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On the Congestion Control in Optical Burst Switching Networks

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Abstract— **Optical Burst Switching (OBS) is a promising switching paradigm that is very suitable to be deployed in the next generation Internet. OBS combines the benefits of various evolving techniques to economize the network traffic through an optical network. However, OBS lacks mechanisms to prevent or eliminate the network traffic congestion. In this paper, we propose to use the Flow Control and Reservation Bits (FCRB) of the Staged Reservation Scheme (SRS) as a congestion control mechanism for optical burst switched networks. The simulation results show that this technique allows the OBS edge nodes to control the network traffic flows, and enables the core nodes to maintain a low burst drop rate.**

Index Terms—**Optical Networks, OBS**

I. Introduction

PHOTONIC networks are becoming the natural choice to be deployed as the backbone infrastructure to support the next-generation high-speed Internet. The emergence of Wavelength Division Multiplexing (WDM) technology, which supports multiple simultaneous channels on a single fiber, provided the network backbone with huge bandwidth. Optical Burst Switching (OBS) [1], [2] makes it possible to support all-optical networks with the current immature optical switching devices and the lack of efficient optical memory (optical buffers) [3]. OBS is intended to combine the benefits of both packet-switching networks [4], [5] and circuit-switching networks [6]-[8].

OBS is an adaptation of a standard known as ATM Block Transfer (ABT) developed by the telecommunication standardization sector of the International Telecommunication Union (ITU-T) for burst switching in Asynchronous Transfer Mode (ATM) networks. OBS network consists of edge (Ingress/ Egress) nodes and core nodes – built from optical and electronic components – connected by WDM links. OBS differs from optical packet switching and the original burst switching concept introduced in the 80s [9]-[10] in that it separates the control and the data, both in time and physical space. In OBS, collections of IP packets assembled into large-size bursts, called Data Bursts (DBs) are sent an offset time after their corresponding control packets, which are generated at the network ingress and sent on a separate wavelengths/channels over a WDM link to the OBS core nodes to announce and reserve the needed network resources for their data bursts. The offset time is needed for the control packets to be processed electronically as they go through O/E/O conversion at the core nodes, and for the switching fabric to be configured, before the arrival of the DBs to the core nodes. Without the need for data buffering, the DBs are switched all-optically, then disassembled back into the original IP packets at the network egress (edge node), as shown in figure 1.

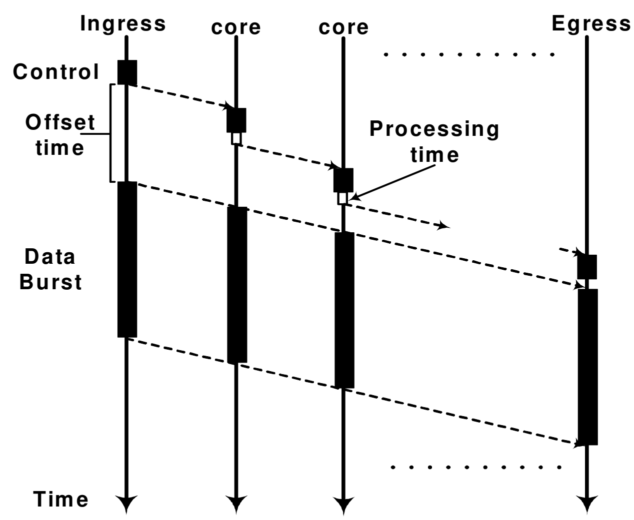

Fig. 1. OBS signaling mechanism

The traditional OBS framework (bufferless system), which is based on the concept of one-way reservation, and its variations [11]-[13] does not provide an optimal solution to handle IP traffic, as the DB (i.e. a set of IP packets) is discarded in its entirety, if the BCP fails to secure the full or even a part of the resources needed to establish an all-optical transmission path for its corresponding data burst. Consequently, and in order to reduce the burst loss probability, many approaches were considered [14]-[17]. Some of the most promising techniques are those based on the concept of data burst segmentation, which was introduced (the concept) to reduce the packet loss probability and improve the network performance in terms of packet delivery. Unfortunately, none of these proposals

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covered the feasibility issues related to the implementation of the burst segmentation techniques. Staged Reservation Scheme (SRS) [18] was proposed for OBS networks based on Just-Enough-Time (JET) protocol [1], where the bust's length (duration) and the offset time information are carried by the BCP. SRS aims to increase the throughput of the core-nodes, and to overcome some of the limitations introduced by the burst segmentation concept.

Taking advantage of the Flow Control and Reservation Bits (FCRB) of the control packets in SRS, a new congestion and flow control mechanism is developed. The introduced mechanism is a simple to implement technique that does not require major changes to the SRS framework.

The number of Data segments (DSs) and their size are explicitly reflected in the FCRB, therefore, FCRB is a good candidate to be used as gauge for congestion and traffic control in the OBS networks, particularly, with the capability of the FCRB to indicate the number of dropped DSs. Using the FCRB to control the traffic flow will effectively reduce the burst overlapping time, which can be translated to reducing the network congestion, therefore, decreasing the burst dropping rate.

This paper is organized as follows. A review of burst segmentation techniques and their associated problems are briefly presented next, followed by a brief introduction to the SRS scheme. In section 4 the proposed congestion technique and its benefits are discussed, then the performance evaluation is shown using a simulation module. Finally, the paper is concluded.

II. BURST SEGMENTATION TECHNIQUES

A measure of efficiency in OBS systems is the burst drooping probability. In order to reduce the burst loss probability, many approaches were considered based on different techniques, such as the use of deflection routing to resolve contention presented by Hsu et al. [14] and Kim et al. [15]. Based on the concept of burst segmentation, other promising techniques for partial burst dropping were introduced. In this section we will present an overview of the main contention resolution techniques based on partial burst dropping strategy.

A. Optical Composite Burst Switching (OCBS)

Proposed by Detti et al. [16], the Optical Composite Burst Switching (OCBS) technique introduces the idea of dropping only the initial part of the burst if all the resources are occupied at the time of the burst arrival. The final part of the burst is transmitted as soon as the needed recourses become free.

Though that this technique allows the packet loss probability to be reduced therefore improving the performance of the network compared to the traditional OBS architecture where the entire burst is dropped, OCBS suffers from the need for Fiber Delay Lines (FDLs). FDLs are needed to delay the data bursts while the control packet is being electronically updated with the new burst size, which is considered as a problem itself, as it increases the electronic processing time needed before forwarding the control packet to the next node.

B. Burst Segmentation

Burst Segmentation was proposed by Vokkarane et al. [17] to reduce packet loss in optical burst switched networks. Designed upon Just-Enough-Time (JET) architecture [13] and it assumes fixed packet size. This approach is comparable to OCBS in that it uses burst segmentation concept. In this technique the data burst is broken into multiple segments that consist of a single packet or multiple packets. Combined with deflection routing, the authors showed that their approach performed better than the "entire-burst-dropping" policy. Two ways were proposed to implement this scheme:

1) Segment-first: The remaining length of the original burst is compared to the contending burst. The contending burst is deflected in case it is the shorter one otherwise the original burst is segmented and its tail is deflected or dropped if the alternate port is busy.

2) Deflection-first: The contending burst is deflected if the alternate port is free. If the alternate port is busy then a similar process to segment-first takes place and the lengths of both original and contending bursts are compared and the tail of the shorter one is dropped, as the alternate port is busy.

There are a number of issues associated with this idea [17]. We believe that the main issues is the need for trail-control-message generation to indicate the segmented burst's new size to the downstream nodes to avoid unnecessarily resource reservation or needlessly contention resolution actions.

III. STAGED RESERVATION SCHEME (SRS)

Staged Reservation Scheme (SRS) [18] was proposed to increase the throughput of the core-nodes, and to overcome some of the limitations introduced by the burst segmentation concept. In SRS, the Burst Control Packets (BCPs) format was reformulated and changed to provide a constant transmission overhead and makes the BCP scalable to higher speeds, as it uses the Flow Control and Reservation Bits (FCRB) as the segments' length indicator instead of flags. As illustrated in figure 2, the new BCPs format contains a new FCRB field, flag field, and SRS-length field, beside the traditional fields that usually include routing information (e.g. Burst destination Address), offset time, etc…

FCRB field: FCRB is created by the edge-node to reflect the permitted segmentations. In the core-nodes, the SRS-length is multiplied by the number of 12 in FCRB to obtain the actual size of the corresponding DB. For example 01112 is an indication that the length of the DB (or truncated DB) is (3 * SRS-length), and it might be segmented into three segments. The size of FCRB is dynamic that may vary from one DB to another, and the burst assembly algorithm controls it.

Flag field: is a sequence of bits with a recognizable pattern that identifies the end of the FCRB field (as its size is not fixed), and the beginning of the SRE-length field.

SRS-length field: contains the length of one DS. However, SRS-length combined with FCRB provides sufficient information about the DB's length and segmentation. To avoid congestion in OBS control-channel, SRS-length should comply with a minimum length, which is the minimum permitted data burst length transmitted over the optical links. The SRS-length may vary from one DB to another.

By adopting SRS dropping policy, if a contention is anticipated in the core-nodes, the resources allocation process will not be aborted (i.e. BCP is dropped and later the corresponding DB is entirely discarded). Conversely, the FCRB field in the corresponding BCP is updated according to the resources that the core-node can provide (or free up). Hence, only the overlapping segments are dropped at the arrival time, allowing part of the DB to be transmitted (i.e. the data length that can be handled by the node at the arrival time). Since the BCPs are updated before forwarding them to the downstream nodes, to reflect the new DBs' length, the need for trailing messages is eliminated, and the contention is resolved at the BCPs level rather than at the DBs level.

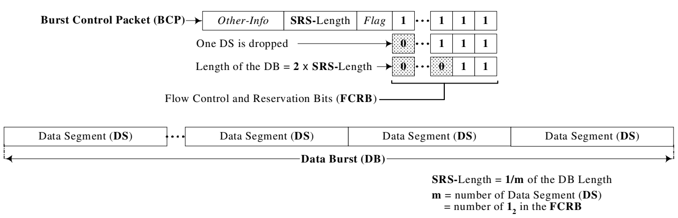

Fig. 2. Illustration of the BCP format in SRS

IV. FCRB Congestion Control Mechanism

Congestion is a complex phenomenon, and it occurs when the traffic load (number of bursts) on the network begins to approach the network capacity. Therefore, a congestion control mechanism is needed to maintain the number of the bursts being transmitted through the network within the limits at which the network performance is acceptable.

By using an explicit congestion avoidance technique, the edge nodes can use as much of the network capacity as possible, while reacting to the congestion in a controlled manner. In the proposed explicit signaling technique, the bits of FCRB are used to indicate explicitly the amount of data (i.e. the number of data segments in the DB) sent and the arrived amount. This signaling approach can work in one of two directions: Forward (to notify the Egress), or Backward (to notify the Ingress).

A. Forward signaling

Notifies the egress node that congestion procedures should be initiated (where applicable) for traffic in the opposite direction of the received bursts. It indicates the number of the dropped data segments, and that the received burst has encountered congested resources. This information could be sent back to the source node, and the end system will exercise flow control upon the traffic sources at the higher layers (e.g. TCP).

B. Backward signaling

Notifies the ingress node that congestion procedures should be initiated (where applicable) for traffic in the same direction as the sent bursts. It indicates the number of data segments dropped, and that the sent burst has encountered congested resources. The ingress node will then lower the number of data segments sent in each DB to be equal to the number of data segments that could get through the network to the destination. Then the number of data segments is augmented progressively until the maximum size of the data burst is reached, or until the FCRB field reports congestion.

V. Performance Evaluation

In order to evaluate the performance of the FCRB congestion control mechanism, a modified version of NCTUns 2.0 [19] is used. Figure 3 shows the packet drop rate versus the traffic load. In the network using the FCRB congestion control, the improvement in terms of packet drop rate is significant, particularly with high traffic loads.

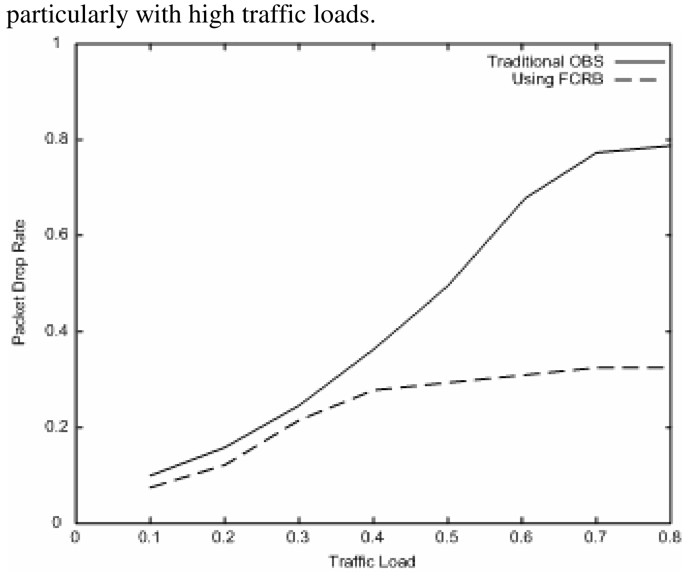

Fig. 3. Packet drop rate versus traffic load

VI. Conclusion

In this paper, an overview of Optical Burst Switching (OBS), and Staged Reservation Scheme (SRS) is provided. A new technique to control the network traffic congestion has been introduced. Based on the Flow Control and Reservation Bits (FCRB) field, the new technique is simple and requires no changes to the SRS signaling protocol of the OBS networks. This will enable the core nodes to maintain a low burst drop rate, and will allow the OBS edge nodes to control the network traffic flow. Therefore, the support of QoS could be easily integrated in the OBS networks, where it is important that traffic flows with different requirements should be treated differently and provided a different quality of service, particularly, during periods of congestion.

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