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Comparative Investigation on the Performance of Hierarchical Time Sliced OBS and Traditional Optical Burst Switched Networks

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***Abstract*—the need for large-bandwidth networks is in continuous growth. Such demands are notivated by the continuous development of bandwidth-greedy applications (BGAs) and the desire to have everything on-line. All-optical networks are the most appropriate infrastructure to meet the requirements of bandwidth greedy applications. Three optical switching paradigms are being developed for that purpose. Among these paradigms, Optical Burst Switching (OBS) is seen as a viable solution. However, OBS is yet to be feasible due to high burst loss as a result of contention at the core node which remains the major issue in this technology and it is caused by the lack of matured and cost effective optical memory in the core routers. To address this issue, two categories of OBS have been proposed: Non-slotted OBS and Slotted OBS. In non-slotted OBS, switching is done in wavelength domain while in slotted OBS, switching is performed time domain. In this paper, we investigate the performance of the two categories. The investigation focuses on studying the impact of burst and wavelength parameters on both categories. We have used computer simulation for the study. Simulation results show that, both burst and wavelength parameters do have considerable impact on the performance of the networks and they also show that slotted outperforms non-slotted OBS.**

***Keywords*—Optical Burst Switching, Wavelength Division Multiplexing, Slotted OBS, non-slotted OBS, Bandwidth-greedy Applications, Internet of everything.**

I. Introduction

The continuous growth of Internet of everything is putting unmatchable stress on current network infrastructures in terms of bandwidth. The desire to have everything online and do everything online has led to the development of new services and applications such as e-health, e-education, e-administration, IPTV, video conference, and others [1].

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To reduce the problems related to electronic network infrastructures and to cope with the rapid growth of the number of Internet users and bandwidth-greedy applications, optical Wavelength Division Multiplexing (WDM) communication systems are being deployed in many telecommunications backbone networks and are slowly finding their way to access networks which has given birth to FTTx technologies.

At backbone level, three optical switching paradigms have been proposed to take advantage of WDM technology and to satisfy the requirements of bandwidth-greedy application. These paradigms are Optical Circuit Switching (OCS) [2], Optical Burst Switching (OBS) [3] and Optical Packet Switching (OPS) [4]. Among the three paradigms, OBS remains the promising paradigms and the most likely to be implemented in the near future. Despite the favoritism of OBS, this paradigm still suffers from high burst loss as a result of burst contention at the core node. Burst contention occurs when two or more bursts contend for the same resource at the same time. In electronic communication networks, contention is solved using buffers at the core network. Since there no mature optical buffers, such devices are not assumed. Therefore when bursts contend some of them must be dropped leading to high burst loss ratio [5] and [6]. To deal with contention issue in OBS so as to reduce burst loss and increase network performance, different architectures have been proposed and analyzed. These architecture are classified into two categories: slotted and non-slotted OBS [7]. Slotted OBS architectures are similar to slotted Aloha concepts. In this class of OBS, switching is done in time domain instead of wavelength domain as is the case in non-slotted OBS. Data channel is divided into timeslots. Incoming data streams from different input ports must be realigned to the slot boundaries to maintain synchronization prior to entering the switching fabric. One of the advantages of slotted OBS is that it allows a burst to be reserved on a timeslot basis instead of unpredictable continuous time as in WDSbased OBS. This leads to more predictable and manageable switching schedule. It also reduces the complexity of wavelength reservation processing. Figure 3 shows various slotted OBS design.

This paper studies the effect of burst and transmission channel parameters on the performance of both categories. Hierarchical Time Sliced OBS (HiTSOBS) proposed in [8].

In [16] we have evaluated the performance of single core node and single wavelength HiTSOBS. The investigations carried out in this paper were implemented on multi-core and multiwavelength WDM network and they

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make use of the findings and the algorithms proposed in [14] and [15] respectively

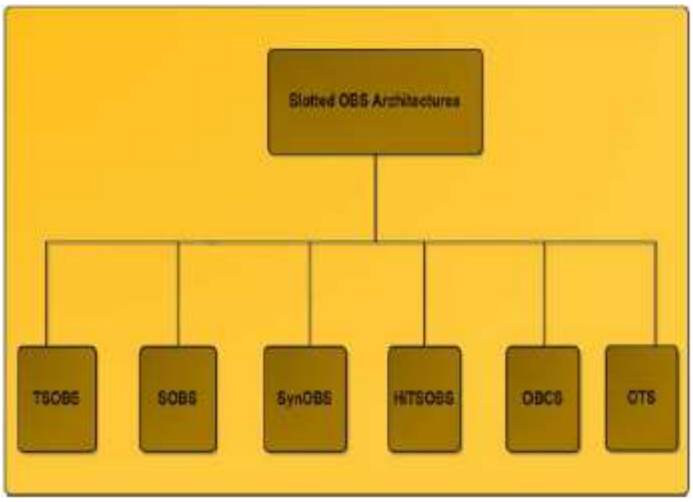

Figure 1: Different Slotted OBS Techniques

The rest of this paper is organized as follows: In Section 2, OBS architecture is described. HiTSOBS architecture and operation are briefly described in Section 3. Simulation environment and parameters are discussed in Section 4. Simulation results are analyzed in Section 5. The paper is concluded in Section 6.

II. Optical Burst Switching Paradigm

In this Section, the operation of OBS will be elaborated. Section 2.1 covers operations, components and functions of OBS. In Section 2.2, different functions of OBS networks are discussed.

2.1 Principles of OBS Operation

OBS network consists of two types of network nodes,an Edge Node which is the interface between OBS network and client networks and a Core Node which makes up the core network of OBS as shown in Figure 2.

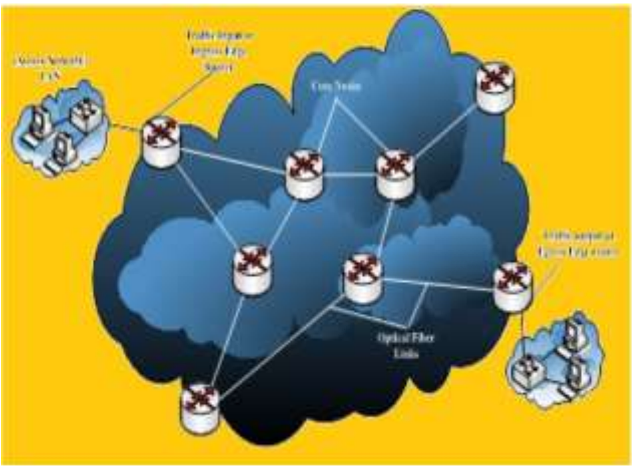

Figure 2: OBS Network Architecture

In optical burst switched networks, data packets from different client networks are aggregated into a larger packet called burst and switched through the network all-optically. Distributed signaling with oneway reservation is used in basic OBS network architecture as shown in Figure 2. In this one reservation technique, a control packet known as Burst Header Packet (BHP) carrying burst information, is first sent in a dedicated out-of-band control channel to set up a connection by reserving appropriate network resources only for the transmission duration of the announced burst. The source node waits for a fixed time known as offset time before sending the corresponding burst. The offset time should be enough to process the control and reserve required resources at each OBS core router before the arrival of the burst. This eliminates the need for electronic or optical buffering. Since resources are reserved only upon the arrival of data and for the period of that data transmission, OBS provides better environment for efficient resources allocation coupled with a higher degree of statistical multiplexing. This is a main difference between OBS and OCS in which resources reservation is static. Additionally, the fact that client packets are transmitted as large burst, it is not mandatory to use fast optical switches which is necessary for normal operation of OPS networks. The operations needed for OBS paradigm are: burst assembly, control packet generation, offset management, route and wavelength assignment, signaling, scheduling and contention resolution as described in [3].

These functions are executed by the Edge and core nodes of OBS. The Edge node performs five functions are executed by an OBS edge OBS (ingress): 1. Burst Assembly; 2. Burst Header packet generation; 3. Signaling; 4. Routing and Wavelength Assignment, and 5. Offset computation for the control packet which is sent prior to the data burst.

Burst assembly is the first process that takes palce in OBS network and it happens at the Edge (ingress) where traffic originating from different clients (e.g., IP, SDH, and ATM) are sorted based on their destinations and aggregated into variable-size packets known as bursts. There are mainly two approaches for burst assembly: Timer-based assembly, size-based assembly or a hybrid approach. The choice of the burst aggregation algorithm has a significant impact on the performance of the OBS network. In timer-based algorithms, a timer is used by the OBS ingress node to determine when to assemble a new burst. In size-based algorithms, a threshold burst size is used to determine the length of the assembled burst. The threshold parameter needs to be carefully chosen; because on one hand, long bursts hold network resources for long time and thus may cause higher burst losses; on the other hand, short bursts cause an increased number of control packets which results in high network overhead. The reader is refered to [3] for the details of other functions of edge node.

The core node perform scheduling and contention resolution. In OBS networks contentionresults in high burst loss ratio. Thus contention resolution is one of the main design objectives in OBS paradigm. Contention occurs when two or more bursts at the core node contend for the same network resource ate the same time. Contention also occurs if a burst arrives at an OBS core node and all local resources are occupied. In the event of contention, several method can be employed to resolve it. Contention resolution techniques can broadly be classified into three: time domain techniques such as the use FDLs, space domain solutions by using deflectiion routing [23], burst segmentation [10] and wavelength domain techniques as discussed in [11]. A combination of these techniques may be used to resolve contention.

III. Hierarchical Time Sliced OBS

One important parameter in time variant OBS that affects the performance of the network is the frame size which has to be pre-configured at all intermediate core nodes. There is an opportunity cost in using small or large frame size. Small frame size increases contention probability due to the fact that the overlapping bursts are more likely to pick the same slot number, while deploying large frame sizes induces larger end-to-end delays due to each flow having access to a reduced fraction of the link capacity; this will lead to significant queuing delay at the ingress edge node. This loss-delay trade-off, determined by frame size, is identical across all traffic flows, and cannot be changed in TSOBS architecture.

To resolve the issues of frame rigidness in both TSOBS [13] and SynOBS [12] and provide QoS provisioning in slotted OBS such as the work in [17], the researchers in [8] have proposed a slotted OBS named Hierarchical Time Sliced OBS (HiTSOBS). In HiTSOBS a flexible and hierarchical frame structure is used. This flexibility allows frames of different sizes to co-exist together in a way that QoS is guaranteed. Additionally, HiTSOBS allows dynamic changes in the hierarchy of the frames according to the mixture of traffic classes thus obviating the need for any other changes in the network. Delay-sensitive traffics (voice and video) are transmitted over frames of higher levels where the frames are of smaller size. While loss-sensitive traffic (email, ftp, web pages and others) are supported by the frames of lower levels. Furthermore, HiTSOBS allows dynamic changes in the hierarchy of the frames according to the mixture of traffic classes thus obviating the need for any other changes in the network.

In HiTSOBS, each frame is subdivided into time slots as shown in Figure 3.

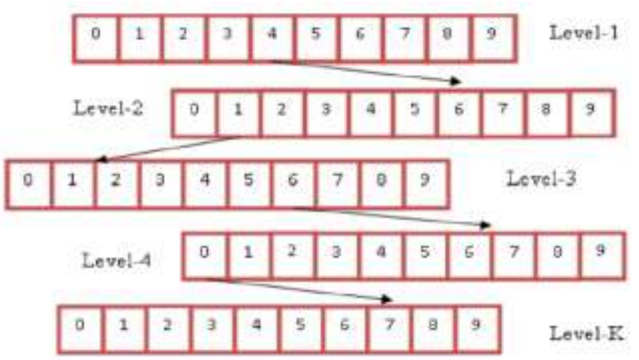

Figure 3: Frame Structure of HiTSOBS

If k represents the time slot at which burst transmission starts, then the top-level (level-1) frame repeats every slot. Thus, a burst transmitted at this level would occupy slots $k, k+r, k+2r+......+, k+(B-1)r$ where B is the average of size of the burst measured in time-slot units. It is important to note that, a slot in the level-1 frame may expand into an entire level-2 frame and so on. Bandwidth occupation per slot in a given level is governed by Equation 1.

$$S_c = \left(\frac{1}{r^i}\right) W_c \qquad (1)$$

In Equation 1, Sc, represents the bandwidth share of a time-slot in a given level of the hierarchy, Wc denotes the total capacity of a wavelength and i represents the order of the level in the hierarchy. For the details operation of Control and Data planes of HiTSOBS, the reader is kindly refered to [8]

IV. Simulation Scenarios and Parameters

To under take the investigations of the impact of burst classes and transmission link parameters on the performance of slotted and non-slotted OBS and to compare the performance of both architecture, the event driven simulator developed by the researchers in [24] was used. The comparison was carried out using the 14 nodes NSFNET topology as shown in Figure 4.

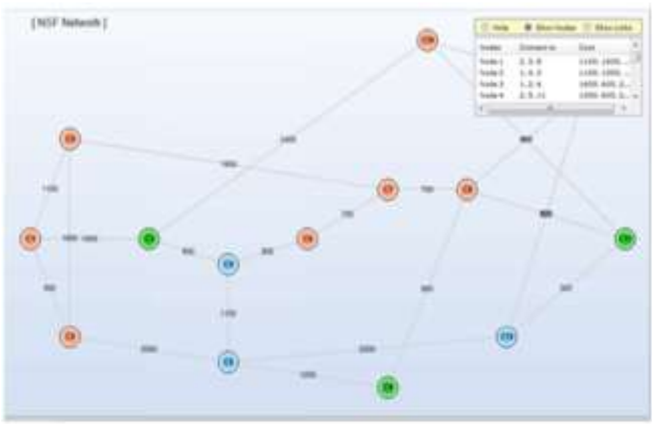

Figure 4: Simulation Topology

Two cases of nodes interconnection were studied:
In case 1, 4 wavelengths per link were used; out of the 4 wavelengths, 3 are used for data transmission while 1 is used for BCP transmission. In case 2, 8 wavelengths per link were used; out of the 8 wavelengths, 7 are used for data transmission while 1 wavelength is used for BCP transmission. Wavelength capacity on each wavelength is 10Gbps. Bursts for flow j arrive as a Poisson process at

rate λ / B bursts per timeslot where B represents the average burst size. Timeslot size was chosen to correspond to 1_, which is consistent with the switching speeds of solid-state optical switching technologies available in the industry [20].

Burst size was fixed at 125 KB [8]. As in [8], 2 levels hierarchy were studied for loss and delay sensitive applications denoted as Class 0 (High Definition Multimedia Video/audio) and Class 1 (normal data: FTP, email, telnet, etc...). Each flow is assigned to a level depending on its Class. Upon arrival of a flows burst at the edge node the edge node reserves a timeslot according to PSTA algorithm described in [15]. In PSTA, timeslots are reserved over a number of frames equal to the burst length and the burst is transmitted on to the core node. As in [3], the slot positions for burst slices for any given flow vary each time the flow becomes newly backlogged; this is important because it helps prevent synchronization and phase locking which complicates the implementation of OPS. Evaluation metrics are burst loss ration and throughput. Simulation parameters are summarized in Table 1.

Table 1: Simulation Factors and Levels

Factors	**Levels**
Number of Wavelengths	4 and 8
Wavelength Capacity (Gbps)	10
Frame Size (Time slot)	10
Burst Size (KB)	125
Time Slot size (µs)	1
Number of Levels in the hierarchy	2: Class 0 and Class 1.
Topology	NFSNET: 14 nodes
Evaluation metrics	BLR and Throughput

V. Results Analysis and Discussions

In this Section, we discuss the results of HiTSOBS and conventional OBS in terms of burst loss ration (BLR). Two factors were used for investigation: Number of wavelength, class of the burst.

5.1 The Impact of number of wavelength

Figure 5 and Figure 6 depict the impact of number of wavelength on BLR for both conventional OBS and Slotted OBS, in this case HiTSOBS..

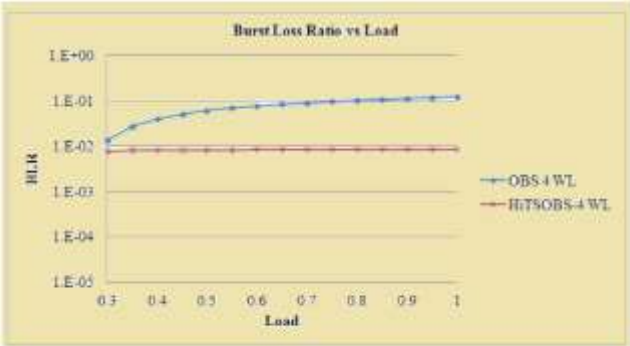

Figure 5: Loss Results Comparison of OBS and HiTSOBS for 4 wavelengths

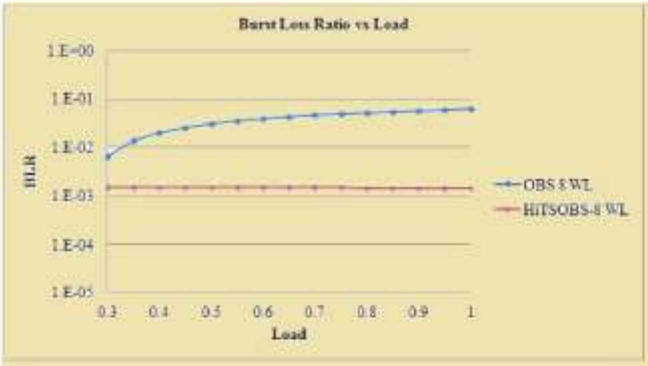

Figure 6: : Loss Results Comparison of OBS and HiTSOBS for 8 wavelengths

From the above figures, we observe that regardless of number of wavelengths per fiber link, HiTSIBS outperforms traditioanl OBS in terms of burst loss ratio. These results are further improved at higher number of wavelengths as shown in Figure 5. The high performance of slotted OBS can be attributed to the efficient use of wavelength where burst are assigned per timeslot and per wavelength.

5.1.2 The Impact of Burst Class

Loss results of classes comparison of both HiTSOBS and non-slotted OBS are shown in Figure 7 and Figure 8.

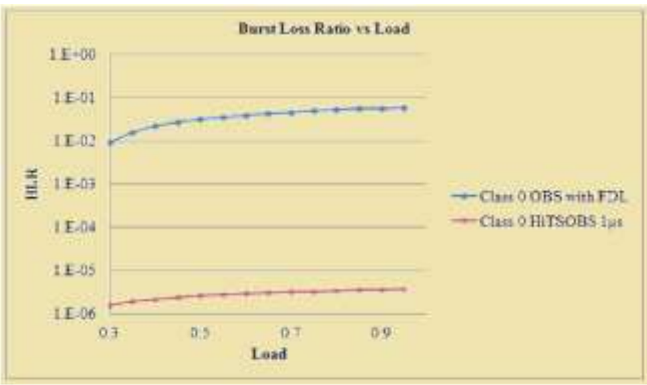

Figure 7: Loss Results Comparison of OBS and HiTSOBS for Class 0 Bursts

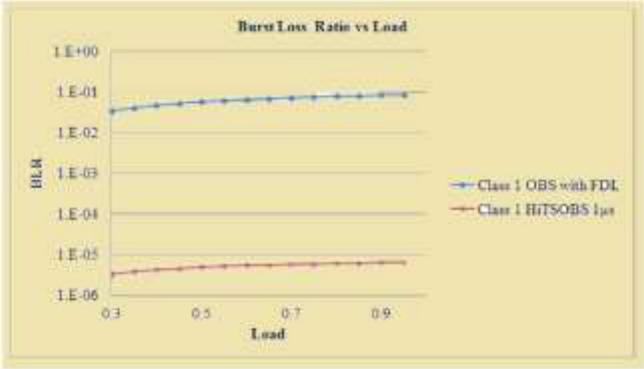

Figure 8: Loss Results Comparison of OBS and HiTSOBS for Class 1 Bursts

Referring to results shown in Figure 7 and Figure 8, one can observe that Class 1 bursts of HiTSOBS with $1\mu s$ timeslot outperforms that of OBS with FDL; this performance is true for both classes. However, class 0 produces better results than class 1 bursts. This is attributed to the fact that higher priority bursts are transported by higher level frames of the hierarchy and thus have lower burst drop probability.

Throughput results are omitted due to space limiations.

VI. Conclusions

In this paper, we have investigated the impacts of burst class and number of wavelength per optical link on slotted and non-slotted OBS on burst loss ratio. The evaluation was carried using computer simulation. Obtained results demonstrate that, HiTSOBS outperforms conventional OBS in the simulation cases and parameters. The high performance of HiTSOBS is attributed to the flexibility of its frame structure. In future work we plan to investigate the effect of other parameters such as burst size, frame and number of flow on the performance of slotted OBS and non-slotted OBS.

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References

[1] J. Wang, R. Prasad, and I. Niemegeers, In house high definition multimedia: An overview on quality-of-service requirements, International Journal of Research and Reviews in Computer Science, vol. 1, no. 1, 2010.

[2] A. Ghafoor, M. Guizani, and S. Sheikh, Architecture of an all-optical circuit-switched multistage interconnection network, IEEE Journal on Selected Areas in Communications, 1990. vol. 8, no. 8, pp. 15951607,

[3] C. Qiao and M. Yoo, Optical burst switching (obs)a new paradigm for an optical internet, Journal of High Speed Networks. 1999. vol. 8, no. 1, pp. 6984.

[4] C. Guillemot, M. Renaud, P. Gambini, C. Janz, I. Andonovic, R. Bauknecht, B. Bostica, M. Burzio, F. Callegati,and M. Casoni, Transparent optical packet switching: The european acts keops project approach, Journal of Lightwave Technology. 1998. vol. 16, no. 12, p. 2117.

[5] T. Venkatesh and C. Siva Ram Murthy, ”Introduction to optical burst switching,” in An Analytical Approach to Optical Burst Switched Networks. Springer, 2010, pp. 1-41.

[6] J. Triay and C. Cervello-Pastor, ”An ant-based algorithm for distributed routing and wavelength assignment in dynamic optical networks,” IEEE Journal on Selected Areas in Communications. 2010 vol. 28, no. 4, pp. 542-552.

[7] F. Farahmand, V. Vokkarane, and 1. Jue, ”Practical priority contention resolution for slotted optical burst switching networks,” 2003.

[8] V. Sivaraman and A. Vishwanath, ”Hierarchical timesliced optical burst switching,” Optical Switching and Networking. 2009. vol. 6, no. 1, pp. 37-43.

[9] N. Ogino and H. Tanaka, ”Deflection routing for optical bursts considering possibility of contention at downstream nodes,” IEICE Transactions on Communications, vol. 88, p. 3660, 2005.

[10] V. M. Vokkarane, et al., ”Burst segmentation: An approach for reducing packet loss in optical burst switched networks,” presented at the 2002. IEEE International Conference on Communications. Conference Proceedings, New York, NY, USA:, 2002.

[11] I. S. Hwang, et al., ”Multicast wavelength assignment with sparse wavelength converters to maximize the network capacity using ILP formulation in WDM mesh networks,” Photonic Network Communications. 2006 vol. 12, pp. 161-172.

[12] Sheeshia, S., & Qiao, C. Synchronous optical burst switching. In Broadband Networks, 2004. BroadNets 2004. Proceedings. IEEE. First International Conference on (pp. 4-13).

[13] Ramamirtham, J., & Turner, J. Time sliced optical burst switching. In INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. 2003. Vol. 3, pp. 2030-2038.

[14] Yahaya, C., Latiff, A., & Mohamed, A. B. (2013). A review of routing strategies for optical burst switched networks. International Journal of Communication Systems, 26(3), 315-336.

[15] Coulibaly, Yahaya, Rouskas, George, Abd Latiff, Muhammad Shafie, Razzaque, M. A. and Mandala, Satria,” QoS-aware ant-based route, wavelength and timeslot assignment algorithm for optical burst switchednetworks”. Transactions on Emerging Telecommunications Technologies, 2015. In Press by Wiley.

[16] Coulibaly, Y., Abd Latiff, M. S., Mohammad, A. B., & Enemusah, H. Performance analysis of a single-node hierarchical time sliced optical burst switching (hitsobs) network. International Journal of Innovative Computing, 2011, Vol. 1 No.1.

[17] Akar, N. and Karasan, E. and Vlachos, K.G. and Varvarigos, E.A. and Careglio, D. and Klinkowski, M. and Sol-Pareta, J. A survey of quality of service differentiation mechanisms for optical burst switching networks. Optical Switching and Networking. 2010. vol. 7, issue. 1, pp. 1-11.

[18] M. Yoo and C. Qiao, ”Just-enough-time (JET): A high speed protocol for bursty traffic in optical networks,” in IEEE/LEOS Technologies for a Global Information Infrastructure, ed: IEEE, 1997, pp. 79-90.

[19] Rodrigues, J.J.P.C. and Gregrio, J.M.B. and Vasilakos, A.V., Enhanced just-in-time plus protocol for optical burst switching networks, Optical Engineering, 2010; vol.49.

[20] Yao, S. and Dixit, S. and Mukherjee, B., Advances in photonic packet switching: An overview, IEEE Communications Magazine, 2000, vol. 38. No. 2. pp. 84-94.

[21] J. Y. W. R. I. McFarland, ”Just-In-Time Signaling for WDM Optical Burst Switching Networks,” J. Lightwave Technol, 2000. vol. 18, pp. 18-12.

[22] B. Wang and N. Lella, ”Dynamic Contention resolution in optical burst switched networks with partial wavelength conversion and fiber delay lines,” in IEEE Global Telecommunications Conference, 2004. GLOBECOM ’04. , 2004, pp. 1862-1866.

[23] Ogino, Nagao, and Hideaki Tanaka. ”Deflection routing for optical bursts considering possibility of contention at downstream nodes.” IEICE transactions on communications 88.9 2005. pp. 3660-3667.

[24] Y. Coulibaly, ”Enhanced Antnet-based Scheme for Route, Wavelength and Time-slot Assignment in Optical Burst Switched Network,” Ph.D. Thesis. Universiti Teknologi Malaysia (UTM), 2011.