# Priority-Based Duplicate Burst Transmission Mechanism in Optical Burst Switching Networks

Tai-Won Um, Hai L. Vu, Jun Kyun Choi, and Won Ryu

*ABSTRACT—This paper proposes a priority-based duplicate burst transmission mechanism in an optical burst switching network to enhance the probability of successful reception of bursts. The performance of the proposed mechanism is evaluated by NS2 simulations. Our results show that the burst loss rate is improved especially under light traffic loads.*

*Keywords—Burst loss recovery, optical burst switching.*

## I. Introduction

Optical burst switching (OBS) [1] is an alternative technology for the future optical Internet. In OBS, if the lightpath cannot be reserved for a pending burst, the burst will be blocked and lost. It has been shown that burst loss rates are very high in OBS networks due to wavelength contention at intermediate nodes [1]. Several methods have been proposed for wavelength contention resolution based on repetitive burst transmission, which can reduce the burst loss rate by recovering blocked bursts by copying traffic. These approaches do not require complex signaling or higher computational processing of control packets. However, the total traffic load doubles, causing higher overall blocking probability in OBS networks [2].

Recently, a repetitive burst transmission mechanism using a differentiated priority has been proposed for OBS networks in [3]. In this mechanism, a source or an intermediate node (called a *cloning node)* makes one or more duplicate bursts with low priority and sends them simultaneously through a path which is disjoint from the original one [3].

In this letter, we propose a priority-based duplicate burst transmission mechanism, which is a generalized form of repetitive burst transmission. The original burst and its duplicate can be sent through the same path or through multiple paths to enhance the probability of successful reception of bursts. When the duplicate burst is lost during transmission, the intermediate node can automatically make another duplicate burst. It enhances the probability of successful reception of bursts while maintaining the number of cloned bursts.

## II. Priority-Based Duplicate Burst Transmission Mechanism

Our proposed priority-based duplicate burst transmission mechanism (DBTM) operates as follows. Before a control packet is sent, every pending burst is copied and assigned a unique sequence number at the ingress node. The control packets are then sent for both the original (pending) burst and its copy. The time offset between the control packet and the original burst is, however, set to be longer than the counterpart time offset between the duplicate burst and its control packet. By setting an appropriate offset time [4], we can guarantee that the original bursts will have a higher priority than other duplicates.

The source sends the duplicate burst first and the original burst later through the same path as shown in Fig. 1. If both the original burst and its copy successfully arrive at the destination, the egress node only selects the one that arrives first among received bursts, and discards others that have the same sequence identifier.

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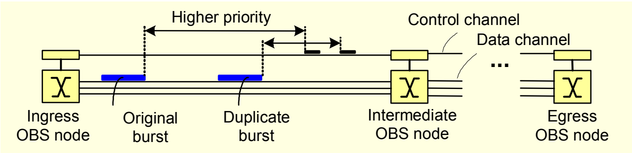

Fig. 1. Duplicate burst transmission through one path.

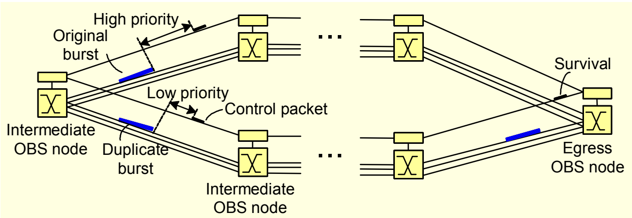

Fig. 2. Duplicate burst transmission through multiple paths.

Under DBTM, the intermediate OBS node maintains a burst-drop record table, which records the sequence number of recently dropped bursts. By using the burst-drop record table, the intermediate node can recognize that the duplicate is lost after examining whether the same sequence number of the received original burst exists in the burst-drop record table. If the previously sent duplicate has been dropped, the intermediate node makes another copy of the incoming original burst and forwards it to the destination. The newly made duplicate burst has lower priority than the original burst and will be sent through the same or a disjoint path together with the original burst as shown in Fig. 2. This intermediate duplication enhances the probability of successful reception of bursts while maintaining the number of cloned bursts.

This intermediate burst duplication can be easily achieved with the optical splitting capability [5]. Because the intermediate node can recognize whether the intermediate duplication should be performed upon receiving the control packet of the original burst, it can configure the burst splitting component before the arrival of the original burst. The intermediate node makes and sends out a duplicate control packet, which is followed by the newly duplicate burst generated through the optical splitting component. For a detailed description of the optical splitting capability, see [5] and [6] and the references therein.

## III. Performance Evaluation

We implemented new OBS modules in the NS2 simulator to evaluate the performance of the proposed DBTM method. Figure 3 shows an NSFNET topology consisting of 19 OBS nodes, in which the number on a link is the distance in kilometers between two adjacent nodes. Bursts arrive at the network according to a Poisson process. The average burst size is set to 1.25 MB in consideration of optical switching efficiency [7], and the length of a burst is exponentially distributed. Each link between adjacent nodes contains four wavelengths, and the link transmission rate is 10 Gb/s. The signal propagation in optical fibers is assumed to be 250 km/ms, and there are no optical buffers in the network. We evaluated the blocking probability of the 13 routes defined in Table 1. The selected routes represent a variety of path lengths, link sharing degrees and mixtures of external and on-route internal traffic process. All routes are shortest paths, except for $R_4$ and $R_7$, which were selected to obtain better route diversity.

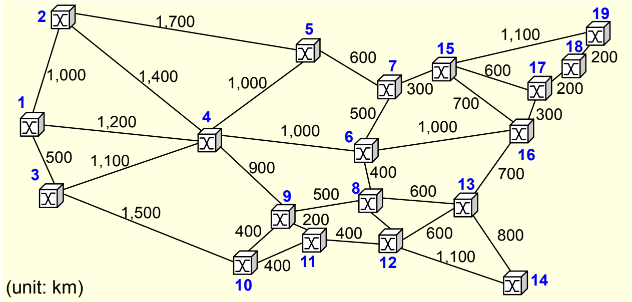

Fig. 3. A 19-node NSFNET with distancs between nodes.

Table 1. NSFNET routes.

| Name | Route hops | Collision routes |
|---|---|---|
| $R_1$ | 1→2→5→7→15→19 | $R_5$, $R_8$ |
| $R_2$ | 8→13→16 | $R_5$, $R_{10}$ |
| $R_3$ | 3→10→11→12→14 | $R_{11}$, $R_{10}$ |
| $R_4$ | 2→4→6→7 | $R_{11}$, $R_8$, $R_9$ |
| $R_5$ | 5→7→6→8→13 | $R_1$, $R_6$, $R_7$, $R_2$ |
| $R_6$ | 6→8→12→11 | $R_{11}$, $R_5$, $R_{12}$ |
| $R_7$ | 7→6→16 | $R_5$, $R_9$ |
| $R_8$ | 8→6→7→15 | $R_1$, $R_4$, $R_{13}$ |
| $R_9$ | 9→4→6→16→17 | $R_4$, $R_7$, $R_{10}$, $R_{12}$ |
| $R_{10}$ | 10→11→12→13→16→17→18 | $R_3$, $R_9$, $R_2$ |
| $R_{11}$ | 2→4→9→8→12→14 | $R_3$, $R_4$, $R_6$, $R_{13}$ |
| $R_{12}$ | 12→11→9→4 | $R_6$, $R_9$, $R_{13}$ |
| $R_{13}$ | 11→9→8→6 | $R_{11}$, $R_8$, $R_{12}$ |

The simulation results were obtained for the OBS using the Just Enough Time (JET) protocol [1], burst cloning [3], and the proposed DBTM mechanism. The performance metrics are the burst loss probability as a function of the offered input traffic load and the number of route hops.

To observe the performance of the proposed mechanism according to the number of transmitted hops, we chose two NSFNET routes, $R_2$ and $R_{11}$. The first route spans two hops in

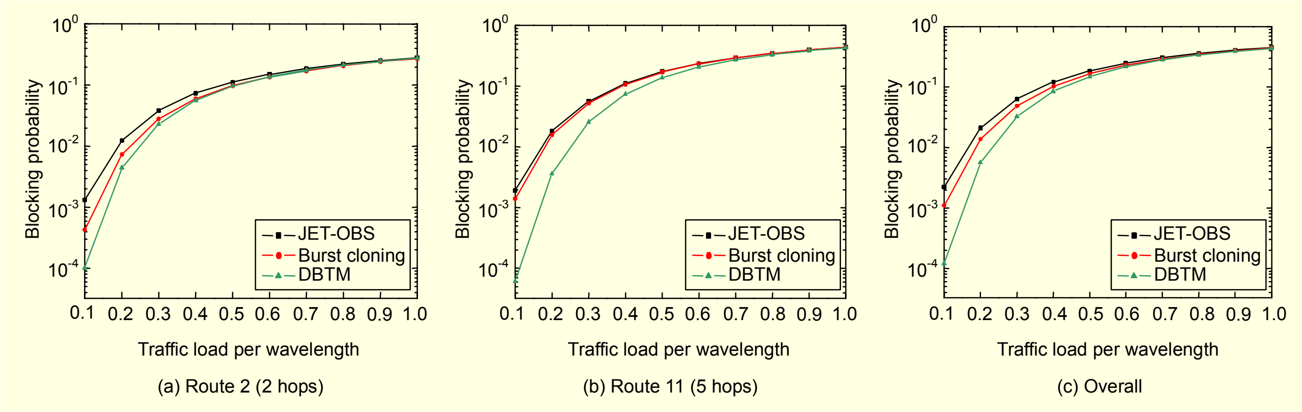

Fig. 4. Blocking probabilities of (a) route 2, (b) route 11, and (c) overall.

competing with two other routes, $R_5$ and $R_{10}$, and the second route spans five hops against four other routes (as shown in Table 1). The comparison results for the two routes between the proposed DBTM and previous OBS schemes are shown in Figs. 4(a) and (b). Both graphs show that our scheme remarkably improves the blocking probability in comparison with that achieved using JET-OBS and the burst cloning method.

In the previously proposed burst cloning scheme, bursts are cloned regardless of whether the duplicate burst suffers collision during its transmission. Cloned bursts with low priority suffer more blocking than original bursts with high priority [4]. Therefore, as the number of hops between the source and the destination increases, the probability of receiving the cloned bursts at the destination is greatly reduced. By comparing Figs. 4(a) and (b), we can ascertain the effect of using burst cloning in an OBS network. When the number of transmitted hops increases from two to five, the effect of using burst cloning is almost negligible in an OBS network.

In the proposed DBTM method, further duplication is also performed as the original burst passes through intermediate nodes whenever the duplicate burst has been blocked previously. The newly generated duplicates at the intermediate nodes notably increase the probability of successful reception even though the number of transmitted hops increases. In the DBTM scheme, low priority duplicates do not prevent high priority original burst transmission. After the original bursts with high priority reserve the optical channels, idle intervals (voids) can be used to transmit low priority duplicates. As the traffic load of original bursts increases, voids on channels decrease and the efficiency of DBTM decreases as shown in Figs. 4(a) and (b). Figure 4(c) shows the overall blocking probability in the studied NSFNET topology. The DBTM scheme improves the burst blocking probability by one order of magnitude in the region of low offered loads in comparison with JET-OBS and the previous burst cloning method.

## IV. Conclusion

This letter proposed a priority-based duplicate burst transmission mechanism in OBS networks. Without interrupting original bursts, low priority bursts can be retransmitted through optical voids unoccupied by original bursts. Receiving low priority bursts at the egress can increase the probability of successful reception without complex signaling or higher computational processing. The simulation results showed a remarkably reduced blocking probability compared to that of the conventional JET-OBS and the previous burst cloning method.

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