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An Effective Traffic Control for both Real-time Bursts and Reliable Bursts in OBS Networks

Yuki Kondo, Takanori Nagano, Yuki Takeda, Young-Bok Choi, Hiromi Okada

***Abstract*—**Optical burst switching(OBS) is considered as one of preferable network technologies for the next generation Internet. The Internet has two traffic classes, i.e. real-time bursts and reliable bursts. It is an important subject for OBS to achieve cooperated operation of real-time bursts and reliable bursts. In this paper, we proposes a new effective traffic control method named Separate TB+LB (Token Bucket + Leaky Bucket : TB+LB) method. The proposed method presents a new Token Bucket scheme for real-time bursts called as RBO-TB (Real-time Bursts Oriented Token Bucket). The method also applies the LB method to reliable bursts for obtaining better performance. This paper verifies the effectiveness of the Separate TB+LB method through the performance evaluation.

***Keywords*—**leaky bucket, OBS, traffic control, token bucket.

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I. Introduction

RECENTLY, the development of the optical switching technology that uses wavelength division multiplexing (WDM) is a pressing need. The construction of an optical network where a large capacity and high-speed transmission are enabled is needed because of a rapid increasing of the network traffic.

Optical burst switching(OBS)[1]is paid attention as an optical switching technology for the network constructions with large capacity and high-speed transmission. However, the burst contention is the critical problem in OBS Networks. It occurs burst loss. OBS has an important subject that cooperated operation in data bursts with different characteristics. In OBS networks, a variety of data bursts exists together. There are two type data bursts together. For instance, one is data bursts that demands real time such as the streaming video and VoIP, and the other is data bursts that demands reliability like E-mail.

The burst contention is the critical problem in OBS networks. For resolving this problem, flow rate control has been introduced into OBS networks[2]. As the flow rate control scheme, the paper adopts the leaky bucket(LB) algorithm which has been used in asynchronous transfer mode (ATM). Fig. 1 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 has many data bursts over definite rate, the data bursts are stored in the data burst buffer while they are waiting for getting tokens. The Separate LB (Leaky Bucket : LB) method was proposed as a method to guarantee the quality of reliable bursts transmission[3]. This method has very effective for reliable bursts transmission when the amount of reliable bursts is large. However, this method cannot achieve cooperated operation when the amount of real-time bursts is large enough to destroy the fairness of the resource usage.

Y. Kondo, T. Nagano, Y. Takeda, H. Okada are with Information Network Laboratory, Department of Electronics Engineering, Kansai University, Japan (phone: +81-6-6368-0820 e-mail: yuki@jnet.densi.kansai-u.ac.jp)

Y. B. Choi is with Department of Electronic Engineering, Tongmyong University, Korea (phone: +82-51-629-1142; e-mail: ybchoi@tu.ac.kr)

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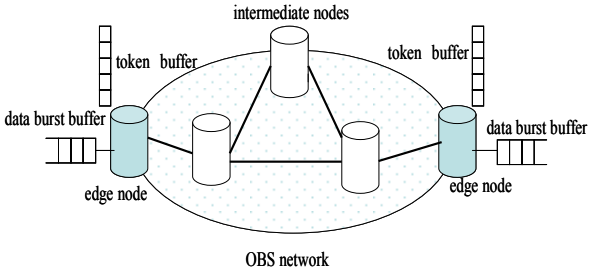


Fig. 1 OBS network with leaky bucket method

In this paper, we propose a new effective traffic control method named Separate TB+LB (Token Bucket + Leaky Bucket : TB+LB) method. This method achieves the cooperated operation of reliable bursts and real-time bursts under the situation with large amount of real-time bursts in OBS networks. The Separate TB+LB method introduces the LB method for reliable bursts, and introduces token bucket (Real-time Burst Oriented Token Bucket: RBO-TB)[4] method for real-time bursts. This paper carries out the performance comparisons of proposed method with the Separate LB methods by using the computer simulations. Numerical result shows the effectiveness of the proposed method.

This paper is organized as follows. In chapter 2, we explain details of the proposed method. Chapter 3 shows the simulation result of the proposed method. We conclude in chapter 4.

II. Proposed Method: Separate TB+LB

In the previous section, we described the problems of OBS and Separate LB method. However, we cannot achieve the cooperated operation in data bursts. The reason is that a variety of data bursts exist together in OBS networks. In this paper, we propose new effective traffic control methods based on leaky bucket algorithm, named Separate TB+LB(Fig. 2). Separate TB+LB is composed of RBO-TB method and LB method. The RBO-TB method is applied to real-time bursts, and the LB method is applied to reliable bursts. Different methods apply to data bursts since data bursts have different characteristics. We explain each method as follows.

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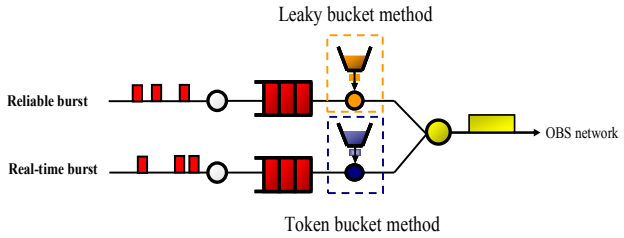


Fig. 2 Separate TB+LB at edge node

1. RBO-TB Method

The control to real-time bursts of the Separate TB+LB method is RBO-TB method. This method achieves low propagation delay to real-time bursts. We consider a more efficient control according to the network situation with the edge node and the core node. So, the RBO-TB method is composed of different control algorithms in the edge node and the core node. The edge node control algorithm is composed of three algorithms and the core node control algorithm is composed of two algorithms. We explain five algorithms as follows.

Edge node control algorithms are as follows:

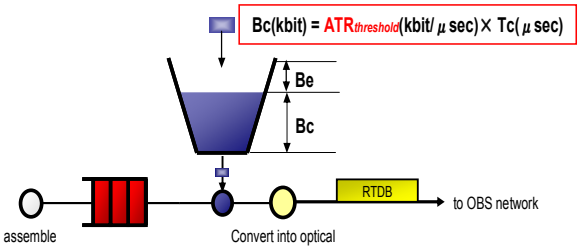
1) Violated real-time burst detection algorithm.
2) Network state distinction algorithm.
3) Traffic control algorithm.

Core node control algorithms are as follows:

4) Network state distinction algorithm.
5) Wavelength limitation algorithm

A. Violated Real-time Burst Detection Algorithm

The violated real-time burst detection algorithm is done only by the edge node. This algorithm is done by comparing the amounts of the token remainder in the sending real-time burst length and the bucket. Fig. 3 is a composition of the violated real-time burst detection algorithm. Be shows the amount of the token that allows the excess transmission, and Bc shows the amount of the token that recovers at constant intervals. It explains operation when the amount of the token in the bucket is assumed to be X(kbit), and real-time bursts of A(kbit) are generated. The token bucket deletes the tokens of A(kbit) in the bucket, and sends real-time bursts for A≦X as no marking burst in the OBS network. The token is not deleted for A>X, and the violation is detected. And, a real-time burst is sent as a marking burst in the OBS networks.



(RTDB : Real-Time Data Burst)

Fig. 3 Violated real-time burst detection algorithm

B. Network State Distinction Algorithm (edge node)

The network state distinction algorithm in the edge node classifies the state of network. The classes are the Slack, the Normal and the Congestion state based on average transmission rate (ATR) of the real-time bursts in the OBS network. The state of Slack shows that the amount of real-time burst is very few. The state of Normal shows that the amount of real-time burst is proper. The state of Congestion shows that the amount of real-time burst is numerous.

The edge node calculates the average transmission rate from (1) with constant intervals. Tc is a token recovery interval in the token bucket. Moreover, the network state distinction algorithm is shown in Fig. 4.

$$ATR = \frac{The\ \ amount\ \ of\ \ real\ \ time\ \ bursts\ \ (kbit)}{Tc\,(\mu\,\mathrm{sec})} \qquad (1)$$

To classify the state of the network into three, the edge node has two transmission rate thresholds. The first transmission rate threshold is slack threshold. The edge node judges network slack state for the ATR≦slack threshold. The second transmission rate threshold is congestion threshold. The edge node judges network congestion state for the ATR>congestion threshold. In addition, the edge node judges network normal state for slack threshold < ATR≦ congestion threshold.

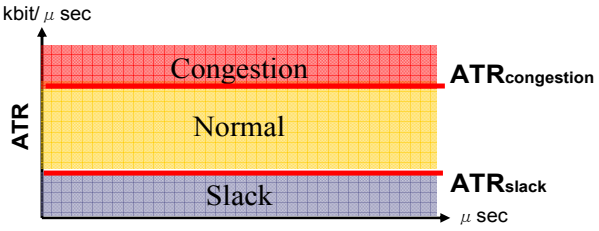


Fig. 4 Network state distinction threshold

C. Traffic Control Algorithm

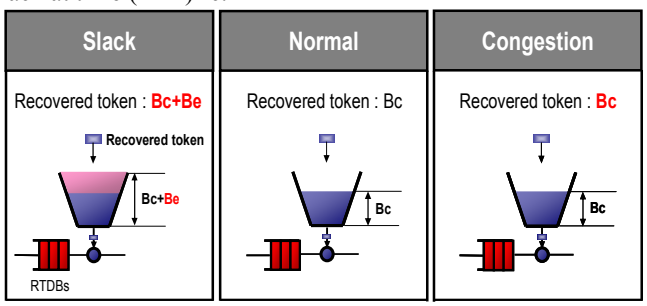
The edge node increases the amount of the recovery of the token of the token bucket as for the traffic control algorithm in the edge node at slack state. Moreover, the edge node lowers the transmission rate of the marking burst at Congestion. Fig. 5 shows the traffic control algorithm in the edge node. The traffic is controlled according to the state classified depending on the network state distinction algorithm. The amount of the token recovery is assumed to be Bc+Be for the slack state. Since the amount of the real-time burst in the OBS network is very small, it should use the network resource a little. Even a little no marking bursts can be sent in the OBS network by increasing the amount of the token recovery up to the maximum capacity. In the state of normal and congestion, the amount of the token recovery is set to Bc. The purpose of this is to send more no marking bursts in the OBS network. When the amount of the recovery of the token of the normal and the congestion state is

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same, the performance of no marking burst is deteriorated. Then, the edge node lowers the transmission rate of the marking burst at congestion state. The band consumption by the marking burst is evaded by lowering transmission rate. As a result, the performance deterioration in no marking burst is evaded. The edge node sets the sending interval of the marking burst by using (2) [5].

$$\text{Transmission Interval } (\mu\text{sec}) = \frac{(\text{Size of real time burst} - \text{Available token})(\text{kbit})}{ATR\ (\text{slack})\ (\text{kbit}/\mu\text{sec})} \quad (2)$$

The edge node lowers the transmission rate of the marking burst by setting the sending interval long. In addition, the edge node sets the sending interval to the marking burst long until returning to the state of slack. The purpose of this is to prevent the state of the network from returning to the state of congestion immediately. Fig. 6 shows the control algorithm corresponding to the state of the network to the marking burst. The edge node sets the sending interval of the marking burst long when entering the state of congestion at time (x-1) Tc as shown in Fig. 6. The edge node sets the sending interval of the marking burst long even if judged the state of normal at time xTc. The edge node immediately sends the marking burst without setting the sending interval long in the OBS network if judged the state of slack at time (x+m)Tc.



(RTDB : Real-Time Data Burst)

Fig. 5 Traffic control algorithm

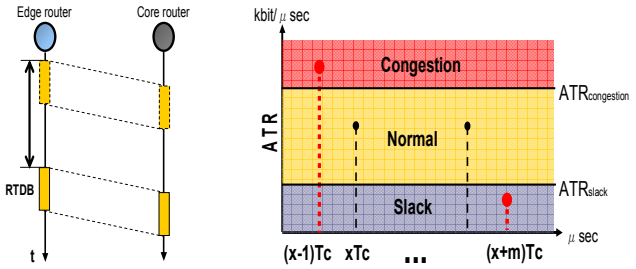


Fig. 6 Traffic control to marking burst

D.Network State Distinction Algorithm (core node)

The network situation distinction algorithm of the core node is done based on availability (Link Utilization Rate : LUR) of connected link. The core node calculates the link availability from (3) with constant interval[6]. T is an interval when the link availability is measured. W is the number of all wavelengths for each link. Moreover, the network situation distinction algorithm is shown in Fig. 7. T is an inspection interval of the link availability. W shows the number of all wavelengths of a link, U is the occupation time of a wavelength in T respectively.

$$LUR = \frac{\sum_{\lambda=1}^{W} U_{\lambda}}{T \times W} \quad (3)$$

To classify the state of the network into three (the state of slack, the state of normal, and the state of congestion), the core node has two link utilization thresholds. The first link utilization threshold is slack threshold. The second link utilization threshold is congestion threshold. The core node judges the state of the network slack for the LUR≦slack threshold. The core node judges the state of the network normal for slack threshold< LUR≦congestion threshold. The core node judges the state of the network congestion for the LUR>congestion threshold.

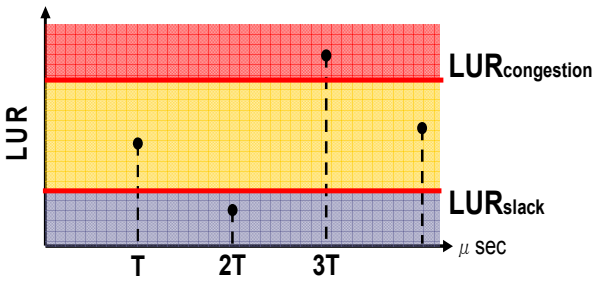
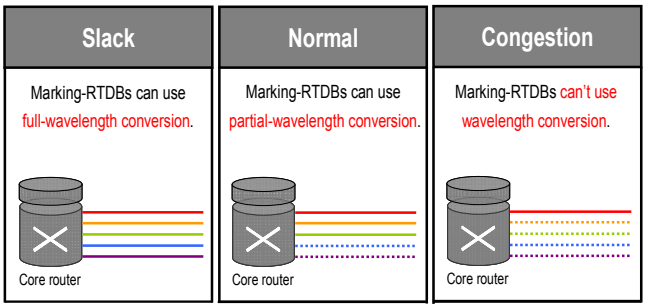


Fig. 7 Network state distinction algorithm (core node)

E. Wavelength Limitation Algorithm

Fig. 8 shows the control algorithm corresponding to the network of the core node. The core node limits the number of wavelengths which can be used for the marking burst according to the network situation. The amount of the real-time bursts in the OBS network is very little at slack state. The core node applies all wavelength conversion to the marking burst. The amount of the real-time burst in the network is an ordinary condition at normal state. To prevent excessive consumption of the network resource by the marking burst, the core node applies the partial wavelength conversion to the marking burst. The amount of the real-time burst in the network is very much at congestion state. To allocate remained network resource to no marking burst, the core node doesn't apply the wavelength conversion to the marking burst. The performance of no marking burst is maintained high by the above-mentioned operation regardless of the traffic variation.



(RTDB : Real-Time Data Burst)

Fig. 8 Wavelength limitation algorithm (core node)

F. Control to reliable bursts

The control to the reliable bursts of the Separate TB+LB method is LB method. The LB method is used only in the edge node. The edge node only confirms the presence of the token in the token buffer. As for the token, the token buffer is collected by a constant route. When the token can be acquired, the edge node sends the reliable bursts in the OBS network. The token is deleted at the same time as sending the reliable bursts. As for the reliable bursts, when the token cannot be acquired, the reliable burst is buffered in the edge node. If the following token can be acquired, the buffered reliable bursts is sent in the OBS network. As a result, the Separate TB+LB method can suppress the amount of the reliable bursts in the OBS network below the definite value.

The Separate TB+LB method applies the appropriate control to both of reliable bursts and real-time bursts under the situation with large amount of the real-time bursts in the OBS network. As a result, the Separate TB+LB method can evade the fairness of the network resource usage by a real-time burst and achieve cooperated operation of both classes.

III. Performance Evaluation

1. Simulation Model

To verify the effectiveness of the proposed method, the performance of the Separate TB+LB method was compared with the Separate LB method by the simulation. The simulation condition is shown below.

[All methods common]
- Network topology: 3×3 mesh topology(Fig. 9)
- Simulation time: 2,000,000μsec
- Wavelength channels of each link : 32
- Traffic model: MMPP
- Wavelength converter: available
- Bandwidth of each channel: 10Gbps
- Data burst-length: 400 kbit(40 μsec)
- Reliable burst ratio: 0.1

[Separate TB+LB method]
(LB method parameter)
- Token recovery interval: 10 sec
- Amount of recovery tokens: 2
- Amount of maximum tokens: 4

(RBO-TB method parameter)
- Parameters in edge node
- Token recovery interval: 7,850 sec
- Average transmission rate congestion threshold: 102Gbps
- Average transmission rate slack threshold: 26Gbps
- Parameters in core node
- Link utilization inspection interval: 1500 sec
- Link utilization rate congestion threshold: 0.8
- Link utilization rate slack threshold: 0.2
- The number of converting wavelengths in partial wavelength conversion: 17

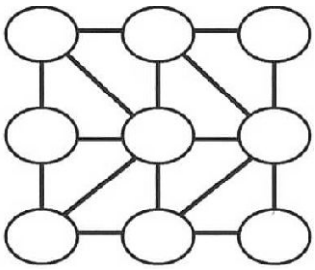


Fig. 9 Network Topology

2. Numerical Results

A. Loss Probability Characteristics

In Fig. 10, the loss probability of the separate TB+LB method is compared with the separate LB method about reliable and real-time bursts. A horizontal axis is the average load and a vertical axis is the burst loss probability. The real-time burst loss probability of the Separate TB+LB method is higher than that of the Separate LB method. The reliable burst loss probability of the Separate TB+LB method is decreased compared with that of the Separate LB method. The Separate TB+LB method applies the RBO-TB method to real-time bursts. The core node of the Separate TB+LB method limits the number of available wavelengths for real-time bursts. Therefore, the core node of the Separate TB+LB method limits the number of available wavelengths for real-time bursts classified into the marking burst by the edge node according to the network state. The Separate LB method doesn't limit the number of available wavelengths for real-time bursts corresponding to the network state. As a result, the real-time burst loss probability of the Separate TB+LB method deteriorates compared with that of the Separate LB method. However, the real-time burst loss probability of the Separate TB+LB method was able to obtain the result within an allowance of the real-time burst loss probability. In this simulation, the ratio of the amount of reliable bursts and real-time bursts is 1:9. The Separate LB method immediately sends real-time bursts to the OBS network. Real-time bursts of the Separate LB method destroy the fairness of the network resource usage in the OBS network. Therefore, the Separate LB method cannot effectively be used for reliable bursts. The Separate TB+LB method limits the number of available wavelengths that can be used for real-time bursts classified into the marking burst.

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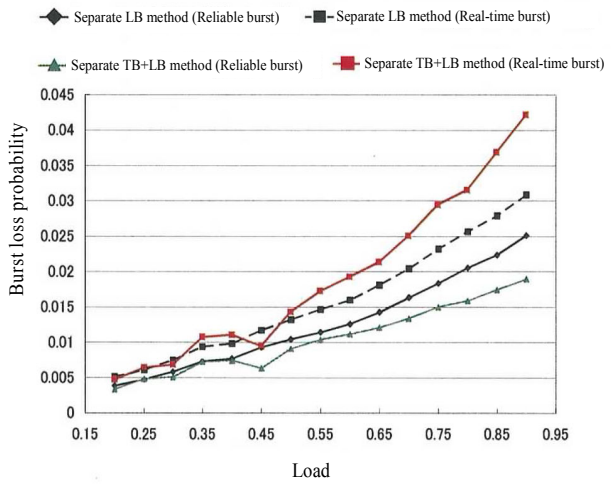


Fig. 10 Burst loss probability characteristics

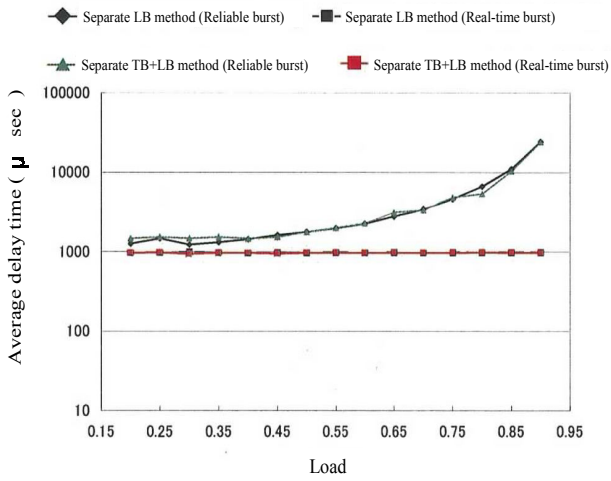


Fig. 11 Average delay time characteristics

Therefore, the Separate TB+LB method can evade the unfairness of the network resource usage by real-time bursts. As a result, the Separate TB+LB method can effectively be used compared with the LB method for the reliable burst. As a result, the reliable burst loss probability of the Separate TB+LB method is decreased compared with that of the Separate LB method.

B. Average Delay Characteristics

In Fig. 11, the average delay time of the Separate LB method and the Separate TB+LB method is shown. A horizontal axis indicates the average load and the vertical axis indicates the average delay time. The average delay time of reliable burst of the Separate LB method and the Separate TB+LB method is growing according to the increase of load, and it is same level. The average delay time of real-time burst of the Separate LB method and the Separate TB+LB method is same level, and it is almost constant according to increasing the average load.

Both of the Separate LB method and the Separate TB+LB method apply the LB method to the reliable burst. The number of reliable bursts that the token cannot be acquired in the edge node increases as the average load increases. The reliable burst that the token cannot be acquired is buffering in the edge node. As a result, The average delay time of reliable burst of the Separate LB method and the Separate TB+LB method is increasing and it is same level.

The Separate TB+LB method applies the RBO-TB method to a real-time burst. The edge node of the Separate TB+LB method sets the sending interval of the real-time burst classified into the marking burst long at congestion state. The sending interval value depends on the amount of the token remainder in the bucket. The sending interval becomes the maximum for empty of the token remainder. However, it doesn't influence the propagation delay of a real-time burst since the maximum sending interval is several microseconds at most. Moreover, the control to the real-time burst classified into the no marking burst in the Separate TB+LB method is only wavelength conversion. As a result, the average delay time of real-time burst of the Separate LB method and the Separate TB+LB method is same level, and it almost becomes constant for the increase of load.

C. Throughput Characteristics

In Fig. 12, the throughput of the Separate LB method and the Separate TB+LB method is shown. A horizontal axis is the average load and the vertical axis is throughput. The throughput of the real-time burst of the Separate LB method and the Separate TB+LB method increases according to the increase of load and it is same level.

Both of Separate LB method and the Separate TB+LB method apply the LB method to the reliable burst. The sending amount of the reliable burst of the Separate LB method and the Separate TB+LB method in the edge node is limited by the LB method. The amount of the reliable burst increases as the average load increases. As a result, the reliable burst throughput of the Separate LB method and the Separate TB+LB method is same level, and it is the monotone increasing according to increasing in the average load.

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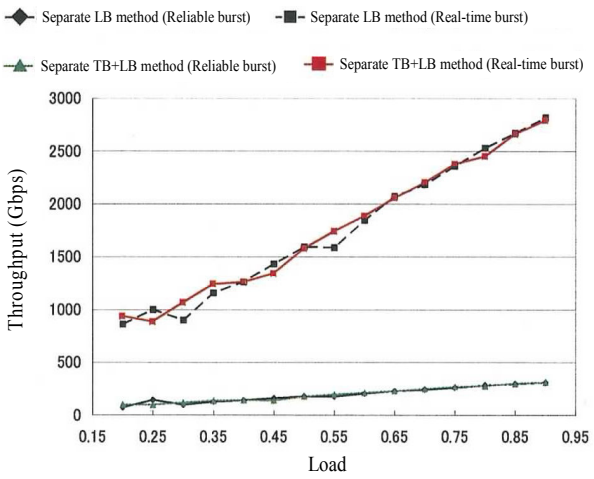


Fig. 12 Throughput characteristics

The Separate TB+LB method applies the RBO-TB method to the real-time burst. The edge node of the Separate TB+LB method gives the delay to the real-time burst classified into the marking burst and limits the amount of sending. However, the delay given to the each real-time burst is several microseconds at most. Therefore, the control to the real-time burst classified into the marking burst of the Separate TB+LB method hardly influences the forwarding amount of real-time bursts. The Separate TB+LB method immediately sends the real-time burst classified into no marking burst in the OBS network. As a result, the throughput of real-time burst of the Separate LB method and the Separate TB+LB method is same level, and it increases according to the increase of average load.

IV. Conclusion

In this paper, we have proposed the Separate TB+LB method to achieve cooperated operation with the reliable burst under the large amount of the real-time burst in the OBS network. The Separate TB+LB method was compared with the Separate LB method which is conventional method, and the results are as follows.

- The Separate TB+LB method achieved the low latency transmission within the tolerance of the loss probability for the real-time burst.
- The Separate TB+LB method has decreased the loss probability of the reliable burst compared with the Separate LB method.

As the above results, it is clarified that the cooperated operation of both classes can be achieved under the large amount of the real-time burst by the Separate TB+LB method.

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