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ENHANCEMENT OF QOS IN VOICE-ENABLED NETWORKS USING COMBINATION OF MPLS AND DIFFSERV

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A thesis submitted in fulfillment of the requirements for the degree of Master of Computer Science (Internetworking Technology)

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DECLARATION

I declare that this thesis entitled "Enhancement Of QoS In Voice-Enabled Networks Using Combination of MPLS and DiffServ" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
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Date	:	August 26, 2014

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Computer Science (Internetworking Technology).

Signature :……………..

Supervisor Name : Dr. Robiah Yusof

Date : August 26, 2014

DEDICATION

To my mother and father who have always loved me

unconditionally and taught me to work hard for

the things that I aspire to achieve.

To my beloved wife who has been a constant

source of support and encouragement

during the challenges of this journy.

To my precious son,"Ghassan",

Whose smile gives me passion and strength

ABSTRACT

At its beginnings, the Internet Protocol was not meant for real-time applications such as voice and video. These conventional IP networks were limited to providing only best-effort QoS model which implies no QoS. Now voice traffic has been transmitted to IP-based networks instead of the conventional Public Switched Telephone Network (PSTN). Therefore, early adopters of this technology have noticed that for voice traffic to function as well as on conventional IP-based network as in PSTN, the transport techniques used by the IP-based network needed some additional policies and technique in place to accommodate the requirements of real-time data traffic. DiffServ is another QoS model used in IP networks, which differentiates IP traffic into classes each with certain priority. Implementing DiffServ, alone, can meet the SLA requirement in term of providing different QoS techniques based on the traffic type, but cannot ensure bandwidth, per-application basis, so congested path may cause jitter, end to end delay or packet loss. MPLS was developed to combine the advantages of the connectionless layer 3 routing and the connection-oriented layer 2 forwarding, and provides per-hop data forwarding where it uses the label swapping rather than the layer 3 complex lookups in a routing table. Implementing MPLS, alone creates an end to end path with bandwidth reservations which guarantees the availability of resources to carry traffic of volume less than or equal to the reserved bandwidth, but MPLS is not aware of the DiffServ classes which considered as a disadvantage. This research project demonstrated the usefulness of combining DiffServ and MPLS in voice-enabled network to enhance voice quality by reducing end to end delay, jitter, and packet loss and proposed a method for analyzing voice applications' requirements based in DiffServ-aware MPLS network.

ABSTRAK

Pada permulaannya, Protokol Internet itu tidak dimaksudkan untuk aplikasi masa nyata seperti suara dan video. Rangkaian-rangkaian IP konvensional terhad kepada menyediakan hanya yang terbaik usaha-model QoS yang membayangkan tidak QoS. Sekarang trafik suara telah dihantar ke rangkaian berasaskan IP dan bukan konvensional Switched Awam Rangkaian Telefon (PSTN). Oleh itu, pengguna awal teknologi ini sedar bahawa bagi trafik suara berfungsi dan juga di rangkaian berasaskan IP konvensional seperti dalam PSTN, teknik pengangkutan yang digunakan oleh rangkaian berasaskan IP diperlukan beberapa dasar tambahan dan teknik disediakan untuk menampung keperluan trafik data masa nyata. DiffServ adalah satu lagi model QoS yang digunakan dalam rangkaian IP, yang membezakan trafik IP ke dalam kelas masing-masing dengan keutamaan tertentu. Melaksanakan DiffServ, sahaja, boleh memenuhi keperluan SLA dalam jangka menyediakan QoS teknik yang berbeza berdasarkan jenis lalu lintas, tetapi tidak dapat memastikan secara jalur lebar, setiap permohonan, jadi jalan sesak boleh menyebabkan ketar, akhir akhir kelewatan atau kehilangan paket. MPLS telah dibangunkan untuk menggabungkan kelebihan sambungan penghalaan lapisan 3 dan lapisan 2 penghantaran sambungan berorientasikan, dan menyediakan per-hop penghantaran data di mana ia menggunakan label pertukaran daripada 3 lapisan lookup kompleks dalam jadual routing. Melaksanakan MPLS, sahaja mewujudkan hujung ke hujung jalan dengan tempahan lebar jalur yang menjamin ketersediaan sumber untuk membawa trafik jumlah kurang daripada atau sama dengan jalur lebar yang ditempah, tetapi MPLS tidak sedar kelas DiffServ yang dianggap sebagai pihak yang rugi. Projek penyelidikan menunjukkan kebergunaan menggabungkan DiffServ dan MPLS dalam rangkaian suara yang dibolehkan untuk meningkatkan kualiti suara dengan mengurangkan hujung ke hujung kelewatan, ketar, dan kehilangan paket dan mencadangkan satu kaedah untuk menganalisis keperluan aplikasi suara 'yang berpangkalan di DiffServ-sedar rangkaian MPLS.

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IP	-	Internet Protocol
QoS	-	Quality of Service
TCP	-	Transmission Control Protocol
PSTN	-	Public Switched Telephone Network
VoIP	-	Voice over IP
MPLS	-	Multi-Protocol Label Switching
DiffServ	-	Differentiated Services
SLA	-	Service Level Agreement
IETF	-	Internet Engineering Task Force
BA	-	Behavior Aggregate
DSCP	-	DiffServ Code Point
PHB	-	Per-Hop Behavior
AF	-	Assured Forwarding
EF	-	Expedited Forwarding
WFQ	-	Weighted Fair Queuing
FEC	-	Forwarding Equivalence Class
LSR	-	Label Switch Router
LSP	-	Label Switch Path
UDP	-	User Datagram Protocol
RTP	-	Real Time Protocol
RTCP	-	Real Time Control Protocol
TCA	-	Traffic Conditioning Agreement
CEF	-	Cisco Express Forwarding
FIB	-	Forwarding Information Base

CPU	-	Central Processing Unit
EXP	-	experimental bits in MPLS Header
TTL	-	Time to Live
OSPF	-	Open Shortest Path First
BGP	-	Border Gateway Protocol
LDP	-	Label Distribution Protocol
ATM	-	Asynchronous Transfer Mode
E-LSP	-	EXP-inferred-class LSP
L-LSP	-	Label-inferred-class L
TE	-	Traffic Engineering
WAN	-	Wide Area Network
LAN	-	Local Area Network
VPN	-	Virtual Private Network
FTP	-	File Transfer Protocol
GUI	-	Graphical User Interface
SLIP	-	Serial Line Interface Protocol
QoE	-	Quality of Experience

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter serves as an introduction to the rest of the research by describing its contents. This chapter describes the research problem statement, the research questions, the research objectives, the research scope and limitation, the research significant and contribution, the research methodology, and the organizational structure of the research.

1.2 Background

At its beginnings, the main objective of the Internet is to transmit data to its destination using the Internet Protocol (IP); which has become the default standard for communication across networks. However, the Internet Protocol was not meant for real-time (i.e., time-sensitive) applications such as voice. Conventional IP networks were limited to providing only best-effort QoS model which implies no QoS, no guarantee for delivering packets to their destinations, and treating packets identically. The conventional IP networks dealt with data traffic that has common characteristics such as burst flow, time-insensitive transmissions, ability to recover after packet loss, and no prioritized flow for critical data traffic according to (Wallace, 2011). In addition, conventional IP networks use transmission control protocol (i.e., TCP) for most data applications which ensures that traffic transported from point to point without errors despite how long it takes to do so.

Now voice traffic has been transmitted to IP-based networks (i.e., VoIP, IP telephony or Voice-enabled networks) instead of the conventional Public Switched Telephone Network (PSTN). Therefore, early adopters of this technology have noticed that for voice traffic to function as well as on conventional IP-based network as in PSTN, the transport techniques used by the IP-based network needed some additional policies and technique in place to accommodate the requirements of real-time data traffic such as supporting small packet payloads, continuously transporting data flow, supporting time-sensitive applications and prioritizing some data flow. However, the potential issues with voice-enabled networks are: the end-to-end delay, jitter, and packet loss. Therefore, there are some primary considerations are addressed to mitigate such issues, for example, providing sufficient bandwidth and reducing end to end delay, jitter, and packet loss (Wallace, 2011) and (Durand et al., 2001). Consequently, carriers (i.e., service provider) must be able to manage QoS in order to satisfy voice-enabled network requirements. Multi-Protocol Label Switching (MPLS) and Differentiated Services (DiffServ) are ideally suited to meet these needs.

DiffServ is another QoS model used in IP networks, which differentiates IP traffic into classes each with certain priority. Once an IP packet is marked with a class, a number of quality techniques can be implemented to ensure the required QoS for time-sensitive packets (i.e., voice packets). This includes avoiding and managing congestion, policing and shaping traffic, and utilizing link efficiently.

MPLS was developed to combine the advantages of layer 3 routing (i.e., connectionless) and layer 2 forwarding (i.e., connection-oriented). In addition, MPLS provides per-hop data forwarding where it uses the label swapping rather than the layer 3 complex lookups in a routing table (Lewis & Pickavance, 2006) and (Kashihara et al., 2009).

Nowadays, service providers defined Service Level Agreement (SLA) for voice services, which is expressed in term of delay, jitter, guaranteed bandwidth, and recovery after failure. According to (Wallace, 2010) SLA requirements are classified to two conditions; first, providing different QoS techniques based on the traffic type, for instance scheduling, queuing and dropping. Second, guaranteeing resource (i.e., bandwidth) per application basis. Using DiffServ can only meet the first condition as assuming there are enough resources for the marked traffic. In fact, traffic may be experienced end to end delay, jitter or packet loss if it goes via congested path. Implementing MPLS can meet the second condition where it provides a path with available resources Besides, MPLS allows choosing alternative paths when the shortest path is congested.

1.3 Problem Statement

The use of IP telephony or voice-enabled network is an inevitable change, that is adapted by many companies; which is replacing the traditional Public Switched Telephone Network (PSTN) due to the significant reduction of cost and resources. However, voice-enabled networks still suffer from quality problems that inherited from the limitation of traditional IP networks (i.e., speed and bandwidth). IP-based networks provide best-effort QoS which does not guarantee the QoS; that results in end to end delay, jitter, and packet loss in voice traffic.

Voice-enabled networks are a real-time traffic that needs assurance of the proper QoS, as a result, there are many mechanisms for fulfilling QoS demand have that been adopted by the IETF such as Multiprotocol Label Switching (MPLS) and Differentiated services (DiffServ). MPLS creates an end to end path with bandwidth reservations which guarantees the availability of resources to carry traffic of volume less than or equal to the reserved bandwidth. MPLS is not aware of the DiffServ classes which considered as a disadvantage. DiffServ allows the allocation of different levels of services to different users and based on the SLA. DiffServ can meet the SLA requirement in term of providing different QoS techniques based on the traffic type, for instance scheduling, queuing and dropping. However, DiffServ cannot ensure bandwidth, per-application basis, so congested path may cause jitter, end to end delay or packet loss. However, to combine the two technologies a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network is needed. This can help services providers or enterprise networks designers to analyze ahead their required voice, MPLS, and DiffServ requirements. Therefore, the problem statement of this research is:

Voice-enabled networks suffer from quality problems that inherited from the limitation of traditional IP networks as they provide best-effort QoS model which implies no QoS. Implementing DiffServ, alone, can meet the SLA requirement in term of providing different QoS techniques based on the traffic type, but cannot ensure bandwidth, per-application basis, so congested path may cause jitter, end to end delay or packet loss. Implementing MPLS, alone creates an end to end path with bandwidth reservations which guarantees the availability of resources to carry traffic of volume less than or equal to the reserved bandwidth, but MPLS is not aware of the DiffServ classes which considered as a disadvantage.

Table 1.1 : Research Problems Summary

	Research problem
RP	Voice-enabled networks suffer from quality problems that inherited from the limitation of traditional IP networks. Implementing DiffServ, alone, can meet the SLA requirement but cannot ensure bandwidth. Implementing MPLS, alone creates an end to end path with bandwidth reservations but it is not aware of the DiffServ classes which considered as a disadvantage.

Table 1.1 summarizes the research problem (RP) to be mapped to the research questions and objectives later on in this chapter. In this research, enhancing the quality of voice traffic is further investigated as well as proposing a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network.

1.4 Research Questions

Based on the problem statement, discussed earlier, this research will answer two primary questions (i.e., RQ1 and RQ2).

RQ1: To what extent MPLS and DiffServ can coexist to provide better QoS for voice-enabled networks?

In order to answer this primary question, it is divided into three secondary questions; by answering these three secondary questions the answer of the primary question (RQ1) can be obtained. RQ1's secondary questions are:

A. What are the parameters of MPLS protocol and DiffServ QoS model? **(RQ1-A)**
B. How to integrate DiffServ QoS model into MPLS network? **(RQ1-B)**
C. How to evaluate the effectiveness of this combination? **(RQ1-C)**

RQ2: Can we propose a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network?

Table 1.2 illustrates the mapping of the research questions to the previously defined research problem. As research problem (RP) can be solved by answering the research primary questions (RQ1) and (RQ2).in addition, RQ1 is divided into three secondary questions (RQ1-A, RQ1-B, and RQ1-C).

Table 1.2 : Research Questions Summary

	RQ	Research Question
RP	RQ1-A	What are the parameters of MPLS protocol and DiffServ QoS model?
	RQ1-B	How to integrate DiffServ QoS model into MPLS network?
	RQ1-C	How to evaluate the effectiveness of this combination?
	RQ2	Can we propose a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network?

1.5 Research Objectives

The research objectives section is comprised of four objectives (i.e., RO1, RO2, RO3 and RO4) in order to answer the previously defined research questions. The overall research objectives are:

1. To identify parameters used in MPLS and DiffServ.
2. To simulate the integration of DiffServ QoS model into MPLS network using OPNET.
3. To test the effectiveness of this combination.
4. To propose a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network.

Table 1.3 : Research Objectives Summary

	RQ	RO	Research Objectives
RP	RQ1-A	RO1	To identify parameters used in MPLS and DiffServ
	RQ1-B	RO2	To simulate the integration of DiffServ QoS model into MPLS network using OPNET
	RQ1-C	RO3	To test the effectiveness of this combination.
	RQ2	RO4	To propose a general method of analyzing the requirements of voice applications based in DiffServ-aware MPLS network

Table 1.3 summarizes the research objectives and maps them to the research questions. The objective RO1 is mapped to the secondary question RQ1-A, and tries to answer it by