Differentiated Services in Optical Burst-Switched Networks

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Optical burst switching (OBS) [1] is a promising all-optical data transport technique to efficiently use the bandwidth offered by wavelength-division multiplexing (WDM) technology. An important issue in OBS networks is how to support quality of service (QoS). Despite the bandwidth availability, a link has at most few tens of wavelengths nowadays. Once, a burst occupies one wavelength, or a fraction of this, during the transmission some bursts will be blocked depending on the offered load 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 [2]. To use these mechanisms in OBS 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 [3]. Thus, it is necessary to develop specific QoS mechanisms for OBS networks.

Several mechanisms have been proposed for providing service differentiation in OBS networks [3], [4]. Zhang *et al.* [4] propose two admission control mechanisms: a static and a dynamic mechanism. Both are based on the number of wavelengths occupied by each service class. In the static mechanism, a fixed set of wavelengths W_i in a given link is reserved for bursts of a given service class i. In the dynamic mechanism, a fixed number of wavelengths W_i, not a fixed set, is reserved for bursts of a given service class i. In this two mechanisms, every node must keep track of the number of wavelengths occupied by bursts of each service class to guarantee that the number of wavelengths occupied by bursts of a given class i does not exceed W_i. As consequence, each node must store a great number of states.

We propose an admission control mechanism for providing QoS in OBS networks. The proposed mechanism admits bursts of a given service class according to network load and a class-associated parameter. Based on this parameter, referred as *load level*, it is possible to differentiate the burst blocking probability experienced by each service class. We also develop an analytical model for the proposed mechanism. The performance of the three mechanisms - static, dynamic and the proposed mechanism - is analytically evaluated according to the blocking probability experienced by service classes. Different scenarios are tested by varying the offered load and the traffic amount of each service class. The results show that the proposed mechanism properly differentiates the services in all analyzed scenarios and always provides a lower blocking probability for the high-priority class in comparison with the other two admission control mechanisms.

I. THE PROPOSED MECHANISM

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. According to the load level, the proposed mechanism differentiates the blocking probability experienced by each service class. A burst of 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 l_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 is the blocking probability of class i. 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. Thus, in the proposed mechanism a node stores fewer states than in other mechanisms such as the static or dynamic mechanisms. The proposed mechanism only stores the load level of each service class and the total number of occupied wavelengths.

The analytical model developed for the proposed mechanism is based on the Erlang loss model [3]. A link is modeled as a *M/M/W/W* queue, where W is the link capacity in wavelengths. Each link can be represented as a continuous-time Markov chain, in which each state ω represents the number of occupied wavelengths ($\omega = 0, 1, 2, \ldots, W$). We assume that the burst link arrival is a Poisson process with rate λ, the burst size is exponentially distributed with mean $1/\mu$ for all service classes, and a burst requires the reservation of only one wavelength. The transition rates are given by $q_{\omega,\omega+1} = \Lambda(\omega)$ and $q_{\omega,\omega-1} = \omega\mu$. The total burst arrival rate, $\Lambda(\omega)$, depends on the proposed mechanism admission criterion. If the load level of class i satisfies the admission criterion, $\Lambda(\omega)$ is given by the burst arrival rate of a class i, λ_i. Otherwise, $\Lambda(\omega)$ is equal to zero. Therefore, the blocking probability of a burst of class i is given by the probability that the chain is in a state $\omega \geq l_i$. Then,

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

II. PRELIMINARY RESULTS

The analytical model of the proposed mechanism is validated through simulation using the Tangram-II tool [5]. This tool is also used 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.* [4]. 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 $W = 8$. The bandwidth of each wavelength is 1.0 Gb/s and the mean burst size is 128 kB for all service classes. The performance of the three mechanisms is evaluated for two service classes, class 0 and class 1, according to the offered load to the network and the amount of traffic of each service class. Class 0 is the high-priority class. For a coherent comparison, it is considered, for the three mechanisms, the same value for the maximum number of wavelengths that bursts of class 1 may occupy. This value is equal to 25% of the wavelengths in a given link.

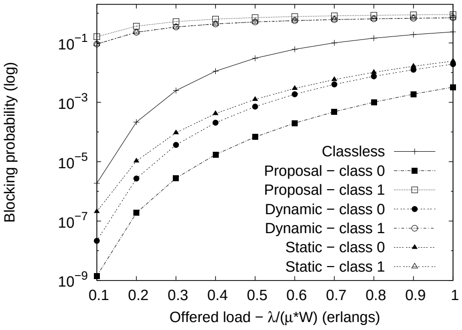

Fig. 1. Impact of the offered load.

To evaluate the impact of the offered load in the blocking probability experienced by service classes, the amount of traffic of each class is fixed. In this scenario, 30% of bursts belong to the high-priority class, class 0. Moreover, bursts of class 1 may occupy, at most, two wavelengths. Fig. 1 shows the burst blocking probability for the three mechanisms and for the network without QoS support, referred as classless network. The proposed mechanism provides a lower blocking probability for class 0 bursts, as the offered load to the network increases. It is a consequence of the admission criterion used by the proposed mechanism that takes into account the total number of occupied wavelengths instead of the number of wavelengths occupied by each class. Therefore, a small number of class 1 bursts is admitted. In other words, the probability that a burst belonging to class 0 arrives to a node at time t and finds a wavelength occupied by a burst of class 1 is reduced. For an offered load of 1.0 erlang, the blocking probability of class 0 provided by the proposed mechanism is six times less than the one provided by the static or dynamic mechanisms. For the same offered load, the blocking probability of class 1 provided by the proposed mechanism is only 23% greater than the one provided by the static or dynamic mechanisms. The better differentiation obtained by the proposed mechanism is because it is more aggressive with the low-priority class traffic.

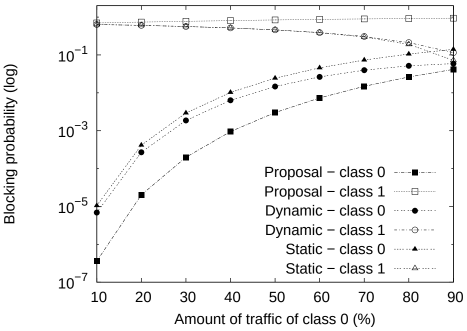

Fig. 2. Impact of the amount of traffic of each service class.

The amount of traffic of each service class also impacts in the performance of the mechanisms. To analyze this impact in the blocking probability, the offered load is fixed at 0.6 erlangs. In addition, bursts of class 1 may occupy at most two wavelengths. Fig. 2 shows that the proposed mechanism provides a lower blocking probability for class 0 bursts, as the high-priority traffic increases. Furthermore, the proposed mechanism is the only one that effectively remains differentiating the services. When the class 0 traffic is greater than 85% the blocking probability provided by the static mechanism for the high-priority class becomes greater than the one provided for the low-priority class. Therefore, the differentiation function provided by the static mechanism is highly dependent of the high-priority class traffic. For the dynamic mechanism, as the high-priority traffic increases, the blocking probabilities of both classes tends to 10^{-1}. Beyond this point the differentiation function is no more effective and the dynamic mechanism works like a classless network.

The preliminary results show that the proposed mechanism effectively differentiates the services providing the lowest blocking probability for the high-priority class. The next step of this work will be the analysis of the performance of the proposed mechanism in a multi-node topology and the proposition of a mechanism to support absolute QoS.

ACKNOWLEDGMENT

This work has been supported by CNPq, CAPES, FAPERJ, FINEP, RNP and FUNTTEL.

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