Comparison of Conventional and Offset Time-Emulated Optical Burst Switching Architectures

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ABSTRACT
Optical Burst Switching (OBS) control architecture considers two different models for management of offset-times in the network. A *conventional* OBS introduces an *offset time* (OT) between a control packet and a corresponding burst in soft-way by delaying the transmission of the burst in respect to the control packet in the edge node. Another idea for an OBS operation comes from Optical Packet Switching (OPS) world and it intends to *emulate* OT by means of an additional *fiber span* (FS) introduced in the data path at the input port of core node. Although the conventional OBS has attracted lots of attention, in this paper we highlight that it possesses many difficulties that can be avoided easily in OT-emulated OBS.
Keywords: architecture, fairness, offset-time emulation, optical burst switching, QoS provisioning.

1. INTRODUCTION

Optical Burst Switching (OBS) is a photonic network architecture directed towards efficient transport of IP traffic [1]. The client packets are aggregated and assembled into large *burst* units at the edge nodes of OBS network. Meanwhile, the control information is transmitted out-of-band and delivered with some offset-time (OT) prior to the data burst in such a way that the intermediate nodes have enough time both to process this information and to reconfigure dynamically the switching matrix. This mechanism allows using slower switching elements in OBS then the ones required in OPS networks. Also, when the burst transfer is finished, the optical path usually is released for other connections. This temporary usage of wavelengths allows for higher resource utilization as well as better adaptation to highly variable input traffic in comparison to OCS networks. Additionally, packets aggregation into data bursts reduce scale of the control information processing.

From the very beginning of OBS technology, there were two distinct architectures considered for such networks [1]. The difference between them comes from different approach to offset-time provisioning. The first one introduces OT between control packet (CP) and corresponding burst in a soft-way in the edge-node. Since this architecture has been deeply studied in literature we will refer to it as a conventional OBS. Another idea for OBS operation comes from OPS world and it intends to emulate OT by means of a fiber span (FS) inserted at the input port of core node. The fiber delays burst arrival with respect to the arrival of its control information and in such hard-way it introduces the OT. Although the conventional OBS has attracted lots of attention it possesses many disadvantages that can be avoided in OT-emulated OBS. In particular, OT-emulated OBS surpasses a conventional OBS in respect to fairness, scheduling efficiency, QoS provisioning, control and routing operation while it conserves main performance characteristics. We discuss all these issues in this paper.

2. OBS ARCHITECTURES

In OBS network control and data information travel separately on different channels. Optical burst is aggregated in ingress node with the client data coming from legacy networks (like IP, ATM) on the edge of OBS network. When the burst aggregation process is finished the edge node builds a control packet that contains control information for switching core nodes.

2.1 Conventional OBS

In conventional OBS network, which is presented in Fig. 1a, the control packet is sent from the edge node prior to the corresponding burst with some pre-transmission offset-time (OT). This offset is set-up in order to provide enough time for processing the control information as well as for configuring the optical switch matrixes in intermediate nodes along the transmission path. When the OT expires the burst is released from the edge node and it crosses the configured nodes whole the way remaining in the optical domain. The offset in conventional OBS incorporates the switching and all the processing times for all the nodes lying on routing path. For this reason the OT here can be seen as a *global* offset that is setup once in the edge node.

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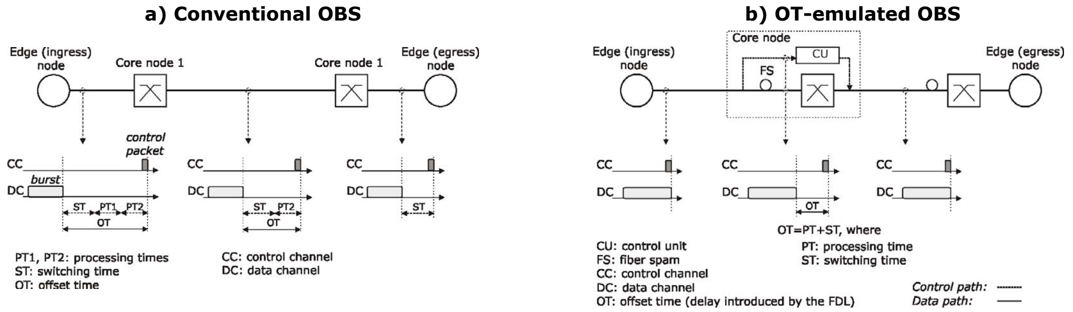

Figure 1. OBS architectures, a) conventional and b) OT-emulated.

2.2 OT-emulated OBS

In OT-emulated OBS architecture there is no global OT setup by edge nodes. On the contrary, each core node introduces its *local* offset by means of additional *fiber span* (FS) inserted in the data path at the input port of the node (see Fig. 1b). Control packet and burst travel are sent together towards the network. When both reach a core node the control packet goes directly to the switch control unit, whilst the burst is delayed in the FS by period OT. During this time the control packet is processed and the control unit can establish the switching element. The important rule is that the control packet, after its processing, is waiting for its burst in memory of the control unit until the OT expires and then they are sent together to the next node. In case no transmission resources are available, both control packet and its burst are dropped.

3. COMPARISON OF OBS ARCHITECTURES

3.1 Fairness

In conventional OBS, whilst the control packet travels through the network its global OT decreases successively at each hop by processing time, which is the time the control packet spends in a core node for processing purposes (see Fig. 1a). Variation of OTs can produce *unfairness* in access to transmission resources [2]. Indeed the bursts with more hops remaining and thus with higher OTs have more chances to reserve output wavelength than the bursts with lower offsets (see Fig. 2a). Notice, that this effect has been exploited in QoS *offset-time differentiation* [3].

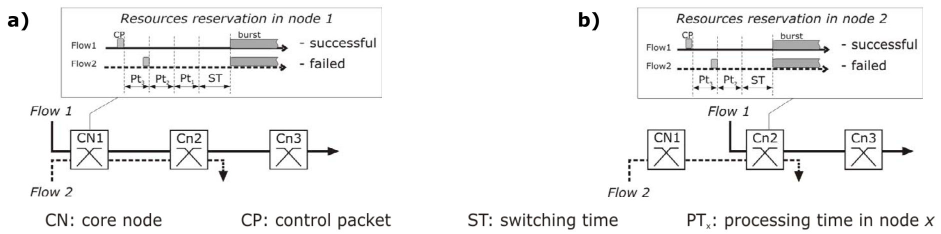

Figure 2. Unfairness in conventional OBS, A) variation of OTs, B) path length priority effect.

Another negative aspect related with the unfairness is the *path length priority effect* [4]. This effect results in higher loss probability of the burst that is close to its destination and that can be easily overtaken by another burst with higher OT that just have been expedited from the ingress nodes (Fig. 2b). Such behavior produces an unnecessary waste of transmission resources on the incoming path that the lost burst has already utilized.

Fig. 3 presents some exemplary results of the unfairness problem. We consider three network topologies called Simple, Nsfnet (US network) and EON (European Optical Network) with 6, 15 and 28 nodes, and 8, 23, and 43 links respectively. Each node is an edge node generating 12.8 Erlangs (0.8 normalised) and each link has 16 wavelengths at 10 Gbit/s. Bursts have exponential distributed arrival time and length (mean 40kB). 1 µs and 10 µs are times considered for switching and processing operations. JET signaling and LAUC-VF scheduling [5] are used. In conventional OBS (see Fig. 3a), we can see that the bursts beginning the trip obtain lower burst loss probability (BLP) than burst having just one remaining hop to reach the destination. On the other side, OT-emulated architecture solves the unfairness problem since the OTs have always the same value (determined at each node by the length of the FS) and therefore a burst has the same chance of any other to access to the transmission resources. In particular, in Fig. 3b we can observe that the BLP is independent of the number of hops remaining to reach the destination.

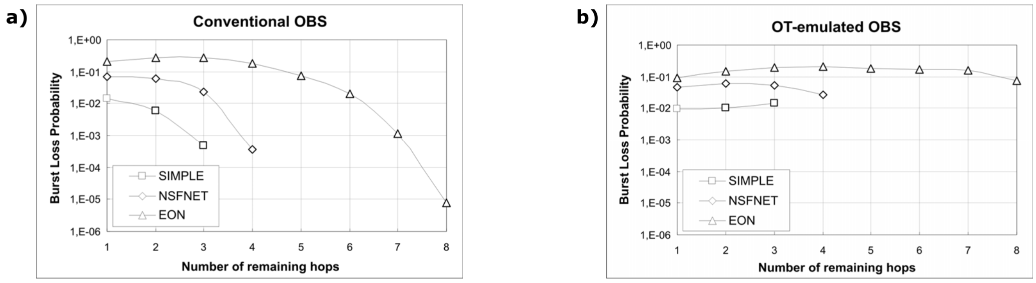

Figure 3. Burst loss probability vs. remaining hops number, in A) conventional and B) OT-emulated OBS.

3.2 Scheduling efficiency

One of key problems in OBS is to schedule efficiently bursts so that the throughput is maximized and burst losses are minimized. For OBS networks without *fiber delay line* (FDL) buffers, the performance of an online best-effort scheduling algorithm depends among other things on offset-times and burst lengths. In particular, the best worse-case performance is achieved when all bursts have the same offset and the same length [6]. Whilst a conventional OBS is characterized by variable offsets, OT-emulated OBS can provide fixed OTs.

Another benefit that comes from OT-emulated OBS is that it allows easily introducing a *processing window* capability that can be effectively exploited by the contention resolution [7, 8] and QoS [9, 10] mechanisms.

3.3 QoS provisioning

Several strategies have been considered in literature to provide contention resolution with QoS provisioning in OBS networks, among which *burst preemption* [10] and *offset-time differentiation* [3] can offer an utmost class differentiation performance. The former allows overwriting resources reserved for low priority bursts be high priority reservation in case of bursts conflict. The later assigns an *extra* offset-time to high priority bursts, what results in an earlier reservation, in order to favors them while the resources reservation is performed.

The general drawback of preemptive mechanisms in conventional OBS is a need for an additional signaling to be used in case of the successful preemption in order to release already reserved resources on the outgoing path. This problem was addressed in [10] and it was shown that such signaling complexity can be effectively avoided in the control architecture based on OT emulation with processing window capability.

The performance of OT differentiation may be affected by the multiplication of effective classes due to the offset variation inside the network [2]. In order to reduce this effect the OT in conventional OBS should be low enough. OT-emulated OBS due to a constant basic OT does not have such limitations.

3.4 Routing

Conventional OBS has some difficulty with providing alternative/deflective routing inside the network. In particular, the edge node should know the routing path prior to the control packet transmission in order to calculate and setup OT accurately. When allowing for alternative routing inside the network, the *insufficient offset-time* problem appears. Therefore, OT should be either calculated for the worst case i.e. for the longest possible alternative path what may result in superfluous burst delay, or additional hardware (an output FDL like in [11]) or control [12] mechanism have to be involved in order to diminish this effect.

In OT-emulated OBS the offset-time is introduced in each core node by means of the input fiber. Therefore, routing path can be created freely inside the network with any alternative routing algorithm.

3.5 Performance

Fig. 4a compares burst loss probabilities obtained in different network scenarios in the function of offered load (see Subsection 3.1 for evaluation scenario details). As we can see, both conventional and OT-emulated architectures offer similar performance.

Fig. 4b shows transmission delays in the function of number of core nodes. Transmission delay produced in OBS network is due to the propagation delay (here, 1ms in 200km link) and the offset introduced for processing and switching purposes (10µs and 1µs respectively). The first factor as well as the processing offset is the same for both conventional and OT-emulated OBS. On the contrary, the switching offset is introduced only once for all nodes in conventional OBS, whilst it is produced every time the burst enters a core node in OT-emulated OBS (see Fig. 1). Nevertheless, as Fig. 4b shows this difference in transmission delays is negligible since the propagation delay is a dominant delay factor; hence both architectures offer similar delay performance. Fig. 4b provides additional transmission delay results obtained for OT-emulated OBS with processing window capability (additional offset of 100µs). In this case, we can see that the performance is only slightly deteriorated in comparison to the two other architectures.

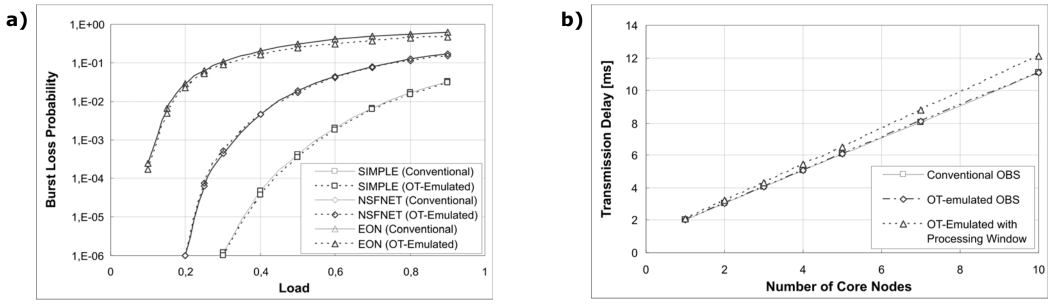

Figure 4. Comparison of the performance, a) Burst Loss Probabilities and b) Transmission Delays.

3.6 Hardware complexity

OT-emulated architecture needs for an input fiber span to be introduced to the data path on the input port of core nodes. Such fiber should not provide high hardware complexity since it can be considered as a part of transmission link. Attenuation of the optical signal (of about 0.2dB/km) should be taken into account when analyzing the power budget and designing the amplification stages. Typical delays necessary for OT-emulated operation would range from a few to tens of µs what results in FS lengths between 1÷20km depending of several factors as switching and processing times, burst lengths and processing window capabilities. It is important to say that there is a need for only one FS per node input port, which compensates the offset-times for all data channels simultaneously. The control channel should be extracted before that stage and brought to the switch control unit. The application of FS might be advantageous in the context of signal regeneration since this fiber could act as a dispersion compensation unit for the optical signal entering the node.

The requirements for memory installed in nodes are lower in OT-emulated then in conventional OBS network. In particular, in the former the burst after its assembly does not have to be stored until the offset time expires, but it is sent towards the network as soon as an available wavelength is found in the output link. On the other hand, conventional OBS requires some additional output buffers in edge nodes, which size depends greatly on the burst length, offset-time as well as arrival process of assembled bursts. Regarding core nodes, OT-emulated architecture needs some buffers for storing control packets after their processing in order to release them together with corresponding bursts. Nevertheless, such buffers should not require large capacities, since the control packets are short and they are kept only for the offset period provided for a singular node. Notice that in conventional architecture the bursts stored in edge nodes may require much more memory due to considerable burst lengths as well as due to buffering times, which have to accumulate a global offset generated for all nodes on the transmission path.

4. CONCLUSIONS

This paper conducts a discussion on pros and cons of two control architectures considered for OBS networks. Taking into account all the arguments provided here there is a motivation for recognizing the OT-emulated architecture as an efficient and functional solution for OBS networks.

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