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A review on a new conservation law in optical burst switching networks

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ABSTRACT

A major challenge in optical burst switching (OBS) networks is how to provide quality of service (QoS). One scheme is burst preemption, in which a high priority burst can preempt a low priority one if there is no available output channel. To analyze the performance of prioritized preemption scheme, a conservation law is widely used without proof in the literature. In this paper, we show that the original conservation law does not hold if the mean burst length of different classes is unequal. We then present an exact model for burst blocking probabilities of multiple priority classes with unequal mean burst lengths by considering the effects of blocking probabilities and preemption probabilities on the mean overall service time. We also propose an approximate model. Our extensive simulation results show that the approximation model can yield accurate solutions under different traffic conditions.

1. Introduction

Internet protocol (IP) over wavelength division multiplexing (WDM), as a key transmission technology, can now provide more than 1 Tbps bandwidth on a single optical fiber. However, such high bandwidth cannot be fully utilized by traditional electronic switches due to the bottleneck of processing speed in the electronic domain. To overcome this problem, optical switching techniques have been proposed [1–3], in which data can be transmitted and switched all-optically.

In OBS networks, IP packets with the same destination and QoS requirement can be aggregated into a large burst at the edge node. Before the transmission of the burst, a control packet (or header) is forwarded from the source to the destination edge, which attempts to reserve wavelength channels along the path for the burst. If the resource is available at an intermediate node, then the switching element will be configured accordingly before the burst arrives. On the other hand, if no wavelength channel is available, the burst will be dropped at the same node [3] or be blocked before burst transmission [4], depending on different signaling schemes.

Regardless of which signaling scheme is used, it is possible that the output channel is not available on a certain link. In the optical domain, this situation can be resolved by using optical buffers, i.e. fiber delay lines (FDLs) [5], in which burst can be delayed for a fixed amount of time. Yet, the usage of FDLs is limited because the size of FDLs may be too large as the length of a delay line is the production of the speed of light and the delay time. Therefore, how to provide differentiated services becomes a major challenge in a bufferless OBS network.

One solution is to use deflection routing [6], in which a burst may be forwarded to an alternative output if its primary output is not available. In this manner, the fiber links in the networks can be used as buffers. Another method is to increase the offset time between the transmission of the header and the burst [7]. However, both methods will increase the end-to-end delay, which may not satisfy certain service requirements.

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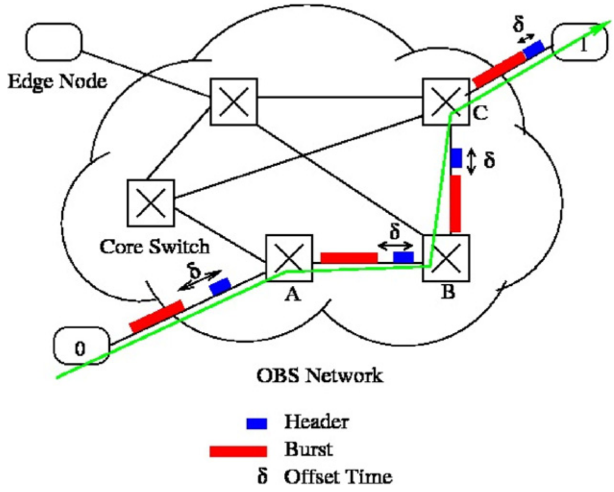

Fig. 1. Architecture of optical burst switching networks.

To avoid the increase of end-to-end delay, a preemptive scheme can be used to provide differentiated services in OBS [8]. In this scheme, a high priority burst can preempt a low priority one if there is no available output channel. Since a burst may contain a large number of IP packets, transmitting a truncated burst may still be useful for upper layer applications.

The burst blocking probability in OBS networks has been studied intensively. For a single class of traffic, classical queuing models such as Erlang-B formula are used (see [9] and references therein). There are additional results dedicated to multiple priority classes of traffic [7–11]. However, they all rely on a conservation law, which is verified only by simulation. The authors in [8,10] simply applied the conservation law to multiple priority classes with unequal mean burst lengths, while the original conservation law in [7] was used to multiple priority classes with equal mean burst length. It is worth noting that the burst blocking probability is also the burst loss probability or burst dropping probability if the entire burst is lost in case of blocking, as is the situation of all the references in OBS mentioned above.

Zeng, Lu and Chlamtac [12] showed that the original conservation law did not hold if the average length of different classes of burst was not equal, and then proposed a new conservation law. Since then, this new conservation law has been widely used to calculate blocking probabilities in OBS (See [13–24], etc.)

In this article, we finalize the results of [12]. We first propose an exact model for burst blocking probabilities of multiple priority classes by considering the effects of blocking probabilities and preemption probabilities on the mean overall service time. To reduce the time complexity, we also provide an approximate model. Extensive simulation results show that the approximation model can yield accurate solutions under different traffic conditions.

The rest of the paper is organized as follows. In Section 2, after briefly reviewing the architecture of OBS networks and the preemption scheme, we disprove the original conservation law for the case of unequal mean lengths. We discuss the new conservation law in Section 3, where we present an exact model for burst blocking probabilities by taking into account the effect of blocking and preemption probabilities on the mean service time. To reduce the computational complexity, we also provide an approximate model of the exact model. We show that the approximate model is equivalent to the original conservation law if the average service time of different classes of burst is identical. In Section 4, we validate the proposed approximate by simulation. Finally, the paper is concluded in Section 5.

2. Burst preemption and the conservation law

2.1. OBS review

Fig. 1 shows the architecture of an OBS network, which consists of a set of edge and core nodes (switches). Traffic from multiple client networks is accumulated at the ingress edge nodes and assembled into data bursts, which are stored in electronic buffers.

Control packets (or headers) are sent out before the transmission of bursts in order to setup lightpaths and configure switching elements. Data bursts will then be transmitted through high capacity lightpaths over the core network, and will be disassembled at the egress edge nodes. Lightpaths will be terminated after the transmission of bursts.

The delay between the transmission of header and burst is defined as *offset time* in the literature. The value of the offset time depends on different signaling schemes. A well-known scheme is JET [3]. In JET, the offset time is set such that the last node has sufficient time to setup its switching element. Figs. 1 and 2 illustrate the burst transmission when the JET scheme is used.