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A Multiclass Admission Control Mechanism for Optical Burst-Switched Networks*

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Abstract. The emerging multimedia applications require multiservice networks to guarantee quality of service (QoS). In this paper, we introduce an admission control mechanism for providing differentiated services in optical burst-switched networks (OBS). The proposed mechanism admits bursts of a given service class based on network load and a class-associated parameter. This parameter, referred as *load level*, differentiates the blocking probability experienced by bursts of each service class. For the proposed mechanism we develop an analytical model. Several scenarios are analyzed by varying the offered load and the number of service classes. In comparison with other similar mechanisms, the proposed mechanism properly differentiates the services in all analyzed scenarios and always provides a lower blocking probability for the high-priority class bursts.

Keywords: Optical burst switching, quality of service, admission control.

1 INTRODUCTION

The new multimedia applications, such as high-definition television (HDTV) and videoconference, demand a large amount of bandwidth. In order to satisfy these applications, wavelength-division multiplexing (WDM) networks are developed. In addition to the bandwidth requirement, the multimedia applications are sensitive to quality of service (QoS) parameters, such as data loss and end-to-end delay. Therefore, it is necessary to develop multiservice networks for guaranteeing the required QoS of these emerging applications [1].

Optical burst switching (OBS) [2, 3] is a promising all-optical data transport technique to efficiently use the bandwidth offered by wavelength-division multiplexing (WDM) technology. Different from optical circuit switching, in OBS the network resources are only held for the burst switching and transmission time. In OBS networks, packets with the same destination address are first aggregated in bursts by the edge nodes of the network. Before the burst transmission, the aggregating edge node sends a control packet to establish an all-optical path in an out-of-band signaling channel. When the control packet

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arrives at an OBS switch that is in the source-destination path, it is converted and processed electronically. If possible, the OBS switch reserves the required resources for the burst. Otherwise, if there are no resources available, the burst is blocked. Most of the signaling protocols used in OBS networks do not require error messages or reservation acknowledgments from OBS switches. The network resources are only held for the burst switching and transmission time. This is one of the main aspects that differs OBS from optical circuit switching. Optical burst switching also differs from optical packet switching since buffers are not needed to store and process bursts. Optical buffers are expensive and somewhat complex so not using them is an advantage.

An important issue in optical burst-switched networks is how to guarantee quality of service (QoS). Despite the bandwidth availability, only a few tens of wavelengths are available per optical link nowadays. Since a burst occupies one wavelength, or a fraction of this, during the transmission some bursts will be blocked depending on the load offered to the network. In addition, the existing QoS mechanisms are proposed for packet switching networks and, at most, are based on management of electronic buffers [4]. To use these mechanisms in optical burst-switched networks, it is necessary to convert the optical signal to the electronic domain at each intermediate node, which limits the data transport rate. Furthermore, optical random access memories (RAMs) are not yet available. Bursts can be only delayed using fiber delay lines (FDLs) nowadays [5]. Thus, it is necessary to develop specific QoS mechanisms for optical burst-switched networks.

In this paper, we propose a multiclass admission control mechanism for providing differentiated services in OBS networks. The proposed mechanism admits bursts of a given service class according to network load and a class-associated parameter. According to this parameter, referred as load level, it is possible to differentiate the burst blocking probability experienced by each service class. Based on the Erlang loss model, we also develop an analytical model for the proposed mechanism. We analytically evaluate the performance of the proposed mechanism according to the blocking probability experienced by service classes. Different scenarios are tested by varying the offered load and number of service classes. The results show that the proposed mechanism always provides a lower blocking probability for the high-priority class bursts in comparison with the other similar admission control mechanisms. Even when increasing the offered load or the number of classes, the proposed mechanism is the only one that effectively differentiates the services.

The remainder of this paper is organized as follows. Section 2 presents related work concerning quality of service in OBS networks. Section 3 introduces the proposed admission control mechanism. The analytical model for the proposed mechanism is developed in Section 4. Section 5 analyzes the performance of the proposed mechanism in comparison with other similar mechanisms, based on their analytical models. Finally, Section 6 concludes this paper.

2 RELATED WORK

Quality of service support is a challenge in OBS networks. Several mechanisms [5–8] have been proposed to address this challenging issue.

Yoo *et al.* [5] propose a modified version of the JET (Just-Enough Time) signaling protocol [2]. A different offset time is associated to each service class. The offset is the time interval between the control packet transmission and the burst transmission. The basic

3 THE PROPOSED MECHANISM

In this section, we introduce the proposed admission control mechanism. We assume that the network employs JET signaling protocol [2]. In addition, we consider that each OBS node supports full wavelength conversion and a burst requires only one wavelength during its transmission.

The use of JET implies that all network nodes must implement the proposed mechanism. In JET, a burst is sent after an offset time without waiting for an acknowledgment. Therefore, when a burst is sent, an edge node can not guarantee that the number of occupied wavelengths in each link of source-destination path is in accordance with the admission criterion. Just after receiving and analyzing the control packet, a node can determine if the number of occupied wavelengths is in accordance with the admission criterion at the instant of the burst arrival. Thus, to guarantee the service differentiation, the proposed mechanism should not be implemented only by the network edge nodes. The proposed mechanism defines a parameter for each service class i, named load level, l_i. The load level must be configured at each node of the network and indicates the maximum number of wavelengths that bursts of a given class i may occupy. If we define W as the number of wavelengths in a given link, the inequality $0 < W_i \leq W$ always holds for every class i.

The proposed mechanism uses the load level to differentiate the burst blocking probability experienced by each service class. A burst belonging to a class i, which arrives at a node at time t_0, is admitted if at t_0 the number of occupied wavelengths is less than the load level W_i. Otherwise, the burst is blocked without sending any error message back to the edge node. Therefore, the higher the load level of class i is, the lower the burst blocking probability of class i is. It is worth noting that the admission criterion of the proposed mechanism is based on the total number of occupied wavelengths, and not on the number of occupied wavelengths for bursts of class i. Therefore, in the proposed mechanism a node stores fewer states than in other mechanisms, such as the static or dynamic. The proposed mechanism only stores the load level of each service class and the total number of occupied wavelengths.

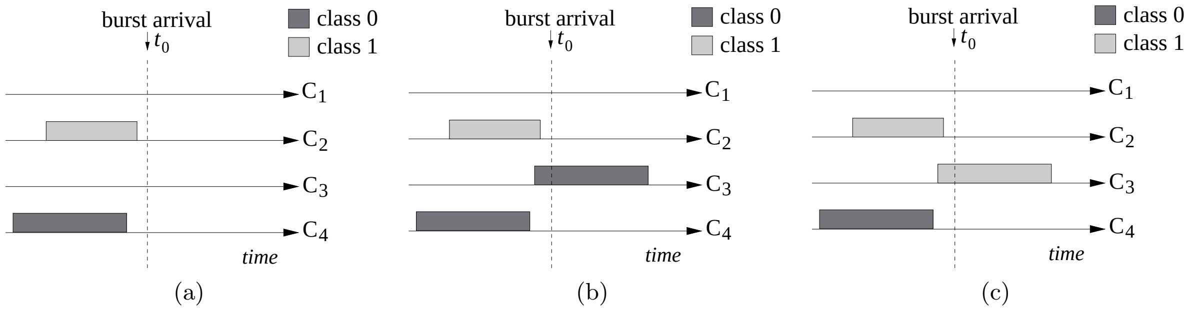


Figure 2: Examples of how the proposed mechanism works.

Figure 2 shows three examples of how the proposed mechanism works for two service classes in one link with four wavelengths ($W = 4$). The high-priority class is class 0. Respectively, the load level of classes 0 and 1 are $l_0 = 4$ and $l_1 = 1$. In the situation illustrated by the Figure 2(a), when a burst belonging to any class arrives at time t_0 it is admitted, once no wavelength is occupied. In Figures 2(b) and 2(c) bursts belonging

From Equations 3 and 4, it is possible to determine the blocking probability of a service class i. The blocking probability of a burst of class i is given by the probability that the chain is in a state $\omega \geq l_i$, where l_i is the load level of class i. Therefore,

$$B_i(\rho_i, l_i, W) = \sum_{\omega=l_i}^{W} \pi_\omega = \sum_{\omega=l_i}^{W} \frac{\dfrac{1}{\omega!\mu^\omega} \displaystyle\prod_{k=0}^{\omega-1} \Lambda(k)}{1 + \displaystyle\sum_{j=1}^{W} \frac{1}{j!\mu^j} \prod_{k=0}^{j-1} \Lambda(k)}, \tag{5}$$

where the offered load to the network by bursts of class i is given by $\rho_i = \lambda_i/(\mu * W)$.

From Equation 5 it is also possible to calculate the effective load in a given link. Then,

$$T = \sum_{i=0}^{n-1} T_i = \sum_{i=0}^{n-1} \rho_i.(1 - B_i(\rho_i, l_i, W)). \tag{6}$$

5 RESULTS

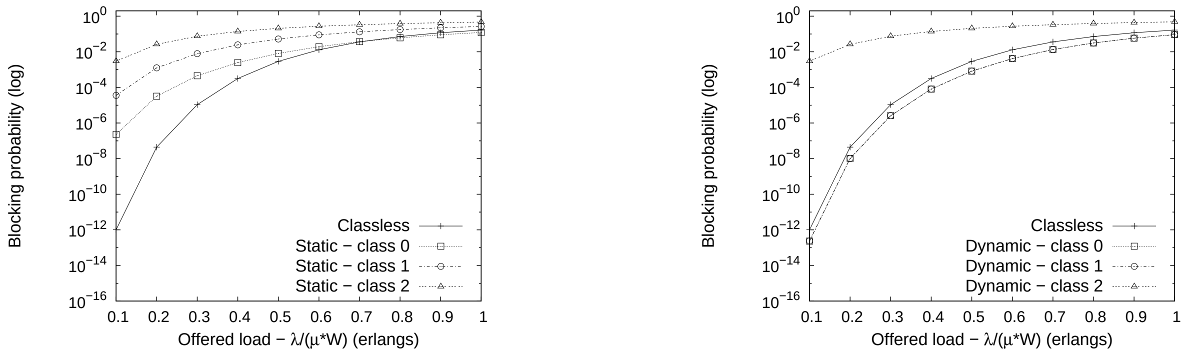
In this section, we present the results from the performance analysis of the three admission control mechanisms. The analytical model of the proposed mechanism is validated through simulation [9] using the Tangram-II tool [10]. We also used this tool to compare the proposed mechanism with the static and dynamic mechanisms. For the static and dynamic mechanisms, we consider the analytical models proposed and validated by Zhang et al. [8]. The analysis considers a scenario with a single node, which admits, or not, the offered bursts to a single link. In this scenario, the link capacity in wavelengths is $W = 18$. The performance of the mechanisms is evaluated for two and three service classes, according to the offered load to the network. In both situations, class 0 is the high-priority class. The capacity of each wavelength is 1.0 Gb/s and the mean burst size is 128 kB for all service classes. In all analyzed scenarios, we consider that all service classes generate an equal amount of traffic ($\rho_0 = \rho_1 = \rho_2 = \ldots = \rho_{n-1} = \rho/n$). The effectiveness of the proposed mechanism is also verified for a larger number of service classes.

5.1 Performance for Two Service Classes

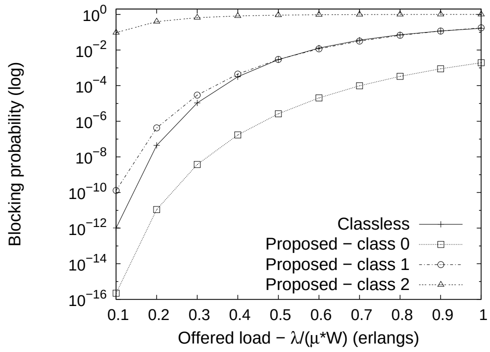
In this section, we consider two service classes, class 0 and class 1. The high-priority class is class 0. For a coherent comparison, we assume, for the three mechanisms, the same value for the maximum number of wavelengths that bursts of class 1 may occupy. We analyze two different scenarios varying this value. In the more aggressive scenario, bursts belonging to class 1 can occupy until 33% of the wavelengths in a given link. Thus, for the static mechanism $W_0 = 12$ and $W_1 = 6$, for the dynamic mechanism $W_0 = 18$ and $W_1 = 6$, and for the proposed mechanism $l_0 = 18$ and $l_1 = 6$. In the less aggressive scenario, bursts of class 1 can occupy until 50% of the wavelengths. Therefore, for the static mechanism $W_0 = W_1 = 9$, for the dynamic mechanism $W_0 = 18$ and $W_1 = 9$, and for the proposed mechanism $l_0 = 18$ and $l_1 = 9$.

Figure 4 shows the blocking probability and the effective load for the three admission control mechanisms and for the network without QoS support, referred as classless network. The effective load is the percentage of the offered load to the networks which is admitted by the mechanisms. In these two analyzed scenarios, the proposed mechanism provides a lower blocking probability for class 0 bursts, as the offered load to the network

experienced by every service class and also provides a lower blocking probability to the class 0.

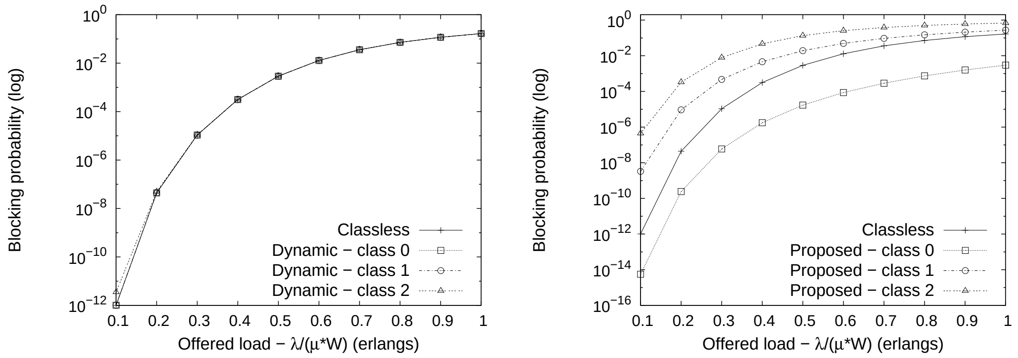


(a) Static mechanism. (b) Dynamic mechanism.



(c) Proposed mechanism.

Figure 5: Performance for three classes: more aggressive scenario - $W_2 = 4$ / $l_2 = 4$.



(a) Dynamic mechanism. (b) Proposed mechanism.

Figure 6: Performance for three classes: less aggressive scenario - $W_2 = 12$ / $l_2 = 12$.

In the less aggressive scenario, we assume that class 2 can occupy up to approximately 67% of the wavelengths. Thus, for the dynamic mechanism $W_0 = 18, W_1 = 14$, and $W_2 = 12$, and for the proposed mechanism $l_0 = 18, l_1 = 14$, and $l_2 = 12$. In this situation, we do not analyze the static mechanism once the number of reserved wavelengths for the low-priority class would be greater than the one reserved for the high-priority class. Figures 6(a) and 6(b) ratify the results previously discussed. The dynamic mechanism provides almost the same blocking probability for the three service classes. Then, we conclude that the dynamic mechanism is very dependent of the class-associated parameter W_i and the amount of traffic generated by each service class. On the other hand, the

differentiates the blocking probability of each class, but the blocking probability provided for the high-priority class is always higher than one provided by the network without QoS support.

The service differentiation provided by the dynamic mechanism is degraded as the gap between the parameter W_i of each class becomes smaller. In other words, the lower the aggressiveness to the low-priority class and the higher the number of service classes, the more susceptible is the dynamic mechanism to the increase of the offered load and to the amount of high-priority traffic. When we consider three service classes and the gap between W_2 and W_0 is 30% of the capacity of the link, the blocking probability of all classes is almost the same.

The proposed mechanism effectively differentiates the services even if the offered load and the number of classes increase. In comparison with the other two mechanisms, the proposed mechanism provides a lower blocking probability for the high-priority class bursts in all analyzed scenarios. The better differentiation is paid by the starvation of the low priority-class in some situations. Furthermore, the proposed mechanism requires fewer states than the other two mechanisms, which turns the optical switching task simpler and more efficient.

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