Decision of the Fiber Delay Line Length in Optical Burst Switching Networks

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Abstract — **This paper shows simulation results with exponential traffic in OBS network. We first describe our scheme. Simulation is done with OPNET tool. From the simulation, we find proper guard-band and FDL length for OBS node. Using this result, we show blocking rate to verify our simulation result.**

Keywords — **Optical Burst Switching, OBS, Fiber Delay Line, FDL, Intra-Session, OPNET.**

1. Introduction

The demands for more network bandwidth are growing at unprecedented rates. For the past couple of decades, the Internet has been a dominant communication infrastructure for transporting data traffic and such an increase is still ongoing. Especially, the explosive growth of Internet traffic in the last decade has resulted in the deployment of DWDM (Dense Wavelength Division Multiplexing) technology, which offers multi-gigabit rates per wavelength, in the core networks. Optical burst switching (OBS) is an approach used for transmission of data over DWDM networks.

Even though OPS (Optical Packet Switching) is very attractive technology, it has some disadvantages, such as the lack of optical RAM (Random Access Memory) and all optical processing capability.

However, in OBS, the data to be transmitted is assembled into bursts. Each burst has an associated control packet, BCP (Burst Control Packet). The BCP carries some information about the burst, such as source and destination address, offset time, and the burst duration. In order to circumvent the disadvantages of OPS, besides the data channels, each link has one or more control channels to transmit the BCP in OBS networks. The BCP is transmitted before the burst on the control channel, while the burst is transmitted at the source after the offset time. The offset time is large enough for the BCP to be processed at each intermediate node before the arrival of the burst. Then, the burst cuts through the optical layer of the intermediate nodes to the destination. Though OBS can overcome some disadvantages of OPS, it has some challenging issues. One of them is contention resolution problem, which happens due to the bufferless core.

Generally, we can classify the contention into two. One is the inter-class contention caused by the different class bursts and the other is the intra-class contention caused by the same class bursts. Approaches for resolving contention include wavelength conversion, optical buffering, deflection routing, and additional QoS (Quality of Service) offset time. These four approaches can be used to resolve the inter-class contention resolution problem and three of these schemes, wavelength conversion, optical buffering, and deflection routing, can be available for the intra-class contention. If wavelength conversion is used, then cost and complexity will be a main obstacle. In deflection routing, the burst is deflected to an alternate port in case of a contention on the primary port. However, deflection routing in the network results in several side effects including looping of bursts and out-or-order packet arrival at the destination. In optical buffering using FDL (Fiber Delay Line), the whole collision burst has to be buffered, but the burst length is not fixed and so the FDL length is variable. In this paper, we focus the decision of the FDL length at the core node.

This paper is organized. Section II describes the decision scheme. Section III shows the simulation results using OPNET simulation tool, and some concluding remarks are presented in section IV.

2. FDL Length Decision Scheme

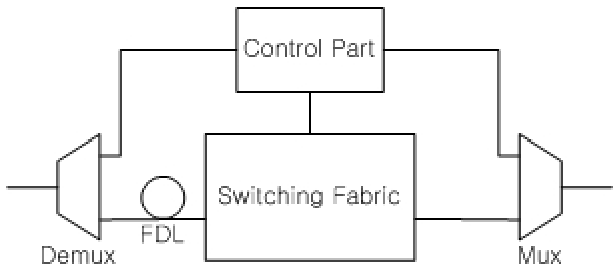

Figure 1. The simplified architecture of an OBS node

The simplified architecture of an OBS node is firstly shown in Figure 1. It can have N input and output fibers; each fiber has W wavelengths for data channels and one or more for control channels. The role of the first component, Demux (Demultiplexer), is to split the input control channel used by the BCPs, and input data channels used by the data bursts. When a BCP reaches an OBS node it is immediately converted in the electronic domain and directed to the control part that determines on which output fiber to send the BCP and the related data burst. A FDL is used to delay the data burst in order to process the BCP. Once the BCP has been processed, it is transferred to Mux (Multiplexer). After offset time, the related data burst is transmitted. Finally, the Mux inserts BCP and the data burst in the output fiber.

One of the major difficulties of OBS is that there is no efficient way to store information in the optical domain; there is no way burst contentions are resolved in the optical domain. Contentions occurs in the network switches when two or more bursts have to exploit the same resource, for example, when two bursts must be forwarded to the same output channel at the same time. The simplest solution to overcome the contention problem is to buffer contending bursts. However, optical RAM (Random Access Memory) does not exist. FDLs are the only way to buffer a burst in the optical domain. Contending bursts are sent to travel over an additional fiber line and are thus delayed for a specific amount of time.

The implementation of optical buffers using FDLs features several disadvantages. FDLs are bulky and expensive. A burst cannot be stored indefinitely on an FDL. Generally, once a burst has entered an FDL, it cannot be retrieved before it emerges on the other side. In other words, FDLs do not have random access capability. Besides that, optical signals that are buffered using FDLs experience additional quality degradation, since they are sent to travel over extra pieces of fiber. The number of FDLs as well as lengths are critical design parameters for an OBS switching systems. The number of FDLs required to achieve a certain burst blocking probability increases with the traffic load. The length of the FDLs is dictated by the burst duration. For the reasons mentioned previously, it is desirable that the need for buffering is minimized.

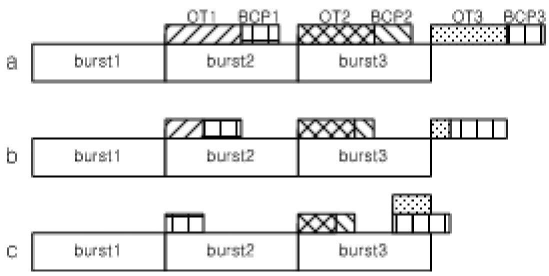

Figure 2. Bursts and BCPs flow

Figure 2 shows some flow. In fact, some gaps, such as intermediate burst gaps and waiting time, are omitted between bursts. There are three bursts, burst1, burst2, and busrt3, and three BCPs, BCP1, BCP2, and BCP3, and three intermediate nodes, a, b and c. In order for us to use our scheme, we add an additional field, which has an accumulated time difference value between the real processing time and the average processing time at each intermediate node, to BCP and we use the number of hops as an offset time value. The average processing time, δ, is assumed in the total OBS network. Let OT_1^a be the remaining offset time between burst1 and BCP1 at the node a. The value is calculated by multiplying offset time by δ and adding it to the accumulated time difference value. Let BCP_1^a be the real processing time of BCP1 at the node a. The burst1 exactly arrives at the destination node because BCP_1^x (x: a, b, and c) for BCP1 is the same as δ. In this case, the additional field has zero because the real processing time and the average processing time are the same. The burst2 arrives at node c earlier because BCP_2^x is not the same as δ. In this case, the additional field has non-zero. Instead, it has minus value because the real processing time is less then the average processing time, and as the additional field is used, the exact arrival time of burst2 can be known. The remaining bandwidth is somewhat used by any other purpose. The second case makes any problems. Just the related bandwidth may be wasted, but it is quite small. The next case causes the biggest problem, the burst blocking status. Burst3 should be cast away because it does not complete the processing of the associated BCP. However, if the additional field and proper FDL are used, the burst to be lost is used correctly. The additional field also has plus value. It means the real processing time is greater than the average processing time. In order to minimize this, we calculate the proper FDL length to be used.

3. Simulation and Results

We assume the bandwidth per wavelength is 10Gbps, we use exponential traffic source, the average processing time is 100nS, and each link has just 2 wavelengths; one is for the control channel and the other is for the data channel.

Table 1. The Overlapping Bits

Load	Overlap(bits)
0.001	367.6
0.01	367.8
0.1	367.9
0.5	367.8

Table 1 shows the degree of overlap as the traffic load changes. The values are converted into the overlapping bits and the average value is 368 bits ($36.8x10^{-9}$S). When both the guard-band and proper FDL are not used, the value means the overlapping degree in the intra-session. We can use this as basic FDL length. Also, we can use this value as basic guard-band. The guard-band is needed to protect bursts and to find corret bits in the bursts at each intermediate node. However, In OBS, the guard-band has two purposes; one is for protecting bursts and the other is for increasing the detection capability, which means each node can use this guard-band to correct the detection level and adjust the bit position.

Table 2. Blocking Rate

FDL length	Blocking Rate
0	$3.679x10^{-1}$
1	$2.547x10^{-1}$
2	$1.764x10^{-1}$
6	$4.045x10^{-2}$
10	$9.206x10^{-3}$
15	$1.446x10^{-3}$
20	$2.308x10^{-4}$

Table 2 shows the simulation results as the FDL length changes. There have been many papers to use FDL to reduce the blocking rate, but any papers don't calculate the FDL length to be needed to reduce the rate, especially in the intra-session. As mentioned early , 1 FDL length is the same as 368 bits. The propagation delay of fiber is 5.5μs/km. 1 FDL is the same as about 6.6909 meters. This table shows the minimal FDL length to have the reasonable blocking rate. The simulation result shows just 20 times of the basic FDL is suitable. This FDL can contain 7360 bits and be converted into about 133.869 meter fiber. This means if 133.869 meter FDL is used, reasonable blocking rate is obtained.

4. Conclusion

In our paper, the FDL length to reduce the blocking rate is calculated. The simulation result shows about 133.869 meter FDL is suitable. Also, 368 bits of guard-band to protect the burst and to facilitate the detection capability at each node is calculated. Even though reliable blocking rate can be obtained using only the proper guard-band, this makes much overhead like ATM. Using both guard-band and FDL can reduce the overhead and system complexity, but increase the performance. Future works are finding the numerical model and applying this result to inter-class cases.

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