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# Dynamic wavelength selection and delayed burst assignment schemes for Optical Burst Switching networks

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ABSTRACT

Optical Burst Switching (OBS) has been proposed as a promising switching technology for the next generation of optical transport networks. In this paper, we address the issue of how to provide proportional differentiated services in OBS networks. Firstly, a Dynamic Wavelength Selection (DWS) scheme is introduced to provide proportional differentiated services in bufferless OBS networks by dynamically assigning more and longer periods of wavelengths to high priority classes. This scheme can also utilize wavelengths efficiently because the wavelengths are shared among different classes. Next, a Delayed Burst Assignment (DBA) scheme is introduced, by which bursts of the high priority class are given a higher probability for reserving wavelengths by scheduling the bursts of the low priority class with a delay to provide quality of service (QoS) in OBS networks. The integration of these two schemes provides proportional differentiated services and improves the burst loss performance by giving the burst head packet (BHP) two opportunities of scheduling its data burst (DB).



## 1. Introduction

With the explosive growth of the Internet and the rapid evolution of Dense Wavelength Division Multiplexing (DWDM), optical fiber seems to be the perfect carrier for future high-speed IP networks. IP-over-DWDM has been considered as a solution for the next-generation networks because it can make the best use of the potential huge bandwidth of optical fiber. To realize an IP-over-DWDM architecture, several approaches, such as Wavelength Routing (WR) [1,2], Optical Packet Switching (OPS) [3,4] and Optical Burst Switching (OBS) [5,6], have been proposed. Of these approaches, Optical Burst Switching (OBS) can achieve a good balance between the coarse-grained Wavelength Routing and fine-grained Optical Packet Switching, thereby combining the others' benefits while avoiding their shortcomings.

In an OBS network (shown in Fig. 1), to eliminate Optical-Electrical-Optical (OEO) conversions and electrical processing loads, which are the bottlenecks of this system, an ingress edge node assembles multiple IP packets with the same egress address into a switching granularity called a burst. A burst consists of a Burst Header Packet (BHP) and a Data Burst (DB). The BHP is delivered on a control channel; its corresponding DB is delivered on a data channel without waiting for a confirmation of a successful reservation. A channel may consist of one wavelength or a portion of a wavelength, in case of time-division or code-division multiplexing [6]. In this paper, the word wavelength is used to mean the same as channel. When the BHP arrives at a core node, the core node converts it into an electronic signal, performs routing, and configures the optical switching fabric based on the information carried by the BHP. The DB remains in the optical domain without OEO conversion when it cuts through the core node.

Several wavelength-reservation schemes for OBS, such as Just-In-Time (JIT) [7], Tell-And-Go (TAG) [8] and Just-Enough-Time (JET) [9] have been proposed. In this paper, we use JET as our wavelength-reservation scheme and assume there are full-wavelength conversions. In a JET scheme, the ingress node waits for a long offset time before

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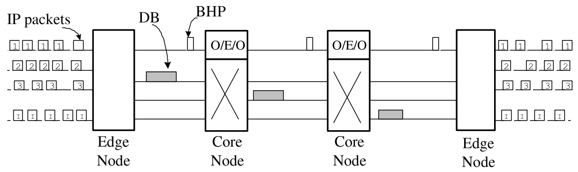


**Fig. 1.** OBS network model.

it starts to transmit the data burst. The offset time is set to be larger than the total processing time of the BHP along its path. Fiber delay lines are thus unnecessary at the core nodes. As we assume there is no buffer in OBS networks, a burst loss event will occur if multiple bursts from different input ports are destined for the same output port at the same time. Burst loss performance is the major concern of OBS networks. In this paper we will only study the burst loss events at the core nodes.

Realizing some kind of service differentiation is listed as one of the important issues for OBS networks. The differentiated services enable Internet users to provide a diverse quality of service (QoS). Higher network usability can be expected as the result of realizing this differentiation. Some methods for realizing differentiated services have been proposed [9–11]. These methods can be divided broadly into two categories, one is a non-proportional method and another is a proportional method. In the non-proportional differentiated services model using an extra-offset-time-based [9] QoS scheme, different offset times are assigned to different priority classes without any buffer in the WDM layer. By providing a larger offset time, a higher priority burst is more likely to have wavelength reserved for it because of its early reservation. However, the difference of the burst loss ratios of each class is unstable because it depends on the traffic load. Although we can change the extra offset times' difference to modify the difference of burst loss ratios, a quantitative solution cannot be found in the approach. We call the proportional differentiated model in an OBS network if the burst loss ratio of one service class is proportional to those of other classes regardless of the traffic load. Hence, in the proportional differentiated model, the burst loss ratio of one class is "predictable" if we know that of another class and is also "controllable" because the network provider can adjust the class differentiation parameters to adjust the burst loss ratios of each class [12]. It can be expected that introducing a proportional differentiated model into an OBS network would be favorable to both network operators and users. Yang et al. [10] introduced an intentional dropping scheme to maintain the proportion of the loss ratios for each class based on a set of predefined parameters. At core nodes, arriving bursts of the lower priority class are dropped when the burst loss ratio of the higher priority class is too high for the proportional differentiated model even when there are idle wavelengths to assign for the lower priority bursts. When the lower priority bursts are dropped, the arrival time of the coming higher priority bursts is unknown. This points to a shortcoming of the intentional dropping scheme: the wavelengths "saved" by the dropping of the lower priority bursts will be wasted if no burst of the higher priority class arrives during these "saved" periods. This results in bad wavelength utilization and high blocking probability.

Some other schemes adopt burst-segmentation[13] or wavelength-preemption[11] techniques to achieve QoS support. In [14,15], Jumpot et al., proposed a bandwidth allocation with wavelength pre-emption (BA-WP) scheme to provide proportional differentiated service. In the BA-WP scheme, when there are no wavelength available for a higher priority burst, the higher priority burst can pre-empt the wavelength that has been assigned to a lower priority burst and generate a control packet at the core node to inform the up-stream and down-stream nodes this change of wavelength reservation.

In this study, we focus on the issue of providing proportional differentiated services with good burst loss performance and simple implementation. First, we introduce a scheme called *Dynamic Wavelength Selection* (DWS) to provide proportional differentiated services in bufferless OBS networks by dynamically assigning more and longer periods of wavelengths to higher priority classes. Compared with general wavelength-continuity-based scheme [16,17], the DWS scheme cannot only adjust the wavelength numbers dynamically when the traffic load changes, but can also utilize the wavelengths more efficiently because the wavelengths are shared among different classes. We also propose another differentiation scheme, named *Delayed Burst Assignment* (DBA) scheme, in which bursts of the low priority class are processed after a delay to ensure that bursts of the higher priority class have a higher probability of wavelength reservation. In DBA, BHPs are buffered electrically so that fiber delay lines are unnecessary at core nodes. In the combination of these two schemes, a BHP of a lower priority class is buffered at the core router when it cannot find an available wavelength. It has an opportunity to reschedule its burst to the wavelengths that have been assigned to higher priority classes but have not yet been reserved. The integrated scheme not only provides proportional differentiated services but also achieves lower dropping probability without any pre-emption or segmentation mechanisms. Compared with existing approaches, the combined scheme does not need to generate any special packets and needs to maintain only a few parameters at core nodes.

The remainder of this paper is organized as follows. Sections 2 and 3 introduce our proposed dynamic wavelength selection and delayed burst assignment schemes. Section 4 discusses the integrated scheme of these two schemes, and Section 5 describes the results of simulations we conducted to examine the performance of our proposed schemes.

## 2. Dynamic wavelength selection scheme

Regarding the QoS frameworks suggested by IETF, two broad approaches have been proposed [18]: Integrated Services (IntServ) and Differentiated Services (DiffServ) [19]. IntServ achieves QoS guarantees through end-to-end resource reservation for packet flows at all intermediate nodes. The resource reservation cannot be achieved unless each node is able to participate. The DiffServ model is more