Simultaneous Burst and Burst Control Packet Transmission Protocol for Optical Burst Switching Ring Networks

Joon-Pyo Park and Man-Seop Lee

ABSTRACT—In this letter, we design a collision resolution protocol for optical burst switching ring networks to avoid burst collision. We define the offset time condition for no burst transmission collision and manage the free time list of nodes for no burst reception collision. In order to improve the throughput, we use a fiber delay line, void-filling, and void-compression. This protocol does not require any additional procedures for bandwidth reservation such as centralized assignment of bandwidth, lightpath setup of WDM ring networks, or token capturing for the burst transmission. The simulation results show that the proposed protocol can achieve high throughput while saving 70% of wavelengths when compared to round robin with random selection, round robin with persistent, and round robin with non-persistent with only destination delay.

Keywords——OBS, ring network, burst collision.

I. Introduction

Optical burst switching (OBS) ring networks are more effective for data traffic than SONET/SDH ring networks and are more realistic than optical packet switching ring networks [1]; however, they have the burst collision problem. Several types of OBS ring protocols have been studied. Among them, wavelength-routed OBS rings, token OBS rings, and request-acknowledgement OBS rings are collision-free [2]-[4]; however, these protocols require the bandwidth reservation procedure, which introduces extra end-to-end (ETE) delay. For this reason, they cannot meet dynamic data traffic demand.

In this letter, we propose an OBS collision resolution protocol which uses the output optical buffer of the fiber delay line (FDL), which is the same length as the offset time. The offset time condition is defined as a collision-free condition. With the offset time condition, the proposed protocol can avoid burst collision and efficiently exploit channel capacity. The next section describes the collision resolution protocol in detail.

II. Simultaneous Burst and Burst Control Packet Transmission Protocol

An OBS ring node can transmit a burst as soon as the burst is ready because it does not require any additional procedures for bandwidth reservation, such as centralized assignment of bandwidth, lightpath setup of WDM ring networks, or token capturing for the burst transmission. Therefore, the OBS rings can reduce ETE delay and efficiently use channel bandwidth. However, because nodes share wavelengths for transmission, more than one node may transmit a burst on the same wavelength for the same destination node. In this case, burst collisions could happen on the same wavelength or at the same receiver. There are two types of burst collision. The first, burst transmission collision, occurs while a node is transmitting a burst. If another burst passes through the node on the same wavelength, two bursts collide on the same wavelength. The other type, burst reception collision, occurs at the destination node. If two or more nodes transmit their bursts to the same destination, bursts may arrive at the node simultaneously. In this case, the destination node may select one of them to be

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Joon-Pyo Park (phone: +82 42 866 6224, email: park94@icu.ac.kr) and Man-Seop Lee (email: mslee@icu.ac.kr) are with the School of Engineering, Information and Communications University, Daejeon, Korea.

received and the other bursts are dropped. In ring topology, unlike mesh topology, bursts do not collide in the intermediate nodes because a node has only one upstream node and one downstream node.

We propose the simultaneous burst and burst control packet transmission (SBCT) protocol for OBS ring networks to remove the burst collision problems and save the resources of ring networks. Figure 1 shows the node structure for the proposed protocol. We assume that the transmitter and the receiver can be tuned to all ranges of data wavelengths and that all nodes share wavelengths for burst transmission. In SBCT protocol, all nodes transmit a burst and a burst control packet (BCP) simultaneously. The FDL delays the burst at the output of the optical cross connector (OXC) by the offset time. Consequently, the BCP precedes the burst by the offset time.

Figure 2 shows how the SBCT protocol effectively schedules burst transmission compared to the typical “just enough time” (JET) OBS. The control wavelength and the data burst wavelength are denoted by λ_c and λ_d, respectively. In Fig. 2(a), we suppose two bursts are passing by a node on the same wavelength. Figure 2(b) depicts how the JET OBS schedules the burst transmission. When the node receives BCP 1, the JET OBS scheduler assigns burst 3 in to be transmitted right after burst 1. The node transmits BCP 3 in the offset time (t_{offset}) before transmitting burst 3. After transmitting BCP 3, the node receives BCP 2 and knows that burst 2 will overlap burst 3. The JET OBS scheduler may cancel the transmission of burst 3 or may drop burst 2 to avoid burst collision. In both cases, the JET OBS scheduler wastes bandwidth; in the former case, a gap occurs between burst 1 and burst 2; and in the latter case, the overlapped part of burst 2 is wasted. The transmitted BCP 3 arrives at the destination node without any interruption. Because of BCP 3, intermediate nodes cannot use the bandwidth reserved by BCP 3 which is not being used.

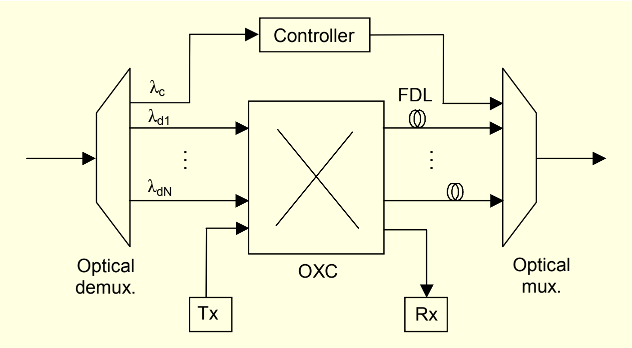

Fig. 1. OBS ring node structure for SBCT.

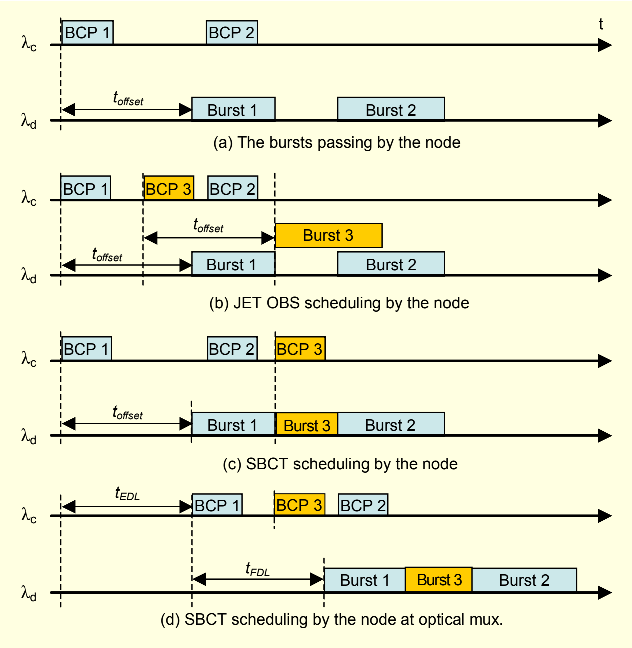

Fig. 2. OBS scheduling diagram.

The SBCT protocol schedules the burst after receiving BCP 2 and transmits BCP 3 and burst 3 at the same time, so the SBCT protocol does not waste bandwidth unlike the JET OBS. From BCP 1 and BCP 2, the scheduler knows the exact information of the gap, which is the unused time slot of the channel between two bursts. The scheduler can make a burst shorter than the gap and transmits BCP 3 and burst 3 at the same time, as shown in Fig. 2(c). Actually, bursts 1, 2, and 3 are delayed by the FDL as shown in Fig. 2(d). If the delay of the FDL (t_{FDL}) is set the same as the offset time, delayed burst 3 can keep the same time gap as the offset time from BCP 3, but because bursts 1 and 2 are delayed too, the offset time between BCPs and bursts is increased by the FDL. However, this increased offset time can be compensated by using two methods. One is delaying BCPs 1 and 2 in the electrical domain by the delayed time of a burst. The other is updating the offset value in BCP as the increased offset time. Figure 2(d) represents the first compensating method in which BCPs 1 and 2 are delayed by the electrical delay line (EDL).

Though a node transmits the burst and the BCP at the same time, two bursts will collide with each other if the BCP is received after the beginning of burst transmission with a shorter offset time than the length of the burst being transmitted by the node. To resolve this burst transmission collision, we define the offset time condition below.

$$t_{offset} \ge t_{\max burst} , \tag{1}$$

where $t_{\max burst}$ is the maximum size of the burst. A burst cannot come until the previous burst transmission is finished.

However, the problem of burst reception collision still occurs. To avoid burst reception collision, the node maintains a free time list for all network nodes, which specifies when the node can receive a burst without burst reception collision; the free time list is updated by monitoring the received BCPs. When

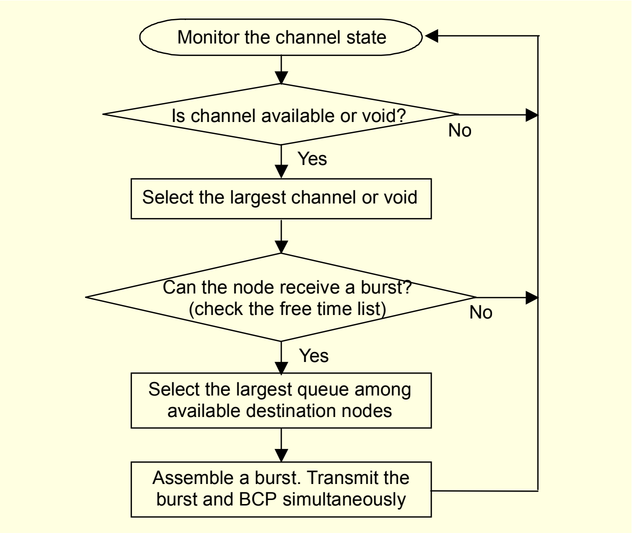

Fig. 3. Flowchart of SBCT protocol.

the node schedules the burst transmission, the SBCT protocol scheduler decides the destination node of the burst by referring to the free time list, so the SBCT protocol can avoid burst reception collision.

Figure 3 shows a flowchart of the SBCT protocol. One of the main characteristics of the SBCT protocol is that when finding available channels, the node makes a burst fit the available channel to maximize channel utilization. To increase channel utilization, we assume that FDL can be selected by a 1x2 optical switch. If the offset time is larger than the original offset time and if there is no burst during the offset time on the same wavelength, the void size can be reduced by the time of FDL by selecting the other path so that the leaving burst does not pass through the FDL. We call this scheme *void-compression*.

The usage of FDL results in overhead of ETE delay. To reduce overhead, it is necessary to decrease the offset time, the delayed time by the FDL. And the offset time limits the maximum size of the burst by (1). Therefore, we can calculate the upper bound of the maximum burst size with the size of the ring network and the number of nodes as

$$t_{\max burst} \le \frac{t_{prop} \cdot \alpha}{N}, \qquad (2)$$

where t_{prop}, α, and N mean the propagation delay, the ratio of FDL delay to the propagation delay, and the number of nodes, respectively. The delay ratio (α) effects the increment of ETE delay: the ETE delay increment from FDL can be reduced by lowering the delay ratio (α).

III. Simulation Results

We established an OBS ring model using an OPNET simulator to verify the performance. Table 1 shows the modeling environments.

Table 1. Modeling environments.

Parameters	Values
Number of nodes	10
Channel capacity	Control channel: 622 Mbps Data channel: 10 Gbps
Number of wavelengths	3, 6, and 9
Size of ring network	225 km
Burst size	Maximum: 100 µs Minimum: 20 µs
Guard time	20 µs
Burst offset time	120 µs

In the simulation, we adopted the single tunable transmitter/multiple fixed receiver scheme of [5]. Between two consecutive bursts, we used the same guard time which is required to reconfigure the optical switch not to lose a burst, as in [6]. The real maximum burst size was 120 µs including the guard time. The burst offset time was set to 120 µs to match the real maximum burst size. We also assumed that Ethernet packets arrive at the node from access networks, and that the packet arrival process follows a modified interrupted Poisson process [4]. The Ethernet packet size was determined by a truncated exponential distribution with an average size of 500 bytes and a maximum size of 1500 bytes. The packet arrival rate was assumed to be 10 Gbps. In the proposed OBS ring network, the data wavelengths are shared by 10 nodes. With those parameter values and assumptions, we simulated utilization, ETE delay, and total throughput of the SBCT protocol in comparison with round robin with random selection (RR-R), round robin with persistent (RR-P), and round robin with non-persistent (RR-NP) with only destination delay (ODD) offsets in [4].

Figure 4 plots the total throughput of the SBCT protocol. Increasing the number of wavelengths from 3 to 9, the throughput improvement is saturated. The simulation results of network performance are summarized in Table 2, comparing SBCT with RR-R, RR-P, and RR-NP. The simulation results confirmed that the proposed protocol, RR-P, and RR-NP have no burst loss caused by burst collision, but RR-P and RR-NP use the home wavelength. In RR-P and RR-NP, a node transmits a burst only onto its own home wavelength. These protocols require the same number of wavelengths as the number of nodes. As shown in Table 2, the proposed protocol outperforms RR-P and RR-NP with only 3 wavelengths while RR-P and RR-NP require 10 wavelengths. The proposed protocol also shows total throughput and utilization two times

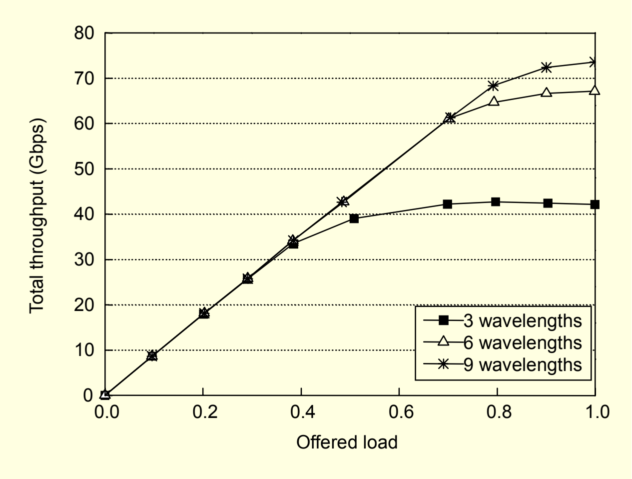

Fig. 4. Total throughput of SBCT protocol.

Table 2. Simulated OBS ring network performance.

Protocol	Number of wavelengths	Utilization (%)	Total throughput (Gbps)	ETE delay (ms)
SBCT	3	81.08	42.7	1.040
SBCT	6	64.46	67.1	0.866
SBCT	9	43.86	73.5	0.838
RR-R	10	12.4	22.1	0.600
RR-P	10	18	38	0.690
RR-NP	10	21	36	0.700

better than RR-P and RR-NP in the case of 6 wavelengths. Thus the proposed protocol can save 70% of the wavelengths when compared to RR-P and RR-NP. In terms of ETE delay, RR-R, RR-P, and RR-NP are better than the proposed protocol. But the difference is not significant as it is in the order of sub-milliseconds.

IV. Conclusion

The proposed SBCT protocol removes burst collision completely. To efficiently exploit the bandwidth, we use FDL and void compression. Because a node transmits a burst and a BCP simultaneously and because the optical delay time is added to the offset time as a burst passes by a node, the node can use the channel bandwidth more efficiently. The simulation results show that the SBCT protocol can reduce the number of wavelengths up to 70% compared to the RR-R, RR-P, and RR-NP protocols with even better throughput. But ETE delay increases 50% compared to RR-R, RR-P, and RR-NP. By shortening the maximum burst size in (2), the increase of ETE delay can be restricted within a low ratio. Therefore, the proposed protocol would be suitable for large OBS ring networks having relatively long propagation delay compared to the offset time.

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