Proportional QoS over OBS Networks

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Abstract

Optical Burst Switching (OBS) is considered as an efficient switching technique for building the next generation optical Internet. An offset-time based scheme has recently been proposed in order to provide quality-of-service (QoS) in OBS networks. Unfortunately, the proposed service differentiation has several problems. The aim of this paper is to address these problems and introduce the concept of proportional QoS into this OBS paradigm. An intentional dropping scheme is proposed so as to give a controllable burst loss probability for different service classes. In order to achieve flexible packet delay differentiation, we extend the well-known waited-time-priority (WTP) scheduler to form a burst assembling scheme. Simulations are conducted to evaluate the performance of our proportional QoS provisioning within OBS networks in terms of burst loss probability and packet delay.

1 Introduction

The explosive growth in IP traffic on the Internet is driving the demands for new high-speed transmission technologies. Wavelength Division Multiplexing (WDM) [1], which can support a number of channels at Gigabit/s within a single optical link, has the potential to transmit data at speeds up to Terabit/s. Therefore, new protocols and management schemes are required above the optical physical layer to use this huge transmission capacity. In order to address and solve these problems, researchers are proposing an IP over WDM networks [2], in which the traffic is transmitted in the optical domain without any O/E and E/O conversion.

However, an all-optical packet switch/router is still not a practical solution for an optical Internet. Optical burst switching (OBS) [4, 5] has been proposed as an alternative to all-optical packet switching. One major difference between optical burst switching and optical packet switching is the switching granularity. In an OBS network, IP packets with the same destinations are assembled together to form a "burst" and then transmitted in the network as an unit. This will help reducing the processing speed requirement on the electronic devices.

At the same time, the *best-effort* service model on today's Internet cannot support diverse service requirements from different IP applications. Much effort has been devoted to QoS provisioning in the Internet. However, in the optical domain, buffering is still a problem since there is no practical optical queueing scheme. This makes those buffer-based QoS schemes not appropriate in an all-optical network. In order to bypass the need for optical buffers, a novel scheme is studied in [6]. By setting an *extra offset time*, QoS in terms of burst loss probability is provided without the usage of buffers.

The rest of the paper is organized as follows. The proportional QoS model is presented in Section 2 as an enhancement of previous QoS models. In Section 3, previous approach to QoS provisioning using *extra-offset-time* is described. The problems associated with this approach are also discussed in this section. In order to provide proportional burst loss probability in the OBS paradigm, we introduce an intentional dropping algorithm in Section 4. Based on the waited time priority (WTP) scheduler used in packet switching networks, we also provide a burst assembling scheme at the edge router in Section 4. Using this burst assembling scheme, we can provide proportional packet delay. In Section 5, the results obtained from the simulations is given. We conclude this paper in Section 6.

2 Proportional QoS

2.1 Previous QoS models

Wide diversity on the service requirements of users and applications on today's Internet makes the *best effort* service model inadequate. There is a great demand for the Internet to be extended with service differentiation. The first approach proposed to replace

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the *best effort* model is *Integrated Services (Intserv)*. Because this approach encounters a scalability problem in its deployment, another approach, *Differentiated Service (Diffserv)* has been proposed. In particular, two categories of *Diffserv* have been identified: Absolute Service Differentiation and Relative Service Differentiation. The latter receives more attention because of its simplicity and its ability to be deployed incrementally. Recently, this relative QoS model has been further refined using a proportional differentiation model, which provides the network operators with quantitative QoS differentiation between service classes [7].

2.2 Proportional differentiation model

In a relative QoS model, we can only guarantee that the traffic from a higher priority class will receive no worse local (per-hop in packet networks) service. However, in the proportional differentiation model, we can quantitatively adjust the service differentiation of a particular QoS metric to be proportional to the factors that a network service provider sets. If q_i is one QoS metric and s_i is the differentiation factor for class i, using the proportional differentiation model, we should have:

$$\frac{q_i}{q_j} = \frac{s_i}{s_j} \qquad (i, j = 0 \dots N) \tag{1}$$

for all pairs of service classes.

It is desirable that the proportional differentiation model holds over not only long time scales, but also short time periods. The reason is that the long term average is not quite meaningful when the traffic is bursty. Therefore the proportional differentiation equation (1) should hold within a short time period τ, which is called *monitoring timescale* in [7]:

$$\frac{\bar{q_i}(t, t+\tau)}{\bar{q_j}(t, t+\tau)} = \frac{s_i}{s_j} \tag{2}$$

where $\bar{q_i}(t, t+\tau)$ is the average QoS metric in the time period τ. This service model is general enough in that the quality differentiation between traffic classes can be defined as a function of various QoS parameters.

In this paper, we try to provide proportionally differentiated burst loss probability and average packet delay in a burst-switching network. However, we point out problems associated with the previously proposed QoS provisioning over an OBS network at first.

3 QoS over an OBS Network

An IP-over-WDM backbone paradigm consists of inter-connected optical burst switching nodes along with the appropriate IP layers. The traffic coming into a switch input port on different wavelengths is de-multiplexed. Selected burst headers are transmitted on a separated control channel and passed to the switch control unit which controls the configuration of the optical switch. After the bursts go through the switch fabric on different wavelengths, they will be multiplexed again are transmitted to the switching nodes downstream.

From the information carried in the header, the switch control unit will know the data burst's destination, length and arrival time. Afterwards, the optical burst switch node can make a *Delayer Reservation* of the capacity needed at the corresponding output port [5]. The reservation information on the capacity at the output link will be kept in the switching control unit and might be referred to whenever necessary.

3.1 Problems in Offset-time-Based QoS

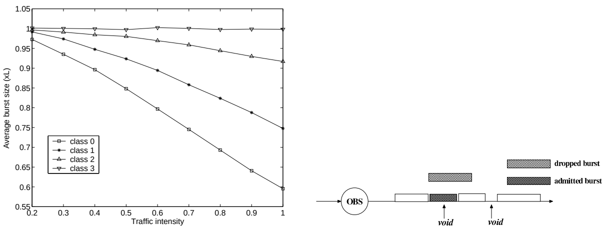
Aimed at introducing basic QoS in an OBS network, an *extra offset time* scheme is proposed in [6]. In addition to the basic offset time needed for switch fabric configuration, an extra offset will be set between the data burst and its header. Having different extra offset times can be exploited to have different priority classes having different burst loss probabilities. However, there are several problems associated with this approach.

3.1.1 Unfavorable End-to-end Delay

When we refer to end-to-end delay, we have to take an extra offset time into consideration. If the extra time difference between two adjacent classes is t_{diff} and the total number of service classes is n, the longest additional delay is $(n-1) * t_{diff}$. In particular, real time applications' packets may be separated by several different data bursts at the burst assembling stage. Hence, the end-to-end delay for data bursts will not be able to represent IP packets' end-to-end delay, which is the key QoS metric that network operators or end-users would care about.

3.1.2 Burst Selecting Effect

In Figure 1(a), we plot the average burst size of the bursts which successfully reserve the capacity within a typical simulation scenario of [6]. It is interesting to find that the offset-time-based scheme tend to select the small bursts for low priority service classes. As the traffic intensity increases, the selection becomes stricter. Our explanation is as follows: since the OBS is asynchronous, high priority bursts with large offset times will break the capacity's free period into discrete small pieces, resulting in a large capacity being "void" on the time axis. Therefore, a burst with smaller size



(a) Burst selecting effect. (b) Burst selecting effect explanation.

Figure 1: Burst Selecting effect and its explanation

will have more probability to fit into those voids (Figure 1(b)).

4 Proportional QoS over OBS network

In the previous section, we pointed out the problems associated with the previous offset-time-based QoS provisioning over an OBS network. In this section, we propose a scheme with controllable QoS differentiation on delay and packet loss probability.

4.1 Intentional Burst Dropping

In our scheme, a low priority burst is intentionally dropped when equation (1) is violated. This intentional dropping will give more or longer free time periods on the output link capacity, which means more opportunity for a high priority burst to be admitted. The details of the algorithm is as follows:

Define:

$loss_i$	bursts dropped of class i;
$arrival_i$	bursts arrival of class i;
s_i	class i's proportional factor;
$ERROR$	a parameter controls accuracy of proportional relations;
$lossrate_i = \frac{loss_i}{arrival_i}$	online blocking probability measurement for class i;

Algorithm:

1. Set two counters recording $loss_i$ and $arrival_i$ to be 0 for each service class i;

2. A burst b_i of class i arrives,
   if b_i can not reserve any wavelength and FDL **then**
   b_i is intentionally dropped, $loss_i + 1$, $arrival_i + 1$
   else if $lossrate_i/s_i < lossrate_N/s_N$ **then**
   b_i is intentionally dropped, $loss_i + 1$, $arrival_i + 1$
   else
   b_i makes reservation on wavelength and FDL, $arrival_i + 1$
   end if

3. Update $lossrate_i$,
   if $Max\{abs(lossrate_i/lossrate_N - s_i/s_N)|\ i = 0\ldots(N-1)\} \le ERROR$ **then**
   go to step 1
   else
   go to step 2
   end if

Resetting counters from time to time will keep the online measurement to be done over the most recent traffic history. This is very important when the traffic is bursty.

In our scheme, we do not need any extra offset time. In comparison with the end-to-end delay in an offset-time-based QoS scheme, the delay experienced by the burst would be much shorter. With a burst assembling scheme explained in the next section, proportional average packet delay will be realized as well.

4.2 Burst Assembling

Before IP packets enter an OBS network, they are "packed" into a burst at the edge router [8]. Because the processing speed of an edge router is limited, buffers should be used for traffic engineering at the ingress point. We believe that by removing the extra offset time, the actual delay that a packet experiences in the optical domain can be negligible. Then the delay at the assembling point will be most of the end-to-end delay for a packet.

4.2.1 WTP scheduler

It has been shown that in a packet network, a proportional average packet delay can be achieved using a Waiting Time Priority (WTP) scheduler [7]. A queue is maintained for each service class. The load of this queue in the recent past is reflected on the waiting-time of the packet at the head of the queue. Suppose the proportional factors that we set are: $s_0 > s_1 > \ldots > s_N$ (with class *0* having the lowest priority). At time t, the scheduling priority of a queue i is: $p_i(t) = w_i(t)/s_i$, where $w_i(t)$ is the waiting time of the packet at the head of queue i. When a packet in a queue needs to be served at time t, the packet at the head of the queue with the largest $p_i(t)$ will be chosen. Using this scheduling scheme, a proportional average packet delay is achieved. The fundamental idea of this scheduler, applying a weighted priority computation is used in the burst assembling process in our scheme.

4.2.2 Burst Assembling at the Edge Router

We propose a burst assembling scheme to emulate a WTP scheduler in packet networks. A queue is kept for each class of packets. A burst will be assembled and transmitted into the OBS backbone when a token is generated at time t. The token's generation is a Poisson process in order to avoid possible synchronization among the burst generations from different sources [3]. The priority for each queue is $p_i(t) = w_i(t)/s_i$, where $w_i(t)$ is the waiting time of the packet at the head of the queue i and s_i is the proportional factor for class i. The queue with the largest $p_i(t)$ will be chosen. Since the packet number in the queue can be significantly large when the traffic load is moderate, we set an upper bound for the burst size: L. If a queue with more than L packets is chosen for burst assembling, the first L packets in the queue will be assembled. A queue with less than L packets will be emptied after the assembling process.

5 Performance Study

The simulation results of our proposed intentional dropping algorithm and burst assembling scheme are presented in this section.

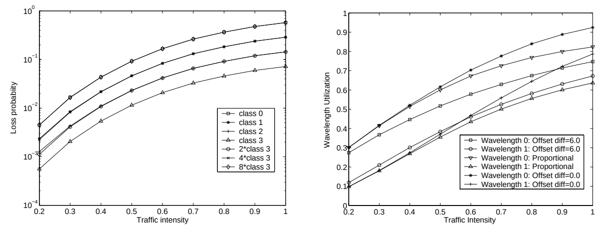
The general simulation scenario for the intentional dropping algorithm is at an OBS node's output link: four classes of Poisson traffic sources with the same traffic intensity; average burst size is L and delay difference between FDLs is L. There is no extra offset time for any of the four classes. Burst loss probability and wavelength utilization (a metric reflecting the amount of IP packets passing through) are checked.

Simulation of the burst assembling scheme is conducted in the following scenario: we assume there are four buffers for four Poisson traffic sources with the same traffic arrival rate; the total packet arrival rate is $r_{traffic}$; The token is generated at a rate r_{token} and the maximum number of packets that a burst can contain is 25.

5.1 Proportional Loss Probability

Figure 2(a) shows the average burst loss probability when we set the proportional factors as follows: $s_0 = 8; s_1 = 4; s_2 = 2; s_3 = 1$. The number of wavelength is 2 and there are 3 FDLs with maximum delay as $3L$. Instead of the uneven differentiation in the offset-time-based scheme, the service differentiation here is completely under control.

Because larger bursts consist of more IP packets, equal burst loss probability does not mean that the



(a) Proportional Burst loss probability.

(b) Wavelength utilization comparison.

Figure 2: Algorithm Performance

same amount of IP traffic has passed through an OBS node. We take the wavelength utilization as the metric for comparison. The wavelength utilization comparison is illustrated in Figure 2(b). The wavelength utilization using the proportional scheme is less than that of the classless one because we intentionally drop some bursts in order to provide a proportional burst dropping probability. However, our scheme outperforms the offset-time-based scheme. This is because our scheme avoids the packet selecting effect. Therefore, the "Void"s shown in Figure 1(b) are rarely generated since there is no extra offset time. Thus bursts with different lengths will have the same opportunity to be admitted no matter which service class they belong to.

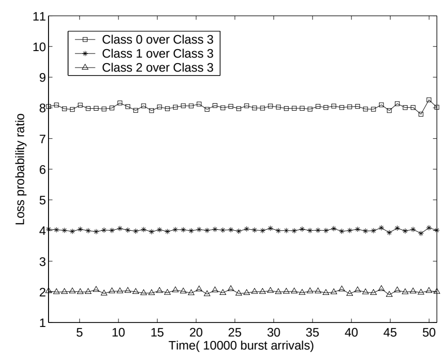


Figure 3: A sample path of the loss probability.

As discussed in Section 2, it is preferable that a proportional scheme can guarantee the proportional relationship among the QoS metrics of each classes even in a short time period. That is, we would like equation (2) to hold even when τ is relatively small. Following the same simulation scenario for the average loss probability while the traffic intensity is 60%,

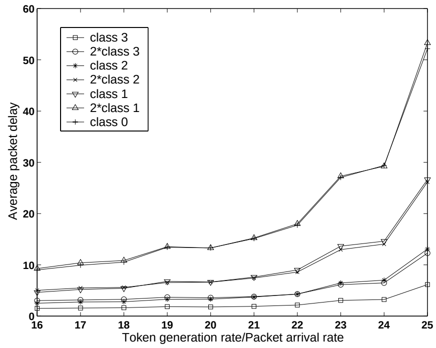


Figure 4: Proportional packet delay.

the ratios between the loss probabilities of each class is computed every 10,000 burst arrivals. The sample path is drawn in Figure 3. Equation (2) is satisfied when the τ is set to be 10,000 burst arrivals, which is a quite small time period in an IP backbone network.

5.2 Proportional Packet Delay

In this set of simulation, the average packet delay instead of the average burst delay is traced by changing r_{token}/r_{packet}. In Figure 4, the proportional factor is as follows: $s_0 = 8; s_1 = 4; s_2 = 2; s_3 = 1$. In general, we can find the proportional relationship between the average packet delay of each class to be kept approximately as we expected. The small deviation is caused by the granularity difference. In the burst assembling scheme, the unit that we manipulate is a burst consisting of tens of packets. We computes the priority using the time information on only one packet at the head of queue. However, in general, the average packet delay at the assembling stage, which might represent the end-to-end delay for an IP packet passing through an OBS network, is under quantitative control.

6 Conclusion

All-optical data transmission has been considered as the key to handle the increasing amounts of IP traffic over the Internet. Currently, all-optical packet switching is not mature. However, optical burst switching provides a good alternative. Because more applications and users require QoS provisioning over the IP traffic. Offset-time-based schemes, a recent attempt to provide basic quality of service (QoS) over an OBS network has been proposed. Several problems with this scheme has been pointed out in this paper.

Among the QoS models proposed recently, the proportional QoS model is an attractive one because of its controllable QoS provisioning manner. In this paper, we present an initial and original research work on introducing a proportional differentiation into OBS networks. An intentional dropping scheme is proposed to give controllable burst loss probability. We also work on another important QoS metric for IP traffic, average packet delay. Aimed at achieving flexible packet delay differentiation, we extend the WTP scheduler to form a burst assembling scheme. Simulations are conducted to evaluate the proportional relationship in the QoS provisioning. These results demonstrate that we can achieve controllable differentiation as a function of burst loss probability and packet delay using simple and practical schemes.

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