Effect of Link Bandwidth, Number of Channels and Traffic Load on Designing Optical Burst Switching Networks

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Abstract A detailed simulation is carried out for analysis of various optical parameters effect on burst loss ratio (BLR) in optical burst switching (OBS) networks. Effects of link bandwidth, number of channels and traffic load are studied. The obtained results show that one parameter can compensate another to reach the same BLR. For example, one can decrease the link bandwidth by 50% and increase the number of channels while maintaining the same BLR. This leads to have many OBS networks designs giving same performance.

Keywords: Optical burst switching, Burst loss ratio, Traffic load, Channel bandwidth, Number of channels.

1. Introduction

At the beginning of the new millennium, several trends can be observed in the field of communications. First, convergence as a dream starts to be a fact with bandwidth requirement and seems to grow without limit for accessing unlimited resources. Internet protocol (IP) based data networks and mainly the internet plays a central role in network convergence. This is not only due to the fact that data traffic has surpassed voice traffic but even more as both of them plus many other services like video will rely on this IP cloud. Second, any increase in the network access bandwidth leads to an exponential bandwidth increase needed in the core of the network to deliver this traffic from its source to its destination. Third, optical technology continues to provide an enormous bandwidth at the physical layer which is not utilized due to problems in switching and routing layers.

In this paper, we will elaborate on these trends and show how they motivate OBS as a new switching paradigm for future transport networks [1]. In Sec. 1, the optical networks and OBS networks are introduced, while Sec. 2 describes the simulation tool and the topology used. Section 3 gives the numerical results for some optical parameters that affect BLR, followed by the conclusion of the work in Sec. 4.

1.1 Photonic Network Evolution

In the late 70s of the 20^{th} century, the first fiber based optical transmission systems was installed. Today, most wide area traffic in communication networks is carried via fibers. Until a few years ago, most systems used a single high speed optical channel and multiplexing was done in the electrical domain.

In 1995, a new technology entered the market in the USA: wavelength division multiplexing (WDM) [2]. This optical multiplexing technique allows better exploration of fiber capacity by simultaneously transmitting multiple high-speed channels on different wavelengths [3-5]. WDM spans from today's point-to-point transport links over add/drop multiplexers (ADM) for ring and mesh networks to networks with higher reconfiguration speeds.

Due to low utilization factor for circuit switching, optical packet switching seems to be a promising technology. But, due to its complexity, it is expected to remain a research topic for some more years.

Recently, OBS is proposed as a new switching paradigm for optical networks requiring less complex technology than packet switching while conserving better utilization than circuit switching networks.

1.2 IP Network Evolution

The Internet is a packet-oriented network based on IP, a connectionless networking protocol. Recent years have seen an increasing demand for bandwidth mainly due to new applications, communication convergence, increased number of users, traffic volume and growing commercial interest in network services. The Internet traffic is bursty in nature making it a typical case for applying OBS.

1.3 OBS Definition and Motivation

OBS is in some way a combination of optical packet switching (PS) and circuit switching (CS). One can describe its main characteristics as:

1. OBS granularity is between CS and PS.
2. There is a separation between control information (header) or setup message and data. Header and data are usually carried on different channels with a separation in time as illustrated in Fig. 1.
3. Resources are allocated without explicit two-way end to-end signaling, instead so-called one-pass reservation is applied.
4. Bursts may have variable lengths.
5. Burst switching does not require buffering.

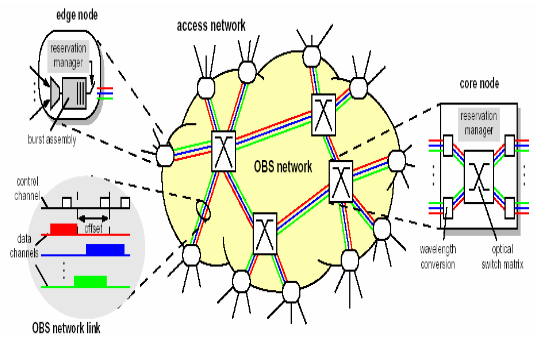

Fig. 1 OBS network.

OBS keeps data in the optical domain and avoids optoelectronic conversion while processing data in electronic domain. On the other hand, all-optical PS is still too complex to perform all processing in the optical domain. Therefore, a hybrid approach like burst switching seems very promising. It keeps data in the optical domain but separates control information which allows sophisticated electronic processing of this control data. Figure 1 shows some of the main characteristics of an OBS network.

There are two types of nodes. In edge nodes, traffic is collected from access networks and assembled into larger data units, so-called bursts. Core nodes serve as transit nodes in the core network. Their main task is switching bursts without extensive processing. To achieve this, some control information containing reservation requests is necessary ahead of every burst's transmission time [6].

These reservation concepts are based on a separation of control information and data. A reservation request is sent in a separate control packet on a different channel while the actual transmission of the data burst is delayed by a certain basic offset. This basic offset enables the intermediate nodes to process control information and set up the switching matrix, thus having a complete established path from source edge node to destination edge node all in optical domain without buffering the data burst in each core node along the path [7]. There are several possibilities to perform reservation of data channel bandwidth. A reservation request is sent in a separate control packet on a different channel while the actual transmission of the data burst is delayed by a certain basic offset, as shown in Fig. 1. This basic offset enables the intermediate nodes to process control information and set up the switching matrix. In contrast to systems with immediate transmission, which send control information together with the burst, the network can do without buffering the data burst in each node along the path.

2. Simulation

2.1 Simulation Software

Network simulator 2 (NS-2) is used as a simulation software in this parametric study. It is one of the best tools in the network simulation market. NS-2 is an open source code with many references and documentation [8-10]. OBS version 0.9 which is an OBS module under the NS-2 is used. Many researchers have used these network simulation tools and their work is published in famous magazines and conferences [11-14].

2.2 Simulation Topology

A simple OBS topology is used. This helps to easily study the considered parameters. The present simulation topology is composed of four edge nodes (S1, S2, D1 and D2) and two core nodes (C0 and C1), Fig. 2.

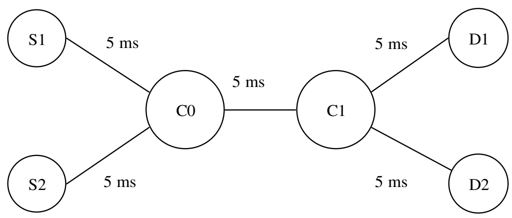

Fig. 2 OBS simulated network topology.

Traffic flows as a Poisson distribution with a burst size of 120,000 byte. Four equal traffic flows are launched between the different sources and destinations (S1-D1, S1-D2, S2-D1 and S2-D2). No fiber delay line (FDL) is used. By using this basic topology, one can simulate contention over a single core link between two core nodes.

2.3 Simulation Studied Parameters

In OBS network design, a very important parameter is always taken into account which is the burst loss ratio (BLR). BLR is needed to be decreased. Some optical factors have a great effect on BLR. If these parameters are studied carefully, a better OBS network design can be achieved. In the following, these parameters are discussed.

A. Traffic load.

Traffic load is the total generated bursts per second from the edge nodes that hit the core nodes. All the studies are done on the core nodes where congestion occurs [11-15]. Bursts are generated from each edge node with a burst rate (BR) varying from 0 to 26400 burst per second. Referring to network topology diagram and traffic flows, one can see that each core node has a BR of 105600 burst/sec (≈ four times of its value at any edge node) leading to a traffic load changing nearly from 0 to 100 Gbps at core nodes. In the rest of this paper we will refer to traffic load as the load in core nodes.

B. Link Bandwidth.

Link bandwidth is the total link capacity. It equals the product of the number of channels times the bandwidth per channel. In the present work, the link bandwidth is studied in the range 10 to 100 Gbps.

C. Number of channels.

As will be seen below, the number of channels per link has an appreciable effect on the BLR. Here, this number is taken from 1 to 30 channels per link.

3. Numerical Results

In the following, the obtained numerical results are presented to illustrate how different parameters affect the performance of the OBS network.

3.1 Effect of Traffic Load

In this simulation, the link bandwidth between all nodes is fixed to 30 Gbps, number of channels is varied from 1 to 30 channels per link and the burst size is taken as 120,000 byte. Traffic load varies from 0 to 100 Gbps. Figure 3 displays the BLR against the traffic load at the core nodes.

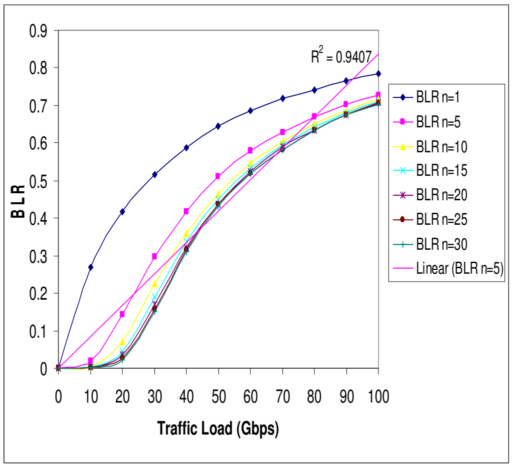

Fig. 3 Relation between BLR and traffic load different number of channels (n).

One can that, the relation between BLR and traffic load is nearly linear, also a linear regression R^2 [15] is calculated for a number of channels n = 5 with a factor of 0.9407, a virtual straight line is drawn to show this linearity. It is clear also that, even if the link is not saturated, there exists some burst drops. This is due contention which occurs if more than one burst needs to utilize the same channel on the same physical link at the same time. Burst drops were previously expected [11-13], but right now they can be calculated! Due to the same reason, the BLR decreases with the number of channels per link. This is clear in Fig. 3.

Figure 3 also shows that the number of channels has a great effect on the BLR but till a value of nearly 10 channels. After that, the number of channels has a negligible effect. This is very important in the OBS network design, to take into consideration the effect the minimum number of channels that gives the desired BLR.

The simulation is repeated at a fixed number of channels (n = 10 channels) and the link bandwidth is varied from 10 to 90 Gbps and burst size is 120,000 byte. Traffic load varies from 0 to 100 Gbps. The BLR against the traffic load at core nodes is studied in Fig. 4.
It can be seen that the BLR decreases with the link bandwidth at the same load. This is due to the time reservation for a channel that decreases which leads to have many free channels, thus

decreasing BLR. This is a continuous dropping which differs from Fig. 3, where nearly after a certain number of channels there is no need to add channels, but link bandwidth can always be added to decrease the BLR.

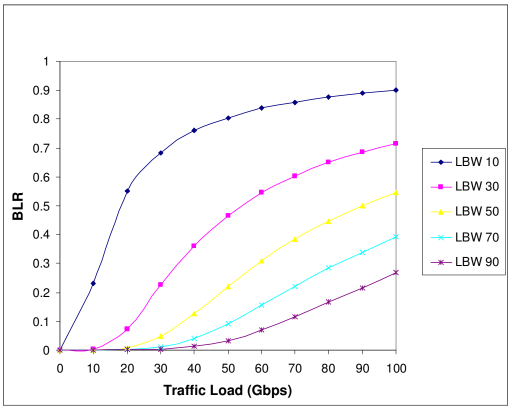

Fig. 4 Relation between BLR and traffic load for different number of link bandwidths (LBW).

3.2 Effect of Number of Wavelengths

In this simulation, we study the effect of the number of channels while fixing the total link bandwidth to 50 Gbps. The experiment is done for different traffic loads. Number of channels will vary from 1 channel (which has the capacity to carry the total link bandwidth) to 30 channels each has 1/30 of the total link bandwidth, Fig. 5.

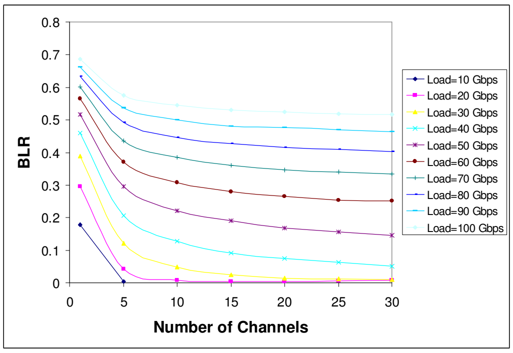

Fig. 5 Relation between BLR and number of channels at different load.

BLR decreases with the number of channels. It can be seen from Fig. 5 the big decrease in BLR for low number of channels. After that, the decrease in BLR is small. This gives us a clew that number of channels has a great effect on the BLR in systems that have small number of wavelengths.

The simulation is repeated to study the effect of the number of channels while fixing the traffic load to 50 Gbps. The experiment is done for different link bandwidths. Again, the number of channels will vary from 1 to 30 channels each has 1/30 of the total link bandwidth. Figure 6 shows the effect of combining the increase in number of channels and increase in link bandwidth which leads to much better BLR. Again, the effect of link bandwidth on BLR is continuous while the effect of number of channels is clear only in the systems of a small number of channels.

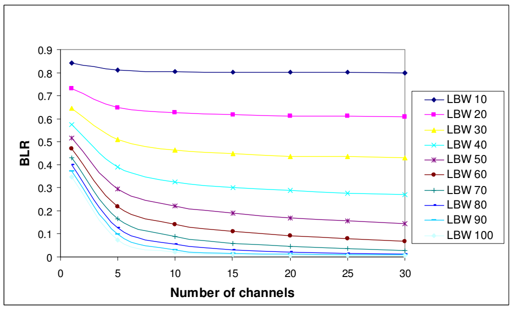

Fig. 6 Relation between BLR and number of channels at different link bandwidths.

3.3 Effect of Link Bandwidth

Link bandwidth is a key parameter that affects BLR. In this simulation, the number of channels is fixed to 3. The effect of different traffic loads is studied. In the simulation, the link bandwidth is taken in the range 10 to 100 Gbps. Figure 7 displays the effect of link bandwidth on BLR. It is noted that, the effect of link bandwidth on BLR is high at lower traffic loads than higher ones. Also, it can be seen that the BLR is high due to the small number of channels.

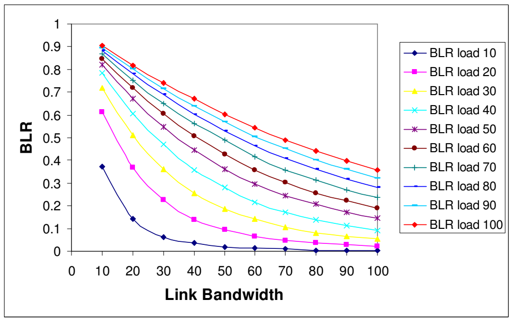

Fig. 7 BLR against link bandwidth at different load.

The simulation is repeated again to study the effect of link bandwidth on BLR at different number of channels at a traffic load 10 Gbps and the obtained results are shown in Fig. 8. It is clear that, at lower traffic loads, increasing number of channels is enough for low BLR even for small link bandwidth.

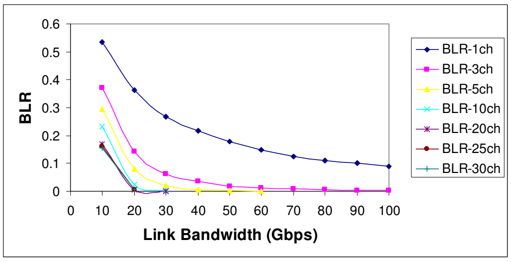

Fig. 8 BLR against link bandwidth at different number of channels.

4.Conclusion

Based on the previous parametric study, it can be seen that different parameters affect the BLR for OBS networks. One can see that the number of channels has a very big effect on the BLR in systems that have small number of wavelengths. Increasing number of channels after a limit is useless. If a lower BLR is still needed to be achieved, link bandwidth must be increased.

From a design viewpoint, one can achieve the same BLR by increasing the link bandwidth or number of channels or both. For example, to carry a traffic load 30 Gbps with required 0.05 BLR, one can use a link bandwidth 100 Gbps with 3 channels, or to achieve the same traffic load and BLR one can use link bandwidth 50 Gbps and 15 channels, etc. Also, to upgrade the previous design that can carry a traffic load of 60 Gbps while preserving the same BLR, one can increase the link bandwidth to 70 Gbps with 15 channels (only upgrade the link bandwidth) or increase link bandwidth to 80 Gbps and decrease the number of channels to 10.

This shows that this parametric study can help in designing and upgrading OBS networks to achieve better BLR or to carry an increased traffic load while maintaining a desired BLR. A designer can tune the desired parameters based on his system and requirements.

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