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Using Differentiated Services to Improve Performance in High Speed Networks

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Abstract: *In this paper we address the issue how to provide QoS control and improve performance in OBS (Optical Burst Switching) networks. In order to provide proportional differentiated services without or with absolute constraints in bufferless OBS networks, a Delayed Burst Assignment (DBA) scheme improves the burst loss performance by giving the burst head packet (BHP) the opportunity of scheduling its data burst. The proposed schemes offer a response for a till now unsolved issue of traffic aggregation, thereby making OBS more practical and efficient.*

Keywords: Optical Burst Switching networks, QoS control, proportional differentiated services, traffic burstiness, burst loss performance.

1. INTRODUCTION

Nowadays, the scale of the Internet enlarges rapidly, and the demand for network bandwidth has been increasing remarkably. Dramatically increased amount of the World Wide Web users have brought more information servers online. Furthermore, the types of network services have been largely increased, and the proportion of multimedia technologies integrated by video and audio becomes larger. All these reasons have made the Internet traffic increase rapidly, and the demand for network bandwidth becomes more urgent than ever.

Since the early days of the Internet, researchers have proposed different ways to utilize network bandwidth. This is due to the high cost of bandwidth (bandwidth rental accounts for about 55% of the Internet Service Providers operating expenses). Having small amount of bandwidth in order to reduce the cost is not an option because on the Internet, there is a well-documented requirement that much more bandwidth be available than is used on average. This is due to the variability and the burstiness nature of the Internet traffic [1]. During normal network operation, 5% to 50% of the available bandwidth is only used. However, two to twenty times more extra bandwidth than is used in average needs to be sit idle to handle “network spikes”, those times when network traffic peaks, using much more bandwidth than what is used in normal circumstances [5]. Consequently, the *best-effort* service provided by the current Internet remains the most used service for those customers who only need connectivity.

Internet was designed for non-real time applications and hence does not provide Quality of Service (QoS) guarantees to applications. However the Internet Engineering Task Force (IETF) has proposed two notable models to meet the demand for QoS: Integrated Services (IntServ) and Differentiated Services (DiffServ). The IntServ model is characterized by resource reservation; before data is transmitted, applications must set up paths and reserve resources along the path. IntServ aims to support applications with different levels of QoS within the TCP/IP (Transport Control Protocol/Internet Protocol) architecture. IntServ however, requires the core routers to remember the state of a large number of connections giving rise to scalability issues in the core of the network. It is therefore *suitable at the edge network* where the number of connections is limited. The DiffServ model is currently being standardized to provide service guarantees to aggregate traffic instead of individual connections. The model does not require significant changes to the existing Internet infrastructure or protocol. DiffServ does not suffer from scalability issues, and hence is *suitable at the core of the network*. It is therefore believed that a significant part of the next generation Internet will consist of IntServ at the edge and DiffServ at the core of the network. As a result, architectures with IntServ at the edge and DiffServ at the core to provide QoS to end applications have been proposed at the IETF. Interconnection of IntServ and DiffServ, in order to exploit the individual advantages of IntServ (per flow QoS guarantee) and DiffServ (good scalability in the backbone), requires a mapping from IntServ traffic flows to DiffServ classes to be performed at the ingress to the DiffServ network.

With the explosive growth of the Internet and the rapid evolution of Dense Wavelength Division Multiplexing (DWDM) technique, optical fiber seems to be the perfect carrier for future high-speed networks. In a DWDM system, each fiber carries multiple communication channels, with each channel operating on a different wavelength [13]. Such an optical transmission system has a potential capacity to provide over 50Tbps bandwidth on a single fiber. Current networks typically consist of four layers: IP layer for carrying applications and services, ATM (asynchronous transfer mode) layer for traffic engineering, SONET/SDH layer for transport, and DWDM for capacity.

With IP traffic as the dominant traffic in the networks, the traditional layered network architecture is no longer adapted to the evolution of the Internet. In the multi-layered architecture, each layer may limit the scalability of the entire network, as well as adding the cost of the entire network. As the capabilities of both routers and OXCs (optical cross-connects) grow rapidly, the high data rates of optical transport suggest bypassing the SONET/SDH and ATM layers and moving their necessary functions to other layers. This results in a simpler, more cost-efficient network that can transport very large volumes of traffic. Such a solution is considered the use of IP over WDM because it can void the functionality redundancy of the ATM and SONET/SDH layers. The best approach to realize an IP-over-DWDM architecture seems to be Optical Burst Switching (OBS) [10], [11], because it can achieve a good balance between the coarse-grained wavelength routing and fine-grained optical packet switching.

A challenging issue in OBS is how to assemble IP packets into bursts at ingress 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. The burst arrival process is determined by the traffic characteristics such as the burst inter-arrival time and the burst length distributions, which are dependent on the burst assembly strategy. Several previous works have presented proposals to improve this strategy [3], [10], [12].

In this paper we address the issue how to provide proportional differentiated services in OBS networks. We introduce a Delayed Burst Assignment (DBA) scheme to provide proportional differentiated services in bufferless OBS networks and then we extend the proposed scheme to provide proportional differentiated services with absolute constraints. The proposed DBA scheme improves the burst loss performance by giving the burst head packet (BHP) the opportunity of scheduling its data burst (DB).

2. PROPORTIONAL DIFFSERV MODELS

The differentiated services enable Internet users to provide diverse quality of service (QoS). Two categories of methods for realizing differentiated services have been proposed [2]: one is non-proportional method and another is proportional method. In the non-proportional differentiated services model using an extra-offset-time-based 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. In OBS, a BHP is processed and sent to the next hop without waiting for the arrival of its DB. After that, if its DB is truncated or dropped, the BHP is unaware of these changes and cannot update its carried information (e.g., burst length). Any attempt to preempt the reserved resources of lower priority classes by higher priority classes is therefore awkward and inefficient. 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. To the contrary 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 [7]. It can be expected that introducing a proportional differentiated model into an OBS network would be favorable to both network operators and users.

2.1 Relative QoS DiffServ model with DBA Scheme

Delayed Burst Assignment (DBA) is a service differentiation technique in which bursts of lower priority are processed after a delay to guarantee that bursts of higher priority are more likely to have wavelengths reserved for them. A service differentiation technique of this kind was proposed in [9]. It provides differentiated services by maintaining a BHP queue for each class and ensures that BHPs of higher priority are processed before BHPs of lower priority. We define BHP queueing delay as the period a BHP spent waiting in the BHP queue. With this algorithm, the BHP queueing delay for the lower priority class is uncontrollable when the higher priority traffic is heavy, and the scheme might deteriorate into a classless one when the traffic load is low (no BHP in queue when the inter-arrival time of BHPs is much longer than the processing time of a BHP). Our new proposed DBA scheme is simpler and cheaper, because no optical buffer but electronic buffer is needed.

DBA divides BHPs into two types: type 1 and type 2. Type 1 has priority over type 2. The bursts of both types have the same offset time. The scheme works as follows:

1. When a BHP of type 1 arrives, it is processed normally and is sent to the next node. When a BHP of type 2 arrives, it is queued in a BHP queue for a waiting time period T_{wait}. Because BHPs are processed electronically, we can delay them in the Random Access Memory (RAM). During this waiting period, the BHPs of type 1 are processed, resulting in a reducing burst loss ratio for this type.

2. When T_{wait} has passed, the BHPs of type 2 are processed and the wavelengths that have not been reserved by type 1 bursts are reserved. T_{wait} should be included in the extra offset time. If it is not included, the BHP's residual offset time will be less than the processing time of the BHP for its remaining route after it has been buffered at intermediate nodes. In this case, the corresponding DB will be dropped by the core node because the BHP could not be processed before the DB's arrival. When T_{wait} is close to zero, the whole system will deteriorate into a classless one because there is not enough time for processing type 1 BHPs. A large T_{wait}, on the other hand, will cause a large extra offset time and a large end-to-end delay.

As we assume there is no optical buffer in core nodes, the end-to-end delay is the sum between end-to-end propagation delay and the end-to-end BHP queueing delay. Here, the last term is defined as the sum of the BHP queueing delays at core nodes during transmission, which should be included in the extra offset time. Let N_{max} be the maximum hop number and T_{exoff} be the maximum required extra offset time in the

OBS network. Then $T_{maxoff} = T_{wait} \times N_{max}$ (i.e., the worst case whereby lower priority BHPs buffered for T_{wait} at each core node). To prevent the end-to-end delay from becoming too large, we introduce the parameter N_r ($N_r \leq N_{max}$), the maximum number of times for a BHP to be queued during transmission. When the number of times a BHP has been queued reaches N_r, the burst will be dropped immediately if it can not find a suitable wavelength in its candidate wavelength set. The required extra offset time is thus limited to: $T_{maxoff} = T_{wait} \times N_r$.

2.2 Absolute QoS DiffServ model

In the previous section we have introduced a scheme for a *relative QoS* model, in which the QoS of one class is defined relatively in comparison to other classes (i.e., a higher priority burst is guaranteed to experience lower loss probability than a lower priority burst). However, no upper bound on the loss probability is guaranteed for the higher priority burst. There are many types of traffic that require strict QoS guarantees (for example, a data transfer operation cannot bear packet loss ratio exceeding a certain threshold). The *absolute QoS* model provides a worst-case QoS guarantee to applications. This kind of hard guarantee is essential to support applications with delay and loss ratio constraints, such as multimedia applications. Zhang et al. [14] proposed an early dropping scheme to drop lower priority bursts to assure higher priority bursts have more probability in reserving wavelength to meet the absolute constraint of higher priority class. However, this absolute QoS model makes no differentiation among the classes when the traffic load is low.

Although it has been accepted that proportional differentiated services with absolute constraints is important [4], there is no scheme in the literature to provide proportional differentiated services with absolute constraints in OBS. Our model defines a system that supports both absolute constraints and proportional constraints, assuring that absolute QoS constraints have higher priority over proportional QoS constraints. When there are conflicts between constraints, the constraints with lower priorities will be relaxed. Besides the parameters already introduced, we add a new parameter Pb_{imax}, the maximum burst loss ratio at each node for class *i*. The scheme is thus realized as the following algorithm:

Step 1. When a burst of class *i* arrives, use DBA algorithm to schedule burst. If schedule is successful, forward it to next hop and create a new entry with the $(N + i)$-th bit set 1; else discard burst and create a new entry with the *i*-th and the $(N + i)$-th bit set 1

Step 2. Push the new entry into the FIFO and pop the oldest entry and compute Pb_i. Then if $Pb_{i-1} > Pb_{max}$ put $a_i = a_{i-1}$; else put $a_i = a_{i+1}$ where a_i denotes the wavelength number.

2.3 Integrated DiffServ scheme for joint QoS

In this section, define an integrated scheme for proportional differentiated services using the DBA algorithm presented in section 2.1 and the *absolute QoS* model presented in section 2.2 to support joint QoS. The core node first use DBA scheme to process BHP and assign wavelength for its burst. If the arriving BHP could not find an available wavelength for its burst, the BHP will be buffered for T_{wait}. So it has an opportunity to reschedule its burst to the wavelengths in its rescheduling wavelength set in which the wavelengths have been assigned to the higher priority class but haven't been reserved yet. The rescheduling wavelength set is dynamically adjusted by the following algorithm in which the absolute constraints have priority over proportional constraints:

Step 1. A BHP arrives and we test if the DBA scheme schedules its burst successfully. If yes, then reservation is done; otherwise get to step 2.

Step 2. Test if the residual offset time is large enough. If yes, BHP is put in queue for T_{wait}, and then we get to step 2; otherwise reservation failed.

Step 3. Test if the rescheduling of the burst on its rescheduling wavelength set was successfully made. If yes, then reservation is done; otherwise reservation failed.

To prevent the end-to-end delay from being too large caused by the BHP buffering at immediate nodes, we use the parameter N_r, representing the maximum buffering times for each BHP during transmission (as defined in section 2.1). The required extra offset time is thus limited also to: $T_{maxoff} = T_{wait} \times N_r$.

3. NUMERICAL RESULTS

To check the efficiency of our schemes we have simulated a multiple hop network with a ring topology on a dedicated platform. The simulation platform was realised in the laboratory of Communications, Faculty of Electrical Engineering, University "Valahia" of Targoviste. We use OPNET as a simulation tool to study the performance of our schemes and compare them with existing dropping schemes especially when the offset times are varied during transmission. The shortest-path-first routing method is used to establish a route between each pair of edge nodes E_i(i=1 to 16), and the maximum hop distance is 10. Bursts are generated at each edge node E_i. We assume that the burst inter-arrival time follows an exponential distribution and the burst size follows a normal distribution. Note that these assumptions are the same as the ones in [12]. The average burst size is 50 Kbytes. All bursts are assumed to have the same initial offset time (the default value is 5ms, which is small enough even for real-time applications). For a core node C_i(i=1 to 16), we assume that each output link consists of 16 wavelengths with a transmission rate of 1 Gbps per wavelength. The basic processing time for BHP at each core node is set to be 0.1 ms. To investigate the service differentiation, we consider four classes, a load distribution of $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4$, and proportional parameters of s_1=1, s_2=2, s_3=4, and s_4=8.

Regarding the performance of the DBA scheme, Figs.1 and 2 show the impact of N_r and T_{wait} on the average burst loss ratios for a low traffic load (0.3) and for a high traffic load (0.89), respectively.

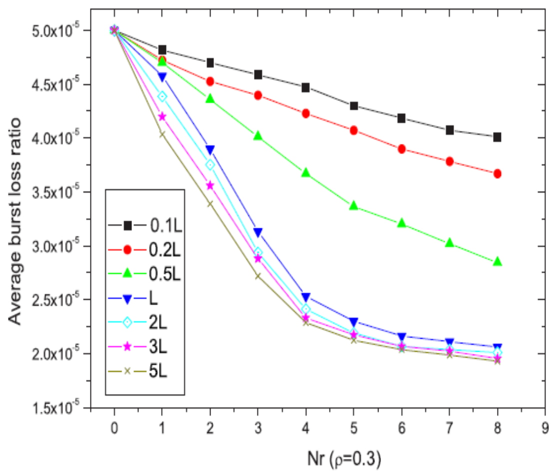

Fig.1 Average burst loss ratios versus N_r with traffic load 0.3

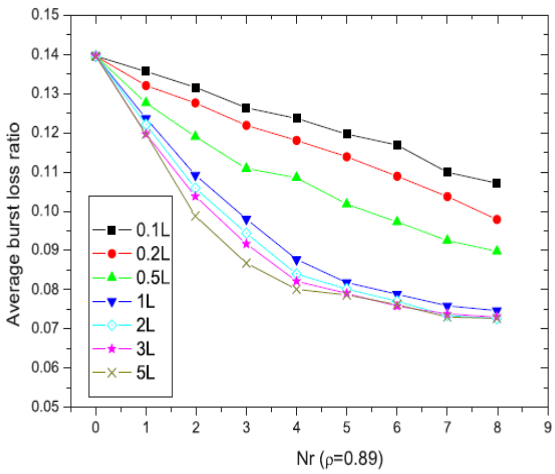

Fig.2 Average burst loss ratios versus N_r with traffic load 0.89

In the figures, the curve "*aL*" denotes the burst loss ratio when T_{wait} is set to a times the average burst length (L). The initial offset time is set to 30 ms. The results indicate that as N_r and T_{wait} increase, the burst loss ratio decreases. However, when T_{wait} exceeds the average burst length duration and N_r exceeds 4, the burst loss ratios decrease slowly and eventually become almost the same. Thus, in the simulations we set 0.4 ms (*average burst length duration=average burst length (50 Kbytes) /bandwidth (1 Gbps)*) and 4 as the default values of T_{wait} and N_r.

Regarding the performance of the integrated scheme presented in section 2.3, the results obtained by simulation show that the proportions of different classes are close to the ratios of predefined parameters and are independent of the traffic load for the integrated scheme. Therefore, the integrated scheme achieves proportional differentiated services for multi-class traffic.

We can see that the lower priority bursts have larger queueing delay than do the higher priority bursts. For example, the queueing delay is several microseconds for class 2, tens of microseconds for class 3, and hundreds of

Table 1. Proportions of simulated burst loss ratios for the integrated scheme

ρ	Pb_2/Pb_1	Pb_3/Pb_1	Pb_4/Pb_1
0.3	2.04	3.98	7.97
0.4	1.99	4.01	7.98
0.5	2.01	4.02	8.01
0.6	2.01	4.02	7.99
0.68	2.00	3.99	7.98
0.75	2.01	3.98	7.97
0.83	1.98	3.99	7.98
0.89	1.99	4.00	8.01
0.93	1.98	3.99	7.98
0.98	2.00	4.00	8.00

Figure 3 shows the end-to-end BHP queueing delay normalized to the average burst length duration for each class during transmission.

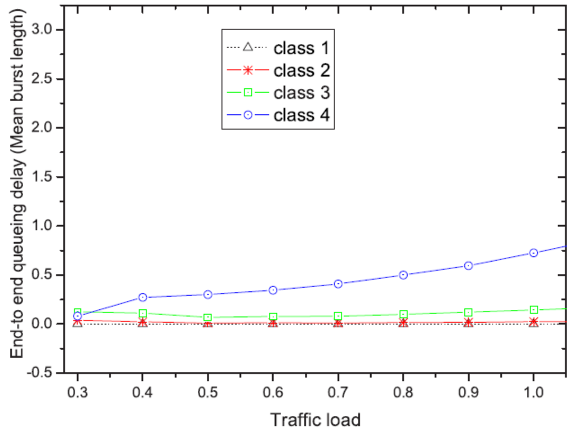

Fig.3. End-to-end BHP queueing delay

microseconds for class 4. The simulation results show that although the integrated scheme improves the burst loss performance at the expense of increasing extra offset time, the increase of end-to-end delay is very small (at most hundreds of microseconds) and would be negligible for real applications.

4. COMPARISON WITH OTHER DROPPING SCHEMES

We have compared in the same conditions of simulations our proposed integrated scheme with other two dropping schemes: the Dynamic Wavelength Selection (DWS) scheme introduced by Du [8] to assign more and longer periods of wavelengths to higher priority classes dynamically and efficiently due to wavelength-sharing and the intentional dropping scheme introduced by Chen *et al.* [4] to maintain the proportion of the loss ratios for each class based on a set of predefined parameters. This last method (denoted in the following as *Drop*) to drop the arriving bursts at core nodes, of the lower priority class, 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 a coming higher priority burst 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.

Figures 5 and 6 illustrate the average burst loss ratio and normalized throughput (i.e. throughput/(link capacity) at each link.

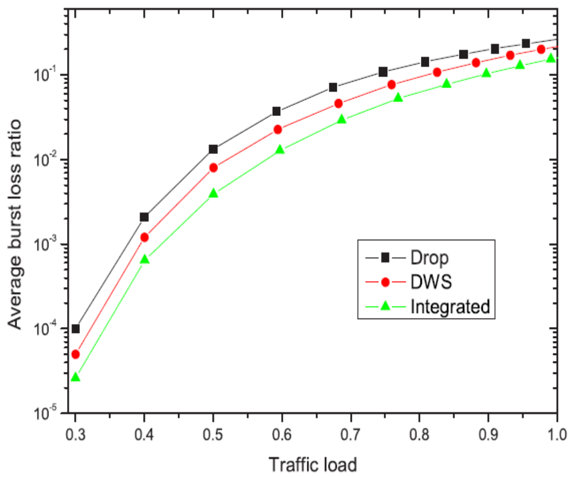

Fig.4. Comparison of average burst loss ratios

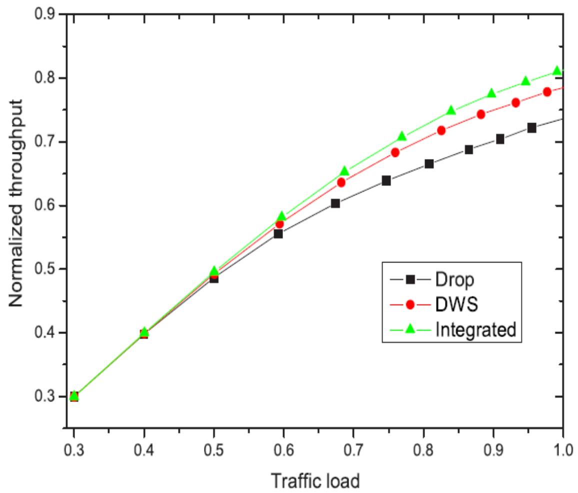

Fig.5. Comparison of normalized throughput

Because each burst does not have the same size, the burst loss ratio differs from the bit loss ratio. Thus, the normalized throughput can be used to evaluate the network performance from another angle than burst loss ratio. The integrated scheme has the highest normalized throughput and the lowest average burst loss ratio, whereas the intentional dropping scheme has the lowest normalized throughput and highest loss ratio at all load levels.

Finally, in our simulations we have use the same ring topology and environment to test the performance of the integrated scheme when performing joint QoS with absolute constraints. We have considered three classes of traffic, class 1 is the highest one, followed by class 2, then class 3. The traffic ratios are assumed to be 10%, 30% and 80% for classes 1, 2 and 3 respectively. For proportional constraints, we set the proportional factors s_1=1, s_2=2, s_3=4. The absolute loss guarantee for class 1 is P_{1Max}= 0.002 and for class 2 is P_{2Max}= 0:008. We set T_{wait}=0.4 ms (mean of burst transmission time) and N_r = 4.

Figure 5 compares the burst loss ratio of intentional dropping scheme (plotted as *Drop* in the figure) with those of the DWS scheme and the integrated scheme. We can see that the integrated scheme provides joint service differentiation for multiclass traffic and has best burst loss performance than the other two schemes because that it does not waste wavelength. For example, the burst loss ratio of the integrated scheme is about 55% that of the DWS scheme and is 30% that of the Drop scheme when the traffic load is 0.3. This is because the BHP in the integrated scheme will be buffered at the core node when it could not find an available wavelength and has an opportunity to reschedule its burst to the wavelengths which have been assigned to the higher priority class but haven't been reserved yet.

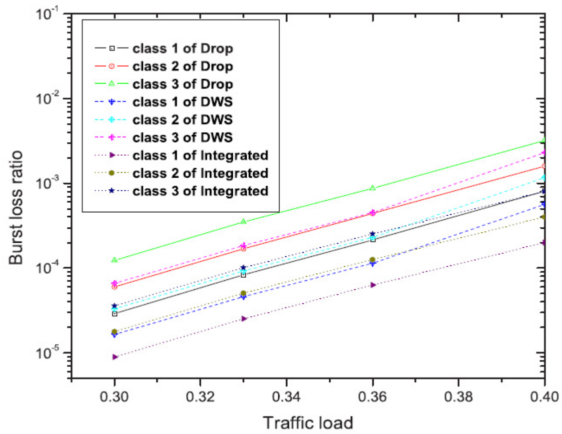

Fig.6. Burst loss ratios for different schemes at low traffic loads (0.3 to 0.4)

5. CONCLUDING REMARKS

In this paper we described how to provide proportional differentiated services in an OBS network. First, we proposed a delayed burst assignment scheme based on relative QoS model and integrated it with an algoritm based on absolute QoS model to support proportional differentiated services without or with constraints in OBS networks. The integrated scheme proved to have the best performance. Through simulation, we also found that when the BHP waiting time period and the maximum number of times for a BHP to be queued exceed some values, the performance is improved smoothly. These results could prevent the end-to-end delay from becoming too large. As an advantage over the existing priority schemes, our integrated scheme does not need any complex burst segmentation or wavelength preemption support, so it have a simple implementation. Moreover, it provides controllable and predictable proportional differentiated services for each class.

For further work we will proceed to test the discussed algorithm over other topologies. Till now the ring topology was the only implemented on the simulation platform. Some tests on a different topology were executed later and mentioned in [6], a novel burst assembly algorithm (named adaptive timer-based algorithm) with traffic shaping functions to reduce the variance of assembled traffic and improve the burst loss performance is introduced.

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