QoS Provisioning for WDM Burst Switched Ring Networks

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Abstract-**This paper considers the Quality of Service (QoS) provisioning mechanisms for the WDM burst switched ring networks. The loss-sensitive service and the delay-sensitive service are discussed. Considering their different requirements, different QoS provisioning schemes are proposed to provision them respectively. The proposed schemes are evaluated through simulation results.**

1. INTRODUCTION

The emerging of the dynamic and various Internet traffic imposed on the internet has prompted the development of optical technologies. One of the main techniques is the Wavelength Division Multiplexing (WDM) technique [1-2], which has emerged as a suitable method to satisfy the high bandwidth demands due to the bursty growth of Internet traffic. Optical Burst Switching (OBS) [3] is a viable switching method under study that can be used to transport data over WDM optical networks. In OBS technology, before a burst transmission, a Burst Control Packet (BCP) is firstly generated to record the information for the corresponding burst, and then is transmitted an offset time earlier than the burst on an out-of-band control wavelength. The burst are transmitted after the pre-calculated offset time, and they cut-through the intermediate nodes without any optical-electronic-optical (O/E/O) conversion. The O/E/O conversion is only needed in the control units to process the BCPs. Therefore, the demands of O/E/O conversion are reduces significantly, which spurs OBS as a viable technology before realizing Optical Packet Switching (OPS).

Various kinds of OBS networks have been studied and most of them have focused on the solutions of the contention problems, as the one-way reservation characteristic decided that the OBS networks with inherently high burst contention. There are three main reasons for the burst contention: the source contention, the channel contention, and the receiver contention. This paper considers the Tunable-Transmitter, Tunable-Receiver (TT-TR) based OBS ring networks, in which all the three kinds of burst contention exist. The contention problems have been focused on in our previous work in [4-7], and have been solved respectively. Besides solving the contention problems, the ability of a network to satisfy the different requirements for differentiated services is also very important. Different traffic demands have different requirements, and QoS provisioning mechanisms are required to satisfy them respectively according to their unique characteristics. This paper considers two kinds of services: the delay-sensitive (C1) service and the loss-sensitive (C2) service. The C1 service should be transmitted in a real-time manner and cannot tolerate high transmission delay, such as the video and the IPTV traffic, etc. While in view of the C2 service, the reliable transmission is required to be satisfied in a best-effort manner. Considering the delay-sensitive characteristic of C1 traffic and the loss-sensitive characteristic of C2 traffic, the paper proposed distributed schemes to service them respectively without increasing any overhead in the header signal or the device demands.

2. SYSTEM ARCHITECTURE

2-1. Network and Node Architectures

The OBS ring network consists of N OBS nodes organized in a unidirectional ring manner is considered. Ring topologies are widely deployed owing to their simple and efficient management, and are being upgraded to support multiple wavelengths using WDM to transport increasing traffic demands. We assume that each fiber link supports $w + 1$ wavelengths, with the first wavelength used as a control channel, and the other w wavelengths used as data bursts. Each OBS node is attached to one or more access networks, and acts as traffic concentrator when transmitting traffic from the various access networks to other OBS ring nodes. In the other direction from the ring to the access networks, an OBS node terminates optical bursts, electronically processes the data packets contained therein, and delivers them to users in the access networks. Each node acts as a source node to insert and send bursts, as an intermediate node to pass through bursts to downstream nodes, and as a destination node to receive bursts.

Figure 1 shows the TT-TR based OBS ring node architecture. We assume that there are W tokens corresponding to the W data wavelengths. From figure 1, we can see that each node is equipped with one optical add-drop multiplexer (OADM), and three pairs of optical transceivers. The first pair consists of a receiver and a transmitter fixed-tuned to the control wavelength, and is part of the control module. The second pair of transceivers consists of a pair of tunable transceiver that can receive and transmit bursts from/to all wavelengths in the ring. The third pair of transceiver is a pair of fixed tuned transceiver enabling data transmission to and data reception from the access network to the OBS ring. In addition, each node has two kinds of first-in first-out (FIFO) queue sets. One set buffers the data bursts for subsequent transmission, thus, there are $N-1$ transmission queues, one for each of the possible $N-1$ destinations in the ring. The other set is the token queue for buffering tokens and serving them according to their arrival order.

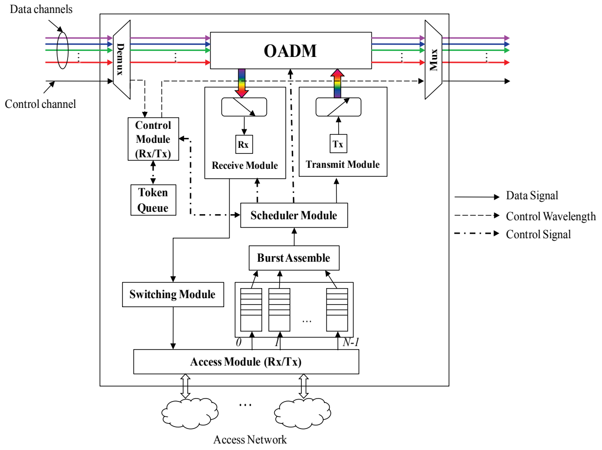
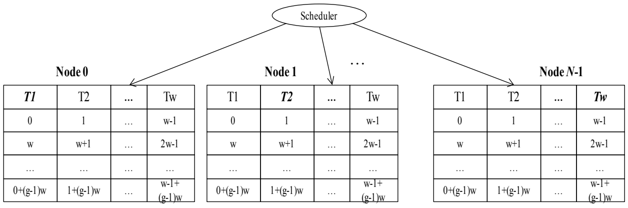


Figure 1 Node architecture based on TT-TR

2-2. Previous works

This part briefly reviews our previous work on managing tokens and MAC protocols for solving contention. There exist three kinds of contention in the TT-TR based OBS ring networks: source contention, channel contention and receiver contention. Different MAC protocols have been proposed to solve them respectively based on multiple tokens. As tokens were assigned to manipulate the accessibility of each wavelength to solve the source contention, the token-release time by each node is crucial to the network performances. The faster tokens are released, the more efficient network resources can be used. Therefore, the paper applies the Token-Release after Transmitting Control-header (TRTC) protocols in which node releases tokens right after transmitting BCPs. To solve the channel contention, the Control Information Table (CIT) was resorted to. Finally, the Queue-Grouping Round-Robin (QGRR) mechanism was proposed to solve the receiver contention. Their processes are briefly described as follows.



Node 0

T1	T2	**...**	Tw
0	1	...	w-1
w	w+1	...	2w-1
...	...	...	...
0+(g-1)w	1+(g-1)w	...	w-1+ (g-1)w

Node 1

T1	***T2***	**...**	Tw
0	1	...	w-1
w	w+1	...	2w-1
...	...	...	...
0+(g-1)w	1+(g-1)w	...	w-1+ (g-1)w

Node *N*-1

T1	T2	**...**	***Tw***
0	1	...	w-1
w	w+1	...	2w-1
...	...	...	...
0+(g-1)w	1+(g-1)w	...	w-1+ (g-1)w

Figure 2 Assignments of Queue Groups in QGRR

W tokens are assigned to the *W* data wavelengths, each token per data wavelength. CIT is a table list which records the reservation information for every burst that was sent out from and cuts through the current node; in addition, it records the time information when a burst arrives at its destination and when the reception of the last bit of the burst is finished. While in view of QGRR, the *N* destination queues are grouped with a total group size equal to the number of tokens. Each Queue Group (QG) is further assigned to each token as shown in figure 2. Therefore, each time when a node captures a token, it cannot execute RR among all the *N* queues but only within the queue memberships in its own queue group. As bursts transmitted on different wavelengths are destined to the different destination nodes, the probability that multiple bursts arriving at the same destination nodes from different wavelengths is eliminated. After solving the mainly contention problems, QoS provisioning will be discussed in the following sections.

3. QoS PROVISIONING SCHEME

In this section, the QoS provisioning schemes for the delay-sensitive (C1) and loss-sensitive (C2) services are discussed respectively.

3-1. Access Protocol for Delay-Sensitive Service

In view of C1 traffic, the End-To-End (ETE) delay should be reduced as much as possible. The ETE delay involves two parts of delays: the queuing delay due to the time waiting for tokens and the propagation delay due to the time transmitting a signal from one point to another. The queuing delay is decided by how frequent a node captures tokens and how frequent queues are served after getting tokens; the propagation delay is dependent solely on the physical distance and two thirds the speed of light, i.e., once the source-destination pair is determined, the hop distance as well as the propagation delay are. Reducing any of the two kinds of delay can help reducing the ETE delay. In view of the former queuing delay, the frequency of getting tokens by a node is determined by the ring size and the token releasing/rotating time. The faster tokens can rotate, the more frequent a node can get tokens. As it is not a viable method to reduce the ring size so as to increase the token rotating time, we consider increasing the servicing speed for real-time destination queues to guarantee QoS for C1 traffic. To reduce the queuing delay for C1 traffic, the C1 destination queues have the priority to use tokens. That is to say, each time when a node gets a token, the priority of queue scheduling is given to the C1 destination queues. If the preferred C1 destination queue is empty, the transmission chance is then given to the traffic buffered in the best-effort destination queues. By doing this, C1 destination queues usually have the priority and their queuing delays are reduced as much as possible.

3-2. Access Protocol for Loss-Sensitive Service

There is no strict delay requirement for C2 applications, but the best efforts are made to reduce the loss rate. The QGRR scheme, which has solved the receiver collision, is applied to serve the C2 traffic. That is to say, each time when a node serves the C2 destination queues according to a captured token j, the queues within the queue group (QG) of token j are selected according to round-robin (RR) manner and served. By doing this, the burst loss for both the C1 traffic and the C2 traffic is reduced, but cannot be avoided completely. This is because general Round-Robin (GRR) is applied within C1 destination queues to guarantee the queuing delay for C1 traffic. As if the amount of queue candidates is reduced, the probability of wasting the chance of using tokens for C1 destination queues is increased, as well as the queuing delay. Therefore, by applying GRR to C1 traffic and QGRR for C2 traffic, the burst contention between C2 bursts are avoided but the burst contention between C1 and C2 bursts cannot be avoided completely. To further reduce the burst loss for C2 traffic, the nearly earliest-free-time (NEFT) algorithm is further proposed.

In NEFT, a new token format and the destination information table (DIT) in each node are used. *N* additional fields denoted by "T_finishi" (T_finish0, T_finish1, …, T_finishn) in tokens are used to indicate the latest available time of the i-th destination. DIT used in each node also has N fields and are called "D_finishi" (D_finish0, D_finish1, …, D_finishn). They are used to record the latest updated available time of each destination node obtained from all passing tokens. It is so-called nearly EFT because the time information in DIT is collected from the limited rotating tokens in a distributed way, and they reflect the EFT as close as possible to the real EFT of all destination nodes, but not absolutely. Each time when a node captures a token, it compares all the "T_finishi" in the token with all the "D_finishi" in DIT. If T_finishi > D_finishi, the value in "D_finishi" is replaced by the value in "T_finishi". By doing this, fields in DIT always record the latest information about the network from all tokens. The processes of serving a C2 burst are described in the following steps.

Step 1: A node captures a token j and get the chance to serve C2 queues;
Step 2: Selects a C2 queue according to QGRR;
Step 3: If the C2 queue is empty, go to step 5. Otherwise, node refers to CIT to check if there is channel contention. If yes, go to step 5; otherwise, go to step 4;
Step 4: Refers to CIT and DIT to check if there is receiver contention, if yes, go to step 5; otherwise, generates and sends BCP for the C2 burst, releases token j, after offset time, transmits the C2 burst;
Step 5: Releases token *j* to next node;

4. PERFORMANCE EVALUATION

4-1. Parameters for Simulation

The network performances of the proposed QoS provisioning mechanisms are evaluated by simulation through OPNET simulator. An OBS ring network with 12 nodes is evaluated and two adjacent nodes are separated by 2km. The number of wavelengths per fiber is set to 5 and running at the rate of 1Gbps, one for control channel and four for data channels. The average burst size is set to 25,000bytes, i.e., 0.2ms in time. Data packets from the access networks arrive at each node in an exponential distribution. The packet size is assumed to follow a truncated exponential distribution. After packets arrive at each ingress node, the node assembles them into bursts according to their destination IDs.

4-2. Simulation Results Evaluation

As the propagation delay in the ring networks cannot be reduced, the network delay is evaluated in terms of the average queuing delay. Simulation results of the proposed QoS provisioning mechanisms are shown in figures 2 and 3. The network performances of C1 and C2 are compared with each other and also with those of no QoS provisioning, i.e., when they were served without any difference. Figure 3 shows the average queuing delay for C1 and C2 traffic with and without QoS provisioning. The curve in the center shows the average queuing delay when not applying QoS and serving both C1 and C2 without any difference. After applying QoS provisioning, the network performance of average queuing delays for C1 and C2 are differentiated and the average queuing delay of C1 traffic has been reduced significantly. Oppositely, the average queuing delay of C2 traffic has been increased dynamically in order to reduce the burst loss as shown in figure 3. The curve in the center of figure 4 shows the burst loss rate for C1 and C2 without QoS provisioning. After applying QoS provisioning, the network performance of burst loss rate for C1 and C2 are separated and C2 shows much improved burst loss rate than those of C1 and schemes without QoS provisioning. Oppositely, the burst loss rate of C1 is increased due to its fast transmission to insure real-time transmission.

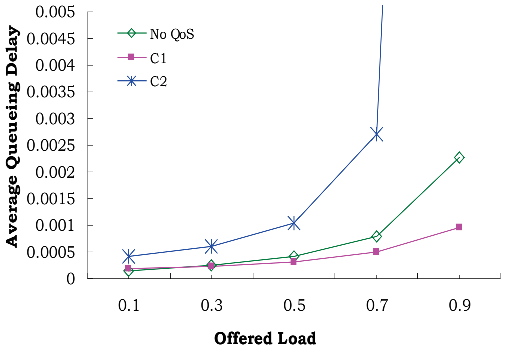


Figure 3 Average Queuing Delay

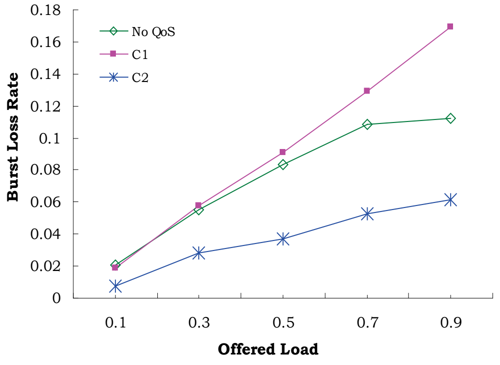


Figure 4 Burst Loss Rate

In order to further evaluate the proposed QoS provisioning mechanisms, we simulated the proposed mechanisms for the C1 and C2 bursts under different network parameters. The network applying bursts with the average size of 0.5ms in time is also simulated and compared with the one using 0.2ms in time. The simulation results are shown in figures 5 and 6. Figure 5 shows the average queuing delays for the C1 bursts with the average burst size of either 0.2ms or 0.5ms have much better performances than those of the C2 bursts. Figure 6 shows the burst loss rates for the C2 bursts with either the average burst size of 0.2ms or 0.5ms have much better performances than those of the C1 bursts. As a result, the proposed QoS provisioning mechanisms can satisfy the delay requirement of the C1 bursts and the loss requirement of the C2 burst, and their performances are differentiated in terms of the delay and loss.

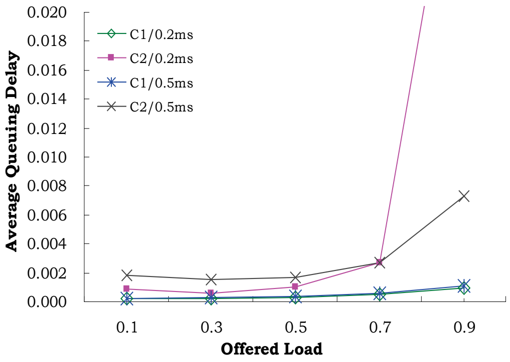


Figure 5 Average Queuing Delay

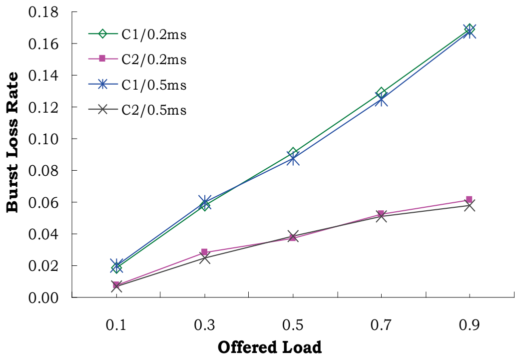


Figure 6 Burst Loss Rate

5. CONCLUSIONS

In this paper, we studied the QoS provisioning mechanisms for both the TT-TR based OBS ring networks. Two classes of services were considered: delay-sensitive/class 1 (C1) and loss-sensitive/class 2 (C2). C1 applications have restrict limit in delay while C2 applications have no restrict limit in delay but require as less burst loss rate as possible. According to their different, different QoS mechanisms were considered. In view of reducing delay for C1 applications, the average queuing delay were reduced by giving priority to Cl destination queues. In view of reducing loss for C2 applications, QGRR with the help of NEFT mechanisms were applied. The network performances of the proposed QoS provisioning mechanisms were simulated and evaluated. The proposed access protocols performed well in differentiating the network performances for Cl and C2 services, and satisfying the different QoS requirements of C1 and C2 applications.

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