

A Preemptive Scheduling Technique for OBS Networks with Service Differentiation

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Abstract—Existing burst scheduling techniques could be improved in terms of bandwidth utilization and QoS support. In this paper, we introduced a new partially preemptive scheduling technique with QoS support. The technique is capable of handling data bursts in parts and may use preemption due to the priorities of data bursts in a multi-service OBS network environment. Simulation studies suggest that more than 50% reduction in dropping probability and approximately 40% improvement in channel utilization is reachable at 0.8 load. The studies also reveal that the new scheduling technique has the ability to predict and control service performance differentiation among defined service classes.

Keywords— Burst scheduling; optical burst switching; multi-service networks; proportional service model.

I. INTRODUCTION

OPTICAL BURST SWITCHING (OBS) has been proposed as a new switching technology that combines the advantages of both optical packet switching and wavelength routing [1]. OBS has temporal and spatial separation between data (in a form of data burst) and control (including header information and routing information). In the context of spatial separation, data burst (DB) and its control information, Burst Header Packet (BHP), travel on different channels [2]. For temporal separation, control information needs to be converted to electronics and processed some time before its corresponding data burst arriving at a core node where it is all-optically switched. This could be realized by introducing a time gap, so called *offset* time, between the data burst and its control information and/or by employing fiber delay lines at the ingress ports of the optical matrix in order to increase a time budget for control information to be processed. As such, scheduling in OBS has to accommodate the coordination of data burst and its control information entity (a smaller packet); therefore, it is a challenging task.

Most of the existing scheduling techniques try to schedule a data burst in its entirety (i.e. binary decision scheduling); if there is even a small overlap (contention), the burst is dropped, causing inefficient utilization. There is also no allowance for preemption of the

capacity occupied by the already scheduled burst(s) in order to make room for the new burst (e.g., with higher priority) to be scheduled. This feature is valuable in QoS provisioning, which is another important issue for the scheduling task in OBS networks. In existing proposals for QoS support in OBS, offset-time [3], segmentation with deflection [4], and intentional dropping [5] are used. In this study, we combine partial preemption with proportional differentiation in order to achieve performance improvement in terms of loss and utilization while providing QoS with controllable service differentiation.

II. PARTIALLY PREEMPTIVE BURST SCHEDULING WITH PROPORTIONAL DIFFERENTIATION

In conventional OBS scheduling, a new incoming DB that overlaps with another already scheduled one is dropped in its entirety even if the overlap is very small. The main objective of partially preemptive burst scheduling is to increase efficiency in bandwidth utilization and decrease packet loss by allowing such overlapping bursts to be scheduled. The partial scheduling separates an overlapping DB into two parts: an overlapping part and a non-overlapping part. There are two options when a contention occurs between a new burst to be scheduled and (an) already scheduled burst(s). As depicted in Fig.1, we may either drop the overlapping part of the new burst (referred to as an overlapping burst) and schedule the remaining part, or preempt the capacity occupied by the overlapped part of the already scheduled burst(s) (referred to as an overlapped burst(s)) and schedule the overlapping burst in its entirety. Such a decision may be taken according to priorities of bursts according to a service differentiation model. In this study, we propose to use a service differentiation model based on proportional resource allocation [6][7][8] and combine it to the proposed partially preemptive burst scheduler. In the service differentiation model, DBs of each class receive service in proportion to their differentiation parameter. Let p_i be a differentiation parameter and c_i be the performance standing of class i , the proportional

differentiation model dictates the following relationship for all pairs of service classes.

$$\frac{p_i}{p_j} = \frac{c_i}{c_j}, \text{ where } (i, j = 0..N \text{ and } N \text{ is the num. of classes}) \quad (1)$$

The proportional differentiation model holds for long time scales. Also the proportional differentiation model is defined over a short monitoring time scale, with period of τ .

$$\frac{\bar{c}_i(t, t+\tau)}{\bar{c}_j(t, t+\tau)} = \frac{p_i}{p_j}, \text{ where } \bar{c}_i(t, t+\tau) \text{ is the average} \quad (2)$$

performance measured over period τ for class i .

Two important features of this model are predictability and controllability. Predictability brings differentiation consistency among classes which means that higher classes are always better or at least no worse than lower classes, regardless of variations in class loads. With controllability feature, network operators can adjust the quality differentiation between classes through selected criteria (e.g. pricing, policy objectives, etc) [8].

According to the model, selected performance measures are distanced from each other in proportion to class differentiation parameters, which are determined by network operators. In this paper, we apply the proportional model to data burst loss and channel usage differentiation and report the improvements in loss probability and utilization with numerical results, as well as the ability to differentiate services among classes.

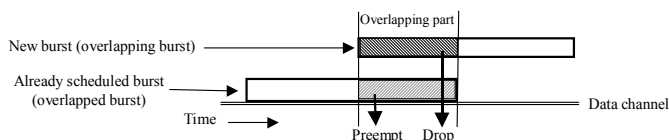


Figure 1 Partially preemptive scheduling

A. Proportional data burst loss

Data burst loss is an important performance criteria in optical burst switching networks as well as delay, utilization, etc. It is particularly important for Internet traffic and all TCP-based applications, which may mostly exist in OBS networks. There are several previously studied techniques to control packet loss which use different buffer management and packet dropping schemes including complete buffer partitioning, partial buffer sharing, multi-class Random Early Detection, etc[9]. The main reason we cannot use most of these techniques in OBS environment is that OBS core nodes do not have enough buffer resources to apply such mechanisms. Instead, for OBS, we propose proportional loss rate differentiation accompanied with

partially preemptive scheduling. The proportional loss differentiation model suggests that burst drops in the OBS core node should be proportional to the corresponding differentiation parameters. By using these parameters, the network operator can control the relative performance spacing between classes based on some dropping policy according to the equation (1). In compliance with the generic proportional differentiation equation (1), we define c_i as the average loss for class i , and p_i as the loss rate differentiation parameter for class i where $p_0 < p_1 < \dots < p_n$ and p_n has the least priority.

B. Proportional data channel usage

We control proportional bandwidth usage among classes to attain service differentiation with partially preemptive scheduling. A usage profile is defined for each class in a proportional manner, like we had for the proportion loss approach. In a compliance with the generic proportional differentiation equation (1), let u_i be the average usage for class i , and q_i be the usage rate differentiation parameter for class i where $q_1 > q_2 > \dots > q_n > 0$ and q_1 belongs to the highest priority class.

C. Algorithms

The algorithm for the partially preemptive scheduling technique with proportional service differentiation is given in the flow-chart of Figure 2. A new DB represented by "n" in the flow-chart is first tried to be scheduled if there is any available channel. In case of channel unavailability depicted in section 1 of the flow-chart, the new DB's proportional service differentiation profile is checked whether to drop the new DB. If the profile agrees to drop, then the burst "b" on channel "x" having the smallest overlapping with the new DB is searched and the non-overlapping part of the new DB is partially scheduled on channel x (section 2). If the new DB cannot be dropped according to its profile, then the algorithm attempts to find a set of already scheduled DBs that are eligible for dropping according to their own current profiles (section 3). If there are any eligible bursts, the one that has the minimum overlapping with the new DB is chosen to be preempted either in part or full in order to schedule the new DB in its entirety (section 4). In case that there is no eligible burst for preemption, the new DB has to be partially dropped in exactly the same way, mentioned in section 2, with a disagreement of its profile which is recorded by a raised flag (section 5).

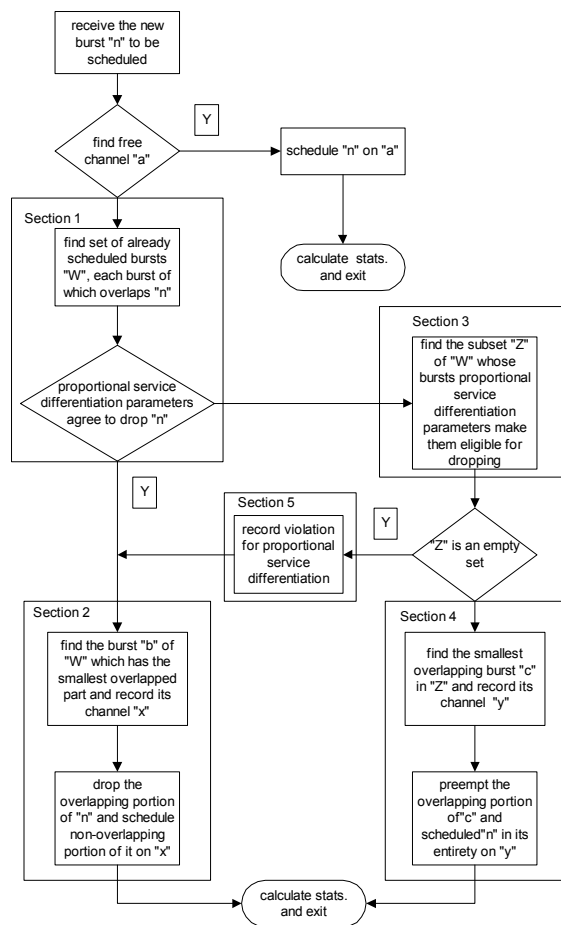


Figure 2 Flow-chart for partially preemptive scheduling technique with proportional service differentiation

III. SIMULATION RESULTS

In this section, we report simulation results of the proposed partially preemptive scheduling with proportional loss and proportional usage differentiation models. Comparison study is performed against the case when no partial preemption is applied with the same number of classes, as well as, with conventional classless void-filling scheduling [10]. The simulations are conducted for an OBS core node's output WDM link with multiple channels. We assume no buffering but full wavelength conversion capability. Four classes C0, C1, C2, C3, are defined. C0 has the highest priority and C3 has the lowest and it is assumed that all four classes have the same arrival rate. The proportion parameters (p_i) of four classes are set as follows: Class0=1.0, Class1=2.0, Class2=3.0, Class3=4.0. For simulations, we used ON_OFF source model to generate bursts. The channel rate is assumed to be 10Gbits/sec and mean burst length be 20Kbytes. If not stated otherwise, we use 4 channels in the experiments.

We first study the comparative performance results of our partially preemptive scheduling technique versus the other techniques at various load conditions. Fig.3 depicts such comparisons when the proportional loss model is employed.

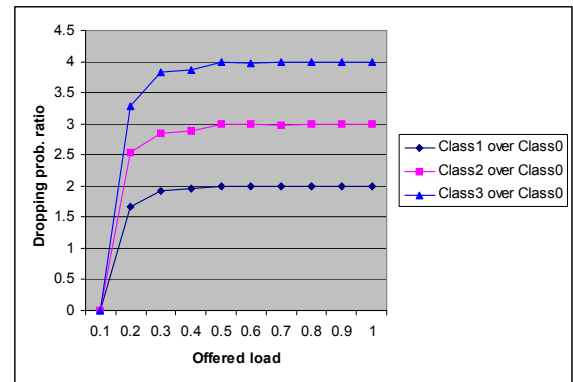


Figure 3(a) Results for proportional loss model : dropping probability ratio vs. offered load

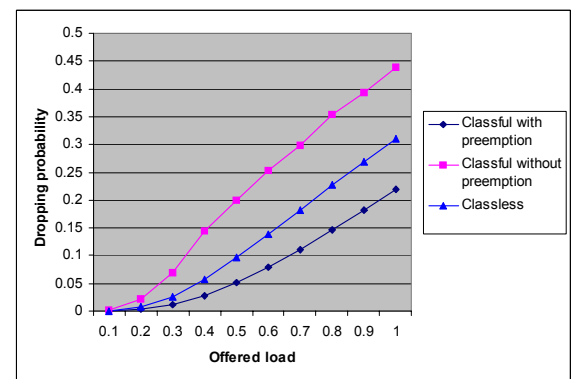


Figure 3(b) Results for proportional loss model : dropping probability vs. offered load

Fig.3(a) indicates that the proportions of (4:3:2) are approximately settled at 0.3 offered load. The reason is that the control mechanism needs some load to start being effective. In Fig.3(b), the proposed proportional loss model with partial preemption (depicted as "Classful with preemption") has the least total dropping probability values among others at all load levels. Proportional loss model without partial preemption (depicted as "Classful without preemption") has 55% more dropping probability at offered load of 0.8 than regular void-filling without partial preemption (depicted as "Classless"). This increase in dropping probability is due to early/intentional dropping strategy that is used to accomplish proportional differentiation. The proposed model reduces the dropping probability more than half the value of the case without partial preemption at offered load of 0.8 in Fig.3(b) while satisfying the proportional differentiation, as shown in Fig.3(a). In

Fig.3(c), the proposed scheduling can also reveal the highest utilization under all load levels. This is basically attributed to the way the scheduler picks the smallest available overlap in consideration for partial scheduling. It is almost linear with increasing offered load while the others tend to saturate. On the other hand, the proportional loss without partial preemption utilizes the link less effectively than classless void-filling because of mentioned early/intentional dropping strategy. Therefore, the proposed partially preemptive scheduling technique is able to improve considerably both utilization and dropping probability while still providing proportional service differentiation.

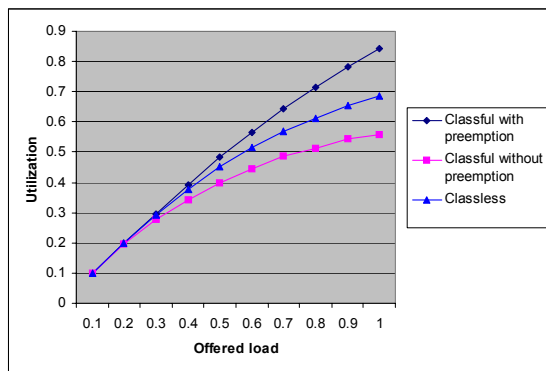


Figure 3(c) Results for proportional loss model : utilization vs. offered load

Next, the performance comparison with varying number of wavelengths is studied. The results are given in Fig.4. Fig.4(a) reveals that the proposed algorithm has the lowest dropping probability in all cases and the ratio between them indicated by the east axis in the figure is increasing. This means that increasing number of wavelength, which seems to be the direction for the future of the technology, strengthens the potential of the proposed scheduling method. Fig.4(b) depicts the effect of varying number of wavelengths to the utilization of the proposed model in comparison with others. They all have an increase in utilization as the number of wavelength increases. Even though the results look like they all are merging as we increase the number of wavelengths, the difference increases between the proposed method with partial preemption and the one without. The difference between the proposed model and classless void-filling reaches the maximum at 16 wavelengths with 6.7 Gbits/sec, beyond this point, as we increase the number of wavelengths, the difference diminishes; however, the proposed model still delivers the highest utilization while providing, at the same time, proportional service differentiation.

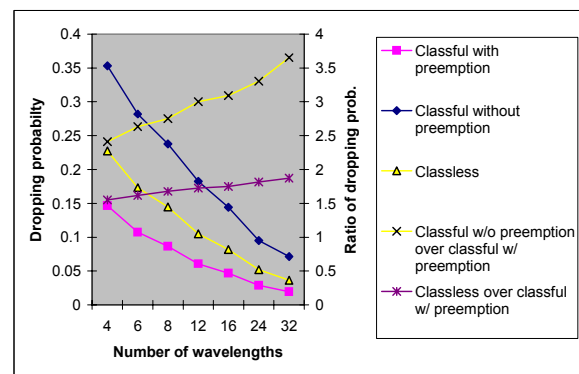


Figure 4(a) Results for proportional loss model : dropping probability vs. number of wavelengths

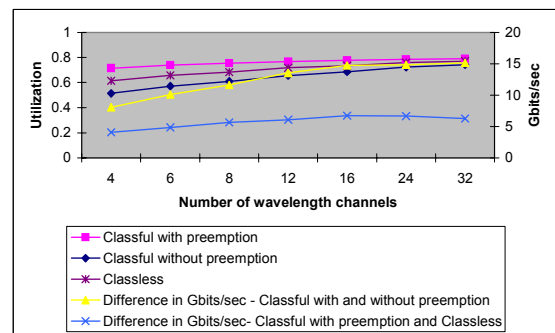


Figure 4(b) Results for proportional loss model : utilization vs. number of wavelengths

In the last set of experiments, we applied partially preemptive scheduling to proportional usage profile where each class is allowed to use a proportion of the bandwidth capacity. The objective of the experiment is to observe if there is any improvement both in dropping probability and utilization. Proportion factors used are as follows: Class0:4.0, Class1:3.0, Class2:2.0, and Class3:1.0. In the first experiment whose results are given in Fig.5(a), we study the effect of offered load to usage profile with partial preemption. Since we provided equal amount of traffic for all classes, we do not start seeing the proportions in usage until approximately 1.8 load. In this case, the partial preemption technique lets the out-of-profile lower class traffic use the available capacity through handling DBs in parts. However, the basic rule is strictly preserved; such that no class with lower usage factor exceeds one with higher usage factor, as can be seen in the same figure. When congestion appears above load 1.0, the control on profile takes over and we start seeing differentiation among classes in terms of proportional usage. Only after total load of 1.6, where each class has 0.4 load (this is equivalent to the load fraction of class0, $0.4=4/(1+2+3+4)$), the mechanism starts controlling the bandwidth usage resulting in the correct proportions. As we see in Fig.5(a), the approximate proportions are reached at the

offered load of 1.8 which is the next offered load level in the experiment just after 1.6. On the other hand, the scheduling without the partial preemption strictly observes the proportions at all load levels because it is not able to use the partial preemption for efficient use of the bandwidth (capacity). Therefore, method without partial preemption has relatively excessive dropping probability than the proposed model, as seen in Fig.5(b). In another experiment, we study the utilization improvement that the proposed model achieves with varying offered load. In Fig.5(c), the model has considerably higher utilization resulting from its efficient use of bandwidth through partial handling and preemption of DBs.

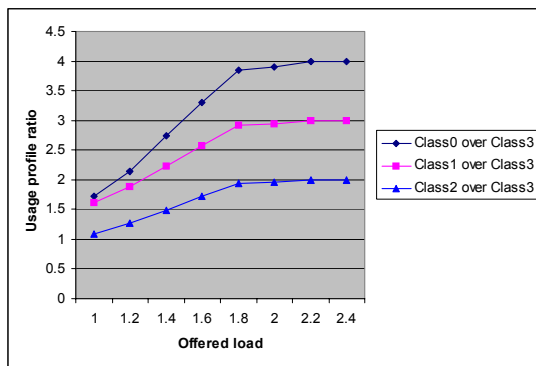


Figure 5(a) Results for proportional usage model : dropping probability ratio vs. offered load

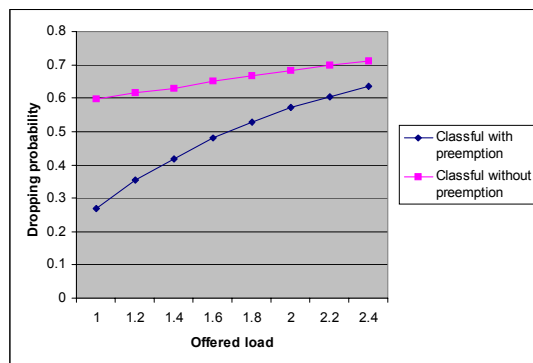


Figure 5(b) Results for proportional loss model : dropping probability vs. offered load

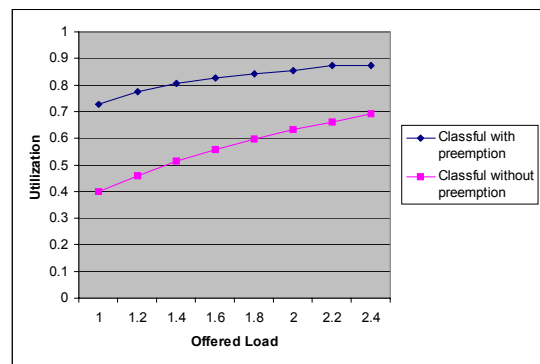


Figure 5(c) Results for proportional usage model : utilization vs. offered load

IV. CONCLUSION

In this study, we proposed a new scheduling technique, called partially preemptive scheduling, combined with proportional service model to provide QoS. Then, we evaluated the proposed scheduling technique and observed a significant improvement in dropping probability (~50% decrease at load 0.8 is possible) as well as in utilization (~40% increase at load 0.8 is also possible). The new technique also provides the ability to predict and control service performance differentiation among service classes. Hence, the results suggest that the technique is promising and may be well worth for further study. The next step would be to study the update and scheduling of burst header packets (control information for data burst) in coordination with the updated data burst.

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