OPTIMIZED BURST ASSEMBLY ALGORITHM FOR MULTI-RANKED TRAFFIC OVER OPTICAL BURST SWITCHING NETWORK

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This dissertation is dedicated to my mother, Fatooma, the one of the kind, for all the love and care she has always provided me, to the soul of my father, Maali, for all the virtues he planted in me, and to all members of my beloved family: Mohamed, Shaimaa, Moustafa and Asmaa for their endless support. Last but not the least to my niece , Limar, the fruit of Al-Maalis, for the way she brightens everyone's life.

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ABSTRACT

Optical Burst Switching (OBS) is seen as the most vital technology for the coming era of Internet backbone infrastructure. The OBS cardinal role, especially for data of high priority belonging to real time systems, makes optimizing the OBS network one of the significant fields of research. Thus, OBS network fulfillment of all requisites and compulsions for optimized performance for all classes of traffic in terms of packet loss and end to end delay is a vital issue of study. This research presents a new optimized multi-class burst assembly algorithm over OBS network to ensure an enhanced performance via appropriate network service that could reduce packet loss rate and delay, especially for high priority classes of data, by the mean of preventing contention along OBS resources. A simulation model using National Chiao Tung University network simulator (NCTUns) simulator has been used to evaluate the performance of the proposed schemes, where the scheme is runned with three types of traffic: Constant Bit Rate (CBR), Variable Bit Rate (VBR) and Available Bit Rate (ABR). The traffic classes served by the proposed scheme can be extended to N number of classes, Where N value is calculated upon the burst size. The scheme is named Multi-Class Adaptive Burst Assembly (MC-ABA), and it represents an optimized version of the Real-Time Adaptive Burst Assembly (RT-ABA), where the MC-ABA not only serves N number of classes of Internet traffic over OBS networks but also considers the intensity of high priority data within each assembled burst to avoid contention and reduces packet loss and delay of high priority data over OBS core nodes. Simulation results showed that MC-ABA scheme could reduce the end-to-end delay and packet loss, besides providing suitable service for all types of data traffic. Generally, the proposed scheme can improve OBS network to be an appropriate environment for high priority traffic.

ABSTRAK

Pensuisan Letusan Optik (OBS) telah meningkat menjadi teknologi paling penting dalam era infrastruktur tulang belakang Internet. Peranan penting OBS, terutamanya untuk data berprioriti tinggi sistem masa nyata, menjadikan pengoptimuman rangkaian OBS sebagai satu bidang penyelidikan yang utama. Oleh itu, pemenuhan semua keperluan rangkaian OBS dan keperluan untuk memberi prestasi optimum kepada semua pengkelasan trafik dari segi kehilangan paket dan lengah hujung-ke-hujung adalah satu isu kajian yang penting. Kajian ini mencadangkan paradigm optimum berbilang kelas baru yang menjamin prestasi lebih baik melalui servis rangkaian bersesuaian antara semua kelas trafik yang dapat mengurangkan kadar kehilangan paket dan masa lengah, terutamanya untuk kelas data berprioriti tinggi, selain mempertingkatkan truput keseluruhan melalui penghalangan rebutan sepanjang sumber OBS. Satu model simulasi menggunakan pensimulasi National Chiao Tung University network simulator (NCTUns) telah dibangunkan untuk menilai prestasi skema yang dicadangkan, di mana skema dibangunkan dengan tiga jenis trafik: Kadar Bit Tetap (CBR), Kadar Bit Bolehubah (VBR) dan Kadar Bit Tersedia (ABR). Kelas-kelas trafik yang diberikan oleh skema yang dicadangkan boleh dipanjangkan kepada N bilangan kelas. Skema ini dinamakan sebagai Penghimpunan Letusan Adaptif Berbilang Kelas (MC-ABA), yang merupakan versi optimum Penghimpunan Letusan Adaptif Masa Nyata (RT-ABA), di mana MC-ABA bukan sahaja menyokong trafik berbilang kelas tetapi juga mengambilkira data berprioriti tinggi dalam himpunan letusan untuk mengelakkan perebutan dan kehilangan paket data berprioriti tinggi dalam nod teras OBS. Hasil simulasi menunjukkan skema MC-ABA mampu mengurangkan masa lengah hujung-ke-hujung,selain menyediakan servis yang sesuai untuk semua jenis trafik data. Secara umumnya skema yang dicadangkan dapat menambah baik rangkaian OBS untuk persekitaran yang sesuai dengan trafik berprioriti tinggi.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The vital role of communications in our everyday life has become indispensable in all fields. The Internet as a cardinal form of modern means of communication facilitates exchanging information, online conversations, business transactions, etc., giving rise to a whale of a wide spread usage of the Internet all over the world.

Some researchers warned of an expected catastrophe as they tackled the rapid increase of internet users from all ages and different sectors via carrying out an accurate statistical study over the last two decades (Miniwatts Marketing Group, 2010). This research pushed scientists to call for smart solutions to be applied for the Internet backbone infrastructure that prevents the Internet expected blast through maintaining a mechanism that yields good heavy traffic management plus cheaper means of Internet transmission and storage (Van der Auwera *et al.*, 2008; Andrikopoulos *et al.*,1999).

Finally the fiber optics was offered as a novel and trustworthy Internet transmission media for the well-known speed it has as well as the massive bandwidth it can provide when compared to the old traditional types of cables used for the Internet backbone infrastructure (Chatterjee and Pawlowski, 1999). The peerless conspicuous high speed nature of light can guarantee high transmission rate where the data is carried over electromagnetic waves by the mean of optical fibres.

Various multiplexing techniques are proposed to provide best transmission media utilization, Wavelength Division Multiplexing (WDM) is one technology that provides high performance and quality rate (Heron *et al.,* 2008; Ishio *et al.*, 1984). It offers two different patterns, first is the Conventional Wavelength Division Multiplexing (CWDM), while the second is called Dense Wavelength Division Multiplexing (DWDM) (Brackett, 1990; Chih-Lung *et al.*, 2008).

Many studies consider the DWDM as a promising technology as it serves various types of data e.g. IP, ATM, SONET/SDH, and Ethernet (Qiao and Yoo, 1999; Laude, 2003. In addition to being protocol independent and also capable of manipulating bit rates between 100Mb/s up to 10Gb/s.

The DWDM is associated with different switching techniques e.g. circuit switching, packet switching, and burst switching. This dissertation is concerned with the Optical Burst Switching (OBS) (Qiao and Yoo, 1999; Jonathan, 1999; Laude, 2003) which is considered as the best concomitant technique when compared to other existing techniques like Al-shargabi (2011). Brief comparison is done between the three techniques in Table 1.1. The OBS amalgamates all merits and benefits of both circuit and packet switching, the out-of-band fashion is applied for signaling scheme where a burst control packet is detached from data burst for them to travel on separate channels as a mean of maintaining optimum resource utilization plus a diminished setup delay.

Table 1.1 Comparison between 3 switching techniques in the fiber optical Networks.

Technique	Bandwidth Utilization	Setup Latency	Optical Buffer	Signal scheme
Circuit Switching	Poor	High	Not required	2 ways out-of-band
Packet Switching	Good	Low	Compulsory	1 way in band
Burst Switching	Good	Low	Not required	1 way in band

Data aggregation and buffering processes are done at the edge nodes of the OBS networks where a burst control packet (burst header; holding all burst data e.g. length, offset time, etc.) is sent first for resource allocation over intermediate OBS nodes, then the data burst follows on a devoted channel, after being held for fixed offset time.

The OBS, as a foreseen sophisticated technology, serves various types of traffic, assists miscellaneous applications, manages different data burst lengths, besides encompassing multifarious techniques for contention resolution and signalling, and therefore it can guarantee best Quality of Service (QoS) providence for the upcoming networking generation (Farahmand *et al.*, 2007; Yoo, 2006; Youngseok and Mukherjee, 2004).

A study carried out by Tao *et al. (2006),* Siu and Jain (1995), Jain (1996) and Ghiassi-Farrokhfal and Liebeherr (2009), categorized the traffic into four classes: Constant Bit Rate (CBR), Variable Bit Rate (VBR), Unspecified Bit Rate (UBR), and Available Bit Rate (ABR) as an Internet traffic taxonomy service, while other studies merged CBR and VBR in one category i.e. real time traffic, as both of the two traffic types are packet loss sensitive where specific conditions should be fulfilled (Ahmadi *et al.*, 1995; Ghiassi-Farrokhfal and Liebeherr, 2009). VBR can lie in both real time and non-real time classification zones.

The OBS network is composed of edge and core routers plus Wavelength Division Multiplexing WDM links. Burst aggregation and corresponding burst control packets are the edge routers responsibility, while data burst switching/routing is held at the Core routers. In the core nodes the Just-Enough-Time (JET) protocol applies the "out-of-band" transmission fashion, where the control packet is detached from dara burst before it travels on a separate channel, for a uni-directional resource allocation. In case of having more than one output-port leading to the same destination, it is most probably that the shortest path is chosen in the unequal Probabilities Outputting Scheme (UPOS) analyzed by Ho (2009). The UPOS does not use a fixed probability for all output-ports which makes it more suitable for the actual Internet traffic environment as it reserve the short path for high priority traffic via prioritizing the multi-class traffic of OBS networks. This technique resulted in a concrete enhancement in QoS through giving high priority classes a pre-emptive chance to allocate Short-Path-Ports (SPPs) and also occupy the idle ports over those classes of low priority level.

A Successive minimal Incremental Routing algorithm (SMIR) offered by Ni *et al.,* (2009) was proposed to provide a class-wise routing paradigm that can be extended from a 2-class to an N-classes OBS network. It periodically updates each path(*i*) between source-destination (s-d) for delivering N-class burst using link costs calculations. SMIR can also perform path re-optimization in case of changes in Internet traffic requirements.

Lack of priority-concept supported algorithms over Wavelength Division Multiplexing (WDM) pushed researchers to offer a pioneer study that proposed a priority-based model to call connection demands over all optical WDM communication (Dutta *et al.,* 2009), where the calls are sorted into three ranks of precedence, and the model proposed appraised the burst blocking/dropping probability under the condition of having prioritized bursts. The research also acquainted the principle of queuing-based channel assignment for a WDM network where the axiom of preference of high-priority bursts to that of lower priority for

transmitting and switching over WDM nodes have been emphasized for handling an omnifarious application/priority WDM network.

Real Time traffic-Adaptive Burst Assembly (RT-ABA) scheme (Al-Shargabi, 2011), is a bright technique for burst composition in an adaptive fashion via avoiding the risk of losing a burst formed only of high priority data, the technique offered enhanced the traditional composite burst assembly schemes by the mean of using a membership value to get two traffic types aggregated in one burst to guarantee fairness among traffic classes and optimize the Quality of Service (QoS) provided. The Internet traffic is exposed to continuous changes in traffic loads, scenarios, etc. Although the RT-ABA could successfully manage to aggregate data bursts accordingly but it classified traffic classes into two classes only: high and low priority.

1.2 Research Motivations

Almost all of the existing research works based on WDM technology do not apply the ranking and precedence techniques (Dutta *et al.*, 2009). This criterion can severely hinder the next generation of WDM networks. Applications and services over Internet are quite different in nature and momentousness; business transactions or telemedicine data should not be equally entertained, by WDM network, in terms of routing and switching, with a simple email or an ordinary file transfer process. Table 1.2 shows a comparison between some of the existing assembly schemes.

Table 1.2 A brief comparison between some of the burst assembly schemes.

Burst Assembly Schemes	Year	Technique	Disadvantages
Threshold-based scheme	(Ge *et al.*, 2000)	The burst assembly parameter used for the Threshold-based scheme is the burst minimum size B_{min}, a burst is formed when the number of bytes of the packets lined up in the destination queue strikes the B_{min}	In case of low traffic this can result in delay time which makes the scheme not suitable for the real time traffic.
Time-based scheme	(Duser and Bayvel, 2002)	All packets arriving within a period of time *T* are huddled in one burst; A timer is set for each destination-queue where all packets in the queue amalgamates into the burst when time= *T*	Not recommended for real-time traffic : 1- big no of control packets of small sized data bursts that results in increased process time of headers at core nodes in low traffic . 2- long bursts formed in high traffic packet: high loss rate at core nodes
Hybrid Time-and-Threshold-based Scheme	(Hu *et al., 2003),* (Burak and Sema, 2006)	The Hybrid Time-and-Threshold-based scheme is a mix of the time and threshold based schemes , it is chosen as the default burst assembly scheme as it amalgamates all merits of the two schemes.	The delay caused at the low traffic still exists as the timer have to stretch to max. for the burst to be sent. In this manner the scheme provided is not that suitable for real time traffic.
Learning-based Burst Assembly (LBA)	(Venkatesh *et al., 2007)*	Adaptive algorithm that applies learning automata, the paradigm attempt to diminish delay time via periodically getting a network loss feedback upon which it reset the assembly time at the edge routers.	Feedback occurs after the loss already exists. thus, it doesn't support the demands of end-to-end traffic and not convenient for real-time traffic.

Real-time traffic restrains special quality requirements. Consequently it is quite essential to assort the multiform applications and various Internet traffic into categorized levels of service to serve them accordingly. Ranking the data burst and packets disseminated and routed over the WDM network will guarantee the

transcendence in service provided, besides limiting burst-blocking, packet-loss and end-to-end delay.

1.3 Problem Statement

The standard OBS technique has undergone some efficient enhancement through recent studies have achieved a recognisable improvement in the QoS in terms of delay and packet loss for real time traffic. However, the existing schemes do not function over all types of Internet traffic.

The RT-ABA scheme is a promising solution, using a membership value (MV), to offer an optimised scheme that fulfils a concrete enhancement over QoS via providing high performance level among real time and non-real time Internet traffic classes. However, the scheme dealt with the Internet traffic as categorised into only two classes; real and non-real time traffic. Besides, all aggregated data bursts are treated in the same way along core nodes without considering the amount of real-time data within each burst which does not maintain the suitable service for real time systems which consequently affected the QoS.

This study proposes a multi-class paradigm that enhances the existing RT-ABA algorithm to be capable of serving all categories of real time and non-real time traffic data bursts. The traffic classes are classified from 0 to N categories, where the traffic class of highest priority, denoted by 0, is given the highest price for subscription, where the association seeking highest traffic service category pays the service provider agency to be allocated for class 0 and therefore it get fastest service with a diminished delay and packet loss guaranteed.

The burst for this Multi-Class ranked scheme for real time and non-real time traffic, named MC-ABA, is assembled in an adaptive technique with different traffic classes referring to their addressed priority level while considering the instantaneously detected Internet state of traffic load. The data burst is then given a calculated factor indicating the amount of real time traffic within the aggregated burst, the factor is saved to the burst header travelling ahead for resource allocation. The higher the factor that the burst header indicates, the bigger the chance for the data burst to gets over the core nodes first i.e. with minimal delay and therefore contention and packet lost are avoided. The MC-ABA guarantees suitable service for each class over OBS network, especially for those burst holding high priorities i.e. holding real time data and prevent burst blocking and high end-to-end delay for data belonging to real time systems and governmental organizations having vital type of traffic.

1.4 Research Objectives

This study endeavors to improve the QoS for Internet traffic bursts served over the OBS network through carrying out some upgrades to the already existing scheme RT-ABA via:

(i) To run the chosen burst assembly scheme for performance evaluation in terms of end-to-end delay and packet loss.

(ii) To enhance the chosen scheme to be able to serve N ranks of data traffic, where the traffic is ranked on economic basis where class 0, of highest priority, is given the most costly subscription fee. This paid type of service ensures a suitable service over OBS network for ranked classes of traffic belonging to different users.

(iii) To save the amount of the high priority data to the burst header travelling ahead; data bursts holding higher share of real time data gets higher priority in scheduling along core nodes.

(iv) To test and evaluate the performance of the proposed MC-ABA Algorithm against the chosen scheme on OBS networks, in terms of packet loss and end-to-end delay.

1.5 Significance of the study

The study presented here offers an optimized form for the RT-ABA as it offers a Multi-Class ranked scheme for real time and non-real time traffic, named MC-ABA after the multi-class RT-ABA, which begets a pre-eminence in QoS provided via offering an n-class traffic scheme. The MC-ABA can handle all categories of traffic by assigning them to ranked category levels (0-N) and manage burst aggregation process with respect to their priority in an adaptive fashion referring to the continuously changing Internet traffic loads.

Moreover, the 0-class, of highest priority level, represents the most vital data over the Internet as it affects real-time systems involved, thus a factor (1-100) indicating the extent of real-time data within the burst is saved to the packet header that is sent ahead for resource allocation and acknowledgement. The core nodes gives priority of allocation and forwarding to the burst holding the highest factor, this process prevents contention for data bursts as they will not have to compete for the already allocated resources as the priority of allocation will be given upon density of high-priority data within bursts. The bursts holding more real-time data will suffer no delay, drop or loss by the hand of this technique consequently it is mostly suitable for real time traffic. Generally speaking the scheme offered is offering a guaranteed enhanced QoS to Internet traffic classes.

1.6 Scope of the Study

The scope of the offered study can be stated as follows:

i. This approach is to be applied over OBS network for data burst aggregation.
ii. The research focuses on applying all types of traffic (0 to N-type) and allows them to be served and assembled accordingly in an adaptive technique.
iii. The scheme calculates the ratio of high priority traffic besides it avoids contention along core nodes and mitigates latency for real time data.
iv. Analysis and comparison with the existing scheme RT-ABA over OBS network is reviewed to guarantee the enhancement in Service and concrete optimization achieved, by the mean of simulation over NCTUns networks simulation code.

1.7 Dissertation Organization

The organization of the dissertation is divided into 5 chapters. Chapter 1 provides the introduction to the study domain, mainly OBS network technology, and the preliminaries of Network Coding concepts. Then it discusses the problem background, problem statement, research objectives and contributions. Chapter 2 provides the intensive literature review of the study area, background, network coding, problems and potential solutions. Chapter 3 provides the research methodology flow used in this research and discusses simulation setup, problem formulation based on the literature review. Then Chapter 4 design and

implementation. Chapter 5 presents the results and conclusion, and finally Chapter 6 presents the future work.

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