Pre-booking for Optical Burst Switching

Huifang Kong and Chris Phillips

Queen Mary College, University of London

Abstract: This research proposes a novel pre-booking mechanism that can operate with previous OBS architecture for providing a self-optimising infrastructure for multi-service "bandwidth on demand" transport. The paper describes the resource pre-booking in detail. Its performance is also assessed in terms of blocking probability and link utilization.

1 Introduction

Recent changes in both the volume and nature of traffic being transmitted across public networks suggest that the infrastructure could be modified to better support such changes. For example, voice traffic, which was once dominant in the market, is being surpassed by different forms of bursty data. In optical networks, bursty traffic is not well suited to the connection-oriented, circuit switched paradigm, be it based on time division multiplexing (TDM) slots or SONET containers. To efficiently transport bursty data requires "bandwidth on demand", using statistical multiplexing between separate streams to maintain a high utilization factor. Optical Packet Switching (OPS) [2] expresses the idea of transporting bursty traffic in Optical networks in a similar way to the Internet Protocol mechanism. However, because of the lack of optical buffering or optical memory, OPS is currently commercially unviable.

Optical Burst Switching (OBS) is a family of alternatives to OPS that implement OPS without the need for any optical buffering. It combines aspects of both circuit and packet switching whilst avoiding their shortcomings [2]. Briefly, in an OBS network, data bursts are assembled from packets at network ingress, and disassembled back into packets at the network egress. Each burst is preceded by its own signalling message called Burst Head Packet (BHP). The BHP travels slightly ahead of the data burst to reserve the path or wavelength, undergoing electro-optical conversion at every hop, whilst data burst is simply switched in all-optical manner.

OBS architectures and signalling schemes have been previously studied in literature [3,4,5] based on Just-In-Time (JIT), Just-Enough-Time (JET), and Tell-And-Go (TAG) mechanisms. They mainly differ in the offset time between the BHP and the corresponding data burst, and how soon before the burst arrival and how long after its departure the switching elements are made available to route other bursts. Contention arises and bursts will be lost or abandoned if the outgoing wavelength or port is engaged by another burst [6]. This problem becomes more acute if the network is to support multiple service levels. Many previous QoS solutions, such as priority-based OBS [7], or service differentiated schemes [8], have tried to control the blocking probability, end-to-end delay, and QoS provisioning by employing adjustable tolerances, assigning different offset times using extra Fibre Delay Lines (FDL), or using deflection routing for different bursts according to their priority or traffic class.

The main objective of this research is to provide a novel pre-booking OBS network management architecture using agent technology to provide a self-optimising infrastructure for multi-service "bandwidth on demand" transport. In contrast to other research, which solve relevant OBS problems by optimising the technology itself, the authors propose that given an existing OBS system, by adding proactive intelligence within the admission control/negotiation at the network edge, using agent technology the performance of a pure OBS system, such as blocking probability, throughput, and Service Level Agreement (SLA) targets, can be improved.

This paper is organised as follows, Section 2 and 3 describes the proposed network architecture and resource pre-booking mechanism. Section 4 analyses the performance in terms of blocking probability and link utilization. Section 5 presents and discusses the results. Section 6 concludes the paper.

2. Proposed Network Architecture

The network architecture [1], as seen in Figure 1, consists of customers, their Service Providers (SPs) and a Carrier Network Operator (CNO)[1]. Competing SPs are introduced to the network edge to provide a market environment. Via their Customer Processor function, they are equipped with mechanisms for traffic prediction, burst manipulation, QoS selection, and admission control, so that they can effectively interact with the carrier network management, in the guise of the Edge Processor.

---

[1] At a later time it is envisioned that there could be multiple competing CNOs vying for business from the SPs, providing an additional degree of flexibility within the carrier data transportation market.

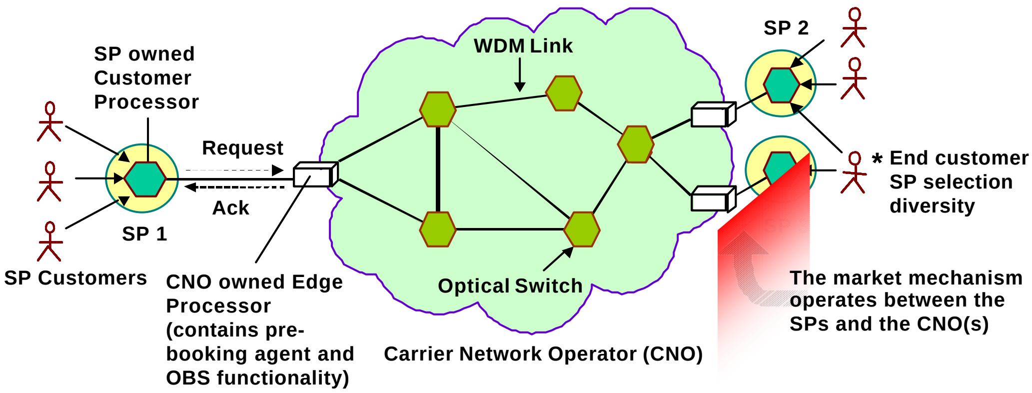

Figure 1:- Network Architecture

The core network management operates as a multi-service commodity market, allowing the various SPs to pre-book network resources at specified times and durations in the future. It mainly consists of Edge Processors (EPs), and core optical switches. EPs located at the network edge incorporate the pre-booking functionality as well as an OBS entity. The pre-booking mechanism uses intelligence to select possible path(s) based on the information from the SP and the anticipated cost from the cost gradient held in its *link state database*; send quote requests to the core to obtain updated cost information; and send acknowledgments back to SP to do more negotiation. The OBS entity within the Edge processor functions as a normal OBS. All the complexity is pushed to the edge of the CNO, in terms of the prediction algorithm and enhanced link state database containing both near-current data and historical information. The core optical switches only use simple tables and rules for recording resource reservations.

3. Resource Pre-booking Mechanism

In each SP system, the Customer Processor (CP), typically located in a router device, predicts future traffic flows from its customer collector networks based on current and historical traffic records and places the predicted traffic information into the resource reservation queue. Reservations can then be aggregated into bulk units and used to formulate appropriate resource request messages. The CP participates in admission negotiation with the Edge Processor (EP) owned by Carrier Network Operator (CNO). It uses resource reservation signalling to negotiate with the CNO for variable length slots between specified network edge points given their anticipated traffic patterns. In terms of traffic itself, it can be classified into three categories: future traffic explicitly pre-booked by the SP's customers; future traffic implicitly predicted by SP's intelligence based on historical traffic patterns[2]; and transient traffic that arrives without implicit or explicit prior knowledge.

Issues concerned with resource reservation signalling and negotiation involve more intelligence and complexity. This is implemented by agent technology. Although this work is beyond the scope of this paper, details are provided in [1].

4. Analysis

In this section, analysis of blocking probability and link utilization is provided, given two groups of traffic - *predicted* traffic and *non-predicted* traffic. It assumes that there are k wavelengths at each fibre, and a wavelength converter is enabled at each OBS entity. At each OBS interface (port or fibre), bursts have a negative exponential inter-arrival distribution with rate λ, and is serviced according to exponentially distributed rate with mean μ. The traffic intensity is thus given by $r = l/(m \cdot k) = r/k$. Thus, the core OBS system behaves like an M/M/k/k loss system [9] for which burst blocking probability can be obtained using the *Erlang B formula* as follows, where $r = r \cdot k$.

$$P = B(k, r) = (1/k! \cdot r^k) \Big/ \left(\sum_{m=0}^{k} 1/m! \cdot r^m\right) \tag{1}$$

In the proposed pre-booking system, the predicted traffic intensity is denoted by r_0, and the non-predicted traffic intensity is denoted by r_1. The total traffic intensity is $r_{all} = r_0 + r_1$. As the predicted traffic is

---

[2] Referring to the customer SLAs and correlating this information with historical traffic patterns may assist the means of prediction. The residual flows that cannot be predicted could be accommodated by the SP booking a basal level of service from the CNO.

completely independent of the non-predicted traffic, and is able to pre-empt resources, its blocking probability is $P_0 = B(k, r_0)$ as in (1). For the non-predicted traffic, the blocking probability can be obtained according to the *Conservation Law* as follows:

$$r_{all}P_{all} = r_0 P_0 + r_1 P_1 \qquad (2)$$

Where P_{all} is the overall blocking probability, P_0 is the predicted traffic blocking probability, and P_1 is the non-predicted traffic blocking probability. So P_1 is finally expressed as

$$P_1 = (r_{all}P_{all} - r_0 P)/r_1 = (r_{all}B(k, r_{all}) - r_0 B(k, r_0))/r_1 \qquad (3)$$

Given its blocking probability, the link utilization for any group of traffic can be formulised as

$$U = (r \cdot P_s)/(k \cdot D) = (r \cdot (1 - B(k, r)))/(k \cdot D) \qquad (4)$$

Where P_s refers to the probability of successful transmission without blocking, and D refers to the data rate on each channel (wavelength).

5. Results and Discussion

Simulations have been carried out using OPNET ™ to investigate the blocking probability and link utilization for predicted, non-predicted, and overall traffic. In order to exclude the affects of routing and topology, the simulation is based on a simple two nodes - one fibre scenario. There are 4 wavelengths per fibre, each wavelength operates at 10Mbps; burst length is distributed by exponential process with mean 50k bytes; and the arrival process for burst data is Poissonian[3].

Figure 2 and 3 show the blocking probability and link utilization, where the ratio of predicted traffic to total traffic load is 40%. The solid lines and shaded points show the simulation results, whilst the empty points display the corresponding analytical results.

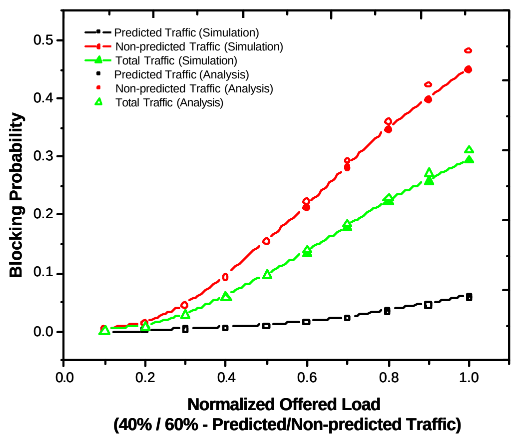

Figure 2. Blocking Probability versus Load

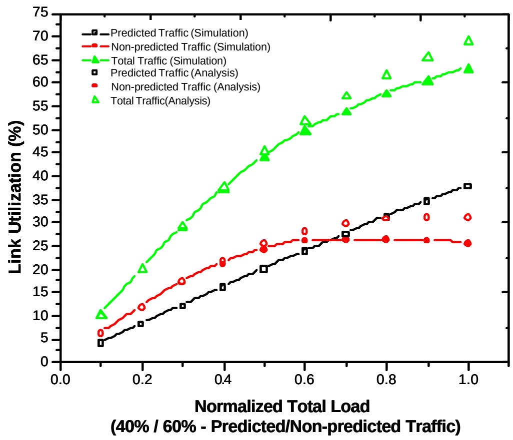

Figure 3. Link Utilization versus Load

With Figure 2, we can see that with the increase of traffic load, the blocking probability of non-predicted traffic increases much more rapidly than predicted traffic, as expected. This is due to the resource pre-emption by the predicted traffic. As wavelength resources are reserved in advance by predicted traffic, this in turn blocks non-predicted traffic when resource contention arises. Also, in Figure 3, for link of up to 0.7 loaded, the contribution to the link utilization made by the predicted traffic increases approximately linearly, implying that the predicted traffic's entry to the network is unimpeded. Of course, this will be to the detriment of the non-predicted traffic. However, when the traffic load reaches certain level (0.7 and beyond in Figure 3), the link utilisation for non-predicted traffic reaches a plateau before starting to decrease. The predicted traffic also begins to experience some degree of blocking between concurrent arrivals of the same class.

Figure 4 and 5 investigate the blocking probability and link utilization with different mixtures of predicted traffic and non-predicted traffic, whilst keeping the total traffic load at 0.8.

---

[3] These values are chosen so as to demonstratethe potential benefits whilst remaining manageable for the simulation tool.

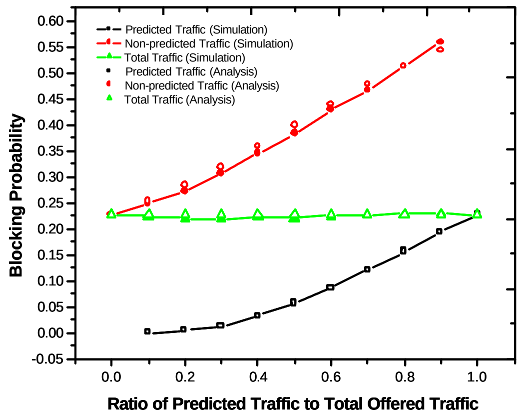

Figure 4. Blocking probability with various mixtures of Traffic

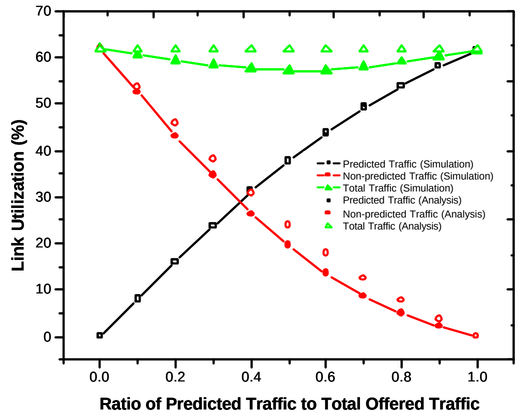

Figure 5. Link Utilization with various mixtures of Traffic

Figure 4 shows that by keeping total traffic load at 0.8 while increasing the ratio of predicted traffic from 0% to 100% of the total traffic, the blocking probability of the predicted traffic is always lower than that of the overall traffic, and the non-predicted traffic is always higher than the overall traffic. Meanwhile, although the blocking probability of both the predicted and non-predicted traffic increases as the ratio of the predicted traffic to the total traffic increases, the overall blocking probability remains constant as expected from equation (1). A similar observation is made from Figure 5, where the link utilization is considered. This demonstrates that simple traffic pre-booking cannot improve the overall traffic performance. However, this situation can be improved by the introduction of more flexible pre-booking, where intelligence at the edge of the carrier network is able to offset burst arrivals to some degree.

6. Conclusions

As a conclusion, compared with non-predicted traffic, predicted traffic is able to pre-book resources and therefore obtains better performance. However, the simple pre-booking system described here cannot improve the overall performance. To truly enhance the overall traffic performance, the system needs more knowledge of the whole network and the traffic arrival patterns. This information can be used to intelligently reserve resources based on knowledge of the residual capacity at a given time, and, possibly encourage adjustment to the traffic arrival processes in negotiation with the SPs.

This research is ongoing. Further work will focuse on traffic prediction based on current and historical traffic patterns, and the agent based negotiation procedure between SPs and CNO to optimise the overall network performance.

References

[1] (Accepted) Huifang Kong and Chris Phillips, “Intelligent Pre-Booking for Optical Burst Switching”, INOC'2003 - International Network Optimization Conference, France, Oct. 2003.

[2] Lisong Xu; Perros, H.G.; Rouskas, G. “Techniques for Optical Packet Switching and Optical Burst Switching”, IEEE Communications Magazine, Volume: 39 Issue: 1, Page(s): 136–142, Jan. 2001

[3] M. Yoo and C. Qiao, "Just-Enough-Time (JET): A High Speed Protocol for Bursty Traffic in Optical Networks", IEEE/LEOS Technologies For a Global Information Infrastructure, pp. 26-27, Aug. 1997

[4] Ilia Baldine, et al, "JumpStart: A Just-in-Time Signaling Architecture for WDM Burst-Switched Networks", IEEE Communications, vol. 40, no. 2, pp. 82 - 89, February 2002

[5] A. Detti and M. Listanti, "Application of Tell and Go and Tell and Wait Reservation Strategies in a Optical Burst Switching Network: a Performance Comparison", Proceedings of the 8th IEEE, ICT 2001, Bucharest, June 2001

[6] M. Yoo, C. Qiao and S. Dixit, "A comparative study of contention resolution policies in optical burst switched WDM networks", Conf. on Terabit Optical Networking: Architecture, Control and Management Issues, Boston, MA, SPIE Vol. 4213, pp.124-135, Nov. 2000

[7] D.Q. Liu and M.T. Liu, "Priority-Based Burst Scheduling Scheme and Modeling in Optical Burst-switched WDM Networks", Proceedings of ICT 2002, June, 2002

[8] Liu, D.Q.; Liu, M.T. “Differentiated Services and Scheduling Scheme in Optical Burst-Switched WDM Networks”, Networks, 2002. ICON 2002. 10th IEEE International Conference on, Page(s): 23–27, 2002

[9] M. Neuts, H. L. Vu, and M. Zukerman, “Insight into the Benefit of Burst Segmentation in Optical Burst Switching” Proceedings of COIN-PS 2002, Cheju Island, Korea, July, 2002