

A Noble Flow Rate Control based on Leaky Bucket Method for Multi-Media OBS Networks

Kentaro Miyoko, Yoshihiko Mori, Yugo Ikeda, Yoshihiro Nishino, Yong-Bok Choi, and Hiromi Okada

Abstract—Optical burst switching (OBS) has been proposed to realize the next generation Internet based on the wavelength division multiplexing (WDM) network technologies. In the OBS, the burst contention is one of the major problems. The deflection routing has been designed for resolving the problem. However, the deflection routing becomes difficult to prevent from the burst contentions as the network load becomes high. In this paper, we introduce a flow rate control methods to reduce burst contentions. We propose new flow rate control methods based on the leaky bucket algorithm and deflection routing, i.e. separate leaky bucket deflection method, and dynamic leaky bucket deflection method. In proposed methods, edge nodes which generate data bursts carry out the flow rate control protocols. In order to verify the effectiveness of the flow rate control in OBS networks, we show that the proposed methods improve the network utilization and reduce the burst loss probability through computer simulations.

Keywords—Optical burst switching, OBS, flow rate control.

I. INTRODUCTION

RECENTLY, due to the great popularization of the Internet, the traffic has increased exponentially. For the explosive growth of multimedia traffic, a serious problem that is the shortage of network capacity has occurred. For resolving this problem, the backbone networks need high speed and high performance with the throughput of over hundreds of Gbps.

Accordingly, the communication systems which need no electronic process and use the optical communication technology have been expected. In order to realize high performance in optical networks, optical burst switching (OBS) [1] [2] [3] has been focused. However, the burst contention is the critical problem in OBS networks. For resolving this problem, the deflection routing method [4] [5] has been investigated. In this method, as a burst contention occurs, the burst which arrives later at an intermediate node is detoured. Although many improvements of the deflection routing methods [6] [7] have been designed, most of them have been unable to avoid the burst loss effectively.

In this paper, we investigate the effectiveness of the flow rate control in OBS networks. In the OBS networks, intermediate nodes have no optical memories. It is difficult for intermediate nodes to cope with temporally fluctuations of the

network load. It is hard to prevent the burst contentions by using only deflection routing, when the network roads are high in the OBS networks. We have proposed leaky bucket deflection method [8]. Here we propose new flow rate control methods based on the leaky bucket algorithm and deflection routing, i.e. separate leaky bucket deflection method, and dynamic leaky bucket deflection method. In these methods, flow rate control is introduced into edge nodes. As the flow rate control scheme, we adopt the leaky bucket algorithm which has been used in asynchronous transfer mode (ATM). The burst loss probability will decrease dramatically in OBS networks applied the flow rate control even if the network load increases. We compare the proposed methods with the conventional methods by simulations and show the effectiveness of the proposed methods.

This paper is organized as follows. In section 2, we describe OBS in detail. In section 3, we explain separate LB deflection method and dynamic LB deflection method. In section 4, we show the simulation results of proposed method. We conclude in section 5.

II. OPTICAL BURST SWITCHING

A. General Aspects of OBS

The basic principle of OBS is to separate channels into a control channel which transmits control packets and data channels. Control packets are converted into electricity and set switches by using O/E conversion at intermediate nodes. Oppositely, data bursts can pass through whole network in optical domain without O/E conversion.

In OBS networks, transmission links have a number of WDM channels, and the channels are assigned dynamically to data bursts. A control packet is transmitted for carrying control information of following a data burst. At an edge node of the network, a data burst is transmitted after waiting for the interval time called offset time. Control packets are transmitted with the unique channel called control channel. Data bursts are transmitted with one of the other data channels. Generally, the length of data bursts is variable and longer than the packet length of optical packet switching. Hence the overhead of the control packet becomes relatively small. The efficiency of bandwidths is high because wavelengths are set free after data bursts in OBS networks are transmitted.

B. Problems of OBS

One of the major problems in OBS is the burst contention. Burst contentions occur when more than two bursts which want to reserve the same wavelength of the same output link

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simultaneously in an intermediate node. We may prevent the burst contentions by using optical buffers. But we cannot use optical buffers because they have not achieved the level of the practical use yet. Thus the deflection routing has been designed.

Fig. 1 shows the basic operation of the deflection routing. Two data bursts which have the same destination node B arrive at node A at almost same time. The two data bursts try to reserve the same wavelength to node B. Here, we assume that data burst 1 arrives at node A earlier than the data burst 2 and reserves Link A-B. Then the data burst 2 cannot reserve Link A-B. The data burst 2 has to choose the deflection routing. The data burst 2 reserves Link A-C-B. In this method, unused links are regarded as virtual link buffers. Contention bursts are detoured onto those links. The overall network efficiency and network performance are improved because the network load is spread to the network which is not used relatively.

When the network load is low, most links are unused and several links are reserved. It is possible to reduce the burst loss probability efficiently. However, as the network load becomes high, burst contentions increase. So the number of bursts which are applied to the deflection routing increases. Therefore the burst loss probability increases and the efficiency of OBS networks decreases.

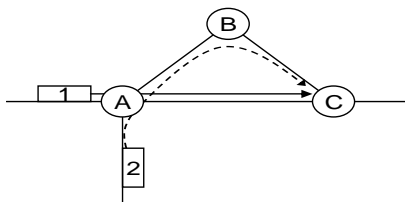


Fig. 1 Basic operation of the deflection routing

Although there are a lot of improvements of the deflection routing, most of them cannot resolve the burst contention effectively when the network load is high. In OBS networks, data bursts are not stored at intermediate nodes because there are no optical buffers. So it is difficult to control the burst contention effectively by the deflection routing only. We need to implement an admission control into OBS networks in order to resolve the problem of the burst contention effectively.

III. DYNAMIC FLOW RATE CONTROL IN OBS NETWORKS

In the previous section, we described the problems of OBS and the deflection routing. However, we cannot resolve burst contentions effectively by using it as the network load becomes high. The reason is that we cannot temporally store data bursts at intermediate nodes in OBS networks without optical buffers. In OBS networks, it needs to perform some flow rate control of the traffic in edge nodes. In this paper, we propose new flow rate control methods based on leaky bucket algorithm and deflection routing, i.e. separate leaky bucket deflection method and dynamic leaky bucket deflection method. We explain each methods as follows:

A. Leaky Bucket Deflection Method

LB deflection method is the basic protocol [8]. Fig. 2 shows an OBS network with the leaky bucket algorithm. At an edge node of the network, a data burst attempts to get a token. It is transmitted if it is successful to get a token. Tokens are generated with a constant rate and are accumulated at the token buffer of the edge node. If the edge node recognizes the arrival rate of data is over a definite rate, the data bursts are stored in the data burst buffer while they are waiting for getting tokens. The delay time for transmitting data bursts to OBS network is called admission delay.

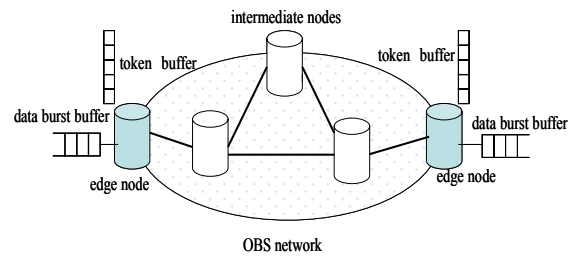


Fig. 2 OBS network with Leaky Bucket method

In the normal method, data bursts are assembled and transmitted into OBS networks at edge nodes. The amount of the data bursts in the OBS networks increase as the network load becomes high. In this case, because intermediate nodes have no optical buffers, the burst loss probability will increase. In the LB deflection method, we introduce the flow rate control in OBS networks. Generated data bursts are controlled with leaky bucket control at edge nodes. Thus it is possible to decrease the burst loss probability in OBS networks by controlling the network flow rate in the definite value. LB deflection method is effective in OBS networks. But LB deflection method is an excess flow rate control. Thus we propose separate LB deflection method and dynamic LB deflection method. Proposed methods classify generated data bursts into two classes, and apply the leaky bucket algorithm only to one of two classes.

B. Separate Leaky Bucket Deflection Method

Fig. 3 shows a separate LB deflection method at an edge node. In the separate LB deflection method, a generated data burst is classified into two, reliable class and real-time class. The data of reliable class can permit the delay but can not permit the burst loss. On the other hand, the data of real-time class can permit the burst loss but can not permit the delay. TCP data communications have the characteristics of reliable class. Packets consisted of voice or video have the characteristics of real-time class. The separate LB deflection method applies leaky bucket to the data bursts of reliable class at edge nodes, but not to real-time class.

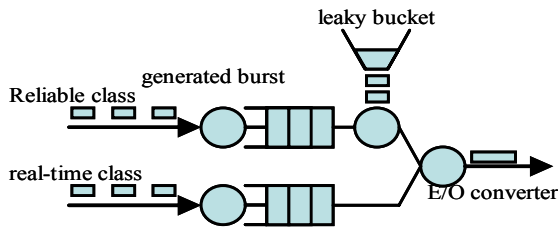


Fig. 3 Separate LB deflection method at edge node

C. Dynamic Leaky Bucket Deflection Method

Dynamic LB deflection method expanded separate LB deflection method. In this method, a generated data burst is classified into two classes as in the case of the separate LB deflection method. The leaky bucket control is applied only to the reliable class. The dynamic LB deflection method adjusts the generation rate of the tokens dynamically. The dynamic LB deflection method can regulate the amount of data bursts according to the network load. In the dynamic LB deflection method, the intermediate nodes and the edge nodes behave as follows:

[Intermediate nodes]

- The network load is checked for fixed intervals.
- If network load is higher than threshold, congestion message is transmitted to data burst sender nodes.
- If network load is less than threshold, available message is transmitted to data burst sender nodes.

[Edge nodes]

- If the congestion message arrives at the node, the generation rate of the tokens decreases by one step.
- If the available message arrives at the node, the generation rate of the tokens increases by one step.

IV. PERFORMANCE EVALUATION

A. Simulation Model

In order to compare the network performance of proposed flow rate control methods and prove the validity of them, we simulate the proposed methods and conventional methods on a computer. The simulation model is as follows:

[In all methods]

- Each link has 16 channels.
- The bandwidth of each channel is 10Gbps.
- The burst length follows distribution which varies between 10(μ s) and 40(μ s).
- The traffic generation model is MMPP.
- There are no optical buffers and FDL in intermediate nodes.
- The percentage of reliable traffic is 80% of the whole.
- The data bursts are not retransmitted
- We ignore bit errors in transmission.

[In all proposed methods]

- The size of the electrical buffers in the edge nodes is infinite.

- The generated-rate of token is 0.5(token/ μ s).
[In the dynamic LB deflection method]
- Checked intervals are average 30 μ s.
- The threshold of network load is 0.8.

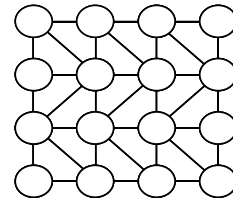


Fig. 4 Network topology

Fig. 4 shows a network topology for the simulations. The length of grid links is 400km and that of diagonal links is 550km.

B. Numerical Results

In this section, by comparing proposed methods with the conventional methods, we consider what affect the traffic flow rate control of proposed methods.

Fig. 5 shows the comparison of the average burst loss probability in OBS networks between the proposed methods and the conventional methods. From this figure, in the proposed methods, we can see that the data burst loss of the proposed methods is lower than one of the normal method. In the normal method, the higher the network load becomes, the higher the burst loss probability becomes. This occurs because an excessive number of bursts are generated and transmitted into the OBS network when the traffic generation is momentarily high.

On the other hand, the burst loss probability is almost identical for any network load in the proposed methods regardless of the load. The proposed methods can moderate a change of the network load by activating the flow rate control. Thus, it is possible to control the burst loss probability regardless of a change of the network load in the methods.

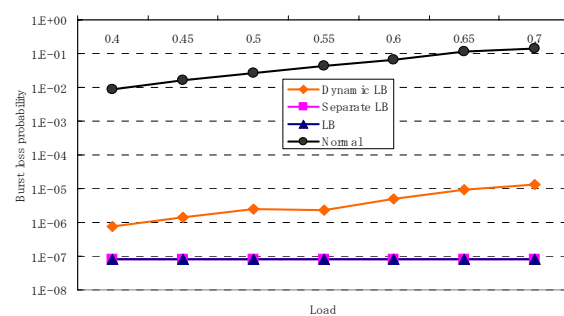


Fig. 5 Characteristics of burst loss probability

Fig. 6 shows the comparison of the burst loss probability for reliable class between the proposed methods and the conventional methods. From this figure, we can reduce the burst loss probability in the proposed methods. In the normal method, the higher the network load becomes, the higher the burst loss probability becomes.

On the other hand, the burst loss probability is identical for any network load in the proposed methods regardless of the load. The worst performance in the proposed methods is better than the best performance in the normal method. In the proposed methods, the flow rate control using leaky bucket is carried out only for the reliable class at the edge nodes. Then, data bursts of reliable class are transmitted into OBS networks almost at constant rate regardless of the momentary high load. The proposed methods can regulate a change of reliable class load due to the flow rate control. Thus, it is possible to control the burst loss probability for reliable class regardless of a change of the network load in the methods.

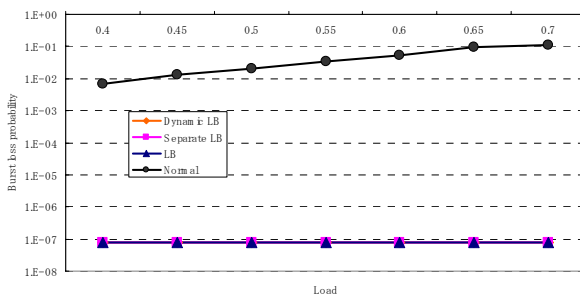


Fig. 6 Characteristics of burst loss probability for reliable class

Fig. 7 shows the characteristics of the average delay time of four methods. From this figure, we can see that the delay time of the normal method is the shortest in four methods. In the normal method, leaky bucket is not applied to data burst transmission. Thus the delay time is constant in the normal method. But the burst loss occurs with high probability in the normal method.

In the separate LB deflection method, as the network load is high, most of the data bursts in the OBS network are real-time class which does not apply to the leaky bucket. The delay time of real-time class is very short. Thus, we think that average delay time of the separate LB deflection method decreases.

We also see that the delay time of the dynamic LB deflection method is the shortest in two proposed methods and LB method. In the dynamic LB deflection method, the generation rate of the tokens changes by the network load. Therefore, the dynamic LB deflection method can decrease the admission delay compared with the other two proposed methods.

Fig. 8 compares the characteristics of delay time for real-time class between the proposed methods and the conventional methods. From this figure, in the LB deflection method, we can see that the delay time for real-time class is the longest among the all methods. In the LB deflection method, the leaky bucket control is applied to both real-time and reliable classes. Thus, the delay time for real-time class increases. Real-time class can not permit the delay. Therefore, leaky bucket is not effective in real-time class. On the other hand the delay time for the separate LB deflection and dynamic LB deflection methods are the shortest in the proposed methods. In these methods, the leaky bucket control is not applied to real-time class. Thus, these methods can decrease admission delay. Therefore, the separate LB deflection and dynamic LB

deflection methods can decrease the delay time of reliable class.

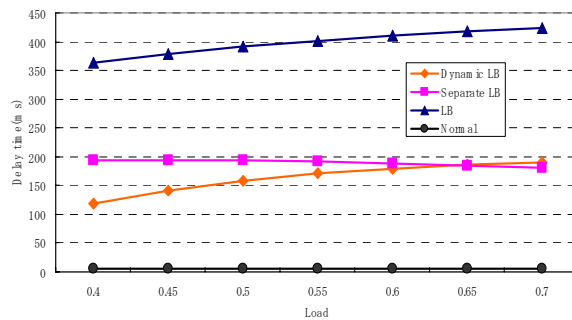


Fig. 7 Characteristics of average delay time

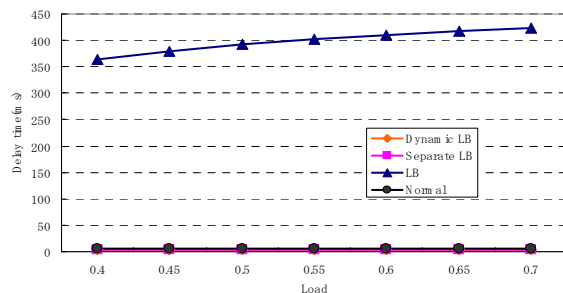


Fig. 8 Characteristics of delay time for real-time class

Fig. 9 shows the comparison of the delay time for reliable class between the proposed methods and the conventional methods. From this figure, in the normal method, we also see that the delay time for reliable class is steady low value regardless of a change of the network load. On the other hand, the delay time in the proposed methods fluctuates by the network load. In the normal method, leaky bucket control is not applied to the reliable class. In the proposed methods applied to leaky bucket control, the admission delay increases as the network load monetarily increases because a large amount of the data bursts are generated. Therefore, the delay time is closely related with admission delay.

The delay time of the dynamic LB deflection method is the shortest in the proposed methods. In the dynamic LB deflection, the generation rate of tokens changes by the network load. Thus, reliable class can effectively utilize idle links. Therefore, the dynamic LB deflection method can decrease the admission delay of reliable class.

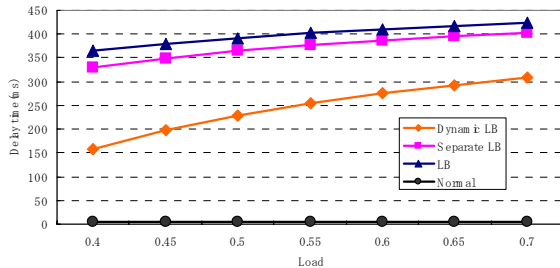


Fig. 9 Characteristics of delay time of reliable class

V. CONCLUSION

For resolving the burst contention problems in OBS networks, we have focused on the flow rate control scheme and proposed two new methods, i.e. separate LB deflection method and dynamic LB deflection method. In this paper, we compared the performance of the proposed methods with that of the conventional methods by computer simulations and have obtained followings.

- From the simulation results, we have found that OBS need to carry out a traffic flow rate control for reducing the burst loss probability for reliable class.
- In the separate LB deflection and dynamic LB deflection methods, we can transmit data bursts of real-time class without buffering delay because the leaky bucket control is not applied to real-time class.
- The dynamic LB deflection method increases the generation rate of token as the network load becomes low. This method can efficiently use the network capacity. Thus, this method has the shortest admission delay in proposed methods.

Therefore, dynamic LB deflection method is the most suitable protocol to reduce the number of burst contentions and improve the network performance in OBS networks.

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