (TE)) and does not follow the IGP, making separate judgments on reserved traffic.

This functionality is primarily used to implement MPLS-based services, such as VPRN, VLL, and VPLS, in big networks where a full mesh of LSPs has reached its scalability constraints. In general, we find that the RSVP-TE Seamless MPLS was more reliable than seamless MPLS based on the analyses and results obtained.

4.2 CONTRIBUTIONS

Operators of MPLS networks, such as Ethio telecom, must optimize their existing network infrastructure, expand the options accessible to existing services, and maybe generate new service offerings without investing more resources. Segment Routing (SR) provides the necessary capability to meet these requirements. In addition to MPLS core networks, many service providers, like Ethio telecom, have introduced mobile backhaul. The interconnection, as well as service delivery, between these multiple domains, should be smooth, with no additional delay, signaling protocol overhead, or flexibility issues, ensuring the best end-to-end QoS and resource usage. Using new emerging technologies, this thesis intends to improve end-to-end network QoS performance by optimizing the Unified MPLS, which is based on SR architecture. This reduces the limits of traditional MPLS architecture and improves service delivery scalability, resource usage, and flexibility in any telecommunications business. For organizations, the study will provide a better knowledge of concepts for information about

MPLS importance, usage, and deployment. MPLS is a novel technology for designing and implementing QoS services and application classes that are reliable, secure, efficient, and standard. For traffic engineering and multicasting, this technique will provide long-term solutions. Internet service providers, satellite operators, and network providers are all involved in the investigation of IP and MPLS in satellite Internet.

This thesis aims to improve end-to-end network QoS performance by using newly emerging technologies to optimize the traditional MPLS architecture. This reduces the limits of traditional MPLS architecture while also increasing the scalability and flexibility of service delivery in any telecommunications industry. It provides new ways of thinking and methodologies to networking systems research in general. The researcher have tried to look at my participation MPLS and simulation MPLS, But then given the time we have and also have seen things in science and tried to apply what we can able. Although the researcher did not make a big contribution to science by doing this, we knew what the study needed to know.

4.3 FUTURE WORKS

While the thesis has accomplished all of the objectives set forth in Chapter One, there are still some concerns to be resolved.

- The following are the inquiries: Study and implement a seamless MPLS solution in Ethiopian telecommunications networks. It is first necessary to identify the different types of routers (or devices) that are utilized in an end-to-end IP network. MPLS and Seamless MPLS capability must be checked on the access devices.
- For independent network traffic treatment, analyze the service per customer VPN and traffic classification.

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APPENDIXES

Appendix: Scripts for Seamless MPLS Configuration and RSVP-TE

Seamless MPLS Configuration

PE_1#show running-config

```
Building configuration...
Current configuration : 3291 bytes
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
!
hostname PE_1
!
boot-start-marker
boot-end-marker
!
vrf definition VPN1
 rd 65108:20
 !
address-family ipv4
route-target export 65108:10
route-target import 65108:10
 exit-address-family
!
no aaa new-model
no ip icmp rate-limit unreachable
!
```

```
no ip domain lookup
ip cef
no ipv6 cef
!
mpls traffic-eng tunnels
!
mpls traffic-eng path-option list name R3-R4-R6-R8-R7-R9
 path-option 1 explicit identifier 1
multilink bundle-name authenticated
!
ip tcp synwait-time 5
!
interface Loopback0
 ip address 10.10.10.1 255.255.255.255
!
interface Tunnel0
 ip unnumbered Loopback0
 tunnel mode mpls traffic-eng
 tunnel destination 10.10.10.9
 tunnel mpls traffic-eng path-option 1 explicit name TO_R4
 tunnel mpls traffic-eng record-route
!
interface FastEthernet0/0
 no ip address
 shut down
 speed auto
 duplex auto
```

```
!
interface FastEthernet0/1
 no ip address
 shut down
 speed auto
 duplex auto
!
interface GigabitEthernet1/0
 description TO.....R3
 ip address 10.10.13.1 255.255.255.252
 ip ospf network point-to-point
 negotiation auto
 mpls ip
 mpls label protocol ldp
 mpls traffic-eng tunnels
!
interface GigabitEthernet2/0
 description TO....PE_2(R2)
 ip address 10.10.12.1 255.255.255.252
 ip ospf network point-to-point
 ip ospf cost 10
 negotiation auto
 mpls ip
 mpls label protocol ldp
 mpls traffic-eng tunnels
!
interface GigabitEthernet3/0
 vrf forwarding VPN1
```

```
 ip address 10.130.200.1 255.255.255.252
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet5/0
 no ip address
shut down
negotiation auto
!
interface GigabitEthernet6/0
no ip address
shut down
 negotiation auto
!
router ospf 1
 router-id 10.10.10.1
 passive-interface Loopback0
 network 10.10.0.0 0.0.255.255 area 0
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng area 0
!
router bgp 65108
 bgp log-neighbor-changes
 neighbor 10.10.10.3 remote-as 65108
```

```
 neighbor 10.10.10.3 update-source Loopback0
 neighbor 10.10.10.4 remote-as 65108
 neighbor 10.10.10.4 update-source Loopback0
 neighbor 10.10.10.9 remote-as 65108
 neighbor 10.10.10.9 update-source Loopback0
 !
 address-family ipv4
  network 10.10.10.1 mask 255.255.255.255
  neighbor 10.10.10.3 activate
  neighbor 10.10.10.3 send-label
  neighbor 10.10.10.4 activate
  no neighbor 10.10.10.9 activate
 exit-address-family
 !
 address-family vpnv4
  neighbor 10.10.10.9 activate
  neighbor 10.10.10.9 send-community extended
 exit-address-family
 !
 address-family ipv4 vrf VPN1
 redistribute connected
 redistribute static
 default-information originate
exit-address-family
!
ip forward-protocol nd
!
!
```

```
no ip http server
no ip http secure-server
ip route 10.10.10.9 255.255.255.255 Tunnel0
ip route vrf VPN1 0.0.0.0 0.0.0.0 10.130.200.2
!
ip explicit-path name TO_R4 enable
next-address loose 10.10.10.4
next-address loose 10.10.10.8
!
route-map TO_TE permit 10
 set interface Tunnel0
!
mpls ldp router-id Loopback0
!
control-plane
!
line con 0
exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
 line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
 line vty 0 4
 login
```

end

PE_2#show running-config

Building configuration...

Current configuration : 2018 bytes

!

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

!

hostname PE_2

!

boot-start-marker

boot-end-marker

!

no aaa new-model

no ip icmp rate-limit unreachable

!

no ip domain lookup

ip cef

no ipv6 cef

!

mpls traffic-eng tunnels

multilink bundle-name authenticated

!

ip tcp synwait-time 5

!

interface Loopback0

ip address 10.10.10.2 255.255.255.255

```
!
interface FastEthernet0/0
no ip address
shut down
speed auto
duplex auto
!
interface FastEthernet0/1
no ip address
shut down
speed auto
duplex auto
!
interface GigabitEthernet1/0
 description TO.....R4
 ip address 10.10.24.1 255.255.255.252
 ip ospf network point-to-point
 negotiation auto
 mpls ip
 mpls label protocol ldp
 mpls traffic-eng tunnels
!
interface GigabitEthernet2/0
 description TO......PE1(R1)
 ip address 10.10.12.2 255.255.255.252
 ip ospf network point-to-point
 ip ospf cost 10
 negotiation auto
```

```
 mpls ip
 mpls label protocol ldp
 mpls traffic-eng tunnels
!
interface GigabitEthernet3/0
 no ip address
 shut down
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shut down
negotiation auto
!
interface GigabitEthernet5/0
no ip address
shut down
negotiation auto
!
interface GigabitEthernet6/0
no ip address
shut down
negotiation auto
!
router ospf 1
router-id 10.10.10.2
passive-interface Loopback0
network 10.10.0.0 0.0.255.255 area 0
```

```
mpls traffic-eng router-id Loopback0
mpls traffic-eng area 0
!
router bgp 65108
bgp log-neighbor-changes
neighbor 10.10.10.3 remote-as 65108
neighbor 10.10.10.3 update-source Loopback0
neighbor 10.10.10.4 remote-as 65108
neighbor 10.10.10.4 update-source Loopback0
!
ip forward-protocol nd
!
no ip http server
no ip http secure-server
!
mpls ldp router-id Loopback0
!
control-plane
!
line con 0
exec-timeout 0 0
privilege level 15
logging synchronous
stopbits 1
line aux 0
exec-timeout 0 0
privilege level 15
logging synchronous
```

stopbits 1

line vty 0 4

login

end