

CPQ: a Control Packet Queuing Optical Burst Switching Protocol for Supporting QoS

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Abstract

In this paper, we propose a Control Packet Queuing (CPQ) protocol based on the Just-Enough-Time (JET) protocol which can provide differentiated services for optical burst switching (OBS) network. Specifically, we apply OBS to support two traffic classes: real-time and non-real-time. Correspondingly, two priority queues are built for control packets in the electrical layer at the OBS nodes. All arriving control packets are first buffered in the queues and then scheduled using the bandwidth reservation algorithm, in which real-time control packets are considered first before non-real-time control packets in reserving bandwidth. Simulation results show that our proposed protocol is averagely 52.72% better than a First Come First Served (FCFS) protocol in guaranteeing QoS of real-time traffic when the offered load ratio of real-time to non-real-time is set at 1:9.

1. Introduction

Optical burst switching (OBS) is an emerging solution to achieve all-optical WDM networks. It combines the advantages of optical circuit switching and optical packet switching [3][4][10]. In the past few years, various solutions have been proposed and analyzed in an attempt to improve the performance of OBS networks.

In OBS networks, the basic switching entity is a *burst*. Prior to transmitting a burst, a control packet is created and immediately sent toward the destination in order to set up a buffer-less optical path for its corresponding burst. After an offset delay time, the data burst is transmitted without waiting for an acknowledgement from the destination node. The optical path exists only for the duration of a burst.

OBS provides a huge bandwidth which could alleviate the increasing demands of Internet traffic; however,

challenges remain on how to provide Quality of Service (QoS) for Internet applications in such a network. For example, applications such as Internet telephony and video conferencing require a higher QoS than electronic mail and general web browsing. In an IP network, many methods have been proposed to implement QoS such as fair queuing, weighted fair queuing, frame-based fair queuing, etc. However, all of these methods are based on employing buffers at the network nodes. To implement the existing QoS mechanisms to differentiate services, all intermediate nodes should have a certain amount of buffer space. However, the use of electronic buffer necessitates O/E and E/O conversions which sacrifice the data transparency. On the other hand, no optical buffer (RAM) is available and the use of fiber-delay lines (FDLs), which can provide a limited delay, should also be avoided as much as possible in the optical layer.

We propose a Control Packet Queuing (CPQ) protocol based on the Just-Enough-Time protocol in this paper. Two classes of services, real-time and non-real-time, are considered here. The bursts in the real-time class have a strict bound on delay and delay-jitter, thus requiring a guaranteed low blocking probability. On the other hand, the bursts in the non-real-time class can tolerate delay but require reliable delivery which can be accomplished by buffering and retransmissions.

In this paper, we assume that no buffers are used in the optical layer, which is highly desirable in all-optical networks. However, buffering is used in the electrical layer for control packets in OBS nodes.

The paper is organized as follows. Section 2 describes the related work on QoS in OBS. Section 3 presents the control packet queuing optical burst switching protocol. Section 4 describes the simulation experiments and results. Section 5 discusses the conclusions and future work.

2. Related work

The Just-Enough-Time (JET) protocol was presented in [5][9]. JET has two features. One is delayed reservation, which reserves the bandwidth on each link for data burst duration. The other is postponing of the arrival of data burst. By providing a delay to the data burst at the local node, JET helps to increase the usage of bandwidth and reduce the number of retransmission. In [2], the authors conclude that JET has the best performance compared with other burst reservation mechanisms in a single-class optical burst switching network. Moreover, [2] evaluates JET by simulations and an approximate analysis in a two-class OBS node. Pros and cons of JET are also given in such a network.

In [6], the authors propose a prioritized OBS protocol based on JET which can provide QoS in bufferless WDM optical networks. Two traffic classes, class 0 and class 1, which correspond to non-real-time and real-time applications, are supported. Each burst belonging to the real-time class is assigned a higher priority by simply using an additional offset time between the burst and its corresponding control packet. The authors, in [6], analyze the lower and upper bounds on the blocking probability of each traffic class, and evaluate the performance of the proposed prioritized OBS protocol. They conclude that real-time traffic can achieve a significantly reduced blocking probability by using a reasonable amount of additional time. In addition, the overall blocking probability and throughput can be maintained regardless of the additional offset time used. Two scenarios are described in [6] (see Figure 1). Assume $\text{req}(i)$ denotes a class i request (where $i = 0, 1$) and l_i be the burst length requested by $\text{req}(i)$. The arrival time is denoted by t_{ai} , and service time is denoted by t_{si} . In the first case in Figure 1 (a), $\text{req}(1)$ arrives first and reserves bandwidth using delayed reservation, and $\text{req}(0)$ arrives afterwards. In this case, $\text{req}(1)$ will succeed. In the second case, $\text{req}(0)$ arrives, followed by $\text{req}(1)$ as shown in Figure 1 (b).

When $t_{a1} < t_{a0} + l_0$, $\text{req}(1)$ would be blocked if normal FIFO queue had been used. However, such a blocking can be avoided by using a large enough offset time so that $t_{s1} = t_{a1} + t_{\text{offset}} > t_{a0} + l_0$. With that much offset time, the blocking probability of class 1 becomes independent of the offered load in class 0, and only a function of the offered load in class 1.

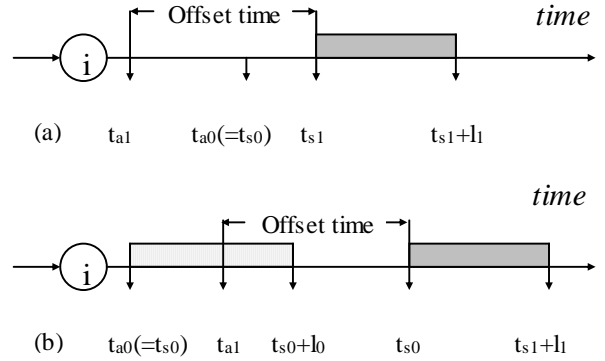


Figure 1. Offset time for guaranteed service

Furthermore, another study [7] extends [6] to support an arbitrary number of classes in IP over WDM networks. In [8], another QoS performance of optical burst switching in IP over WDM networks is presented. However, it is based on using limited number of FDLs.

3. Control packet queuing optical burst switching protocol

In this section, we will describe our control packet queuing optical burst switching protocol. The protocol is based on JET which is described in [5][9].

Two classes of service are considered in the paper: class 0 and class 1. Class 0 corresponds to the best effort or non-real-time services for applications such as transporting plain data, while class 1 corresponds to guaranteed or real-time services for applications involving audio and video communications. Since class 1 traffic should be delivered with a strict bound on delay, and requires a low blocking probability, it is given a higher priority for bandwidth reservation.

In Section 2, we have discussed that many queuing-based mechanisms cannot be used in optical networks because of the technical limitations of deploying buffers in the optical layer. However, the OBS network allows the possibility to use buffers for control packets in the electrical layer. The control packet contains the information about its corresponding burst, and is electronically processed by the ingress OBS node and all the subsequent nodes along the path to the destination user. Therefore, the control packets cannot be transported transparently in an OBS network. It is feasible to buffer the control packets in the electrical layer at the OBS nodes. Our new protocol is based on the usage of queues for control packets in the electrical layer at the OBS nodes.

Two queues are built in the protocol, q_0 for class 0 control packets and q_1 for class 1 control packets. The size of q_0 and q_1 is limited by the memory resource in the

OBS node. Moreover, a *time window* Δt is associated with these two queues. The control packets will be in a particular window $[t_1, t_1 + \Delta t]$ if the control packet arrives in that interval. All incoming control packets in the particular window are buffered and are kept in the corresponding queues. There is *offset time* between the control packet and its corresponding burst. A bandwidth reservation algorithm is invoked to allocate bandwidth for the bursts in the two queues. Furthermore, First Come First Served (FCFS) is used for control packets in the same queue. The bandwidth reservation algorithm at a single node is shown as the follows (see Figure 2).

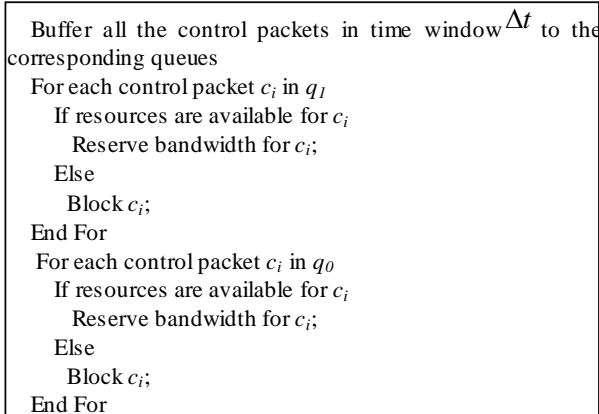


Figure 2. Bandwidth reservation algorithm

The bandwidth reservation algorithm shows that class 1 is always scheduled before class 0 in time window Δt , which indicates that class 1 has more priority than class 0 in reserving bandwidth. Moreover, the algorithm is greedy for class 1 as long as there is bandwidth available. On the contrary, class 0 is transmitted as best effort. After the control packets are processed, the control packets which reserve bandwidth successfully, as well as the resource information (reserved wavelength, reserved time slot, etc.) will be stored in a list. The OXC will decide whether forward or block the corresponding bursts upon the list.

There are 3 factors which can affect the performance of the protocol: time window, queue size and offset time. First, more control packets can be buffered with a larger time window. Nevertheless, this also increases data latency. By using a small time window, data latency can be decreased. However, few control packets can be buffered and it does not help to improve the performance. Second, the queue size is related to the time window. On the one hand, the larger the time window is, the larger the queues that are required. On the other hand, the queue size also influences the time window. The arriving control packets out of the queues will be blocked even if they are in the same time window. Moreover, the queue size is

also limited by the memory resources in the system. Finally, the offset time is another important factor which may affect the data latency and queue size. We will evaluate the three factors in Section 4.

4. Simulations and results

In this section, numerical results from simulation of the control packet queuing OBS protocol are presented. We used an enhanced version of the SIMON simulator in this study. SIMON [1] is a simulator for wavelength-routed optical networks, and does not support OBS network simulation. By extending it, we can also evaluate OBS networks using SIMON. The NSF network (see Figure 3) was used for the simulation studies. The following conditions are applied to our simulations:

- Uniform call distribution in network.
- Blocking probability includes source and destination busy conditions.
- 100,000 calls and zero to 100 Erlang network-wide load for all simulations.
- Shortest Path Routing Algorithm is applied using the number of hops as the metric.
- In each network, bidirectional links with one fiber in each direction were used.
- 16 wavelengths are available in each link.
- Call arrivals are Poisson and holding times are exponentially distributed.

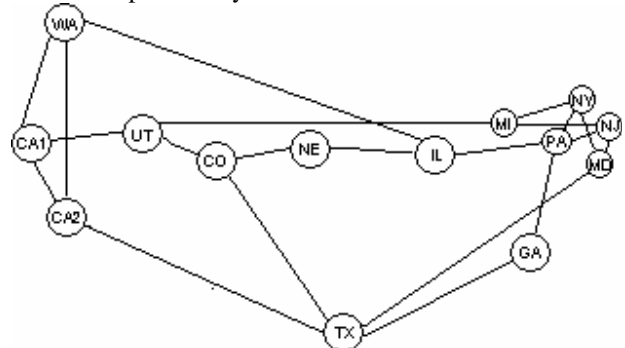


Figure 3. NSF network

The offered load ratio of class 1 to class 0 is set at 1:9 in the simulations. To compare the performance of control packet queuing protocol with another protocol, the straightforward FCFS protocol is also implemented.

Figure 4 and Figure 5 show the results of comparison of the CPQ and the FCFS. In all, there are four types of traffic: FCFS class 0, FCFS class 1, CPQ class 0 and CPQ class 1. Figure 4 shows that class 1 traffic has better performance with the CPQ protocol, especially when the load of the network (in Erlang) is greater than 70. Moreover, because class 1 traffic consumes more bandwidth with CPQ, it also degrades the performance of class 0 traffic. However, Figure 5 shows that the total

blocking probability in the network is almost the same, which indicates that CPQ does not degrade the blocking probability of the network. On average, the blocking probability of class 1 traffic in CPQ is 52.72% better than that with FCFS and the blocking probability of class 0 traffic in CPQ is 21.73% worse than it in FCFS. Additional simulations show that class 1 traffic in CPQ always fares better than class 0 no matter how much the relative offered load of class 1 is (see Figure 6).

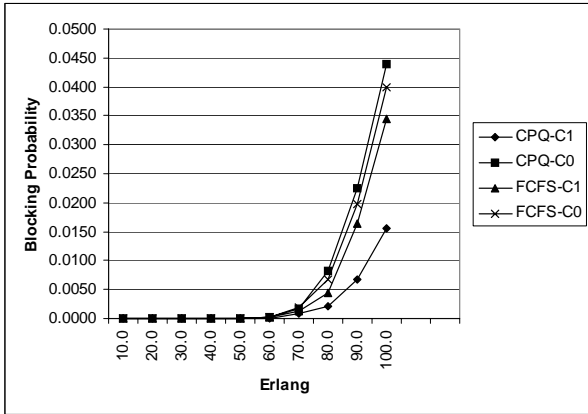


Figure 4. Comparison of performance of different traffic.

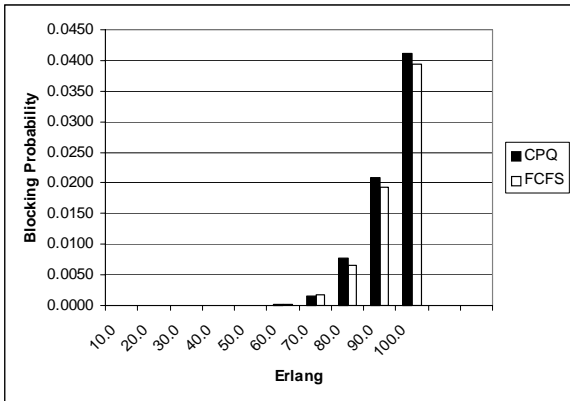


Figure 5. Total BP in CPQ and FCFS. Time window = 0.5s, Offset time = 0.25s

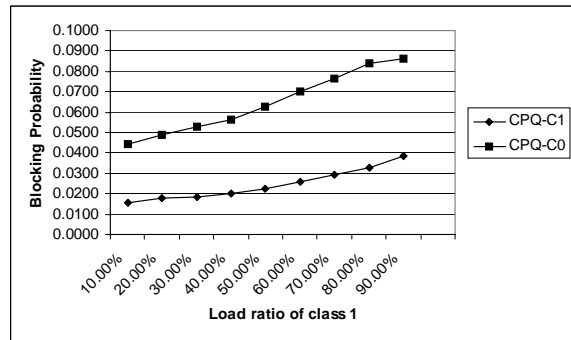


Figure 6. Comparison of BP for different load ratios. Time window = 0.5s, Offset time = 0.25s, Erlang = 100

Figure 7 shows the influence of the time window on the blocking probability of the traffic class 0 and class 1. It indicates that CPQ has better performance with a larger time window when the offset time is fixed. It is reasonable because more control packets can be queued in a larger time window. Figure 8 shows the influence of offset time on the blocking probability of traffic, which indicates that CPQ prefers a small offset time. Especially, when offset time is greater than 0.8s, the performance drops quickly. In the previous simulations, we select time window of 0.5s and offset time of 0.25s. As the figures show, the time window and the offset time both affect the performance. However, the offset time has more influence on the blocking probability. Finally, because the arrival of data burst is delayed in both JET and CPQ, both protocols require buffers to reserve the departure control packets. Therefore, CPQ has no more memory requirements than JET. A typical queue size at a single node is about 200 Kbytes in our simulation when there are 100,000 calls and the load, in Erlang, equals 100.

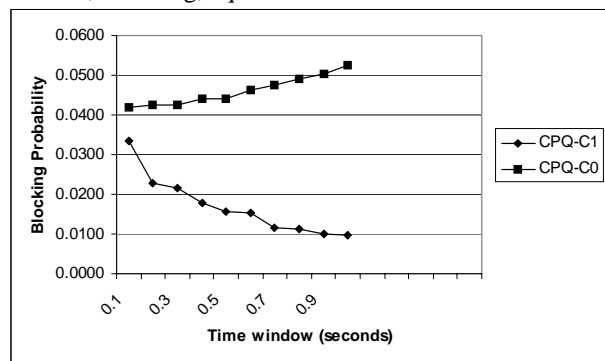


Figure 7. Time window and BP. Offset time = 0.25s, Erlang = 100

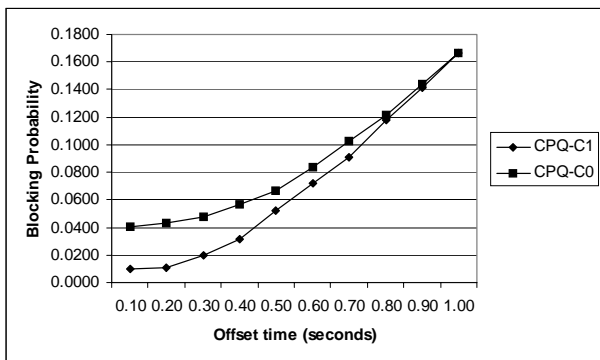


Figure 8. Offset time and BP.
Time window = 0.5s, Erlang = 100

5. Conclusions and future work

In this paper, we describe a control packet queuing protocol which supports differentiated services in an OBS network. The simulation results show that the real time applications which are denoted by class 1 traffic have a better performance using the CPQ protocol than with FCFS protocol. Moreover, CPQ is also easily deployed in OBS networks. The time window, the queue size and the data burst offset time are three important factors which affect the performance of CPQ.

We discuss only two classes of traffic in this paper. However, it is easy to extend the CPQ protocol to support arbitrary number of classes. Additionally, because queues are used for control packets, different policies could be used in scheduling, such as, for example, weighted queues.

References

- [1] B. Ramamurthy, D. Datta, H. X. Feng, J. P. Heritage and B. Mukherjee, "SIMON: a simulator for optical networks," in *SPIE Proceedings, All Optical Communication Systems: Architecture, Control Network Issues*, vol. 3843, pp. 130-135, Sep. 1999.
- [2] C. Gauger, K. Dolzer, J. Späth, and S. Bodamer, "Service differentiation in optical burst switching networks," In *Proceedings of the 2. ITG Symposium on Photonic Networks*, pp. 124--132, Dresden, March 2001.
- [3] C. Qiao and M. Yoo, "Optical burst switching (OBS)—A new paradigm for an optical Internet," *J. of High Speed Networks*, vol. 8, pp. 69–84, 1999.
- [4] L. Liu, P.-J. Wan, and O. Frieder, "Optical burst switching: the next IT revolution worth multiple billions dollars?" *MILCOM 2000. 21st Century Military Communications Conference Proceedings*, Volume: 2 , pp. 881 - 885 vol.2, 22-25 Oct. 2000.
- [5] M. Yoo and C. Qiao, "Just-enough-time(JET): A high speed protocol for bursty traffic in optical networks," *IEEE/LEOS Technologies for a Global Information Infrastructure*, pp. 26–27, Aug. 1997.
- [6] M. Yoo and C. Qiao, "A new optical burst switching (OBS) protocol for supporting quality of service," in *SPIE Proceedings, All Optical Communication Systems: Architecture, Control Network Issues*, vol. 3531, pp. 396–405, Nov. 1998.
- [7] M. Yoo and C. Qiao, "Supporting multiple classes of services in IP over WDM networks," in *Proceedings of IEEE Globecom*, pp. 1023–1027, 1999.
- [8] M. Yoo, C. Qiao and S. Dixit, "QoS performance of optical burst switching in IP-over-WDM networks," *IEEE Journal on Selected Areas in Communications*, Volume: 18 , Issue: 10 , pp. 2062 – 2071, Oct. 2000.
- [9] M. Yoo, M. Jeong, and C. Qiao, "A high speed protocol for bursty traffic in optical networks," In *SPIE Proceedings, All Optical Communication Systems: Architecture, Control Network Issues*, vol. 3230, pp. 79–90, Nov. 1997.
- [10] T. Battestilli and H. Perros, "An introduction to optical burst switching," *IEEE Communications Magazine*, Volume: 41, Issue: 8, pp. S10 - S15, Aug. 2003.