UNIVERSITI PUTRA MALAYSIA

LAMBDA-BASED PRIORITISATION IN MULTICHANNEL OPTICAL IP NETWORK

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By

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My beloved wife, children and parents

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in partial fulfillment of the requirements for the degree of Master of Science

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The explosion of the Internet and its application creates demand for more network resources and bandwidth. The internet traffics such as voice, video and interactive applications are more susceptible to delay and jitter while bursty data traffic such as e-mail and file transfer are more sensitive to loss.

To accommodate the bandwidth demands, the trend of the network also experiences a major change from copper-based to optical fibre transmission link. Besides of its many superior properties, optical fibre has an extraordinary limitless bandwidth.

However increasing the bandwidth in respond to the need of bandwidth demands is not necessarily an appropriate solution. As more and more applications use the bandwidth, congestion still occurs. Therefore, the Quality of Service (QoS) is introduced into the network. Different type of Internet traffic requires different treatment while propagating along the network and thus requires a specific QoS characteristic.

In this research, the traffic is split into four levels of priority classes that require different levels of QoS treatment. Each class of traffic is transmitted at different wavelength (λ). The highest priority class deserved the best QoS treatment while lower priority classes needs the lower QoS treatment. Therefore, there are four channels to carry four types of traffic. The Sub-Carrier Modulation (SCM) technique is used to carry the optical traffic and it is transmitted on to the optical communications link using Wavelength Division Multiplexing (WDM) technology.

The Fiber Delay Line (FDL) that acts as an optical buffer is used to resolve the contention on the input port at the receiver. During the contention resolution, the lower priority traffic is buffered while transmitting the higher priority traffic.

The simulation results show that the highest priority traffic gets the best treatment while propagating in the network. The performance of the highest priority traffic is the best whereby it has low loss, low delay and yet high throughput and efficiency. The lower priority traffic sustains high loss, longer delay but low throughput and efficiency.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PERLAKSANAAN PEMPROSESAN PRIORITI BERASASKAN LAMBDA DI DALAM RANGKAIAN IP OPTIK

Oleh

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Peningkatan yang mendadak terhadap trafik Internet dan aplikasinya menyebabkan permintaan yang banyak terhadap sumber-sumber dan kapasiti rangkaian. Trafik Internet seperti suara, video dan aplikasi intertaktif adalah sensitif kepada kelengahan dan ketidakpastian kelengahan manakala trafik data yang besar seperti mail elektronik dan penghantaran fail adalah sensitif kepada kehilangan penghantaran.

Untuk mengatasi masalah permintaan kapasiti rangkaian ini, arah tuju rangkaian mengalami perubahan yang besar dan berubah dari rangkaian berasaskan kuprum kepada rangkaian penghantaran gentian optik.

Walaubagaimanapun, kaedah penyelesaian dengan menambahkan kapasiti rangkaian bukanlah satu kaedah yang tepat. Apabila semakin banyak aplikasi menggunakan kapasiti rangkaian, masalah kesesakan rangkaian masih terus berlaku. Oleh itu, Perkhidmatan yang Berkualiti (QoS) diperkenalkan kepada rangkaian. Trafik Internet yang berbeza memerlukan kaedah pengurusan yang berbeza apabila

bergerak di sepanjang rangkaian. Oleh itu, ciri-ciri QoS yang lebih spesifik diperlukan untuk setiap trafik Internet.

Dalam penyelidikan ini, trafik dipecahkan kepada empat kategori keutamaan, yang memerlukan keadah pengurusan yang berbeza bagi setiap satunya. Setiap kategori trafik dihantar dengan menggunakan jalur gelombang (λ) yang berbeza. Trafik berkeutamaan tertinggi memerlukan keadah pengurusan QoS yang terbaik. Sebaliknya, trafik berkeutamaan rendah memerlukan keutamaan pengurusan QoS yang rendah. Oleh itu, terdapat empat saluran untuk penghantaran empat jenis trafik. Kaedah Modulasi Sub-Pembawa (SCM) digunakan untuk membawa trafik optik dan ianya dihantar dengan menggunakan talian komunikasi teknologi Pemultiplex Pembahagian Jalurgelombang (WDM).

Talian Lengah Fiber (FDL) yang bertindak sebagai penampan optik digunakan untuk menyelesaikan masalah perebutan pada laluan masuk di penerima. Semasa penyelesaian perebutan, trafik berkeutamaan rendah ditampan sementara trafik berkeutamaan tinggi dihantar ke penerima.

Hasil keputusan simulasi menunjukkan trafik berkeutamaan tertinggi mendapat keputusan yang terbaik semasa penghantaran di dalam rangkaian. Prestasi trafik berkeutamaan tertinggi adalah yang terbaik di mana ia mengalami kehilangan yang rendah, kelengahan yang sedikit tetapi perlepasan dan keberkesanan yang tinggi. Trafik berkeutamaan rendah pula mengalami kehilangan yang tinggi, kelengahan yang banyak dan perlepasan dan keberkesanan yang rendah.

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TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL SHEETS	viii
DECLARATION	x
LIST OF TABLES	xiv
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xvii

CHAPTER

1 INTRODUCTION
- 1.0 Introduction 1.1
- 1.1 Research Background 1.3
  - 1.1.1 The Requirement for QoS of IP 1.3
  - 1.1.2 The Problem Statement 1.5
  - 1.1.3 The Objectives of The Research 1.6
  - 1.1.4 Scope of Works 1.8
- 1.2 A Brief Methodology of The Research Project 1.8
- 1.3 Thesis Overview 1.9

2 ENABLING TECHNOLOGIES: QoS IN OPTICAL IP NETWORK
- 2.0 Introduction 2.1
- 2.1 Quality of Service 2.2
- 2.2 Evolution of QoS in IP Network 2.2
  - 2.2.1 Best Effort Services 2.3
  - 2.2.2 Integrated Services (IntServ) 2.3
  - 2.2.3 Differentiated Services (DiffServ) 2.5
    - 2.2.3.1 Per-Hop-Behaviour (PHB) 2.8
    - 2.2.3.2 DiffServ Operation 2.10
- 2.3 OSI 7 Layer Architecture 2.11
  - 2.3.1 The Optical Layer 2.13
    - 2.3.1.1 Optical Transmission Section (OTS) 2.14
    - 2.3.1.2 Optical Multiplex Section (OMS) 2.14
    - 2.3.1.3 Optical Channel (OCh) 2.14
  - 2.3.2 Higher Layers in OSI 7 Layer 2.15
- 2.4 Evolution of Optical IP Network Architectures 2.16
  - 2.4.1 IP over AAL5/ATM over SONET/SDH 2.17
  - 2.4.2 IP over SONET, Packet over SONET (POS) 2.17
  - 2.4.3 IP over WDM 2.18
- 2.5 Contention Resolution Techniques in Optical Network 2.19
  - 2.5.1 Deflection Routing 2.20
  - 2.5.2 Wavelength Conversion 2.21
  - 2.5.3 Optical Buffering Using Fiber Delay Lines (FDL) 2.23

2.5.3.1 Fixed-delay FDL Buffer 2.24
2.5.3.2 Variable-delay FDL Buffer 2.24
2.5.3.3 Hybrid FDL Buffer 2.25
2.6 Optical IP Transmission Using Sub-Carrier Modulation (SCM) Techniques 2.26
2.7 Packet Header Processing Techniques 2.27
2.8 Conclusion 2.29

3 NETWORK MODELING
3.0 Introduction 3.1
3.1 The Network Model 3.1
3.2 The Transmitter 3.2
3.3 The Transmission Line 3.4
3.4 The Receiver 3.4
3.4.1 The Optical Splitter 3.5
3.4.2 Optical Demultiplexers 3.5
3.4.3 Photo Detector 3.6
3.4.4 Electrical Filter 3.6
3.4.5 Packet Header Processor (PHP) 3.6
3.4.6 Fixed-delay Fibre Delay Line (FFDL) 3.7
3.4.7 Variable-delay Fiber Delay Line (VFDL) 3.7
3.4.8 Optical Switch 3.8
3.4.9 Tunable Photo Detector (TPD) 3.8
3.5 A Novel Threshold Time (t_{th}) Policy 3.8
3.6 A Unique Contention Resolutions Policy 3.9
3.7 Conclusion 3.11

4 SIMULATION TECHNIQUES, RESULTS AND DISCUSSION
4.0 Introduction 4.1
4.1 Simulation Techniques 4.1
4.1.1 The Design Parameters 4.1
4.1.2 The Performance Parameters 4.2
4.1.3 Simulation Method 4.2
4.2 Simulation Results 4.3
4.2.1 Throughput 4.3
4.2.1.1 Throughput at 2.5 Gbps Bit Rate 4.3
4.2.1.2 Throughput at 10 Gbps Bit Rate 4.5
4.2.1.3 Relationship Between Throughput and Bandwidth Utilisation 4.6
4.2.2 Packet Loss 4.7
4.2.2.1 Packet Loss for 2.5 Gbps Bit Rate 4.8
4.2.2.2 Packet Loss for 10 Gbps Bit Rate 4.9
4.2.2.3 Total Packet Loss 4.9
4.2.3 Delay 4.11
4.2.3.1 Delay for 2.5 Gbps Bit Rate 4.11
4.2.3.2 Delay for 10 Gbps Bit Rate 4.12
4.2.3.3 Comparison Delay for 2.5 Gbps and 10 Gbps Bit Rate 4.13
4.2.4 Efficiency 4.14
4.2.4.1 Efficiency for 2.5 Gbps Bit Rate 4.14
4.2.4.2 Efficiency for 10 Gbps Bit Rate 4.15

4.2.4.3 Average Efficiency for 2.5 Gbps and 10 Gbps Bit Rate 4.16
4.3 Conclusion 4.18

5 CONCLUSIONS
5.0 Concluding Remarks 5.1
5.1 Future Works 5.2

REFERENCES R.1
APPENDICES
Appendix A A.1
BIODATA OF THE AUTHOR B.1

LIST OF TABLES

Table		Page
1.1	Priority Mapping Table	1.7
3.1	Priority to Wavelength Mapping	3.3
3.2	The Unique Threshold Time Policy Develop Under This Study	3.10
4.1	Bandwidth Utilisation for 2.5 Gbps and 10Gbps Bit Rate	4.7
4.2	Packet Loss for 2.5 Gbps and 10 Gbps Bit Rate	4.11
4.3	Delay for 2.5 Gbps and 10 Gbps Bit Rate	4.14
4.4	Average Eficiency for 2.5 Gbps and 10 Gbps Bit Rate	4.17

LIST OF FIGURES

Figure		Page
1.1	QoS Roles in Traffic Management	1.4
2.1	IPv4 TOS Byte and Values Defined	2.6
2.2	DiffServ Fields	2.7
2.3	Logical View of a Packet Classifier and Traffic Conditioner	2.10
2.4	The OSI Reference Model	2.12
2.5	Optical Transport Network (OTN) Architecture as Defined by ITU-T	2.13
2.6	Protocol Stack Evolution for IP over Optical	2.16
2.7	Deflection Routing Technique in Shufflenet	2.21
2.8	Wavelength Conversion Technique	2.22
2.9	Fixed-delay FDL Buffer	2.24
2.10	Variable-delay FDL Buffer	2.24
2.11	Hybrid FDL Buffer	2.26
2.12	Sub-Carrier Modulation Technique	2.27
2.13	Packet Header Processing	2.28
3.1	Point-to-Point Optical IP Network	3.1
3.2	The Packet Loss of The Simulation at 10000 Bits Packet Length	3.3
3.3	The Receiver Block Diagram	3.5
3.4	Contention Resolution Using A Unique Threshold Time (t_{th}) Policy	3.9
3.5	Threshold Time (t_{th}) Percentage	3.11
4.1	Throughput (%) versus Arrival Rate (Mbps) for 2.5 Gbps System	4.4
4.2	Throughput (%) versus Arrival Rate (Mbps) for 10 Gbps System	4.5
4.3	Bandwidth Utilisation for The System at 2.5 Gbps and 10 Gbps	4.6

4.4	Packet Loss (%) versus Offered Load for 2.5 Gbps System	4.8
4.5	Packet Loss (%) versus Offered Load for 10 Gbps System	4.9
4.6	Total Packet Loss at 2.5 Gbps and 10 Gbps Bit Rate	4.10
4.7	Delay (µs) versus Arrival Rate (Mbps) for 2.5 Gbps System	4.12
4.8	Delay (µs) versus Arrival Rate (Mbps) for 10 Gbps System	4.13
4.9	Efficiency versus Arrival Rate (Mbps) for 2.5 Gbps System	4.15
4.10	Efficiency versus Arrival Rate (Mbps) for 10 Gbps System	4.16
4.11	Efficiency versus Arrival Rate (Mbps)	4.17

LIST OF ABBREVIATIONS

AAL5	-	ATM Adaptation Layer 5
AF	-	Assured Forwarding
APS	-	Automatic Protection Switching
ATM	-	Asynchronous Transfer Mode
CoS	-	Class of Service
OADM	-	Optical Add-Drop Multipxer
OAM&P	-	Operations, Administration, Maintenance and Provisioning
bps	-	bits per second
BER	-	Bit Error Rate
BPSK	-	Binary Phase Shift Keying
DCS	-	Digital Cross-connects
DHCP	-	DiffServ Code Point
DiffServe	-	Differentiate Services
DLCI	-	Data Link Control Identifier
DMUX	-	Demultiplexing
DWDM	-	Dense Wavelength Division Multiplexing
ECP	-	Electronic Control Processor
EF	-	Expedited Forwarding
FDL	-	Fiber Delay Lines(s)
FFDL	-	Fixed Fiber Delay Line
Ghz	-	Giga Hertz
HDLC	-	High-level Data Link Control
IETF	-	Internet Engineering Task Force
IntServ	-	Integrated Services

IP	-	Internet Protocol
ITU	-	International Telecommunication Union
ISP(s)	-	Internet Service Provider(s)
ISO	-	International Standards Organisation
KEOPS	-	KEys to Optical Packet Switching
$LiNbO_3$	-	Lithium Niobate
MPLS	-	Multi Protocol Label Switching
MBZ	-	Must Be Zero
OAM&P	-	Operations, Administration, Maintenance and Provisioning
OBS	-	Optical Burst Switching
Och	-	Optical Channel
OEO	-	Optical-Electrical-Optical
OMS	-	Optical Multiplex Section
OOK	-	On-off Keying
OS	-	Optical Splitter
OSI	-	Open System Interconnection
OTN	-	Optical Transport Network
OTS	-	Optical Transmission Section
OXC	-	Optical Cross Connects
PDA	-	Photo Detector Array
PHB	-	Per Hop Behaviour
PHP	-	Packet Header Processor
PLF	-	Payload Filter
POS	-	Packet Over SONET

PPP	-	Point-to-Point Protocol
QoS	-	Quality of Service
RFC	-	Request For Comment
RSVP	-	Resource ReSerVation Protocol
SLA	-	Service Level Agreement
SCM	-	Sub-Carrier Multiplexing
SDH	-	Synchronous Digital Hierarchy
SONET	-	Synchronous Optical NETwork
TCP	-	Transport Control Protocol
TDM	-	Time Division Multiplexing
TE	-	Traffic Engineering
TPD	-	Tunable Photo Detector
TLS	-	Tunable Light Source
TOS	-	Type of Service
TWC	-	Tunable Wavelength Converter
VC	-	Virtual Circuit
VFDL	-	Variable-delay Fiber Delay Line
WDM	-	Wavelength Division Multiplexing

CHAPTER ONE

INTRODUCTION

1.0 Introduction

The explosive growth of the Internet creates demand for more network resources as more and more users running more and more applications. It is predictable that the growth of the Internet traffic doubles every four to six months [Coffman, 1998]. If this growth rate continues, the aggregate bandwidth required for the Internet will be about 280Tb/s by 2005 [Sevcik, 1999].

In responding to the high bandwidth requirements, the trend of the network also experiences a major change from copper-based to optical fibre transmission link. In practically all cases in which fibre is used today, it is deployed in transmission links as a direct substitute for copper. This is because of its many superior properties: extraordinary bandwidth, low loss, low cost, light weight and compactness, strength and flexibility, immunity to noise and electromagnetic interference, security and privacy and corrosion resistance [Stern, 1999][Palais, 1998].

Traditionally, whenever the traffic volume increases, network managers will continually add more expensive capacity in effort to satisfy the needs of their customers, and yet, network remains congested. A new breed of aggressive and bandwidth hunger applications that use network to carry voice and video traffics compound this struggle.

A tremendous effort takes places to combine all kind of communication services- voice, multimedia and data – into a completely IP-based packet-switched mode of operation. Hereby, the transportation of packets directly over photonics in the form of IP over fibre will play a major role.

IP over optical architecture evolution has undergone dramatic changes from Internet Protocol (IP) over Asynchronous Transfer Mode (ATM) over Synchronous Optical NETwork (SONET)/Synchronous Digital Hierarchy (SDH), IP over SONET and finally IP over Wavelength Division Multiplexing (WDM). IP over WDM has been envisioned as the winning combination due to the ability to be the common revenue-generating convergence sub-layer and WDM as a bandwidth rich transport sub-layer [Nasir, 2000].

The technologies of WDM and Dense WDM (DWDM) offer great bandwidth utilization over a single fibre transmission line. WDM is a proven method of increasing bandwidth by a factor of 30 at 50% of the cost of alternate methods. These cost advantages are particularly significant in cases which new fibre builds are avoided by using WDM equipment [Stern, 1999].

WDM promises to multiply the bandwidth capacity of optical transmission medium many folds. The principle behind it is the transmission of multiple digital signals using several wavelengths so that there is no interference among them.

1.1 Research Background

In this section, the motivation of the research works, the problems attempted to be solved and the objectives are stated and explained.

1.1.1 The Requirement for QoS of IP

The increasing demand of the multimedia applications for quality, reliability and predictability of the services motivate many network managers to apply the Quality of Service (QoS) into the network. Different types of Internet traffic that consists of voice, video and interactive multimedia applications alongside data systems, require different treatments when propagating in the network. Voice, video and interactive applications are more susceptible to delay and jitter while bursty data traffic such as e-mail and file transfer are more sensitive to loss.

Although fibre optic offers huge bandwidth for the transmission link, this does not guarantee a quality of service delivery especially during the congestion period.

Figure 1.1 illustrates the QoS roles in traffic management. During the congestion period, if the traffic is not well managed, the throughput will reach 100% and abruptly drop. The interactive traffic suffers freeze and possible timeout. A non-critical traffic could eat up bandwidth for critical applications. In the worst case, the throughput can drop to nearly 0% until the traffic is cleared and throughput increases again.

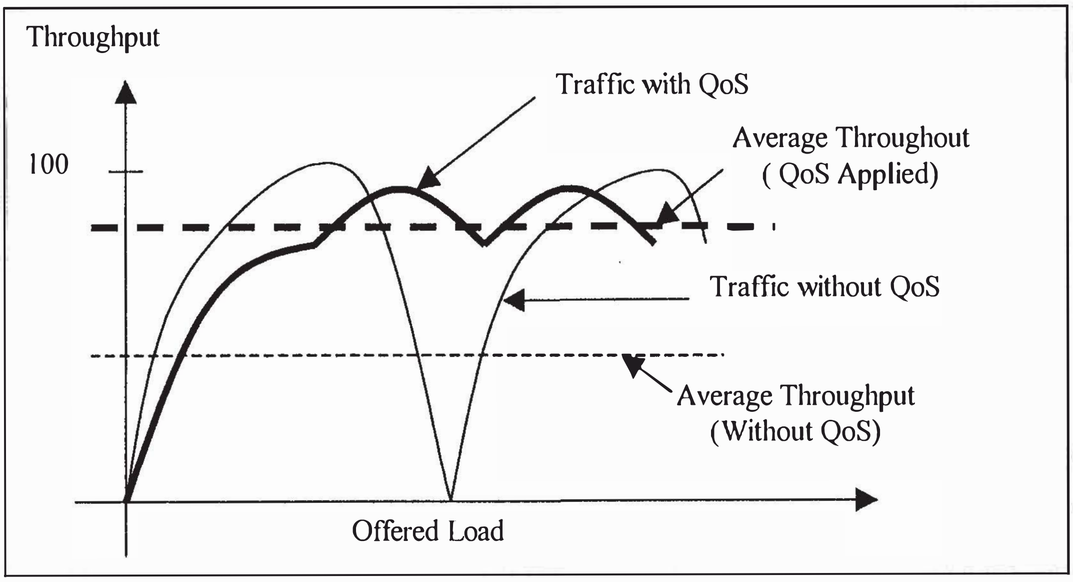

Figure 1.1: QoS Roles in Traffic Management

This phenomenon is caused by the behaviour of the packet flow in the network. Packet in a flow can follow different paths between input and output ports. To be useful, all packets composing a flow must arrive at the destination successfully to be constructed into the original message at the transport layer. Since packet in a flow may experience different delays, the packets may be out-of-order, or lost in the intermediate network nodes. The higher layer protocol, Transport Control Protocol (TCP) is responsible to recover the corrupted flows before passing them to the applications.

However, extensive corrupted flows due to the congested network profoundly affect the performance of the TCP which cause [Bennet, 1999]:

- Unnecessary retransmission
- TCP retransmits the lost packet later than it normally does because of the obscured packet lost

- Inaccurate estimation of round-trip time
- Inefficiency of the TCP at the receiver due to serious burden on it
- Losing self-clocking at the TCP and the traffic becomes highly bursty

On the other hand, during congestion period, the managed traffic has a better throughput. Using proper congestion avoidance and detection, the low priority packet is discarded and higher priority packet is allowed to pass through. The average throughput for managed traffic is much improved as compared to the unmanaged traffic.

1.1.2 The Problem Statement

Different class of services is normally defined at the packet level in the network. In the transmission link, the packets traverse from node to node regardless of their services and intermediate transmission medium. All packets are equally served. However, when the packets arrive at the receiving node, these packets contend amongst each other for the output port. Under the absence of proper packet handling, only few packets may successfully be received by the receiver, other packets might be dropped or discarded. This is due partly to the long processing time which is based on electronics processing, through several stages. A receiver will have to convert signals from optical domain to electrical, and then has to rearrange the packets before the allocated fields can be determined for further processing. The requirement for *opto-electronic-optic* (O-E-O) conversion also leads to not only reduced processing speed but also scalability concern [Nasir, 2000].