Improving OBS Efficiency

S. Li, M. Wang, E. W. M. Wong and M. Zukerman

Electronic Engineering Dept., City University of Hong Kong, Hong Kong SAR, m.zu@cityu.edu.hk

ABSTRACT

In optical burst switching (OBS), a source node, without reserving network resources end-to-end, transmits bursts in available wavelength channels through a sequence of Optical Cross Connects (OXCs). While it saves time, OBS has a weakness that if for a given burst at a given OXC all the channels in a trunk on its route to its destination are occupied, the burst is either dumped or deflected to longer routes. This may adversely affect efficient use of network resources. This paper describes and compares numerically a range of approaches that improve OBS efficiency by addressing the problem of ineffective utilization.

Keywords: optical burst switching, utilization, effective utilization, throughput.

1. INTRODUCTION

Optical burst switching(OBS) [1]-[2] is an optical switching technology for transmitting data from any source node (edge router) through the core network to a destination node (another edge router). In OBS networks, packets with the same destination are aggregated at the source node and form data bursts. Then, these assembled bursts are individually transmitted over the network based on one-way reservation, where a burst control packet (BCP) is sent on a separate control channel, normally with some offset time ahead of the burst, to reserve wavelength channels along the burst transmission path. OBS aims to achieve faster connection than optical circuit switching (OCS) [3]-[6], and to avoid energy consuming processing of individual packets and excessive overhead due to guard-band provision between packets, as in optical packet switching (OPS) [7]-[9].

OBS is often compared with OCS [10]-[14]. The authors in [10]-[11] showed that under some conditions, the throughput (or goodput) of OBS networks is less than that of OCS networks. Zalesky [12] showed that for some cases, with the same utilization, the blocking probability in OCS networks is lower than that in OBS networks.

To explain why sometimes OBS has lower throughput than OCS, in [15] we view utilization as composed of two parts: effective utilization and ineffective utilization - to distinguish the channels used by bursts that eventually reach their destinations, and bursts that are dumped before reaching their destinations, respectively. While both types of utilization compete for the same pool of resources and contribute to blocking probability, effective utilization translates into network goodput, but ineffective utilization does not. Accordingly, considering effective and ineffective utilizations can provide insight into OBS performance and efficiency. When the blocking probability increases, the probability that a burst is blocked and dumped before reaching its destination also increases. This in turn increases the ineffective utilization, and consequently both effective utilization and goodput suffer. In the worst case, it may cause congestion collapse. We review here three methods that aim to reduce ineffective utilization and to increase effective utilization and network goodput in OBS. They are: EBSL [16], Dual Mode and OBS with Threshold [17] and compare their performance numerically. This paper is written from a teletraffic perspective ignoring all physical layer issues (e.g [18]).

1.1. EBSL

In [16], we introduced a new strategy, named EBSL, that combines: emulated-OBS (E-OBS) [19], burst segmentation [20]-[25] and least remaining hop-count first (LRHF) [25]-[26]. These three methods complement each other in EBSL to combat the potential collapse of the goodput and effective utilization in OBS.

E-OBS is a wavelength reservation scheme that aims to improve OBS performance. In E-OBS, an additional fiber delay unit is inserted in the data path at each core node to postpone the burst an offset time, so that a burst and its BCP is sent together by the edge node and they are either sent together to the next core node or dropped together after the offset time expires at a core node. E-OBS reduces the control complexity in the original OBS networks [1] and alleviates the adverse effect of the so-called phantom bursts that may be generated in preemption techniques.

Burst segmentation and LRHF are two contention resolution strategies. During contention, burst segmentation enables dumping of only the parts (segments) of a contending burst which overlap with other bursts, instead of dumping the entire burst. There are two approaches to perform segmentation: one is to dump the overlapped segments belonging to the tail of the earlier burst (tail segmentation) [21] and the other approach is to dump the overlapped segments belonging to the head of the contending burst (head segmentation) [20,27]. We use tail segmentation in EBSL. LRHF is a preemptive priority strategy where the priority depends on the route a burst follows. With LRHF, in every wavelength channel, each transmitted burst can be preempted by any newly

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arriving burst that has a strictly less remaining number of hops to its destination. This means that on average bursts that have already used up significant network resources have lower probability to be preempted and hence higher probability to reach their destinations.

In EBSL, we enable the contending bursts with higher priority to preempt the overlapped segments of an earlier burst with lower priority and the preempted segments of the earlier burst are dumped. Then, we consider packet blocking probability instead of burst blocking probability as the appropriate performance measure. EBSL strategy works well in heavy load when the ineffective utilization is quite high. Heavy load periods are not uncommon [27] and any Internet protocol should maintain network efficiency during such periods.

1.2. Dual Mode

A Dual Mode network [17] aims at reducing or avoiding the ineffective utilization in the network while maintaining the fast reservation advantage of OBS at the same time. When the network is not congested, we use OBS mode to transmit the bursts. Since in this range the network blocking probability is small, the ineffective utilization is also small. When the network is congested, to avoid the collapse of the effective utilization, we change the mode of some sources of congested routes to OCS.

We use two congestion thresholds for any trunk which are common in various congestion control mechanisms. We call them: congestion and recovery thresholds which indicate when to turn on OCS mode and when to turn back to the OBS mode, respectively. When the utilization of a trunk exceeds the congestion threshold, the relevant switch will send a congestion alarm to all its source nodes that use its output congested trunk, then these source nodes will turn into OCS mode for the bursts which use the congested trunk and end-to-end lightpath will be reserved for such bursts. The bursts that are already being transmitted before the alarm and the ones that are sent by other source nodes will still be transmitted hop by hop in OBS mode. Then, after the utilization of the congested trunks is decreased to the level of the recovery threshold, the relevant switch informs the source nodes that use these congested trunks to turn their mode of operation to OBS. In this way, the wastage of resources used by the eventually blocked bursts in OBS is avoided during congestion periods and users still benefit from fast burst connections during underload traffic conditions. This scheme requires that the two switching technologies (OBS and OCS) will exist in the network in all switches.

1.3. OBS with Threshold

OBS with Threshold [17] is a simplified version of Dual Mode strategy that does not require including OCS technology in switches. Instead of changing the mode to OCS, in OBS with Threshold, when any source node receives an alarm message associated with a congested link, it will dump and/or delay (depending on its buffering capacity) all the new bursts that will use the congested trunks, and then when this resource node receives the alarm-end message, it will start to send bursts again to the network. Note that if the congestion and recovery thresholds in Dual Mode are both set to 100%, then at 100% the mode is changed to OCS and no traffic is sent, so the OCS node never has effect. Therefore, the Dual Mode strategy is equivalent to OBS with Threshold in the case where the two thresholds are set to 100%.

2. THE SIMULATION SETUP

Our comparison of the above-mentioned OBS schemes and strategies rely on discrete-event simulations based on the following setup. We use a 6-node ring network shown in Fig. 1 with 6 unidirectional trunks, where the length of each trunk is 1000km. We only consider six 3-hop SD pairs, all in clockwise direction, and having different source nodes. The burst arrival processes to all SD pairs follow identical and independent Poisson processes. Each trunk in the network has 50 wavelength channels.

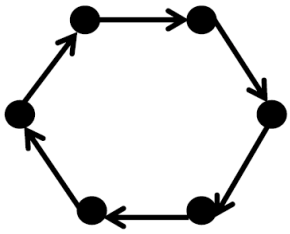

Figure 1. 6-node ring network topology

In our model, we set the 1-hop offset time to 10 μs. We assume that all burst lengths are independent and exponentially distributed and the mean burst duration time is set to 2 ms (2.5 Mb data burst at 10 Gb/s) following [16]. Each packet size is 1250 Bytes, thus on average there are 250 packets per burst. The switching

time between the BCP and the data burst is below μs in fast switching [29], which is quite small compared to the burst duration, so we ignore the switching time. We also ignore the propagation delay of the alarm and alarm-end messages.

3. NUMERICAL RESULTS

In this section, using simulation results for the 6-node ring network, we demonstrate that both EBSL and OBS with Threshold (here we only consider the case where both thresholds are 100% where OBS with Threshold is equivalent to Dual Mode) can significantly improve the goodput and effective utilization. The simulation results are mainly under heavy traffic conditions where OBS is most vulnerable to congestion collapse.

The results are shown in Fig. 2. Error bars for 95% confidence intervals based on Student's t-distribution are provided for all the simulation results although in many cases the intervals are too small to be clearly visible.

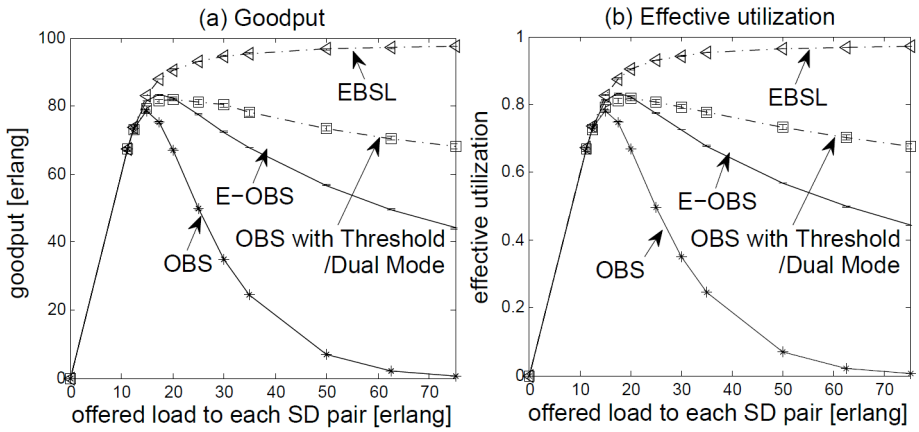

Figure 2. The goodput and effective utilization in a 6-node ring network with all 3-hop paths SD pairs for OBS, E-OBS, EBSL, and OBS with Threshold/dual-mode.

In Fig. 2, we observe that for the present case EBSL which benefits from the compound effect of E-OBS, Burst Segmentation and LRHF performs the best with no visible evidence of congestion (effective utilization) collapse. Next is OBS with Threshold/Dual Mode with only a slight effect of loss of effective utilization under congestion. Third comes E-OBS which interestingly performs far better than the traditional OBS. Notice that the traditional OBS discriminates in favour of bursts in their early hops because the offset is shortened in every hop [18]. This contradicts the philosophy of LRHF, and causes significant dumping of bursts on their last hop which increases ineffective utilization. By comparison, in E-OBS, no such discrimination exists and bursts have the same probability to be dumped in any hop.

4. CONCLUSION

In this paper, we have compared by discrete-event simulation, various schemes and strategies that can increase the effective utilization so that increase goodput in OBS networks. In the case of our simulation set-up, EBSL performs better than OBS with Threshold and Dual Mode (where congestion threshold = recovery threshold = 100%). We have also observed in the case studied that E-OBS can achieve significant improvement over the traditional OBS although it still suffers degradation of effective utilization. All in all, without considering physical layer limitations, the key message of the paper is that OBS has the potential to be enhanced to achieve efficient operation without collapse of effective utilization and still retains its advantage of fast reservation over OCS.

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