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MANAGING CONTENTION AVOIDANCE AND MAXIMIZING THROUGHPUT IN OBS NETWORK

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Abstract

Optical Burst Switching (OBS) is a promising technology for future optical networks. Due to its less complicated implementation using current optical and electrical components, OBS is seen as the first step towards the future Optical Packet Switching (OPS). In OBS, a key problem is to schedule bursts on wavelength channels whose bandwidth may become fragmented with the so-called void (or idle) intervals with both fast and bandwidth efficient algorithms so as to reduce burst loss. In this paper, a new scheme has been proposed to improve the throughput and to avoid the contention in the OBS network. The proposed scheme offers the same node complexity as that in general OBS networks with optical buffers. Also, it avoids burst blockings in transit nodes, turning it into an efficient and simple burst contention avoidance mechanism. Simulation results show that the proposed scheme has improvement of 15% in terms of burst loss probability as compared to OBS existing schemes and also maximizes the throughput of the network without deteriorating excessively other parameters such as end to end delay or ingress queues.

Keywords: Optical burst switching, Burst loss, Throughput, Contention.

1. Introduction

Several switching approaches are currently being considered for all-optical networks: optical circuit switching (OCS), optical packet switching (OPS) and optical burst switching (OBS). The main drawback of OCS is the circuit setup time, which can take more than the circuit holding time. On the other hand, no setup time is incurred with OPS, but the packet header has to be interpreted in the electrical domain on a hop-by-hop basis, which is very challenging for Gbps speeds. Thus in

Abbreviations

BTU	Burst transceiver unit
CP	Control packets
CU	Control unit
DB	Data burst
FDL	Fiber delay lines
OBS	Optical burst switching
OCS	Optical circuit switching
OPS	Optical packet switching

in order to accommodate current technology, optical burst switching (OBS) was proposed by Chen [1]. Optical Burst Switching (OBS) is a switching paradigm, which is faster and more flexible than Optical Circuit Switching and less complex to realize than Optical Packet Switching.

In this paper, an efficient scheme has been presented to avoid contention and to maximize throughput for optical burst switched networks. The results obtained show that the proposed scheme provides 15% performance in terms of burst blockings. In fact, it makes true the objective of a loss free network, at the expense of introducing a small extra delay (tolerable) to access the optical channel.

The remainder of the paper is organized as follows. Section 2 reviews the OBS and its performance related issues for WDM networks. The operation of the proposed scheme to maximize throughput and to avoid contention in OBS network is discussed in Section 3.Simulation parameters and assumptions made are given in Section 4. Section 5 analyses the OBS network performance and discusses the results extracted from simulations. Finally, Section 6 summarizes the main conclusions and future scope of the paper.

2. Optical Burst Switching and Related Issues

An OBS network (as shown in Fig. 1) consists of edge nodes at the periphery of the network and core nodes inside the network. Edge nodes aggregate packets from upper layer into optical data bursts (DBs) and keep them in the optical domain. Each optical burst has an associated control packet (CP). CP is sent in a separate control channel and processed electronically at each node, in an attempt to schedule its corresponding data burst. Typically, the CP contains information about the arrival instant of the incoming burst and also about the burst size. Consequently, the output wavelength is reserved only for the burst transmission time, possibly adding a guard band. This one-way signaling is called as Just Enough Time (JET). One-way signaling is more efficient than two-way signaling for optical networks with high bandwidth-delay product. The out-of-band manner lowers the transmission bit rate and O/E/O conversion speed of control signal. It also makes the control channel sharable for multiple dense wavelength division networks (DWDM) burst channels, which leads to a better link utilization.

In OBS, the optical burst is transmitted without confirmation. Thus, chances are that the output wavelength cannot be reserved in an intermediate switch. As a result, the burst will be dropped. A number of burst scheduling algorithms have been proposed to minimize the burst dropping probability. Assuming wavelength conversion capabilities are available at the switch, there are a number of wavelengths to choose from. Precisely, the scheduling algorithms differ in the way the wavelength selection is performed. The simplest approach is to choose the first available wavelength. This approach leads to a very high utilization of the wavelengths that are probed first. An alternate approach is to consider the smallest void (in duration) among the ones the optical burst fits in. Though, this scheme reduces fragmentation, but at the expense of a higher computational cost. In evaluating the scheduling algorithms, two fundamental issues have to be considered. First, the burst size is a random variable. Secondly, the offset time is also a random variable. This is a consequence of the different distances of the burstifiers to a given switch, in number of hops.

The burst scheduling algorithm is a critical issue in OBS switch architecture. Therefore, a number of proposals have appeared in the literature [2-4]. Iizuka, M. [2] proposed a scheduling algorithm minimizing voids generated by arriving bursts in optical burst switched WDM network. In the proposed scheduling algorithm, when the burst which has arrived at optical core router at a certain time can be transmitted in some data channels by using the unused data channel capacity(it is called void). The proposed scheduling algorithm selects the data channel in which a void newly being generated after the burst transmission becomes minimal. It is seen that the proposed algorithm improves burst loss ratio but end to end delay increases.

Scheduling algorithms have been discussed by Clement, J.W. [3]. Horizon does not utilize any void intervals and thus is fast but not bandwidth efficient. On the other hand, LAUC-VF VF (Latest Available Unscheduled Channel-VF) can schedule a burst as long as it is possible but has a slow running time. Cohen, R.J. [4] implemented integrated contention resolution and control algorithm in optical burst switching with respect to burst loss probability and network throughput. Simulation results show that the proposed approach behaves well in practice and responds quickly to any change in network status, while improving the overall network performance and is also void of any packet re-orderings.

If the scheduling algorithms are examined in a loss probability range below 10^{-5} then the performance of the different scheduling algorithms is very much alike. However, the computational cost radically differs from one algorithm to another. Thus, the choice of a scheduling algorithm is conditioned by the switch loss probability regime. Most interestingly, it turns out that an apparently worse algorithm performs better, if the computational cost is taken into account.

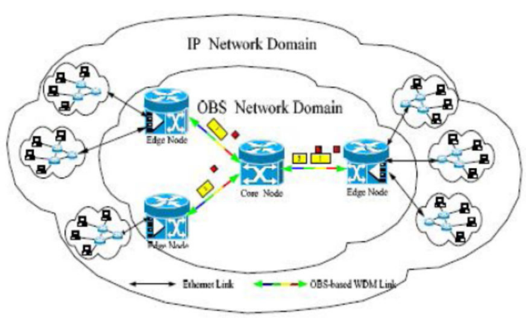

Fig. 1. Optical Burst Switched Network [5].

In general OBS networks, nodes processing control packets (CPs) usually follow the first-come-first-served discipline; they can only know about previously scheduled data bursts (DBs), but cannot predict the information of incoming DBs. As a consequence, this leads to inefficient resource utilization [6]. Similarly, although existing OBS networks with optical buffers [7] have buffered the CPs with the same delay of the DBs using fiber delay lines (FDLs) in order not to alter the offset between the CPs and the DBs, scheduling the DBs is still based on the arrival sequence of CPs. Thus, resource allocation is inefficient.

Although optical buffers are not mandatory in OBS networks, studies show that using FDLs as optical buffers can effectively improve the network performance [4, 6, 7]. In an OBS network with FDLs, when a control packet cannot successfully reserve a wavelength at an output port for its corresponding data burst, it will try to reserve the available FDL with the shortest delay instead.

There are two different node structures in OBS networks with FDLs: one is that each link has a dedicated FDL module (called as FDL share per link); the other is that each node has only one FDL module to be shared by all links (called as FDL share per node). The difference between FDL share per link and FDL share per node mainly lies in the hardware cost and the efficiency of FDL utilization. FDL share per node needs much less single FDL elements and much less wavelength converters. But the trade-off is that it needs more ports in the optical switch. Since wavelength converters are expensive, in terms of minimizing hardware cost, FDL share per node is a better choice since it is less bulky and utilizes FDLs more efficiently than FDL share per link.

Also, it has been shown that the offset time emulated OBS outperforms the conventional OBS in terms of fairness, scheduling efficiency, QoS provisioning, control and routing operation while conserving main performance characteristics of the conventional one [8].

Based on the literature survey, the following is the comparison of various contention resolution schemes of OBSTN (as shown in Table 1.)

Table 1. Comparison of Contention Resolution Schemes of OBSTN.

Scheme	Advantages	Disadvantages
Wavelength Conversion	Low burst loss	Expensive technology
FDL buffer	Simple and mature technology	Bulky FDLs
Deflection Routing	No extra hardware requirement	Out of order arrivals; possible instability
Burst Segmentation	High efficiency, lower burst loss	Immature, high complexity, extra delay and increased signalling

3. Proposed Scheme to Avoid Contention and to Maximize Throughput

The following is the brief description of the proposed scheme

- In the proposed scheme, simple core nodes and smart edge nodes are considered. The electronic data processing and buffering are performed mainly in the edge nodes while the core node concentrates on all-optical switching. This optimizes mature electronic technologies and state-of-the-art optical technologies.
- Offset time emulated OBS with FDL share per node architecture is used.
- The transmission and switching of the burst are operated in an asynchronous manner, which simplifies the implementation by avoiding synchronization between nodes.
- IP traffic has become dominant traffic in backbone optical networks thus variable-sized burst are used in the proposed scheme as it matches the natural form of IP packets.
- The edge node is designed to send/receive local Gigabit Ethernet frames and also to forward bursts like the core node. It consists of a burst transceiver unit (BTU) handling burst assembly/disassembly and an optical switching unit performing burst forwarding. At the egress edge node, when a burst is received through local switch matrix, the BTU receiver simply disassembles the received burst back into multiple Gigabit Ethernet frames, which will be forwarded to their next hops in a conventional way.
- In the proposed scheme, a 2×2-node core switching node with up to 4 wavelengths per port based is used which is based on a spectral-temporal space switch. The main function of core node is to realize optical burst switching. It consists of an electronic processing unit and an optical switching unit. The optical switching unit consists of couplers, MUX/DEMUXs, an optical switch matrix, power equalizers and amplifiers. The optical switch matrix is composed of four non-blocking thermo-optic switches with a switching speed of less than 3ms. Each burst cuts through core node, so its format and bit rate can be arbitrary. The action of switch matrix is controlled by the electronic processing unit according to the routing and control information contained in the control signal. The power equalizer and amplifier are used to equalize and amplify the power of burst channels respectively. The switching core node applies a contention resolution strategy resorting to wavelength conversion and temporal delays. The main node functionalities include control packet reading and processing followed by tunable wavelength conversion, tunable optical delays, burst scheduling algorithm and node element control [5, 9-11]. Tunable delay line (TDL, actually selectable delay line) allows adjusting the delay of the burst in order to avoid burst collisions in the time domain. The electronic processing unit is composed of two parts: the control signal processing part and the management & control part. The former performs route searching, channel scheduling, control signal updating and forwarding. The latter conducts optical switches configuration, as well as supervision and control of optical devices, such as power equalizers and amplifiers. This switch architecture gives flexibility to the design regarding the configuration of the core node. It is capable of supporting burst, flow and wavelength switching.
- In the proposed scheme, each source uses the control channel to convey transmission requests to each destination. Each destination independently

schedules bursts over control intervals, using the control channel to return the granted schedule slots to each source.

- The control signal is generated simultaneously and transmitted before its corresponding burst with the offset time. The control packet is converted to an electronic domain. It is sent to control unit (CU) of core switching node and its content is read to extract routing and burst duration information.
- If CP is not processed within the offset time, the incoming burst is optically forwarded to FDL to wait the end of control packet processing at CU. The processing results in delaying the burst to avoid collision at the output port. According to this decision, CU assigns the burst to available output port with assigned wavelength along with the required delay time.
- Under the proposed scheme, a source receives schedules from multiple destinations demanding multiple transmissions over a common time interval. In this case, the source has an opportunity to resolve this collision by selecting a single destination to transmit to. Thus, a higher throughput is achieved under the proposed scheme but at the expense of increased scheduling delay.
- In the proposed scheme, available wavelengths are searched in the wavelength set and if any wavelength is available then the availability of tunable delay lines is checked.
- In case a free delay line is found, the proposed scheme searches for available wavelengths and selects one that has the least void with the latest forwarded burst. The request for burst scheduling contains a burst duration value and an output port number.
- In case of unsuccessful attempt, the request is rejected and the burst is lost while recording the overflow of the tunable delay lines and the request rejection.
- For contention resolution, the proposed scheme employs optimal routing as follows:
    - ➢ Source node sends out a control packet;
    - ➢ Intermediate nodes process the control packet and attempt to reserve the channel in anticipation of the burst that would follow.
    - ➢ Source node sends out the burst after offset time;
    - ➢ If there is no available egress channel for the burst at a node, at first it is checked whether the current node is sender or not. If the current node is the sender, then deflection routing is not done. Instead, after some wait time, the sender retransmits a burst control packet and subsequently the burst is retransmitted.
    - ➢ If the current node is an intermediate node, then the current intermediate node computes a performance measure and does the threshold check on that performance measure. Accordingly, it decides whether to deflection route or drop and notify sender to retransmit.
- Analytical models derived in [12] have been used to obtain blocking probability and throughput.

The proposed scheme described above reduces unnecessary deflection routing at the intermediate nodes as well as at the sender and prevents contentions which are caused by inefficient deflection routing.

4. Simulation

To analyze the performance of proposed scheme, the simulation tool used is an event simulator based on OMNET++. It is capable of simulating either labeled or burst control packet (BCP) OBS node/networks. It includes the same functionalities as those of the test bed node (in particular the same scheduling algorithm). It can also take into account BCP collisions.

The following are some of the assumptions and simulation parameters that are used to analyze the performance of the proposed scheme.

- The simulation topology consists of 12 edge nodes and 6 core nodes. Each fiber has 16 wavelengths as shown in Fig. 2.
- The input network traffic is in the form of data bursts and follows the Poisson distribution.
- The data burst length is an exponential distribution.
- The offset time is always large enough to prevent a burst from catching up with its corresponding burst header packet.
- There is no wavelength conversion at all nodes in the network.
- The burst length depends on a variable period of assembly and a maximum burst length.
- The Just-Enough-Time (JET) signalling protocol is used to reserve network resources.
- When a new data burst arrives at an edge node, it randomly chooses a destination from the rest of the nodes in the network. Djikstra's shortest path routing algorithm is used for routing bursts in the network.
- Control packet processing time is 10 μs. Switch fabric configuration time is 5 μs.
- Link propagation delay is 3 ms. Packet size is 1000 bytes
- Maximum burst length is 1 MB. Offset time is 50 μs.
- All nodes are assumed to receive the same offered load in the network.
- The minimum burst length is 19,000 bytes.
- 95% confidence intervals are obtained for all simulation results.

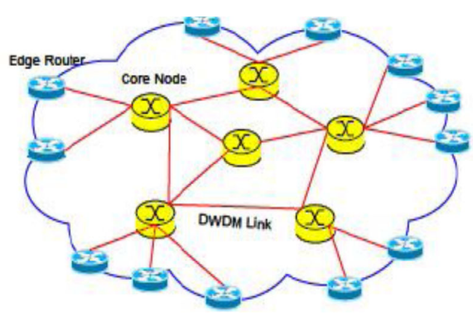

Fig. 2. Network Topology with 12 Edge Nodes and 6 Core Nodes [9].

5. Results

From Fig. 3, it is observed that the proposed scheme has 15% better performance in resolving contention resolution. Although the proposed scheme requires the same hardware complexity, its delayed reservation decision utilizes resources more efficiently and therefore more data burst (DBs) are served. Simulation result shows that when the network load is increasing, the proposed scheme has lower burst loss probability as compared to conventional OBS. The proposed scheme uses FDL (2 μs) to delay data bursts and thus the scheduler resorts data bursts according to their arrival times in order to utilize bandwidth more efficiently. Also, the burst contention has been effectively resolved.

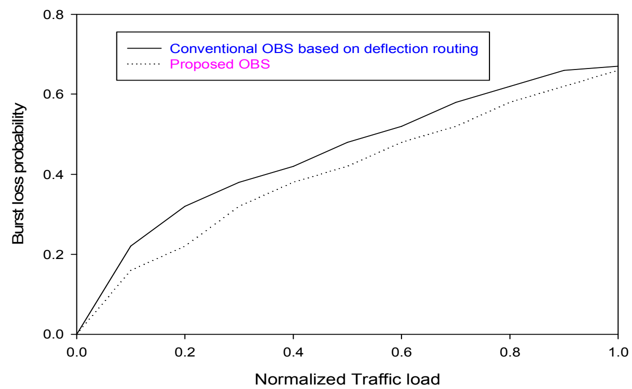

Fig. 3. Burst Loss Probability vs. Normalized Traffic Load.

Figure 4 shows the average end-to-end delay as a function of the network traffic load. The delay calculated is composed of the following delays: burst assembly, channel access, offset time, burst transmission, propagation and reception. The result obtained show that the average end to end delay is worse in comparison to existing OBS schemes but not so much worse than it may be expected, i.e., tolerable.

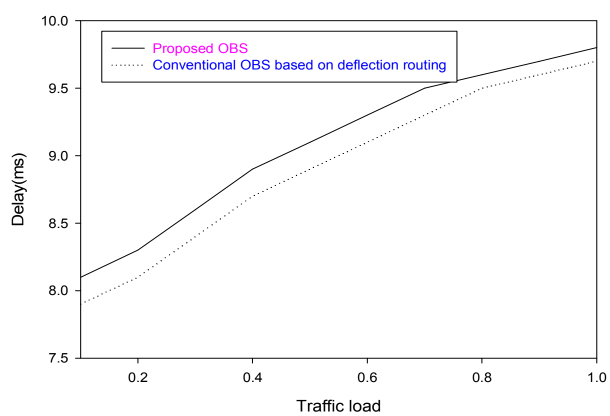

Fig. 4. Delay vs. Normalized Traffic Load.

Due to the 15% improvement obtained in terms of burst blocking with the proposed scheme, it is observed that throughput (resource utilization) of the network increases with increasing traffic load (as shown in Fig .5).

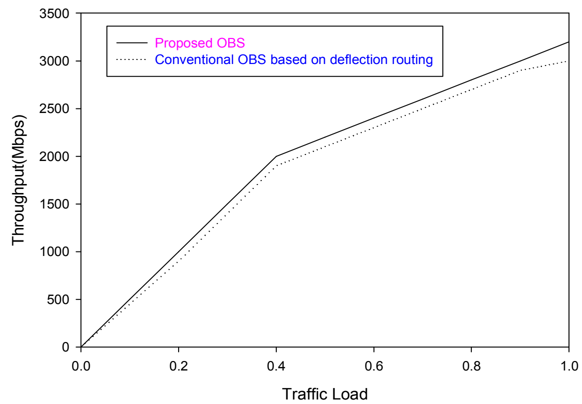

Fig. 5. Throughput vs. Normalized Traffic Load.

6. Conclusions and Future Work

The bottlenecks of OBS are burst processing speed, configuration speed and switching speed of optical switches. Based on existing OBS networks with optical buffers, a new efficient scheme has been proposed to enhance the OBS performance. The proposed scheme allows extra electronic processing of control packets to utilize the network resources more efficiently. Compared to other conventional OBS schemes, the proposed scheme decreases the complexity, minimizes the number of burst contentions, making into reality the objective of a loss free network at the expense of introducing some extra average channel access delay but improves the network performance in terms of burst loss probability and throughput when the network is highly loaded. The proposed solution provides a viable approach for future high performance OBS networks.

As future research lines, an efficient way of managing the channel access priorities would be analyzed. This, as well, would offer a method to provide fairness between nodes. The foreseeing work consists in achieving the test bed and in evaluating experimentally the efficiency of the proposed scheme implemented in the field programmable gate array (FPGA). Experimental results will be compared with simulation predictions.

References

1. Chen, Y.; Qiao, C; and Yu, X. (2004). Optical burst switching: A new area in optical networking research. *IEEE Network Magazine*, 18(3), 16-23.
2. Iizuka, M; Sakuta, M.; and Nishino, Y. (2002). A scheduling algorithm minimizing voids generated by arriving bursts in optical burst switched WDM network. *Proceedings of GLOBECOM 2002*, 3, 2736-2740.

3. Ljolje, M.; Inkret, R.; and Mikac, B. (2005). A comparative analysis of data scheduling algorithms in optical burst switching networks. *Proceedings of ONDM 2005*, 2, 493-500.
4. Garg, A.K. (2009). Integrated contention resolution & control algorithm (ICRCA) for optical burst switched networks. *International Journal of Fiber and Integrated Optics*, 28(5), 366-375.
5. Yoo, S.J.B. (2006). Optical packet and burst switching technologies for the future photonic Internet. *Journal of Lightwave Technology*, 24(12), 4468-4492.
6. Li, C.Y.; Wai, P.K.A.; and Li, V.O.K. (2005). Novel resource reservation schemes for optical burst switching. *Proceedings of IEEEICC 2005*, 5, 1651-1655.
7. Lu, X.; and Mark, B.L. (2004). Performance modelling of optical-burst switching with fiber delay lines. *IEEE Transactions on Communications*, 52(12), 2175-2183.
8. Klinkoski, M.; Careglio, D.; and Solé-Pareta, J. (2006). Comparison of conventional and offset time-emulated optical burst switching architectures. *Proceedings of ICTON 2006*.
9. Mneimneh, S. (2008). Matching from the first iteration: An iterative switching algorithm for an input queued switch. *IEEE/ACM Transactions on Networking (TON)*, 16(1), 206-217.
10. Rostami, A.; and Wolisz, A. (2007). Impact of edge traffic aggregation on the performance of FDL-assisted optical core switching nodes. *IEEE International Conference on Communications*, 10(1), 222-234.
11. Garg, A.K. (2010). An optimal wavelength reservation technique for optical networks. *International Journal of Technology and Applied Science*, 1, 1-3.
12. Garg, A.K. (2012). A novel hybrid approach for efficient network utilization of OBS. *International Journal of Software Engineering and Its Applications,* 6(1), 47-60.