EBB4034 FINAL YEAR PROJECT II

OPTIMIZATION OF MOBILE TRANSPORT NETWORK USING INTERNET PROTOCOL/MULTI-PROTOCOL LABEL SWITCHING (IP/MPLS) APPROACH

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CERTIFICATION OF APPROVAL

Optimization of Mobile Transport Network using

Internet Protocol/Multi-Protocol Label Switching (IP/MPLS) Approach

by

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Approved:

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project. The work is of my own except as specified in the references and acknowledgements, and the original work contained in the report have not been undertaken by any unstipulated sources.

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NGO LIP CHEE

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ABSTRACT

This report focuses on a research-based project of the title 'Optimization of Mobile Transport Network using Internet Protocol/Multi-Protocol Label Switching (IP/MPLS) Approach'. Current protocols utilized in mobile transport network are approaching a saturation point in terms of capacity to cater for a massive consumer demand growth in the network. Persistence on the conventional approaches will require much more expenditure with less encouraging revenue. Thus, much work need to be pumped into a newer and more effective alternative namely IP/MPLS. An upgrade of support node gateways and a network transmission algorithm are key elements of the project. A performance assessment of the proposed algorithm based on the Quality of Service (QoS) is also very crucial. Validation of the algorithm via the "OPNET" modeler suite software simulation results analysis is also to be carried out to define the best gateway for mapping process. A robust and flexible IP/MPLS approach will consequently results in a better network performance thus providing more opportunities for a more dynamic network growth for the benefit of mankind. The resulting approach can be further improved via continuous research and development (R&D) to produce a more reliable and resilient protocol. IP/MPLS will surely provide the vital boost to usher in the next generation of networking.

ACKNOWLEDGEMENT

First and foremost, I would like to convey my appreciation to my project supervisor, Dr. Mohd Zuki Yusoff and graduate assistant (G.A), Mr. Firas Ousta for all the valuable guidance and encouragement throughout the project leading to the achievement of the objectives backed up with satisfactory results. I would also like to express my gratitude to my parents and colleagues for all sincere support and assistance without any hint of hesitation. Last but not the least, I would like to thank those who were involved directly or indirectly in making the project a success. Thank you.

List of Figures and Tables

Abbreviations and Nomenclature

ARP	Allocation/Retention Priority
ATM	Asynchronous Transfer Mode
BE	Bandwidth Engineering
CAPEX	Capital Expenditure
CR-LDP	Constraint-based Routing Label Distribution Protocol
DES	Discrete Event Simulation
DiffServ	Differentiated Service
DSCP	Differentiated Service Code Point
E2E-QoS	End-to-End Quality of Service
FEC	Flow Equivalence Class
GBR	Guaranteed Bit Rate
GGSN	Gateway GPRS Support Node
GPRS	General Packer Radio Service
GUI	Graphical User Interface
IETF	Internet Engineering Task Force;
IGP	Internet Gateway Protocol
IntServ	Integrated Service
IP	Internet Protocol
LER	Label Edge Router
LSP	Label Switched Path
LSR	Label Switch Router
LTE	Long Term Evolution

MBR	Maximum Bit Rate
MLTE	Multi-Layer Traffic Engineering
MPLS	Multi-Protocol Label Switching
OPEX	Operating Expenditure
OPNET	Optimized Network Engineering Tools
OSI	Open System Interconnections
OSPF	Open Shortest Path First
QoS	Quality of Service
R&D	Research and Development
RIP	Routing Information Protocol
SGSN	Serving GPRS Support Node
SLIP	Serial Line Internet Protocol
TCO	Total Cost of Ownership
TCP	Transmission Control Protocol
TE	Traffic Engineering
THP	Traffic Handling Priority
TOS	Type of Service
UDP	User Datagram Potocol
UMTS	Universal Mobile Telecommunications System
WiMAX	Worldwide Interoperability for Microwave Access

CHAPTER 1: INTRODUCTION

1.1 Background of Study

The format and the order of messages exchanged; transmitted or received between dual or multi-entities depicts a protocol [1]. Different communication tasks are accomplished via a variety of protocols. Kurose and Ross [1] specified that the format of the packets (packages of information) interchanged between routers and end systems each with a unique address are governed by the Internet Protocol (IP). The absence of a continuous connection between communicating end points provides IP with a connectionless characteristic for packet transfer across an internetwork.

The IP also offers best effort services in delivering packets; packages of information [2]. It means no additional actions are taken when packet deliveries complications arise [2]. Furthermore, Dye, McDonald, and Rufi [3] mentioned "IP is unaware of its job quality performance and has no means of informing the sender about reliability problems". This leads to the establishment of Integrated Service (IntServ) and Differentiated Service (DiffServ) strategies by Internet Engineering Task Force (IETF) to guarantee Quality of Service (QoS) over IP networks.

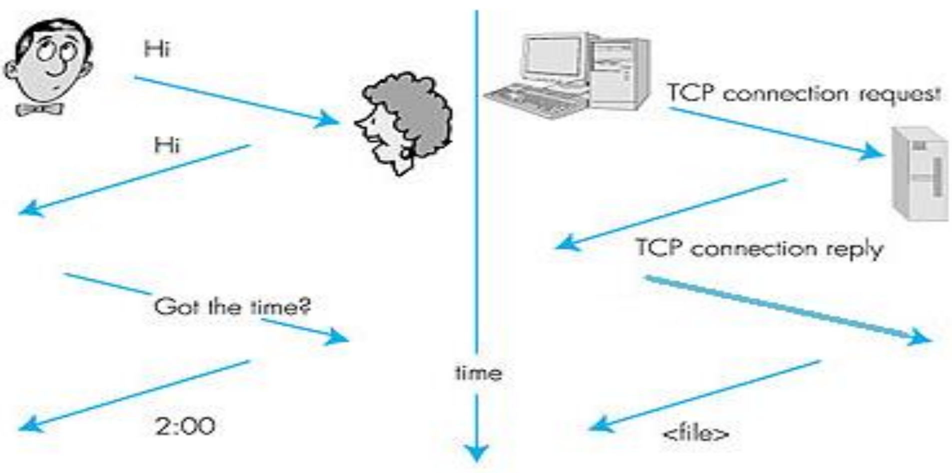

Figure 1: Human Protocol versus Internet Protocol (IP) [15]

In addition, Multi Protocol Label Switching (MPLS) protocol is another QoS approach with promising prospects to be implemented in the next generation networks. Internet Protocol/Multi-Protocol Label Switching (IP/MPLS) has greatly developed as a foundation for various networks [4]. Significant impacts brought forth by IP/MPLS includes the fusion distinct mobile transport networks for different radio technologies, reduction of the operating expenditures (OPEX), and convergent networks on a robust and consistent infrastructure [4].

Furthermore, IP/MPLS also offer a boost to Long Term Evolution (LTE) and mobile Worldwide Interoperability for Microwave Access (WiMAX) technologies [5]. The implementation of MPLS/DiffServ enabled IP backbone takes advantage of MPLS traffic engineering capability and the quality of service guaranteed by DiffServ approach [11]. However, to utilize a MPLS/DiffServ based backbone network, QoS parameter mapping should be applied.

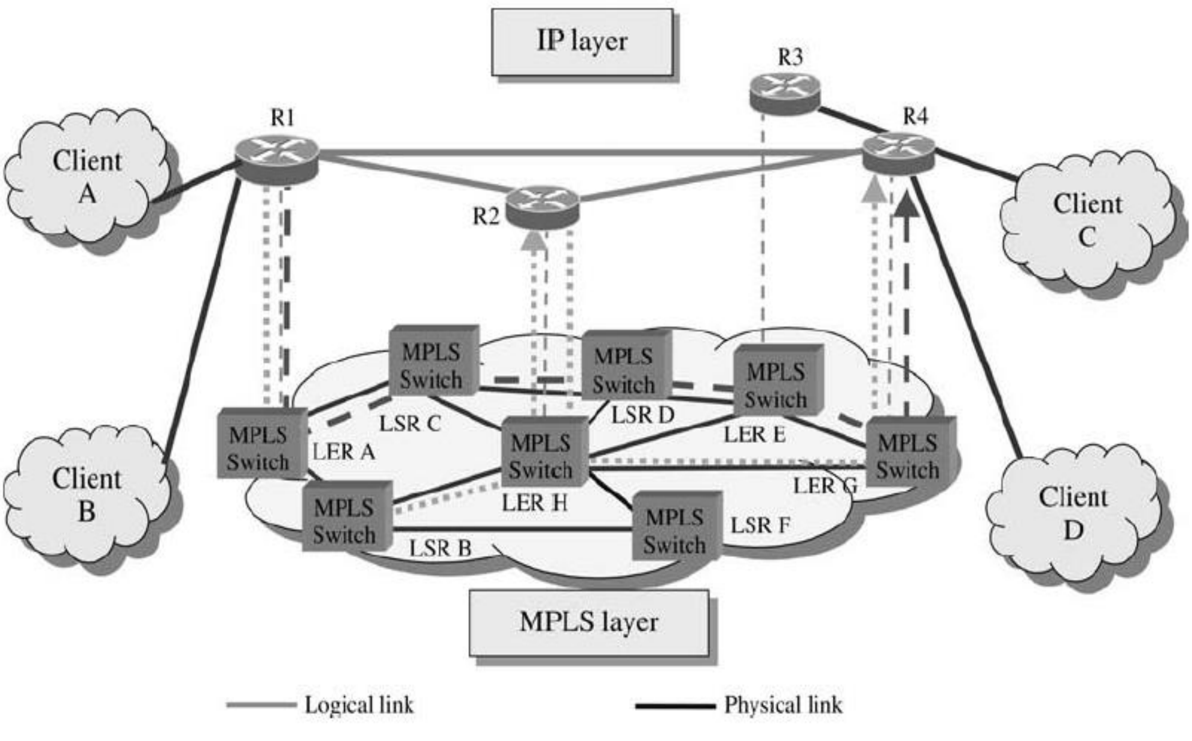

Figure 2: IP/MPLS Reference Scenario [12]

1.2 Problem Scenario

New 3G-data services are a medium of revenue generation for mobile operators. However, greater mobile backhaul costs are necessary for a substantial increase in bandwidth essential for the services' operation [4]. Higher expenses will be a major setback for the conventional expansion of the backhaul network to cater for the escalating bandwidth requirements. Network costs overshadowing service revenues will ultimately result in a catastrophic mobile network.

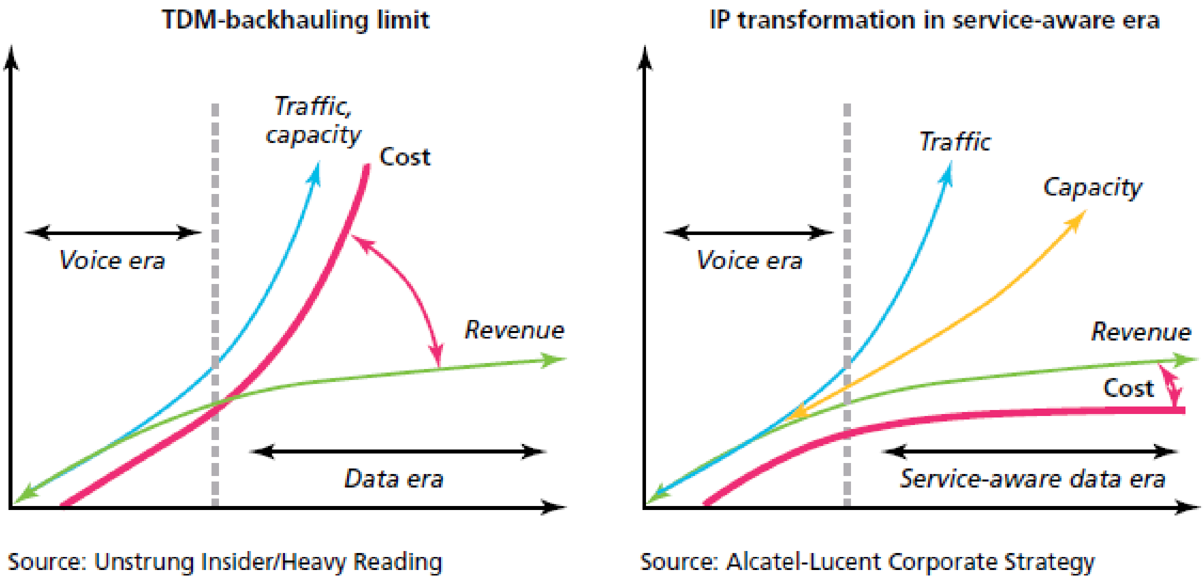

Figure 3: Decoupling Transport Costs, Capacity and Revenues [4]

Inevitably, data demand significantly outweighs the available network capacity. Therefore, proactive measures should be drafted and implemented for an urgent network upgrade. Quality of Service (QoS) and Resiliency Management are keys points to ponder on for the migration towards packet-based backhaul networks [6]. In addition, a concurrent accommodation of many generations of technologies and the ability to cater for 4G or LTE is vital in mobile backhaul networks [6].

Traffic engineering in assorted networks is very crucial in the functionality of the public Internet backbone networks due to the escalating requirements for a greater quality of service. One of the main aim traffic engineering is to assist the smooth transport of IP traffic through a given network in the most efficient manner utilizing the available network resources. Limited functionality of conventional IP routing had hampered traffic engineering in the Internet thereby limiting the quality of service. Recent developments in technologies such as multiprotocol label switching have brought up new possibilities in addressing the limitations of conventional routing.

1.3 Problem Statement

Greater mobile backhaul costs will be prominent due to substantial bandwidth increase requirement. This will ultimately inhibit a progressive mobile network growth.

1.4 Objective(s) and Scope of Study

1.4.1 Objectives

The aim of the project is to examine the use of IP/MPLS as a transport network to optimize end-to-end quality of service (E2E-QoS) over the Universal Mobile Telecommunications System (UMTS) wireless systems. The following measures will be taken to in accordance with the project's objective:

1. An upgrade of Gateway GPRS Support Node (GGSN) and Serving GPRS Support Node (SGSN) gateways to perform QoS parameter mapping between MPLS/DiffServ and Universal Mobile Telecommunications System (UMTS) Classes of Service.
2. An algorithm for the transmission UMTS originating traffic across MPLS/DiffServ enabled IP core backbone network.
3. Evaluation of the proposed algorithm's level of performance by studying the performance, from QoS point of view, for one application.
4. Analysis of the simulation results based on the OPNET software to conclude the best gateway for mapping processes.

1.4.2 Scope of Study

1. Fundamentals of networking.
    - Computer Networks and the Internet
    - Transport Layer
    - The Network Layer
2. Transmission Control Protocol/Internet Protocol (TCP/IP).
3. Multi-Protocol Label Switching (MPLS).
4. Optimized Network Engineering Tools (OPNET) modeler suite.

1.5 Relevancy and Feasibility

This research-based project aims to put forth IP/MPLS as an alternative to conventional protocol utilized in the mobile transport network. IP/MPLS boasts higher scalability and also provides legacy service support [7]. These two traits are essential in order to cater for the accelerating bandwidth requirement in accordance to the rapid growth of subscribers in the mobile network. The mobile backhaul costs will be a crucial criteria be considered. An IP/MPLS based network will benefit from reduced latency and jitter, and improved QoS performance for delay-sensitive traffics. This will consequently lead to optimized operating costs.

Within the timeframe for the Final Year Project; FYP I and FYP II, a carefully devised plan is devised for specific tasks. This is to ensure the achievement of vital milestones set at the initial stage of the project itself. These milestones will serve as checkpoints en-route to achieving the ultimate goal of the project by the end of FYP II. Within the two semesters, major project activities will revolve around research and software simulation. The information gathered from the research activities will contribute necessary data for the OPNET modeler suite simulation to be carried out. Important parameter extracted from the simulation results will be thoroughly analyzed.

1.6 Organization of Report

In this proposal, optimization of the mobile transport using Internet Protocol/Multi-Protocol Label Switching (IP/MPLS) is being discussed. The introduction reveals the background of study, problem statement, and the aim of the project. The literature review further discusses on the project in accordance to previous work done in related fields and highlights its significance in a technologically progressive world today. The methodology section deliberates on the implementation of specific approach towards achieving the project's objective. The project is more inclined towards a research approach while incorporating the OPNET software for simulation purpose. The results and discussion section contains analysis of the vital network parameters extracted from the simulation results. The last section consists of the conclusion drawn based on the project findings and also some relevant recommendations for future work.

CHAPTER 2: LITERATURE REVIEW

In a progressive technology-oriented community, a constant soaring demand for more service ultimately gives rise to some issues in the network. A significant demand boom impairs the network operators attempt to balance out the data traffic density with the existing network bandwidth via conventional approaches. Projected expenditures also greatly overshadow the trend of revenue generated. This scenario initiates an extensive effort being harnessed in coming up with a sustainable approach to optimize the mobile transport network.

Innovation Observatory [7] defines Multi-Protocol Label Switching (MPLS) as a protocol-agnostic mechanism for a connection-oriented approach MPLS or connectionless data transport. Innovation Observatory [7] also mentioned that MPLS resides between the Data Link Layer and the Network Layer of the Open System Interconnections (OSI) model. Therefore, MPLS somehow acts like an interface between the two layers. Labels which are an analogy to the mailing address being utilized in the postal system are added to a distinct class of data prior to propagation over virtual network by the MPLS routers.

The IP/MPLS Forum [5] deliberated on the vital role of backhaul in mobile networks for data transport within a mesh network. In a tech-savvy community nowadays, the significant rise of demand to existing network capacity has resulted in a “bottleneck” scenario [8]. IP/MPLS Forum Technical Committee [8] mentioned that up to 30% of mobile operators operating expenditure is directly contributed by the backhaul requirements as reported by Yankee Group (2005). Consequently, a shift toward a more practical MPLS-enabled infrastructure which boasts a significant expenditure reduction is necessary to counter the issue. Future network implementing this approach will be more diverse in terms data traffic flow in a single cell site, thus the opportunity to initiate a market of innovative services in the long run.

‘Integrated Packet Transport Network’ solution based on ‘Liquid Transport’ approach as proposed by Nokia Siemens Networks and Juniper Networks, offers a more convenient alternative in a complex transport networks nowadays [9]. The approach bears encouraging indication to efficiently counteract a significant complexity hike in transport networks through the integration of high capacity optical infrastructure with the IP/MPLS and control layers which surpasses conventional approaches. The consequent overall operating expenditure (OPEX) and capital expenditure (CAPEX) is also much lower [9].

Parra, Hernandez, Puente, and Sarmiento [10] suggested that current routing options introduce undesirable delays, data traffic congestion and service quality depreciation. IP networks data transmission via the Asynchronous Transfer Mode (ATM) and MPLS respectively behaves in a distinct manner. Distinction of both approaches can be seen through different characterization parameters. IP/MPLS edge out IP/ATM in terms of bandwidth usage optimization for priority traffic in a network [10].

Barakovic, Bajric and Husic [11] highlighted on "MPLS Differentiated Services (DiffServ)" techniques as a bridge for future extension of service diversity. Analysis of simulations carried out based on the technique indicates an optimized overall delay and packet loss reduction is achievable [11]. However, QoS design issues and traffic engineering must be handled thoroughly to ensure the development of a robust transport approach in accordance with the next generation of multi-service networks. Thus, much work still needs to be done to refine and engineer the proposed technique before taking the center stage of future networking. When the time comes, a theoretically sound technique that offers a high degree of practicality is to be expected.

Bosco, Manconi, Sabella and Valentini [12] reported a paradigm shift to a multi-service MPLS network bandwidth management methodology. The advantages of 'Bandwidth Engineering (BE)' in comparison to conventional IP networks are discussed. Consequently, a more efficient resource management in the 'BE' module is present and attributed to the bandwidth resource optimization while maintaining optimal service quality [12]. The algorithms employed in 'BE'; a smart algorithm and a dynamic routing (DR) algorithm are also deliberated with the support of validated simulation results [12].

Puype, Colle, Pickavet and Demeester [13] deliberated on the bright prospect of transport network optimization via 'Multi-Layer Traffic Engineering (MLTE)'. 'MLTE' is more dynamic by offering more flexibility and adaptability to accommodate network users' continuously demand growth directly proportional to the technological evolution [13]. 'MLTE'-related algorithms and parameters in the IP/MPLS approach are also discussed thoroughly. Analysis of important IP/MPLS network parameters with increasing flow load based on a case study scenario on the 'pan-European 28-node backbone network' was also conducted.

The IP/MPLS approach was also discussed in terms of maximum coverage at minimum costs. Trade-offs present in the IP/MPLS approach was examined. An algorithm named "Maximum Coverage at minimum Cost (MC^2)" was derived and validated based on simulations on the "PAN European" network [14]. Performance evaluation on the algorithm shows an improvement in terms of the traffic demand coverage aspect while incurring slightly more costs [14]. Nonetheless, the algorithm still manages to provide greater coverage without the necessity of a significant increase in expenditures.

The implementation of a policy-based QoS framework for the UMTS is justified with several concrete reasons. Convenience in terms of network device configuration is afforded to the network operators through Policy-based QoS control [18]. Business level policies can be automatically translated to suitable information for configuring network devices in addition to the provision of a more thorough view of the network devices [18]. Authorization of users is a prerequisite to avoid abuse of the available network resources guaranteed by the UMTS. Failure to comply with this requirement will cause denial of access to the resources triggering discontent with the quality of service provided [18].

The Packet Data Protocol (PDP) carries the QoS parameters for packet user in the UMTS network [19]. The protocol is identified in the User Equipment (UE), Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN) by a vector composed of a PDP context identifier, a PDP type, a PDP address, an access point name and QoS profile [19]. Conversational, streaming, interactive and background are defined classes of service in UMTS. Maximum Bit Rate (MBR), Guaranteed Bit Rate (GBR), Traffic Handling Priority (THP) and Allocation/Retention Priority (ARP) are the most important QoS parameters used for traffic differentiation [19].

Juniper Networks [20], deliberated that cost optimized transport is made possible with the introduction of IP/MPLS in the mobile backhaul network.

Furthermore, ABI Research and Yankee Group state that the solution is 3-5 times more cost effective than conventional approaches [20]. Besides that, MX Series platforms of Juniper Networks consume 90% less power in comparison with two other leading vendors over five years [20]. The total cost of ownership (TCO) is lower through the Juniper Networks' cost optimized transport. This is supported via a study by Network Strategy Partners states that "Ethernet aggregation on the MX Series results in 47% lower TCO" [20]. The establishment of a more efficient operation, administration and maintenance (OAM) initiative will contribute to a significant reduction in the operating expenditure (OPEX).

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

A solid understanding of the networking fundamentals is also crucial in order to aid in the development of the project. Thus, much time would be allocated for information gathering and studying on the subject matter from a variety of credible sources available; books, journal articles, research papers and online forums. This would set the foundation for the smooth progression of the project devised for the whole semester.

3.2 Software

This is a research-based project requiring a simulation tool; Optimized Network Engineering Tools (OPNET). It was the product of a project by Alain Cohen's (co-founder and current CTO & President) for a networking course while he was at Massachusetts Institute of Technology **(**MIT). OPNET is a software tool capable of modeling and simulating a wide range of networks. Student(s) will be closely guided and assisted by a PhD student and GA, Mr. Firas Ousta in the utilization of OPNET for simulation purposes throughout the project.

Wired and wireless networks' modeling, simulation, and analysis are provided by OPNET Modeler 14.5. It is also equipped with Graphical User Interface (GUI)-based debugging and analysis features. A lager collection of wired/wireless protocol and vendor device models equipped with respective source codes is also supported by the modeler [16]. Furthermore, evaluation on enhancements to standard-based protocol can also be done via the modeler features.

Besides that, the simulation runtime is also reduced with the aid of the OPNET Modeler's parallel and distributed simulation capabilities [16]. The resultant simulation results can also be easily interpreted using various effective visual representations which also enables ease of results correlation. Thus, the OPNET Modeler 14.5 is very well suited to be utilized in this project due to the vital advantages that it has to offer.

Four simulation technologies supported by OPNET are [17]:

1. Discrete Event Simulation (DES)
2. Flow Analysis
3. ACE Quick Predict
4. Hybrid Simulation (within the DES environment)

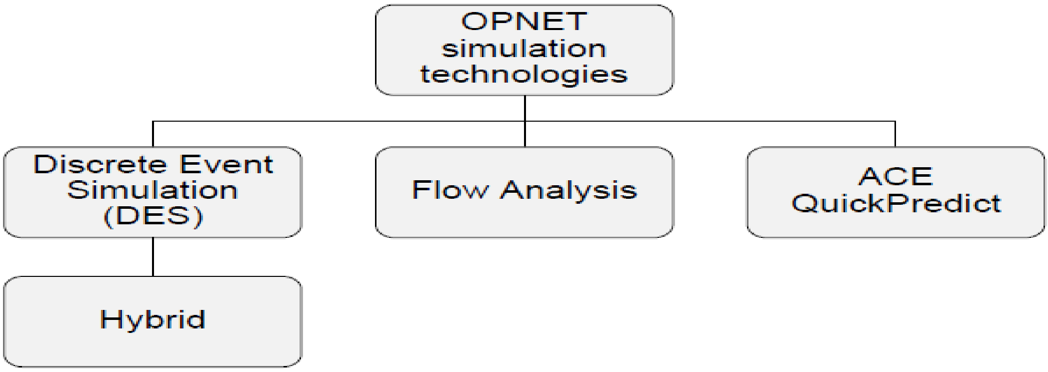

Figure 4: OPNET supported simulation technologies [17]

A project-and-scenario approach is adopted by the OPNET Modeler to model networks [17]. In OPNET, a project refers to a collection of network-related scenarios [17]. A minimum of 1 scenario will exists in a project. Meanwhile, scenario depicts a unique configuration for the network [17]. Configuration elements include topology, protocols, applications, traffic, and simulation settings.

Simplified OPNET simulation workflow [17]:

1. Create a project
2. Create a baseline scenario
    - 2.1 Import or create a network topology
    - 2.2 Import or create traffic
    - 2.3 Choose statistics to be collected
    - 2.4 Run the simulation
    - 2.5 View the results
3. Duplicate the scenario
    - 3.1 Make changes
    - 3.2 Re-run the simulation
    - 3.3 Compare the obtained results
4. Repeat Step 3 if needed

Simulation Flow Chart

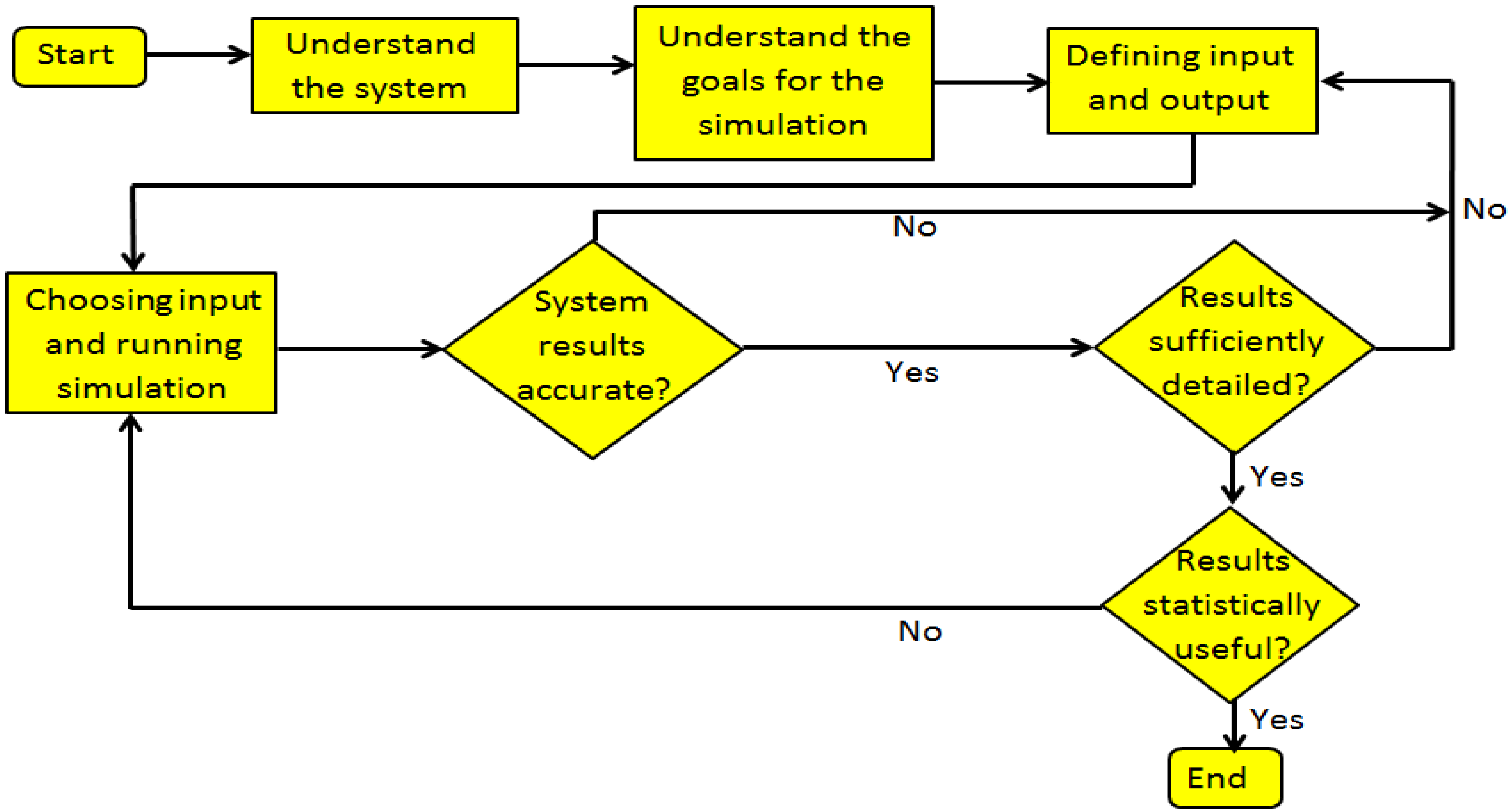

Figure 5: OPNET Simulation Flow Chart

3.3 Key Milestones

Listed below are the main checkpoints planned throughout the project. The checkpoints serve as a benchmark to the overall progress of the project.

1. Getting well-accustomed with fundamentals of networking, Transmission Control Protocol/Internet Protocol (TCP/IP), and Multi-Protocol Label Switching (MPLS)
   [week 1 – week 8].

2. Mapping of Quality of Service (Qos) parameter within Gateway GPRS Support Node (GGSN) and Serving GPRS Support Node (SGSN) [week 9 onwards].

3. OPNET software simulation results analysis for the determination of the best gateway for mapping process [week 9 onwards]

3.4 Gantt Chart

FYP I

No.	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Tropic															
2	Preliminary Research Work															
3	Submission of Extended Proposal Defense						28/6		**Mid-Semester Break**							
4	Proposal Defense															
5	Project Work Continues															
6	Submission of Interim Draft Report														15/8	
7	Submission of Interim Report															23/8

Figure 6: FYP I Gantt Chart

FYP II

No.	Detail / Week	1	2	3	4	5	6	7	Mid-Semester Break	8	9	10	11	12	13	14	15
1	Project Work (Simulation)																
2	Progress Report Submission									11/11							
3	Pre-SEDEX / ElectrEx												4/12				
4	Draft Report Submission														16/12		
5	Final and Technical Report Submission															23/12	
6	Viva																30-31/ 12

Figure 7: FYP II Gantt Chart

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Simulation Scenarios

Internet Protocol (IP) Scenario

The Internet Protocol (IP) is used for routing and the nodes are **not configured to use Multi Protocol Label Switching (MPLS).**

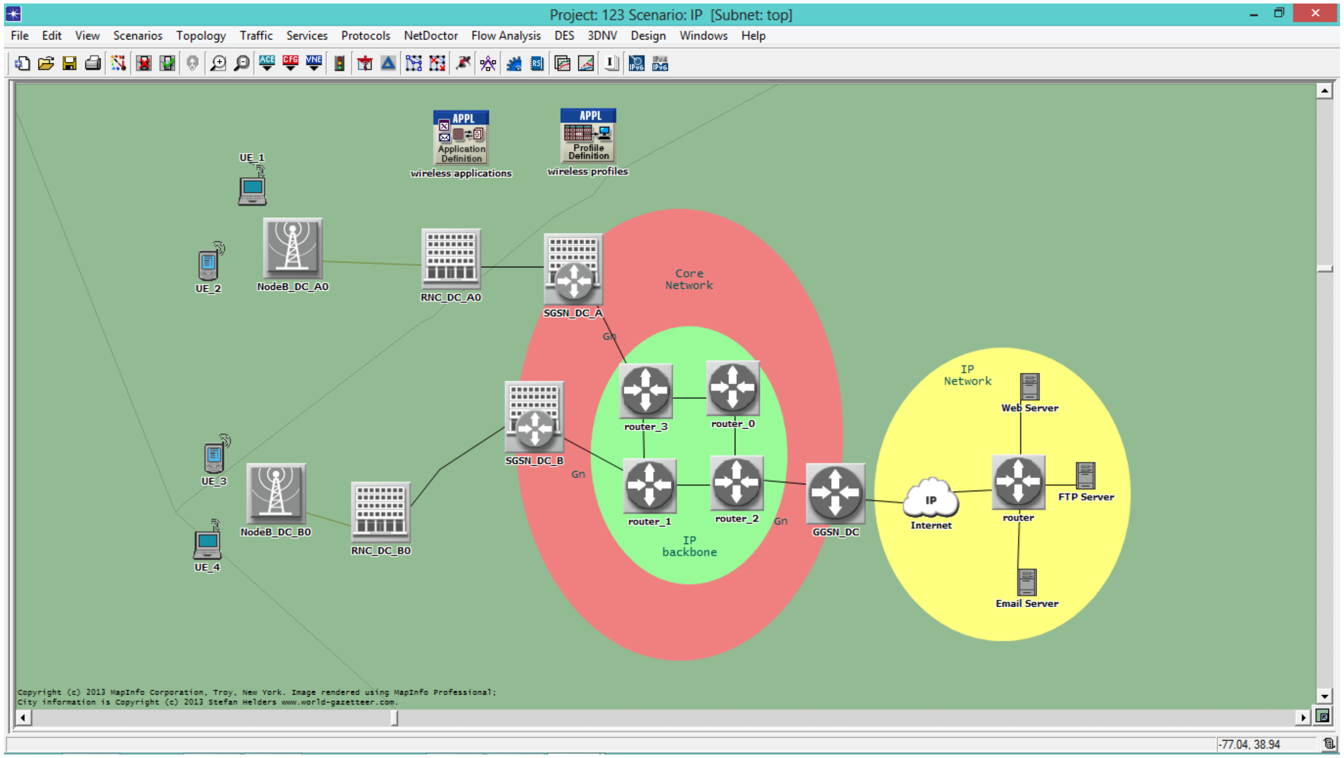

Figure 8: IP Scenario

IP/ Multi Protocol Label Switching (MPLS) Scenario

This scenario demonstrates MPLS, to better route the traffic along the desired routes. **MPLS Label Switched Paths (LSPs)** are **used to specify** the **routes**.

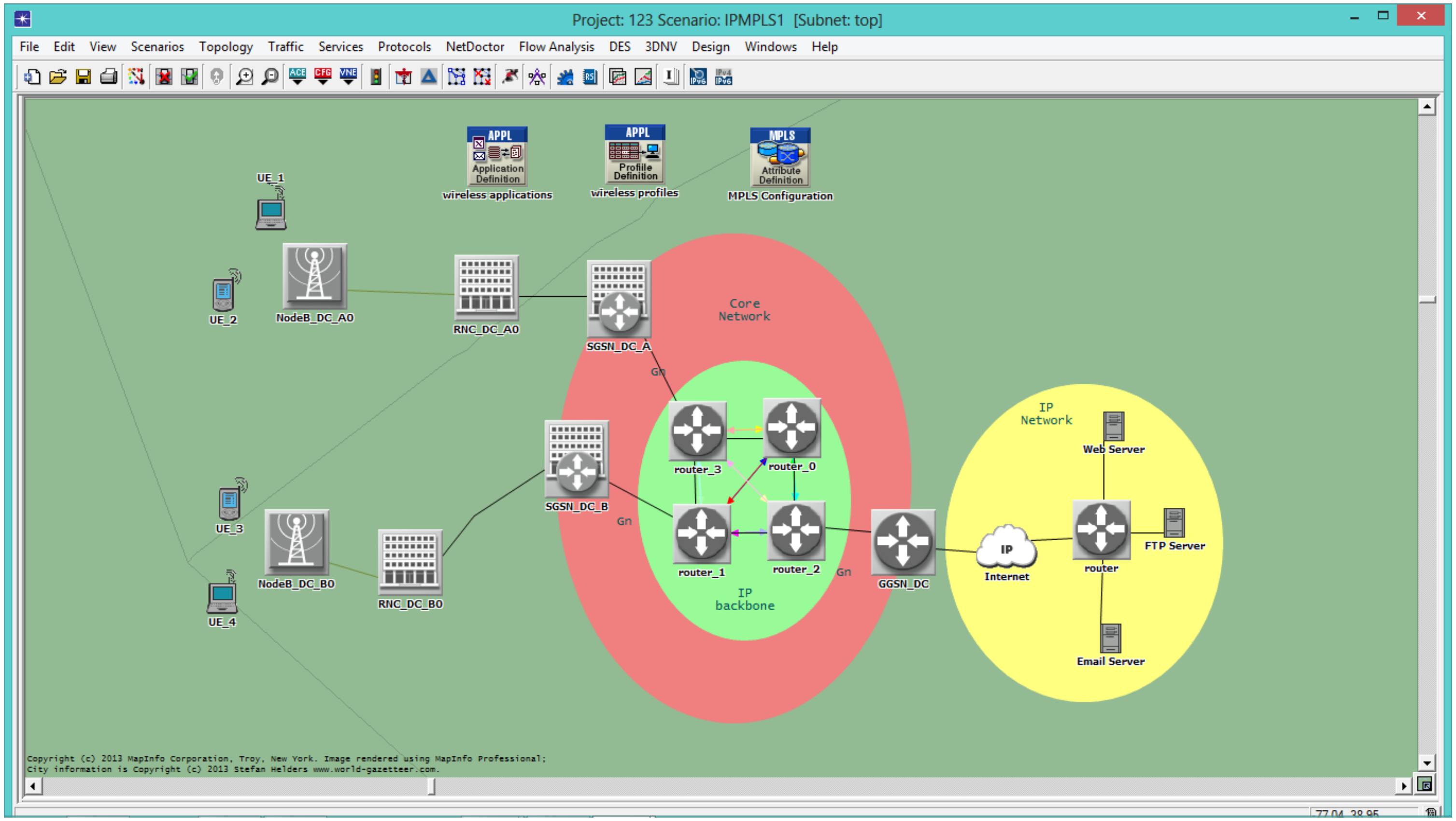

Figure 9: IP/MPLS Scenario

4.2 Scenarios Details

Nodes

1. **umts_wkstn**

   UMTS workstation is represented by this node model. The workstation consists of applications running over TCP/IP and UDP/IP. The "IP Forwarding Rate" attribute determines the required for packet routing. Packet routing is based on first-come-first-serve basis. Output interface transmission rates dependent queuing at ports may occur.

2. **umts_node_b**

   Node-B which handles the interconnection of the user equipment the radio network controller (RNC) and the rest of the UMTS network is depicted by this node.

3. **umts_rnc_ethernet_atm_slip**

   UMTS Radio Network Controller (RNC) is represented by this node. It serves as an RNC of a UTRAN in a UMTS network. The UMTS RNS can support and manage up to 8 Node-Bs.

4. **umts_sgsn_ethernet_atm9_slip**

   UMTS Serving GPRS Support Node (SGSN) is represented by this node. It is responsible for the mobile stations data handling within in geographical service area.

5. **ethernet4_slip8_gtwy**

   This node model represents a gateway that supports IP. It is able to cater up to eight serial line interfaces and four Ethernet hub interfaces.

6. **umts_ggsn_slip8**

   The UMTS Gateway GPRS Support Node (GGSN) is represented by this node. This node is vital for the internetworking between different networks. The "IP Forwarding Rate" attribute of the node determine the period for packet routing.

7. **ip32_cloud**

   This model represents an IP cloud. Destination IP address-based routing are imposed on any IP packets arriving on any cloud. This node is able to cater up to 32 configurable data rate serial line interfaces. The packet latency attribute of the node determine the amount of time to route each packet. The routing is based on first-come-first-serve basis. . Output interface transmission rates dependent queuing at ports may occur.

8. **ethernet_server**

   A server with applications supporting TCP/IP and UDP/IP is represented by this node. The connected link's data rate translates to the operational. Full-duplex or half-duplex configuration of the Ethernet MAC in this node is possible. The IP Forwarding Rate attribute determine the period required for packet routing. The routing is based on first-come-first-serve basis. Output interface transmission rates dependent queuing at ports may occur.

Links

1. **PPP_DS3**

   Two nodes utilizing IP can be connected via this link. It supports the ip3_dgram with data rate up to 44.736 Mbps.

2. **ATM_OC3**

   ATM switches, gateways, and station nodes are connected via this link with configurable data rates. It supports the ams_atm_cell packet format.

3. **10BaseT**

   This link represents an Ethernet connection. A combination of the various including stations, hubs, bridges and switches can be connected via this link. This link can support ethernet packets with data rates up to 10Mbps.

Paths

MPLS_E-LSP_DYNAMIC

This is a model of dynamic Label Switched Path (LSP). When this path model is used, CR-LDP will establish an LSP from the source node of this LSP to the destination node of this LSP.

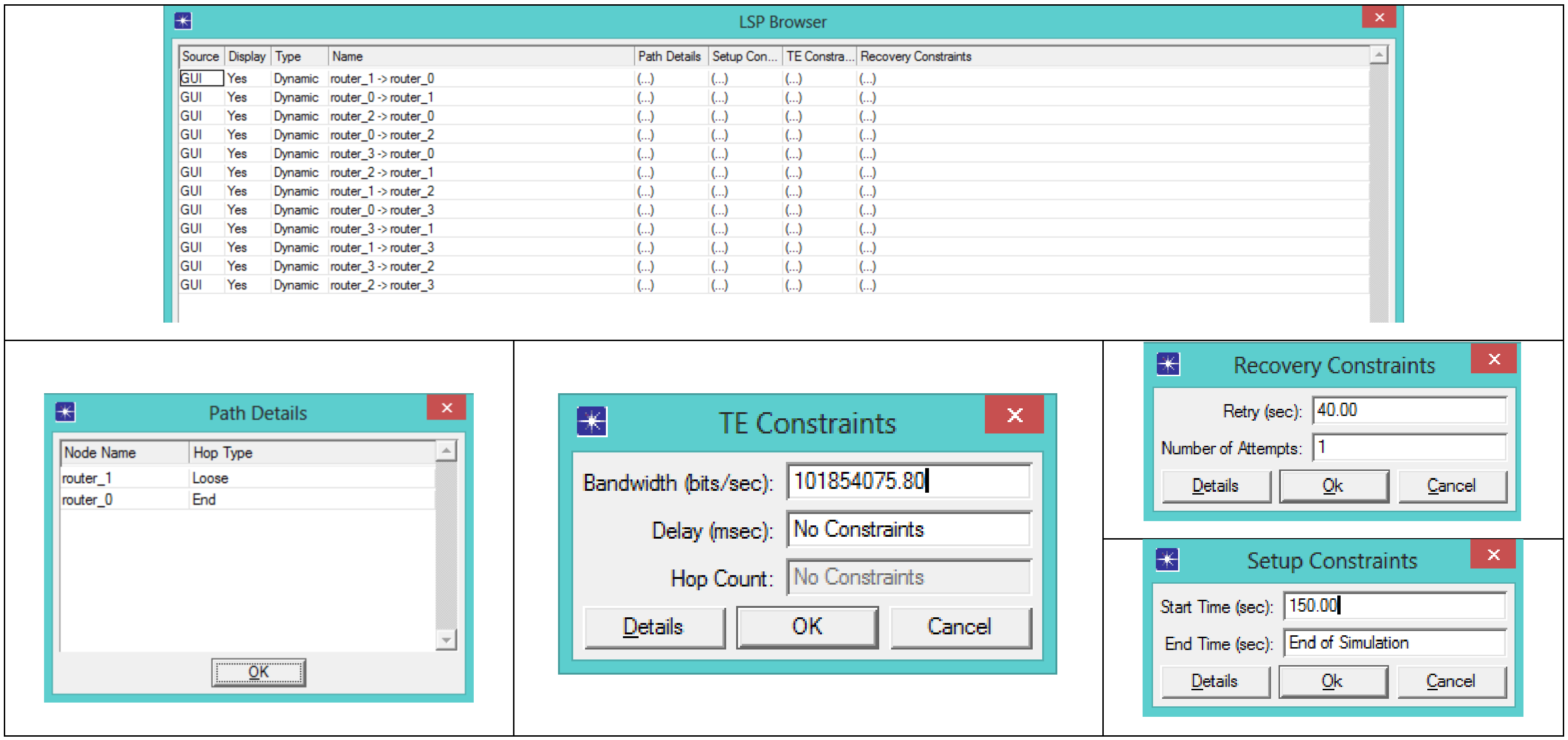

Figure 10: MPLS Scenario LSP Configuration Details

Wireless Application Config Node Attributes

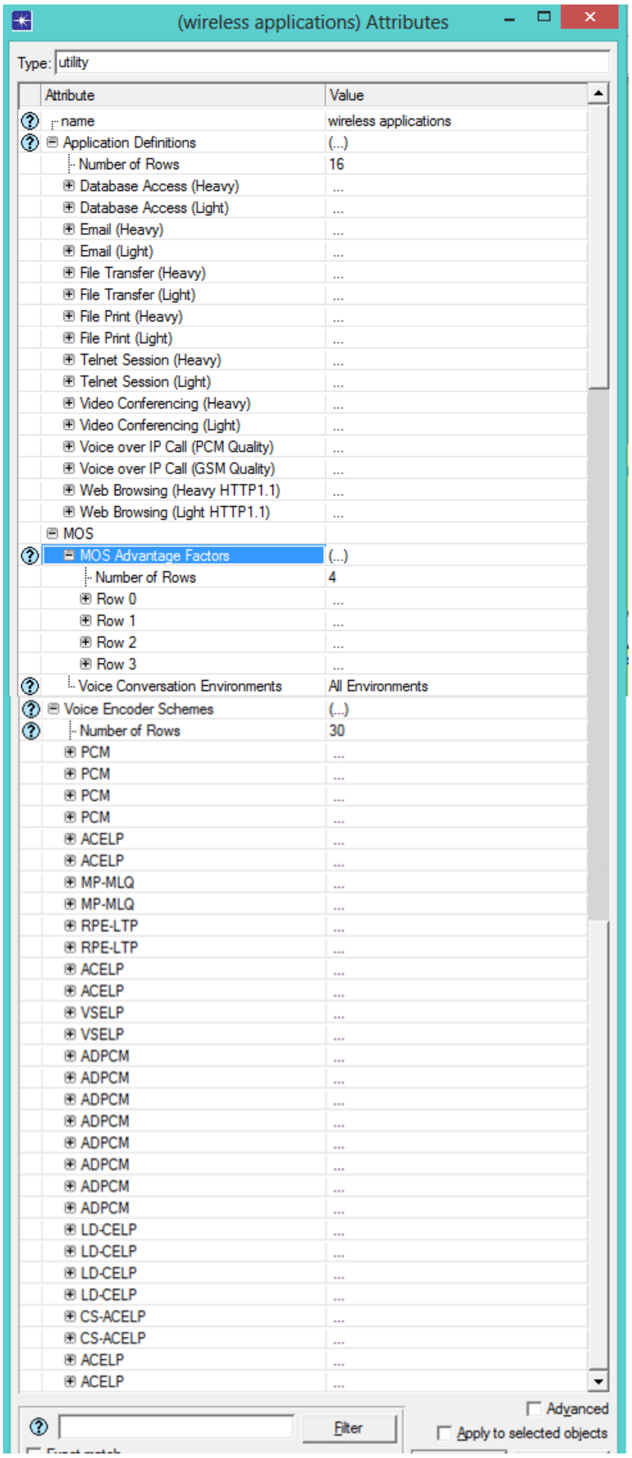

Figure 11: Wireless Application Configuration Details

Different applications are configured using the wireles application config nodes to be established in the UMTS workstation nodes. Each application can be assigned to different workstation nodes.

Wireless Profile Config Node Attributes

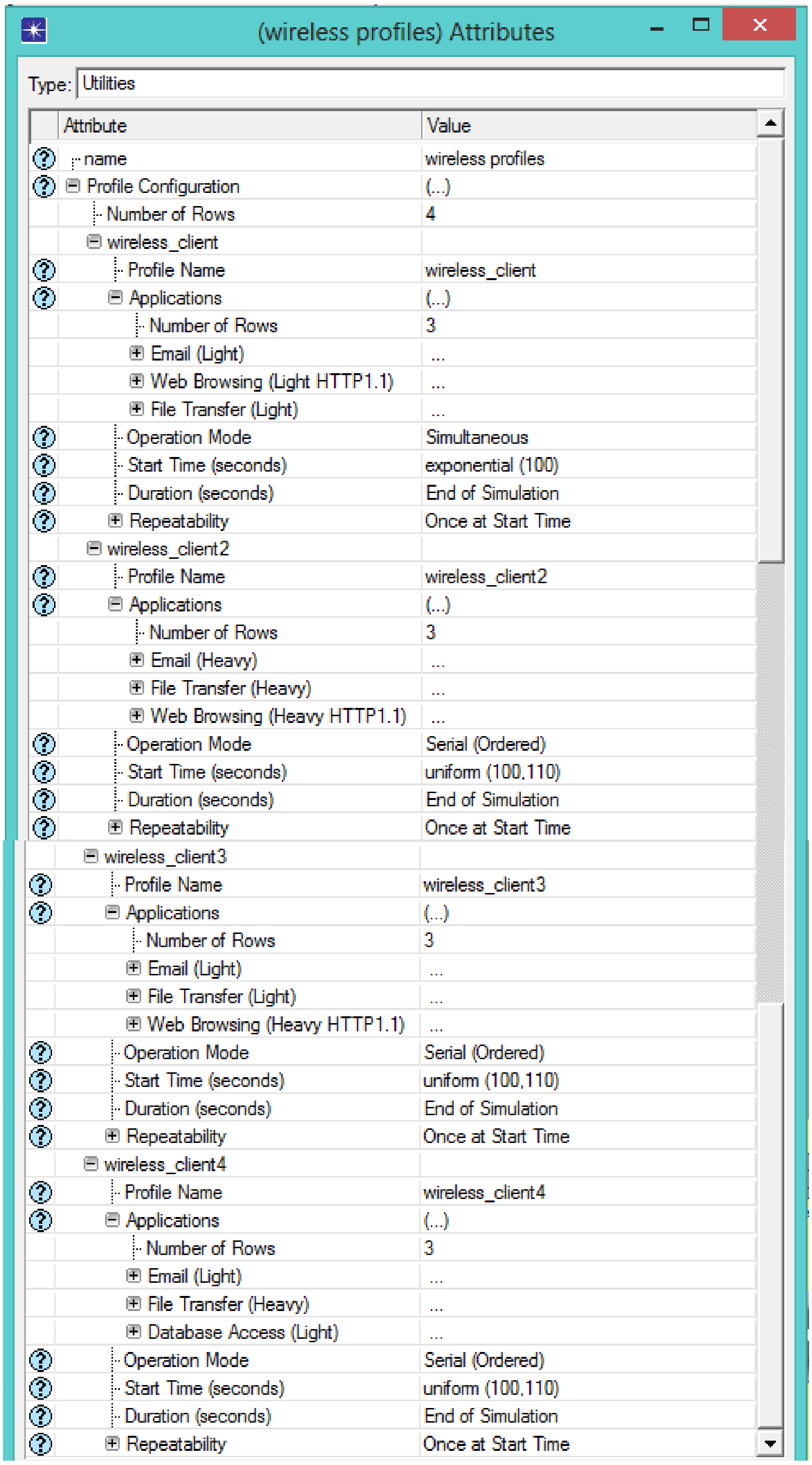

Figure 12: Wireless Profile Configuration Details

Different profiles with different sets of applications are configured using the wireles profile config nodes to be established in the UMTS workstation nodes.

MPLS Config Node Attributes

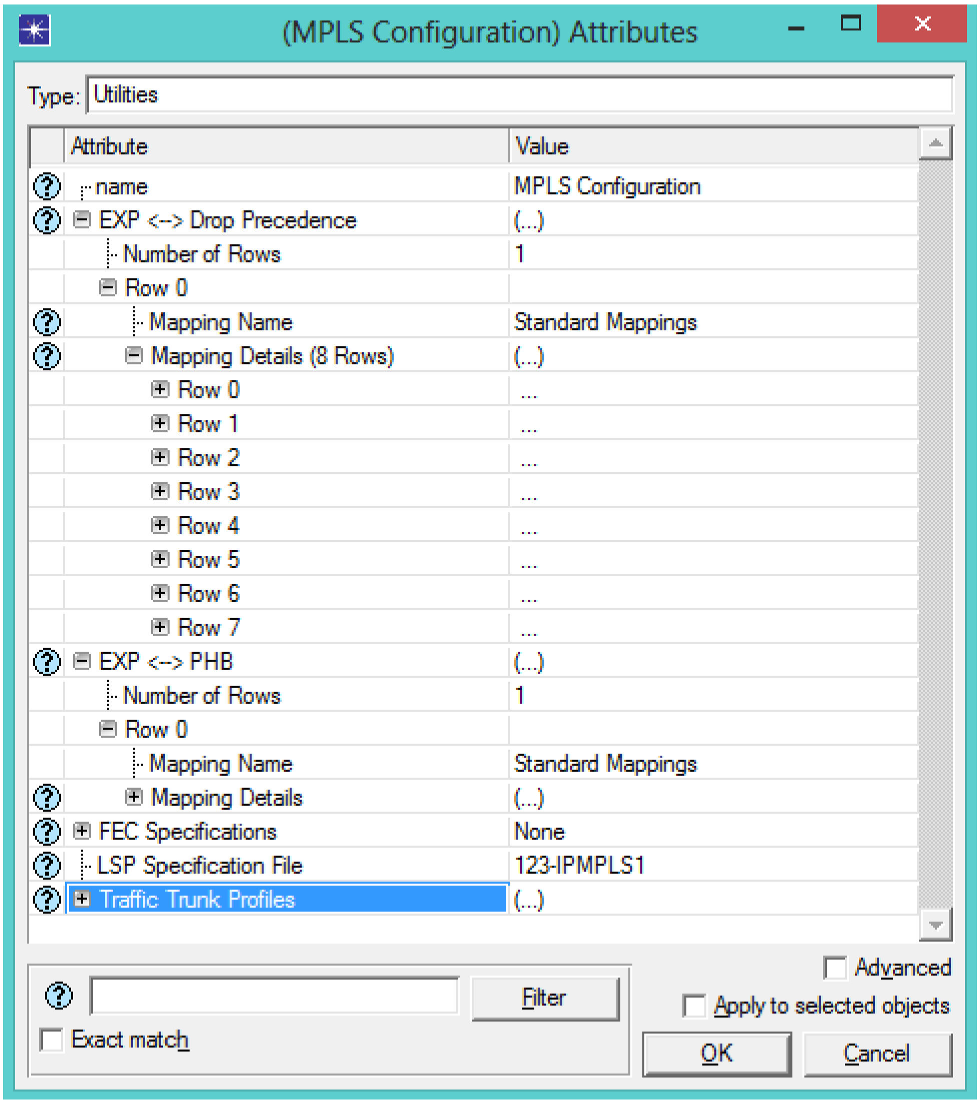

Figure 13: MPLS Configuration Details

The vital MPLS parameters are being configured via the MPLS config nodes. This includes mapping details, flow equivalence class (FEC) specifications and traffic trunk profiles. Careful configurations of these parameters are necessary to ensure the proper functioning of MPLS in the network.

4.3 Result Analysis

IP Scenario

The IP is a protocol used in this scenario is for the exchange of routing information between gateways within an autonomous network. Network protocols can utilize the information for transmission route specification. The IP used for routing and the nodes are not configured to use Multi Protocol Label Switching (MPLS).

IP/MPLS Scenario

A conventional IP-routed network is converted to a switched-like network with better transport efficiencies through Multi-Protocol Label Switching (MPLS). This scenario demonstrates MPLS, to better route the traffic along the desired routes. MPLS Label Switched Paths (LSPs) are used to specify the routes. Label-switched paths (LSPs) are utilized for particular source-destination pairs instead of hop-by-hop packets forwarding.

Specific network statistics are being focused on for the simulation results analysis part; average email upload and download response time, average IP background traffic delay, average IP number of hops, average UMTS end-to-end delay, and the average UMTS uplink and downlink tunnel delay for both simulation scenarios. These are the resultant global statistics from the OPNET discrete event simulation (DES) being carried out.

Average Email Upload Response Time (sec)

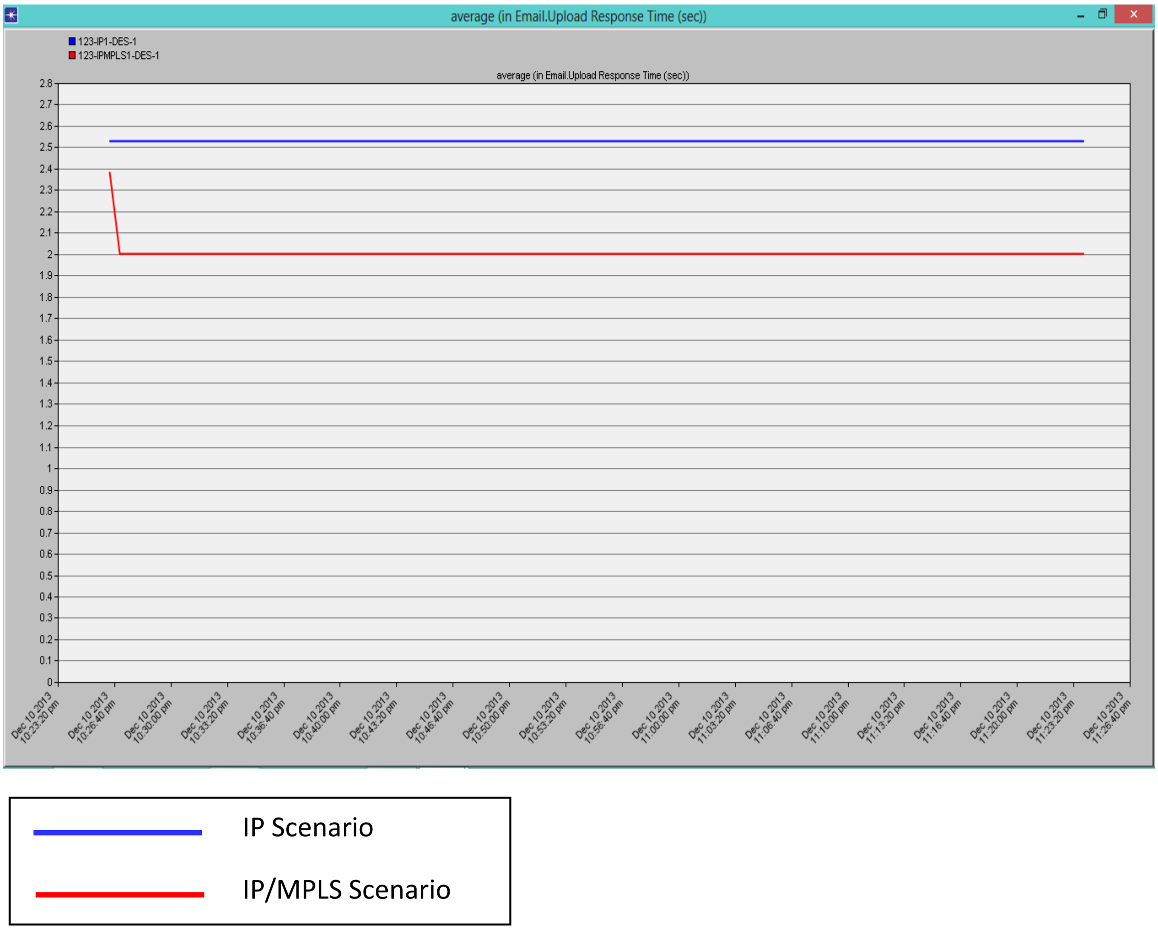

Figure 14: Average Email Upload Response Time

The email upload response time denotes to the duration of time between emails sent to the email server and receiving the corresponding acknowledgments. The connection setup signaling delay is also taken into account for the response time.

The figure above shows that the average email upload response time for the IP scenario and the IP/MPLS scenario are around 2.5 seconds and 2 seconds respectively. The average email response time for the IP scenario is around 0.5 second mores that of the IP/MPLS scenario. A longer period for the email download response depicts more delay before a response is received. Thus, a longer upload response time is less desirable.

Average Email Download Response Time (sec)

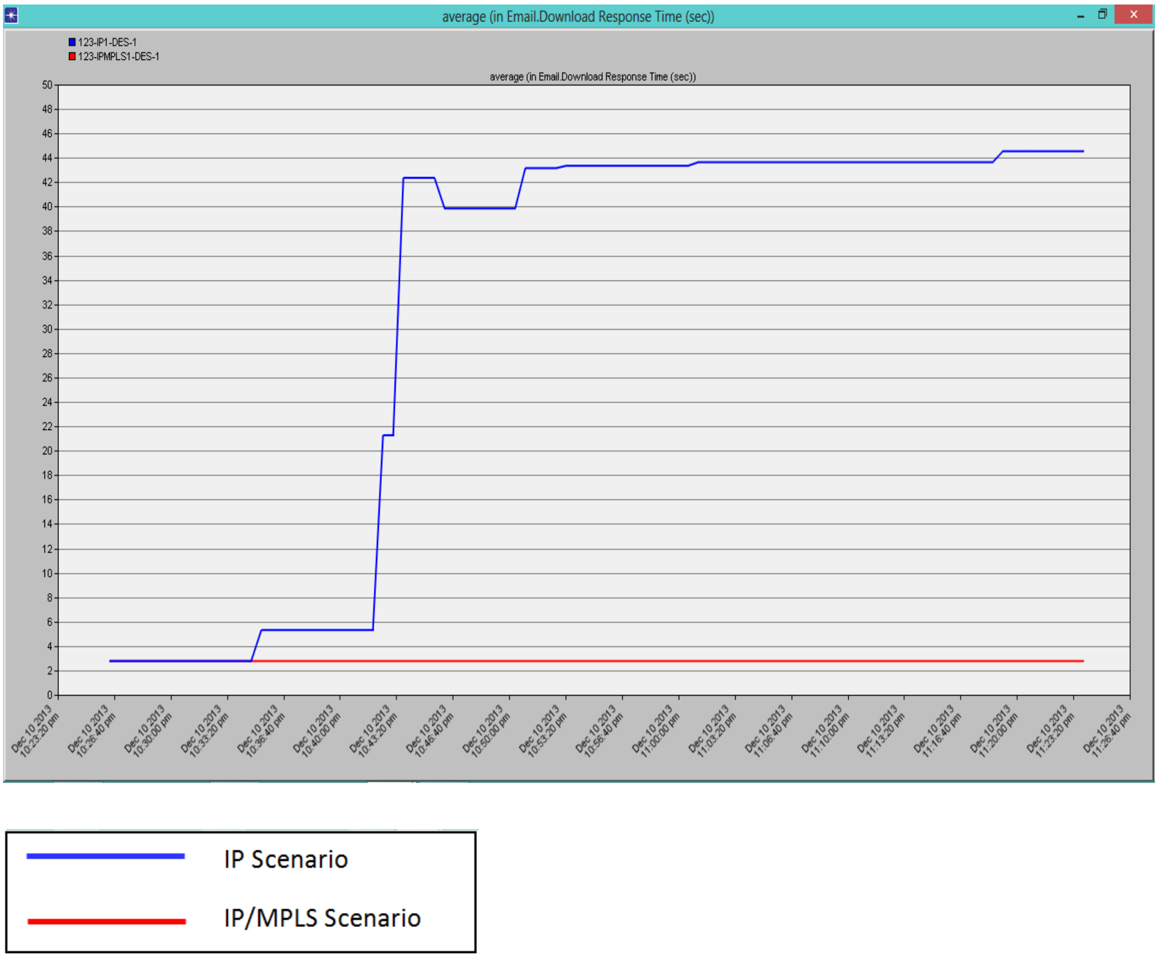

Figure 15: Average Email Download Response Time

The email download response time of a network refers to the duration of time from the sending of email requests and the receiving emails from email server. The connection setup signaling delay is also taken into account for the response time.

The figure above shows that the peak average email download response time for the IP scenario and the IP/MPLS scenario are around 44 seconds and 3 seconds respectively. The peak average email response time for the IP scenario is almost 15 times that of the IP/MPLS scenario. The fluctuations in the average email download response time for the IP scenario is mainly due to the signaling delay. A longer period for the email download response depicts more delay before a response is received. Thus, a longer download response time is less desirable.

Average IP Background Traffic Delay (sec)

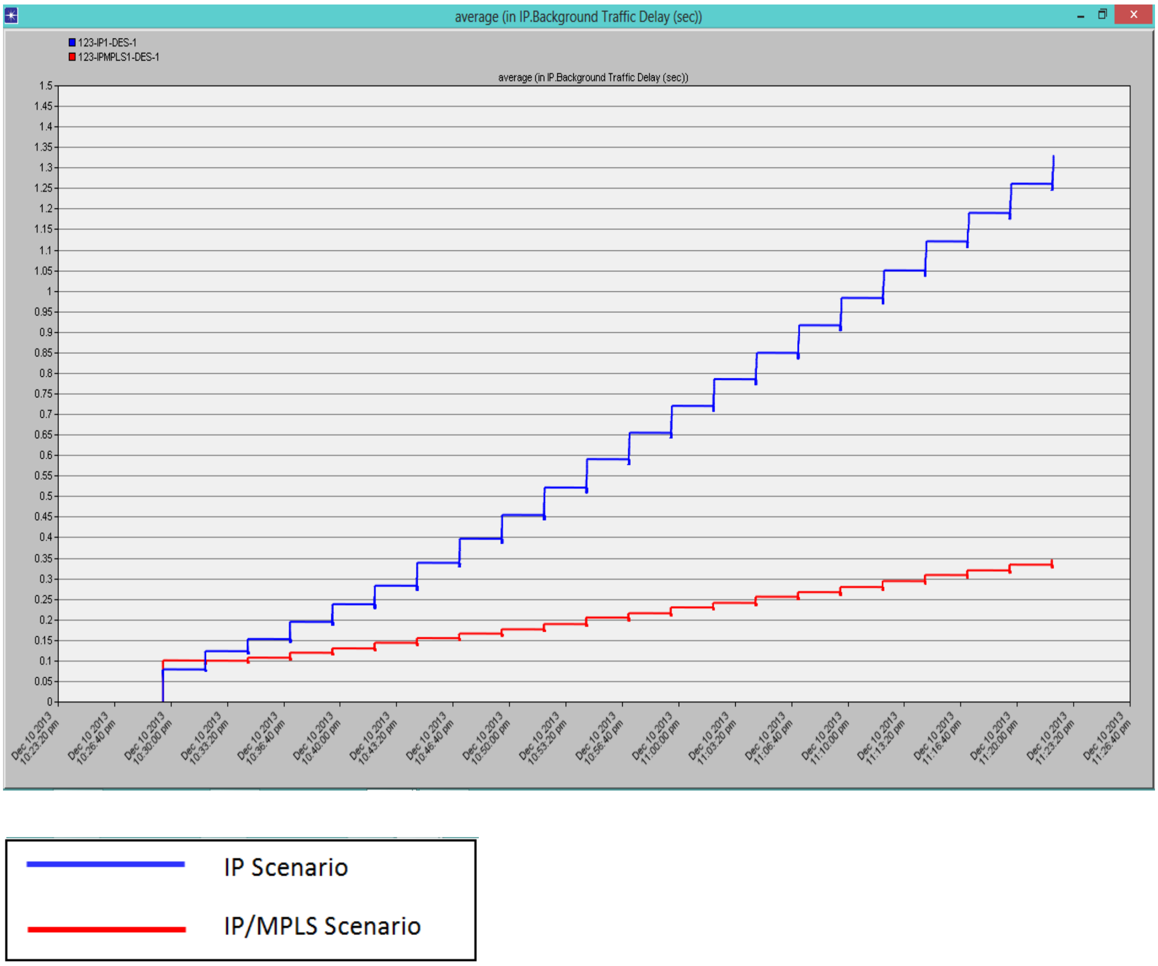

Figure 16: Average IP Background Traffic Delay

The IP background traffic delay corresponds to the end to end delay experienced by information about a background traffic flow while it propagate from source to destination.

The average IP background traffic delay for the IP scenario is experiencing an increment at a rate of 0.05 second to 0.10 second as the simulation progresses. For the IP/MPLS scenario the increment is at a lower rate of only 0.025 second. A higher value of the IP background traffic delay will contribute highly to the overall end-to-end delay. Since it is desired for a transport network with minimal delay, the IP background traffic delay will be required to be at a minimal and acceptable rate.

Average IP Number of Hops

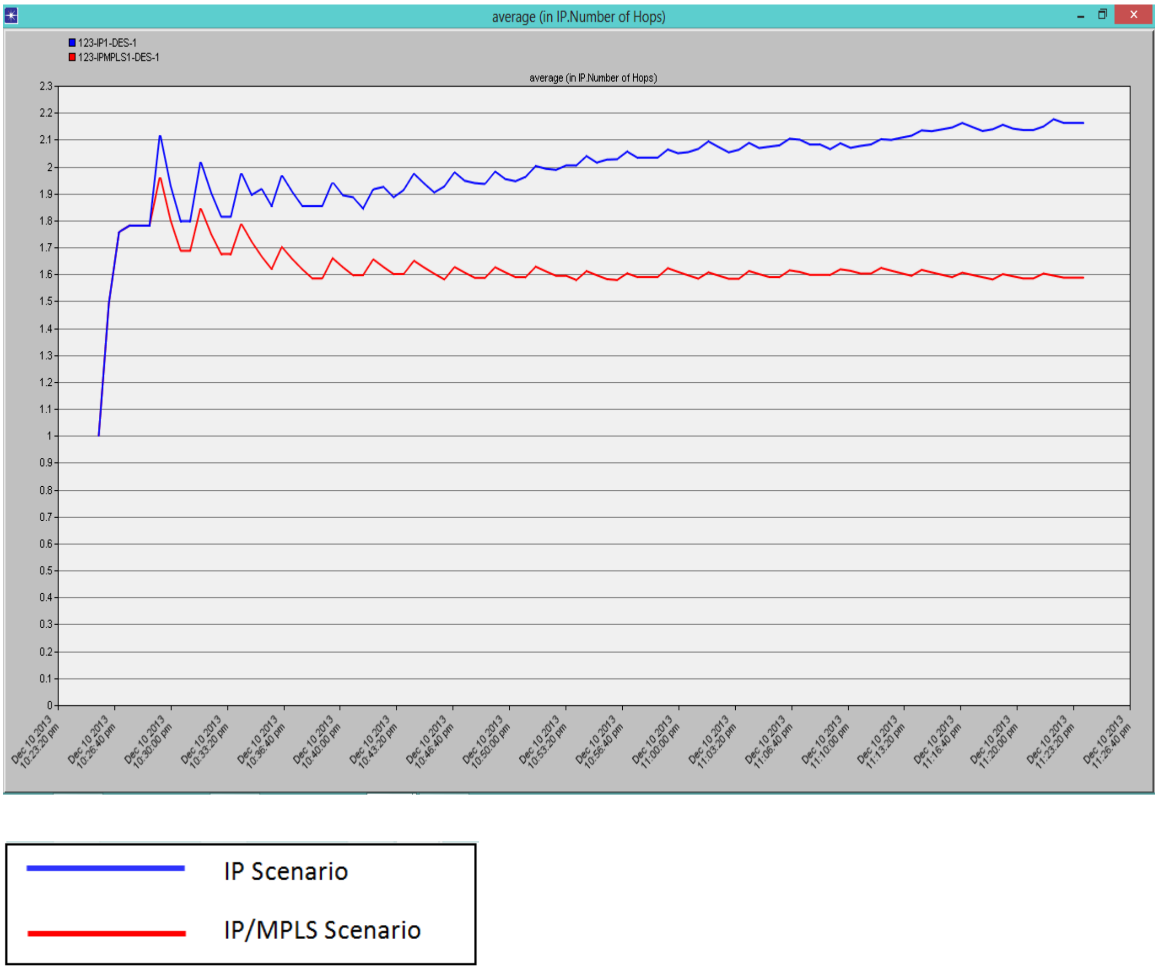

Figure 17: Average IP Number of Hops

A hop refers to one portion of the path between source and destination in a network. During a communication process, data packets pass through a series of intermediate devices. A hop occurs each time packets are passed to the next intermediate device. This statistics gives the average number of IP hops taken by data packets reaching at a destination node.

The peak average numbers of hops throughout the simulation for the IP and IP/MPLS scenarios are 2.15 and 1.95 respectively. In general, a greater number of hops will consequently lead to a greater amount of transmission delay in the network. Thus, it is more desirable to have a lower number of hops which translates to a reduction of the overall transport network transmission delay.

Average UMTS End-to-End Delay (sec)

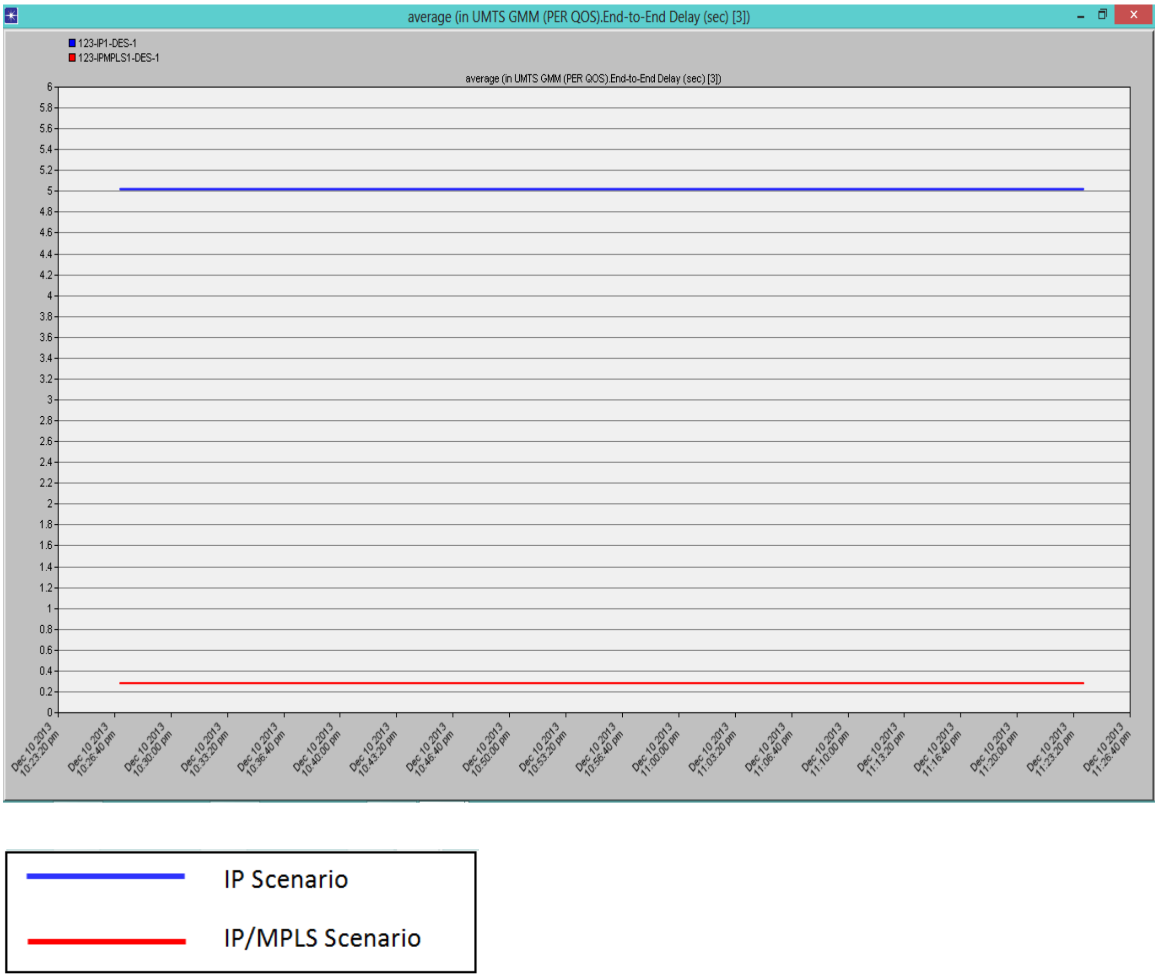

Figure 18: Average UMTS End-to-End Delay

Total time taken for the transmission of a packet at a source to it's intended destination across a network depicts the End-to-end delay. The transmission delay, processing delay and also the propagation delay are all accounted for in the overall delay. The total time required for the sending IP packets' from the source IP nodes to the user equipment at the destination is represented by this statistic.

The average UMTS end-to-end delay for the IP and IP/MPLS scenarios are 5 seconds and 0.3 seconds. The IP scenario's average end-to-end delay is almost 17 times that of the IP/MPLS scenario. A lower end-to-end delay is more desirable and will result in less packet transmission time required across a network.

Average UMTS Uplink Tunnel Delay (sec)

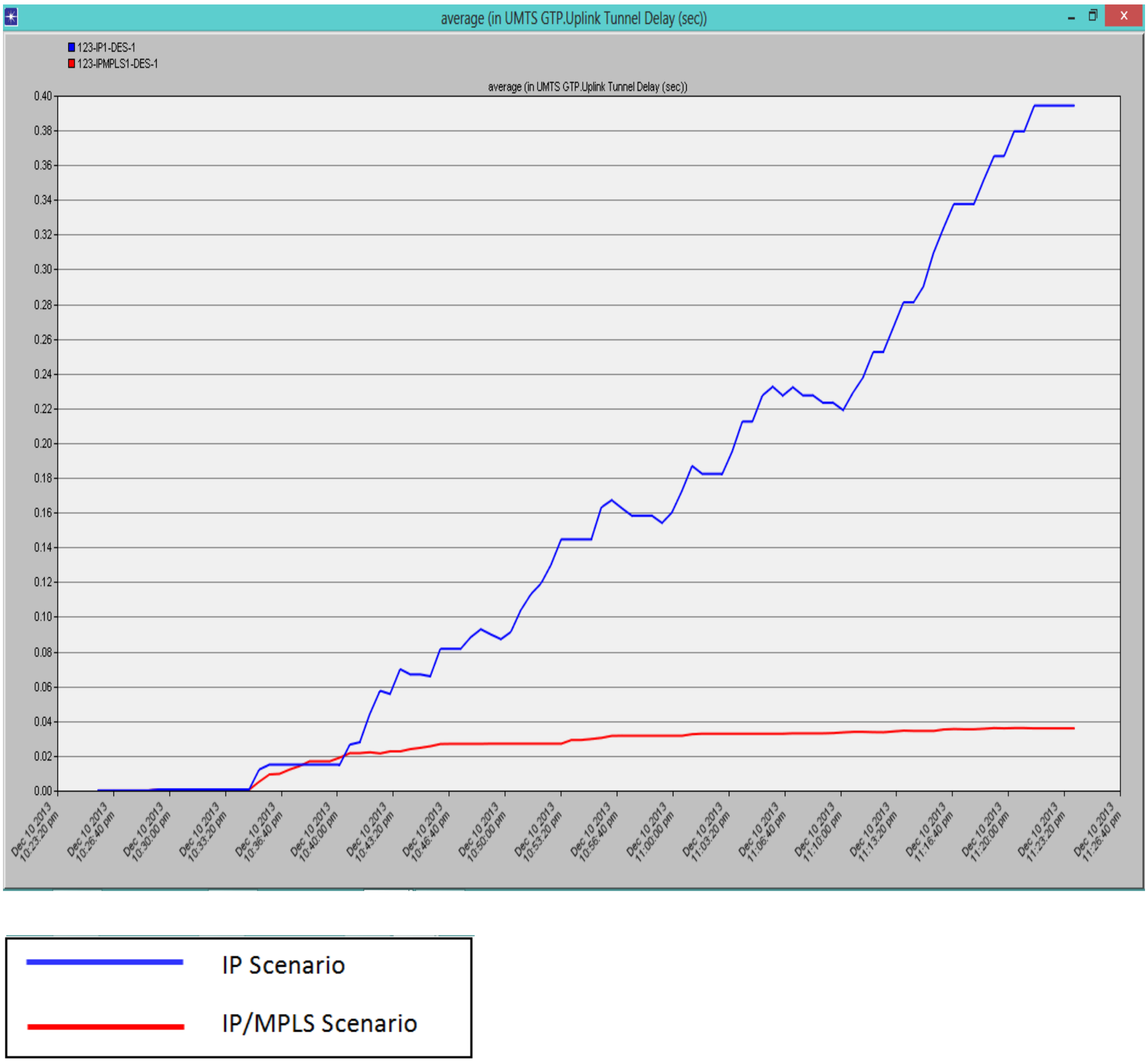

Figure 19: Average UMTS Uplink Tunnel Delay

The tunnel uplink delay shows the duration of time that a packet requires to go through a tunnel until it reaches the destination end point (RNC, SGSN or GGSN) node.

The peak average UMTS uplink tunnel delay for the IP and IP/MPLS scenarios are 0.40 seconds and 0.04 seconds. The IP scenario's peak average uplink tunnel delay is 10 times that of the IP/MPLS scenario. A shorter uplink tunnel delay is more desirable and will result in less delay for the transmission of a packet through a tunnel to the destination.

Average UMTS Downlink Tunnel Delay (sec)

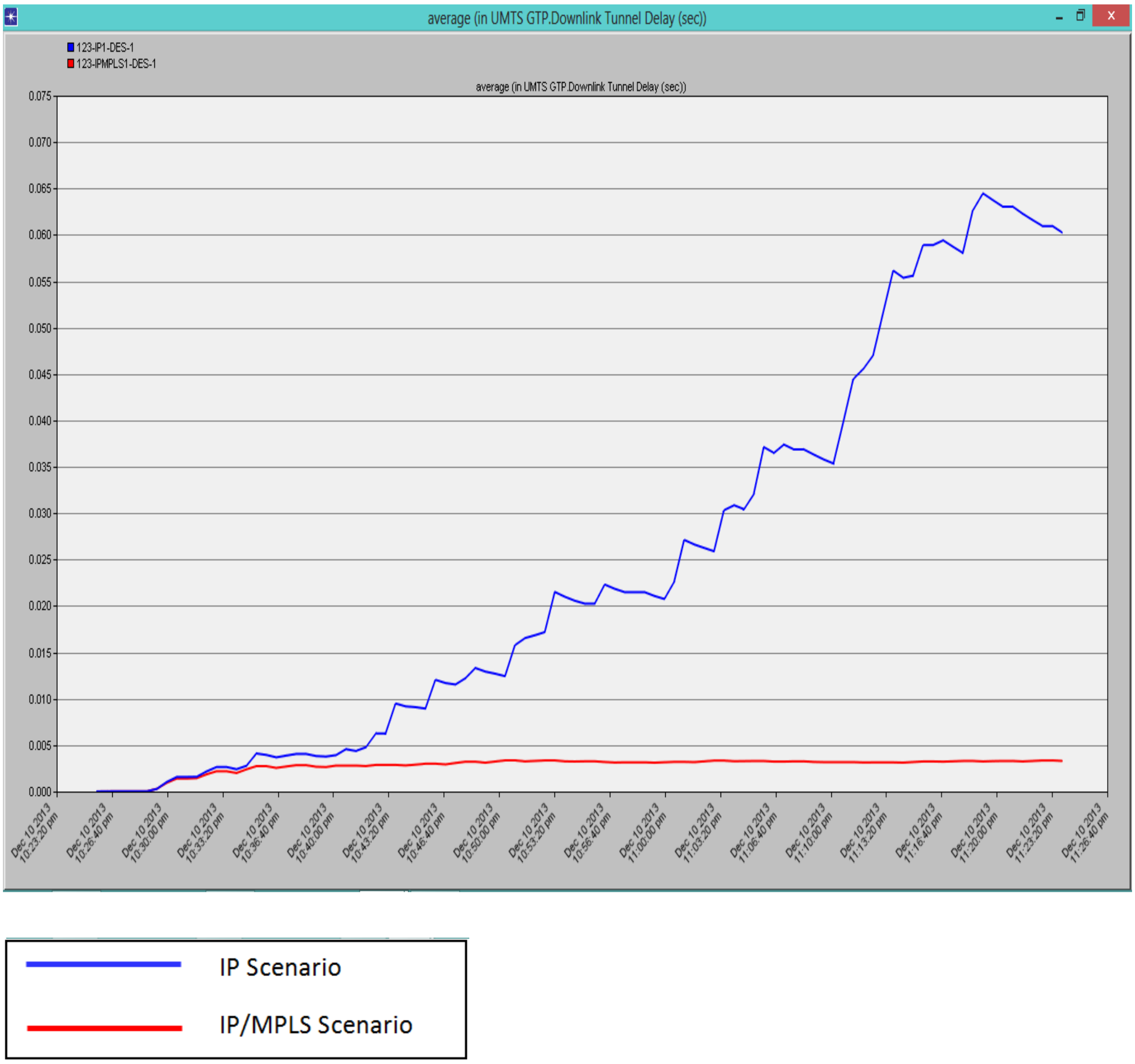

Figure 20: Average UMTS Downlink Tunnel Delay

The tunnel downlink delay shows the duration of time for packet propagation through a tunnel until the destination end point (RNC, SGSN or GGSN) node.

The peak average UMTS downlink tunnel delay for the IP and IP/MPLS scenarios are 0.065 second and 0.003 second. The IP scenario's peak average uplink tunnel delay is almost 22 times that of the IP/MPLS scenario. A shorter uplink tunnel delay is more desirable and will result in less delay for the transmission of a packet through a tunnel to the destination.

The analysis of the OPNET simulation in the form of the network global statistics reveals that through the implementation of IP/MPLS in the network's IP backbone, the network performance is improved. Lower response time (email upload and download), IP background traffic delay, number of hops, UMTS overall (end-to-end) delay, and tunnel delay (UMTS uplink and downlink) is visible in comparison to the conventional IP scenario. The enhancement of a packet-switched network that uses Internet Protocol (IP) in the core network through the introduction of the Multi-protocol label switching (MPLS) standard certainly produce encouraging results.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The optimization of the quality of service over the UMTS will contribute to a more efficient network operation, administration, and maintenance (OAM). Consequently, this will lead to lower network downtime and more efficient forwarding capability which will reduce the network total cost of ownership (TCO). This will lead to lower mobile backhaul costs thus contributing to a significant reduction in the overall operating expenditure (OPEX). Thus, IP/MPLS is a viable approach for the optimization of the mobile transport network to contribute to the betterment of the quality of service experienced by the users.

5.2 Recommendations

Further analysis on different vital network parameters should be employed to further validate the effectiveness of IP/MPLS. A more robust and flexible mobile network will definitely offer more convenience for the consumers. Thus, further research and development (R&D) initiatives on the IP/MPLS approach should be taken into serious consideration to further aid in the evolution to the future mobile transport network.

REFERENCES

[1] J. F. Kurose and K. W. Ross, *Computer Networking: A Top-Down Approach*, Fourth ed. Boston, Massachusetts, United States of America: Pearson Education Inc., 2008.

[2] A. Leon-Garcia and I. Widjaya, *Communication Networks: Fundamental Concepts and Key Architectures*: McGraw-Hill, 2006.

[3] M. A. Dye, R. McDonald, and A. W. Rufi, *Network Fundamentals: CCNA Exploration Comapnion Guide*. Inianapolis, Indiana, Unites States of America: Cisco Press, 2008, pp 33-58.

[4] "Strategic White Paper: Deploying IP/MPLS in Mobile Networks ", Alcatel-Lucent, Rep. CPG2896100928 (10), 2010.

[5] I. M. F. T. Committee, "MPLS in Mobile Backhaul Networks Framework and Requirements Technical Specification," presented at the IP/MPLS Forum 20.0.0, Oct. 2008.

[6] A. Rawat and S. M. Prabhu, *MPLS Mobile Backhaul Initiative (MMBI) for 3G/WiMAX/LTE*, Tech Mahindra Ltd., 2010. Available: http://www.techmahindra.com/Documents/WhitePaper/Whitepaper_MPLS_Mobile_Backhaul_Initiative.pdf

[7] "MPLS-TP and IP/MPLS Their Applicability for Metro Networks", Innovation Observatory Ltd., Cambridge, 2012.

[8] *Use of MPLS in Mobile Backhaul Networks* [Online]. Available: http://www.broadband-forum.org/technical/ipmplstechspec.php

[9] (2012, 04/06/2013). Combining IP/MPLS and transport reduces costs and increases efficiency. Available: http://www.nokiasiemensnetworks.com/news-events/insight-newsletter/articles/combining-ipmpls-and-transport-reduces-costs-and-increases-efficiency

[10] O. J. S. Parra, C. A. Hernández, F. J. Puente, and D. L. Sarmiento,

"Performance Evaluation in IP/MPLS Networks," *IEEE*, 2008.

[11] J. Barakovic, H. Bajric, and A. Husic, "QoS Design Issues and Traffic Engineering in Next Generation IP/MPLS Network," presented at the 9th International Conference on Telecommunications (ConTEL), Zagreb, Croatia, pp. 203-210, 2007.

[12] A. Bosco, E. Manconi, R. Sabella, and L. Valentini, "An Innovative Solution for Dynamic Bandwidth Engineering in IP/MPLS Network with QoS Support," *Photonic Network Communications*, pp. 37-42, 2004.

[13] B. Puype, D. Colle, M. Pickavet, and P. Demeester, "Multilayer traffic engineering for multiservice environments," *Photonic Network Communications*, pp. 150-159, 2008.

[14] M. Yannuzzi, X. Masip-Bruin, R. Serral-Graci`a, E. Marin-Tordera, A. Sprintson, and A. Orda, "Maximum Coverage at Minimum Cost for Multi-Domain IP/MPLS Networks," in *IEEE INFOCOM*, pp. 6 -10, 2008.

[15] M. Khan. *Computer Networks*. Available: http://www.enggpedia.com/computer-engineering-encyclopedia/dictionary/computer-networks/1607-computer-networks

[16] "Riverbed® OPNET Network R&D Solutions for Network Equipment Manufacturers, Service Providers, and Research Organizations," R. Technology, Ed., ed, 2013.

[17] R. Dunaytsev, "Network Simulators: OPNET Overview and Examples," ed: Tampere University of Technology, 2010.

[18] W. Zhuang, "End to End Quality of Service in UMTS Systems," in *Telecommunications Networks - Current Status and Future Trends*, D. J. Ortiz, Ed., ed China: InTech, 2012, pp. 99-127.

[19] C. M. Sarraf, F. Ousta, N. Kamel, and M. Z. Yusoff, "UMTS Universal Mobile Telecommunications System: Development of Standards for the Third Generation," presented at the 4th International Conference on Intelligent and Advanced Systems (ICIAS2012), pp. 291-295, 2012.

[20] "IPMPLS Mobile Backhaul Network delivers High Performance Transport at Lower TCO," United States, 2011.