A Performance Comparison According to Number of Wavelengths and Topologies on PCSA Reservation Mechanism for OBS

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Abstract

A performance comparison according to different number of wavelengths and topologies on OBS has been studied in this paper. Preemptive Channel Scheduling Algorithm (PCSA) has been used as reservation mechanism in OBS. In terms of performance criteria, loss rate in bytes, access delay and end-to-end delay are considered. A 2-state MMPP (Markov Modulated Poisson Process) traffic generator is used. Four different types of Mesh and Ring topologies are used. NS2 Network Simulation tool is used for our tests. In OBS algorithms, bursts are created using a hybrid model that takes into account both timeout and maximum length threshold mechanisms. In nodes, in order to satisfy QoS requirements, priority based queuing and Regulative Wavelength Grouping (RWG) are used. In priority based queuing, packets (bursts) are sent according to their priority order. In this study, the effects of generated traffic according to the topologies and the effects of increased number of wavelengths are shown by access delays. According to the simulation studies, the success of byte drop rate increases while the number of wavelengths increases. The results that obtained on mesh topologies are better than the results of ring topologies according to our simulation results.

1. Introduction

Optical Networks provide solutions to many problems (i.e. increase of BW demand, etc.) on existing communication networks. They provide a common network infrastructure for different types of service with high capacity. Adjustment of bandwidth on demand is also possible in a flexible way [1]. Accordingly, three main optical switching methods are becoming appealing: Optical Circuit Switching (OCS), Optical Packet Switching (OPS) and Optical Burst Switching (OBS).

Data is transmitted over an existing lightpath with sufficient bandwidth in OCS. The general mechanism of OPS technique is similar to electronic packet switching. In OPS, every packet has an optical header. In intermediate nodes, this header is processed with O/E conversion and data is delayed by using fiber delay lines (FDL) in optical domain while the header is processing, so the routing for optical packet is done. Although it is similar to electronic packet switching in terms of basic properties, it lacks of using store & forward mechanisms like electronic routers because of the lack of optical RAM. Usages of FDLs are preferred in order to avoid packet loss in case of contention.

OBS is designed as an intermediate solution between OCS and OPS. An OBS network consists of core nodes and end devices which are connected to each other with fiber lines. An OBS core node consists of an optical cross connect (OXC), electronic switching control unit and signaling processors [2]. An OXC is a non-blocking switch that transmits the optical signal received from input port to the output port without any conversion to electronic signal. OBS end devices consist of an OBS interface which may be an IP router, ATM switch or Frame Relay switch. Each OBS end device is connected to an OBS ingress core node. End devices collect the traffic coming from different networks (ATM, IP or FR), arrange the traffic according to the address of the destination end devices and create the bursts at variable size data units [3]. A control packet that provides information about the burst such as burst length, destination and class of service is generated for each burst. This control packet is sent to the network before the burst. It propagates through the burst's path and processed on each node in electronic domain. The function of control packet is to inform the intermediate nodes about the burst and to create a temporary reservation on each needed node between the source and the destination. [4].

In OBS literature, there are two main approaches for reservation process, immediate reservation and delayed reservation [4]. Immediate reservation is used in Just In Time (JIT) [5], delayed reservation technique is used in most of the other approaches like Horizon [6], Just Enough Time (JET)[3]. In our previous study [7], we compared the existing reservation techniques JIT, JET, Horizon and decided that JET is the best one. We have shown that PCSA is better than JET in terms of byte drop rates in [8].

In this study, the effects of different number of wavelengths and different topologies on PCSA reservation mechanism by using RWG [9] QoS algorithm, are shown by simulation results.

This paper is organized as follows in section 2; PCSA(Preemptive channel scheduling algorithm) and RWG(Regulative Wavelength Grouping) QoS Algorithm of OBS have been summarized. In section 3, our simulation environment is described, in section 4 our tests are discussed and in the last section our study discussion is concluded.

2. PCSA Reservation Mechanism and RWG QoS Algorithm in OBS

2.1. PCSA Reservation Mechanism

PCSA includes some improvements to JET to minimize the gaps between bursts and to increase channel utilization with consideration of quality of service. If a collision occurs on the outgoing wavelength for a burst, JET only uses wavelength conversion under LAUC_VF(Latest Available Unscheduled Channel with Void Filling) form to overcome collision. In case, if any free wavelength from the beginning to end of the burst service time cannot be found, the burst will be dropped. However by arranging the reservation of reserved wavelengths, a free space can be found for the incoming burst. Since OBS uses the early reservation technique it gives us the opportunity to do this kind of arrangements. In PCSA, with consideration of quality of service, the on demand wavelength conversion technique of [10] and segmenting burst technique of [11] are used to improve the channel utilization. These techniques bring into much computational load however they have a desirable contribution on success.

2.2. RWG QoS Algorithm

In OBS networks, providing quality of service is a challenging problem. We can examine QoS in OBS from two different points of view: QoS mechanisms at edge nodes and QoS mechanisms at core nodes.

In our study, packets arriving to edge nodes are buffered according to their destinations and priorities in to different queues and then bursts are created. Therefore, each burst will consist of packets that have the same destination and the same class of service. After the burst creation procedure each burst queued at entry points of links according to their classes. If a higher priority traffic class includes bursts in its queue, these bursts will be prioritized for transmission and then transmitted according to their destination.

In the core nodes, the reservation is made before the arrival of a burst. A control packet should be sent to the link just before the burst in order to make the reservation. This control packet is transmitted to the next hop without any delay just after the switching process. It is difficult to prioritize the traffic classes in the core nodes because of OBS structure. To cope with this difficulty, in our previous study we propose a new QoS mechanism called Regulative Wavelength Grouping (RWG) [9]. In RWG mechanism, the number of wavelengths for each traffic class, is arranged for adjusting the burst drop probability of traffic classes under a specific threshold value and is used for providing priority levels in core nodes.

RWG arranges dynamically the number of wavelengths that are reserved to each traffic class, in nodes. Thus RWG should guarantee the throughput of each traffic class in core nodes. In RWG, the number of wavelengths reserved for a given traffic class (Ci) at time t is shown as Wci. The drop rate of class Ci (i = 0, 1, 2) cannot increase above a predefined maximum threshold value Pthresh(Ci) for the whole network. There are two approaches for RWG: Regulative Static Wavelength Grouping (RSWG) and Regulative Dynamic Wavelength Grouping (RDWG) [9]. RSWG is less complex and simpler than RDWG, but RDWG is more efficient in terms of network performance [9]. In this study we used RDWG algorithm for support QoS in core nodes.

3. Simulation Environment

Our simulation is performed with the Network Simulator 2 (NS2) framework. Every node operates as both edge and core node. The edge node collects packets from the client network at the entry points of the OBS network, and prepares bursts to be sent to the core network. The core node's function is switching bursts to their output ports. We assume that all core nodes have full wavelength converters.

In our simulation tests, optical links between the nodes have two versions. First version has 9 wavelengths where 8 of them are used as data channels. Second version has 17 wavelengths where 16 of them are used as data channels. For each configuration, one wavelength is used as control channel. Network links are duplex with a 10Gbit capacity on each way.

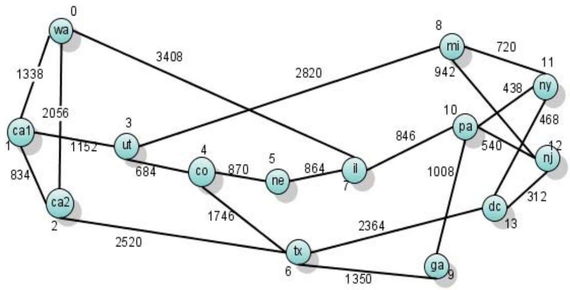

Fig. 1. NSFNET Mesh Topology

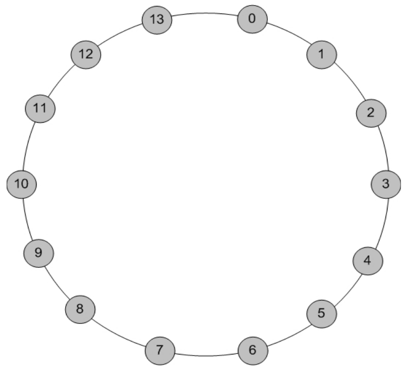

Fig. 2. Complex Ring Topology

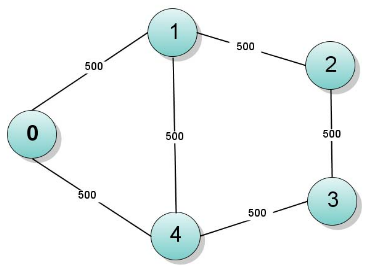

Fig. 3. Simple Mesh Topology

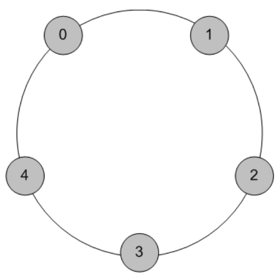

Fig. 4. Simple Ring Topology

NSFNET, Complex Ring, Simple Mesh and Simple Ring Topology have been chosen as four different topologies. Network topologies are shown in Fig. 1, 2, 3 and 4. The distances between nodes on Simple Mesh, Simple and Complex Ring topologies are 500 km.

In our simulation, two state MMPP traffic generator is used. We generated three different sizes of packets. 10% of traffic is 50 bytes length packets, 40% of traffic is 500 bytes length packets and 50% of traffic is 1500 bytes length packets [12].

The generated traffic also consists of three Classes of Service (CoS): Class of Service 0 (CoS0), Class of Service 1 (CoS1) and Class of Service 2 (CoS2). CoS0 is used for high priority traffic (i.e. Real Time Traffic). CoS1 is used for medium priority (i.e. Video on Demand) and finally CoS2 presents best effort internet data traffic with the lowest priority. Generated packet percentages of traffic classes from high to low priority are shown in Table 1.

Table 1. Packet Percentages of Traffic Service Classes

CoS0	CoS1	CoS2
10%	40%	50%

Every edge node in the network generates packets to send to each one of the other edge nodes (one destination per packet), according to a uniform distribution. In edge nodes, burst assembly algorithm uses a hybrid method which includes maximum burst size and burst timeout control mechanisms. Maximum burst sizes of each traffic class are 32KB for CoS0, 64KB for CoS1 and 96KB for CoS2. Burst timeouts of each traffic class are 250 µsec for CoS0, 500 µsec for CoS1 and 750 µsec for CoS2. In edge nodes, there are also 500KB buffers (one buffer per CoS) which work in a prioritized manner.

It takes an amount of time to process the reservation messages in core nodes. The selected offset time for bursts is related to maximum number of hops for a packet and the processing time of the reservation message. A fixed processing and offset time is chosen for PCSA algorithm. For PCSA processing time is set to 30 µsec, offset times is set to 250 µsec [8]. Total simulation time is 5 seconds. Table 2 shows number of wavelength limits set for the RDWG algorithm [9].

Table 2. Parameters of RWG

	CoS0	CoS1	CoS2
Max W Number	8	7	6
Min W Number	8	5	3

4. Simulation Results

Performance criteria for comparison; byte loss rates, access delay and end-to-end delay are taken into consideration.

4.1. Wavelength Related Results

This section includes byte drop rate, access delay, and end-to-end delay results according to different number of wavelengths.

In Fig. 5, byte drop rates of PCSA for different service of classes are shown according to the traffic priorities. In 16 wavelengths version, the amount of traffic among the network is twice of the amount of traffic in 8 wavelengths version. Since each wavelength is able to carry the same amount of data, the same load value can be applied to both versions. But, statistical multiplexing manner affects the results on OBS as shown in Fig. 5.

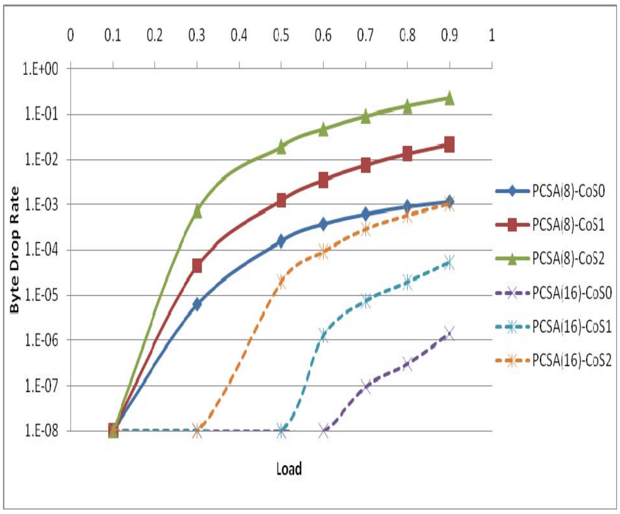

Fig. 5. Byte Drop Rates on NSFNET According to Number of Wavelengths

At the same time, the effects of QoS algorithms can be seen apparently because of the increase in the number of wavelengths. The success of high priority traffic is better in 16 wavelengths version and also the success of low priority traffic is better than 8 wavelengths version.

In Fig. 6, according to wavelength number access delay values of OBS are shown under multi-service traffic structure on NSFNET topologies.

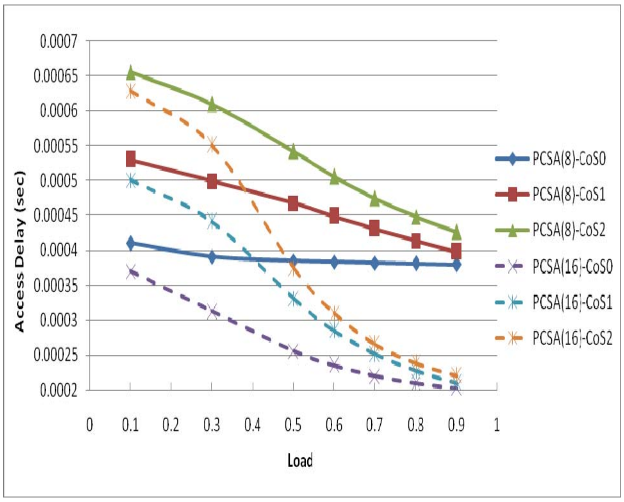

Fig. 6. Access Delay on NSFNET According to Number of Wavelengths

OBS, we can examine the time for a packet to take service on optical domain in three stages. At first stage, the packets are classified for their destinations and priorities. Then, they are stored in the buffers according to this classification for waiting burst assembly. Second, the created bursts wait in another buffer according to their traffic class for a free outgoing channel. At this stage, the buffers are served in a head of line (HOL) manner. At last stage, the created bursts wait an offset time before being sent on the outgoing channel. This offset time allows the control packet to make necessary reservations on intermediate nodes. In OBS, the access time for a packet comes to ingress node is the total delay amount of these three stages.

The same burst creation methods are used for both of wavelength versions. As shown in Fig. 6, access delay results of 16 wavelengths version are lower than 8 wavelengths version. This is because the burst creation method is able to create bursts faster if there is dense incoming data.

In OBS, the burst assembly time and offset delay time are extremely high compared to the delay of burst waiting time in prioritized buffer for a free outgoing channel. During burst creation, burst threshold value and time are chosen according to the traffic priorities. These parameters are chosen lower for high priority traffic. Fig. 6 shows that access delay values of high priority traffic are lower than the access delay values of low priority traffic for the same number of wavelengths.

In OBS, while the traffic load increases the burst creation in burst assembly stage can be done faster. Because, under high load conditions, the bursts reach the maximum burst length limit and then they are created. On the other hand, while the load increases the waiting time of bursts in buffers will increase too. However, compared to the burst assembly delay, the waiting time in burst buffers is very short. So just it is seen in Fig. 6, the access delays are decreasing in OBS while the load increases.

End-to-End Delay can be defined as the transmission time of a data packet from ingress node to egress node for the burst. In other words, it is transmission time of successful data packets through the network. For OBS, the end-end delay value can be calculated as access delay plus propagation delay plus FDL delays (if used). Since the FDL delay value is too small compared to the access and propagation delay values, we can say that for all optical networks;

End-to-End Delay ≈ Access Delay + Propagation Delay

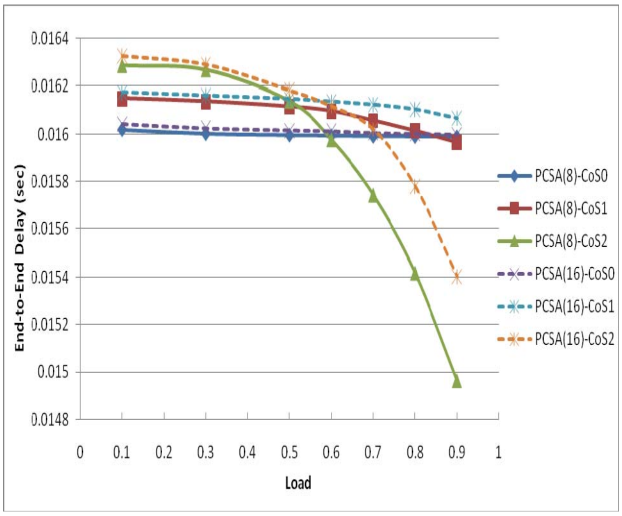

Fig. 7. End-to-End Delay on NSFNET According to Number of Wavelengths

In this work, the propagation delay is constant for packets that are from the same source to the same destination. Because algorithms like deflection routing are not used for collision resolution. So we can say that the end-to-end delay values of OBS are changing according to the access delay values. In simulation results we see that, since the long distance packets have more loss probability than short distance packets, the mean end-to-end delay value of packets decreases while the load increases. In OBS, the burst assembly times and offset delays differs for each traffic service class so that the end-to-end delays differ for each class. In 16 wavelengths version, since there are lots of packets that arrive to their destinations and the average end-to-end delay is calculated, the results are higher than 8 wavelengths version.

In both cases, when the load increases, reduction in end-to-end delays of CoS2 bursts depends on the QoS mechanism. The drop rate of low priority traffic increases in case of contention of low and high priority traffics. When contention occurs, low priority bursts which have longer distance between its source and destination drop, the other ones are transmitted to their destinations. This situation becomes distinctive as the traffic load increases. The slopes of access and end-to-end delays are different from each other in the same cases because of the reason mentioned above.

Fig. 7 shows the effects of QoS mechanisms and the number of wavelengths which are used in our tests. The effect of the chosen algorithm on end-to-end delays is more apparent in 16 wavelengths version.

4.2. Topology Related Results

This section includes the test results on mesh and ring topologies. In the graphics, just the high priority traffic (CoS0) results have been presented. Low priority traffic (CoS1 and CoS2) results are similar to high priority results and have not been presented in graphics.

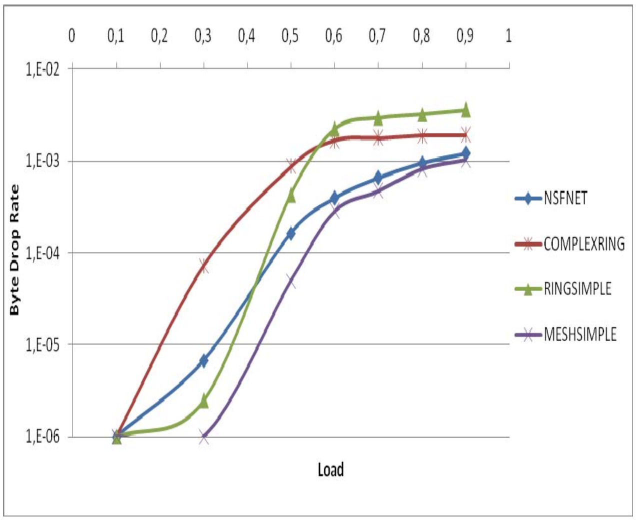

Fig. 8. Byte Drop Rates According to Topologies

As shown in Fig. 8, simple topologies have lower byte drop rates than complex topologies in low priority traffic. After 0.5 load, mesh topologies are more successful than ring topologies in term of byte drop rates. The traffic generations over topologies are decided according to the highest loaded link. Traffic load distributions may differ for each topology. Traffic distributions are heterogeneous for mesh topologies and homogeneous for ring topologies. In ring topologies, more contentions occur because of this high traffic load and there is more data loss than mesh topologies.

Fig. 9 presents the access delay values for different topologies. Simple topologies have lower byte drop rates than complex ones since more packets are generated on simple topologies for same traffic distributions. Furthermore, on simple topologies, burst creation processes faster than complex topologies since more packets are generated on one node.

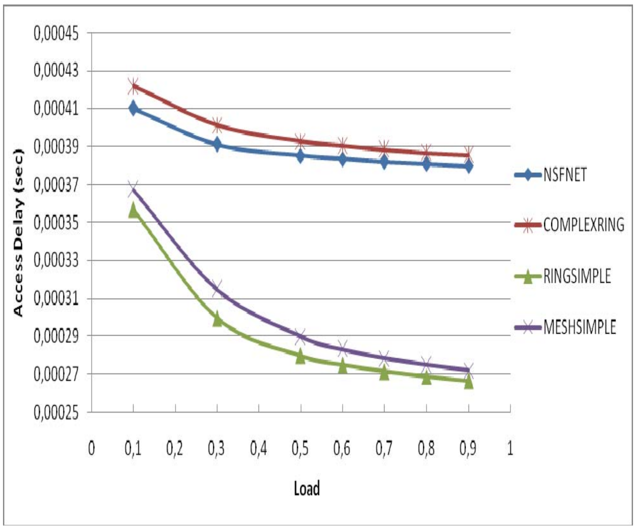

Fig. 9. Access Delay According to Topologies

As mentioned before in section 4.1, besides access delay values, the other important parameter is propagation delay for end-to-end delays. Propagation delay values differ by topology types. Fig. 10 shows the expected end-to-end delay values of simple topologies which are lower than other topologies. NSFNET end-to-end delays are significantly higher than complex ring topology because of long distances between nodes.

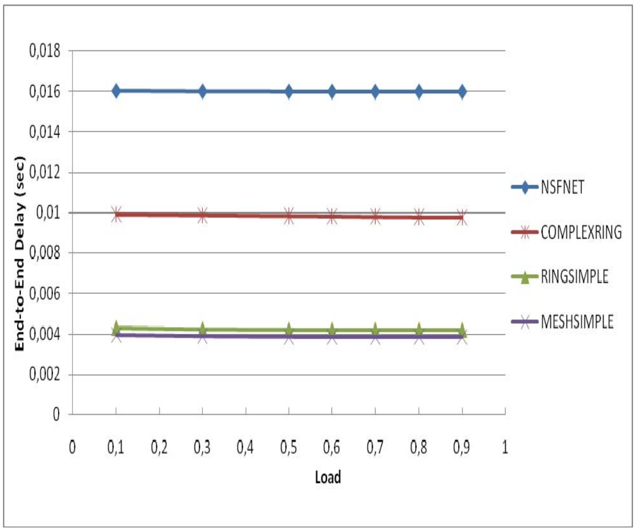

Fig. 10. End-to-End Delay According to Topologies

5. Conclusion

The effects of different number of wavelengths (8 and 16) on PCSA by using RDWG QoS algorithm have been studied on NSFNET topology and also the success of byte drop rates have been examined due to the increase in number of wavelengths. These results show the positive and distinct effect of PCSA and used QoS algorithms in case of increasing number of wavelengths. Along with high performance effects, the disadvantage of this situation is the increase in cost. Also, low access delays values are obtained by using same parameters and by changing the number of wavelengths on different simulation tests. In the latter section, mesh and ring topologies have been studied. In our studies, the results obtained on mesh topologies are better than ring topologies in terms of byte drop rates. Therefore, we indicate that mesh topologies have advantages on variable length data in OBS technologies.

6. Acknowledgment

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