Optical Burst Switching Network Testbed

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Abstract: In this paper, several key technologies of optical burst switching (OBS) network are implemented and experimentally verified. The TCP performance over OBS is experimentally investigated on this testbed and multi-QoS traffic transmission on the testbed are demonstrated as well. Currently, an interconnection experiment between OBS and GMPLS network are also reported.

Keywords: optical burst switching, TCP, QoS

1. Introduction

Optical burst switching (OBS) [1] has been receiving increased attention worldwide as a promising technology for building the next-generation network. In OBS networks, a control packet is sent ahead of time on control channel to reserve resource at intermediate nodes for data burst, and then the associated data burst consisting of multiple assembled IP packets are transmitted and switched along the configured route all-optically in OBS networks.

To implement the OBS network, a lot of challenges must be solved. In physical layer of OBS network, high-speed assembling and scheduling technologies are required as well as burst-mode transmitter and receiver [2-4]. In higher layer, OBS technology is designed for supporting future IP over wavelength division multiplexing (WDM) network, and due to the domination of TCP traffic in current IP traffics, it is very important to investigate the performance of TCP over OBS network. Some simulation results show that the TCP performance is very sensible to burst loss [5-6]. However, there are other different results showing that the TCP performance over OBS network is much more robust even in the case of burst loss probabilities as high as 1% [7].

Quality of service (QoS) provision issue becomes more and more important in OBS networks with the emergence of applications with different demands. In general, QoS can be provided by introducing differentiation at some point in the network, such as differentiated offset times, differentiated burst assembly, and differentiated scheduling [8-11].

In this paper, an OBS testbed is developed to provide a platform for investigating above mentioned key technologies in OBS network [12]. Burst assembling and scheduling are implemented with high-speed FPGA technology and burst-mode transmitter and receiver are demonstrated as well with fast clock and data recovery

(CDR) time and high receiving sensitivity. Based on this OBS testbed, the TCP performance over OBS is experimentally investigated [13]. Experimental results show that the performance of TCP traffic is greatly degraded by burst loss probabilities. Moreover, attaching higher QoS level to TCP traffic is also contributive to the improvement of TCP performance. A multi-QoS traffic transmission is also demonstrated on the OBS network testbed [14], and puts an extra effort on TCP transmission over OBS to investigate its end-to-end performance.

2. OBS network testbed

Fig.1 shows the OBS network testbed. It consists of three edge nodes and four core nodes. Each edge node is connected with core node through a pair of fibre links in which three WDM data channels and one dedicated control channel are included. Bit-rate for all channels is 1.25Gb/s. Edge node provides user interface including 8 Fast Ethernet ports and 2 Gigabit Ethernet ports to access IP-based traffic. Input packets are classified according to their egress nodes and QoS demands, and then assembled into data bursts based on assembly algorithm. Assembled bursts are launched into OBS network following a control packet by an offset time. Core node functions as electrical processing of control packets and configuration of optical switching matrix according to the information provided by control packet. Finally, IP packets are disassembled out of bursts at egress edge node and dispatched to their corresponding destinations.

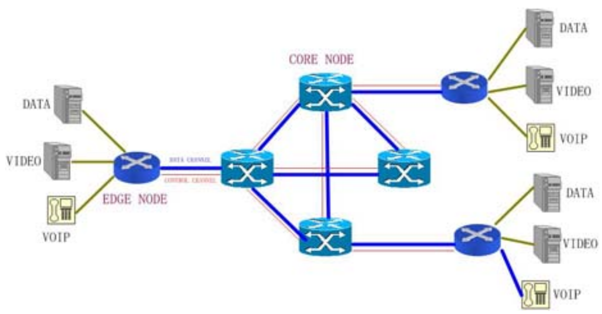


Fig.1. Optical burst switching network testbed.

With the consideration of flexibility and scalability, burst assembler and scheduler in the testbed are implemented with embedded processor and high speed FPGA respectively. When latest available unused channel with void filling (LAUC-VF) [15] algorithm is employed, maximum processing delays of scheduler at core node and edge node are 2.5us and 10us respectively. Moreover, an optical switching fabric with switching speed less than 100ns is also developed [12].

3. Experimental Verification

When FF-VF algorithm is employed, Fig.2 shows scheduling result for bursts with three kinds of QoS demands (their offset times are 1750us, 900us and 50us respectively). The upper of this figure shows the BHPs on control channel, and the corresponding bursts are showed in the two different data channels at the bottom of this figure. Due to the fact that the load is different for traffic with different QoS demands, bursts with different lengths are generated from assembler. Only bursts with lower QoS demand, namely with shorter burst length, are assigned to low priority channel λ1.

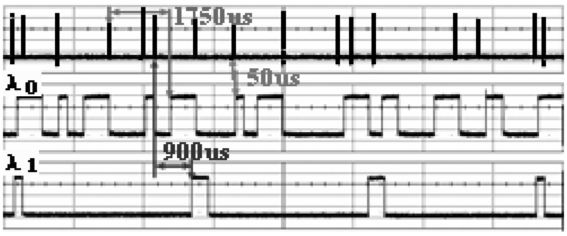
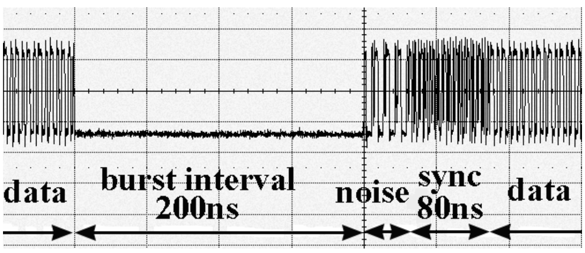
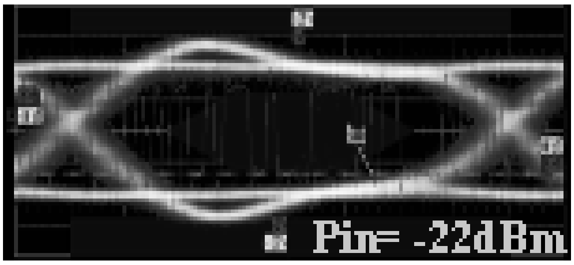


Fig.2. Scheduling results at edge node

Fig.3(a) shows the measurement results of the burst-mode receiver. In this OBS testbed, there are preambles of 200ns attached to the header of each data burst for fast recovery of clock and data at receiving end. It can be seen from this figure that it actually takes less than 80ns to recover the clock and data correctly form incoming data burst, which means that the synchronization preambles can be reduced further to improve the link utilization efficiency. Even in the case of the 200ns time interval of two neighbouring bursts, the two data bursts also can be received correctly, shown in Fig.3(a), that indicates the 10us guard band for data bursts is enough and also can be greatly reduced to improve transmission efficiency. In addition, the clearly opened eye-diagram of bursts at receiving power of -22dBm, which is shown in Fig.3(b), means the high receive sensitivity of the designed burst-mode receiver.



(a)



(b)

Fig.3. Receiving Bursts (a) and Eye-diagram(b)

4. TCP Transmission Experiments

The experimental setup for TCP transmission is shown in Fig.4. Only two edge nodes and one core node are used for simplicity. Standard interface such as Fast Ethernet and Gigabit Ethernet are provided to access IP-based traffic. In this experiment, burst assembly algorithm with fixed time and length threshold is applied, and for burst scheduling algorithm LAUC-VF is used.

As shown in Fig.4, a TCP server is connected to one edge node and the client is connected to the other one, by which a TCP connection can be set up through the OBS network. Four Gigabit Ethernet ports of the IP data quality analyzer are connected to the two edge nodes respectively, by which controllable traffic load is provided to simulate TCP traffics with different QoS requirement in OBS network. In the TCP transmission, a maximum congestion control window of 64KBytes and maximum segment size of 512Bytes are employed in the TCP server.

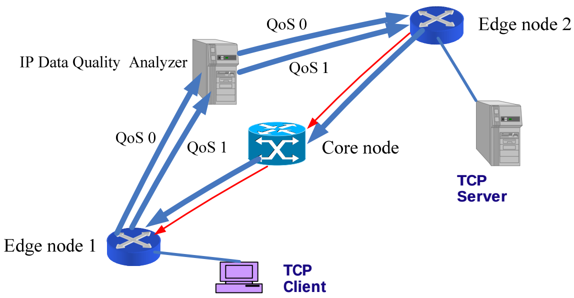


Fig.4. TCP transmission experiment in OBS testbed

5. Experimental results and discussions

In this paper, the TCP performance over OBS is experimentally investigated on OBS testbed [5][6]. Experimental results show that the performance of TCP traffic is influenced in the case of burst loss, both for ACK burst and data burst. But ACK burst loss affect less than data burst loss on TCP throughput performance, caused by TCP slide Window control mechanism. Moreover, considering that QoS provision is provided in OBS network, contention resolution mechanism of dropping ACK burst when network is busy is proposed in further investigations.

5.1 TCP throughput

In TCP transmission experiment, the network is configured to dropping bursts at certain loss probabilities. The assembly time is set to 1ms, burst length is 90kbytes and offset time is fixed to 1ms. One FTP server connected with edge node 2 is set to send data to TCP client on edge node 1 through OBS testbed. The burst loss probability varies from 1% to 0.1% to investigate the TCP transmission performance in OBS network.

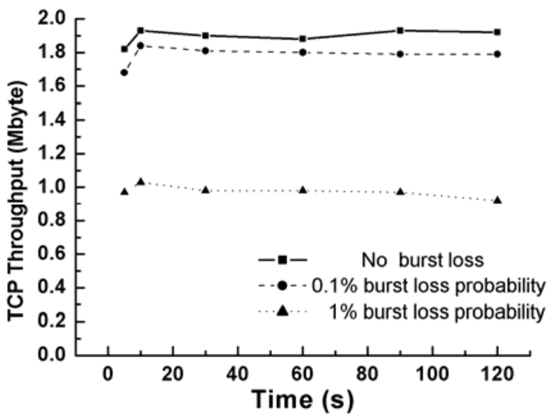
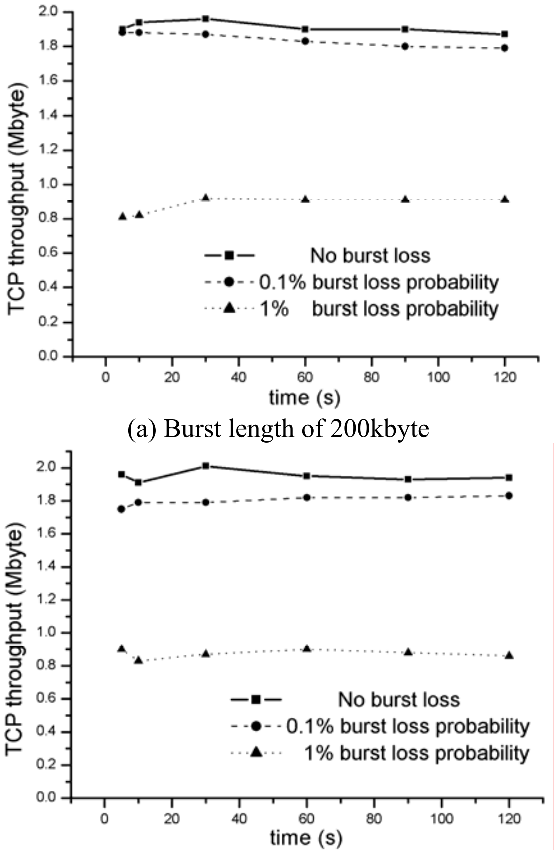


Fig.5. TCP throughput in OBS network

According to the experiment results shown in Fig.5, burst loss probability of 0.1% only causes an average throughput decreasing of 6%, compared with the case of no burst loss. As the burst loss probability increased to 1%, the performance of TCP throughput degrades greatly. The average throughput decrease to 50% compared with the case of no burst loss. This is different from the result in [7], in which TCP throughput only decreased 5% in average in case of burst loss probability of 1%. Further experiments are made about how the burst loss affect TCP throughput as the burst length changed. In this case, the burst length is set to 200kbytes and 400kbytes respectively.



(a) Burst length of 200kbyte

(b) Burst length of 400kbyte

Fig.6. TCP throughput with different burst length

Fig.6.(a) and (b) show that as the burst length increased to 200kbyte and keeping constant burst loss probability of 0.1%, only 3.7% TCP throughput decreasing is achieved which means better TCP performance is obtained. As increasing the length to 400kbyte, the average decreased throughput is only 8%. It can be explained that there is a tradeoff between burst lengths when transmitting TCP flows. Bandwidth efficiency can be improved as the burst becomes longer, but TCP sources synchronization will decrease when lose large burst.

From this experiment it can be concluded that OBS network is supposed to be robust in TCP traffic transmission under burst loss probability below 0.1%.

For TCP transmission over OBS network, TCP setup, ACK packets and data segments are all buffered and then assembled into bursts at the edge node, and this causes to the increasing of round trip time (RTT) in TCP layer and results in the decrease of available TCP bandwidth, that is so called delay penalty. This conclusion is proved by both of experimental results and simulation results. As shown in Fig.7, with the increasing of assembling time, the RTT in TCP layer increases linearly and causes the decreasing of TCP bandwidth from 86Mb/s to about 25Mb/s for one TCP thread. Even double the TCP threads, the TCP bandwidth still decreases to less than 50Mb/s. In this experiment, the RTT is roughly measured with Ping command.

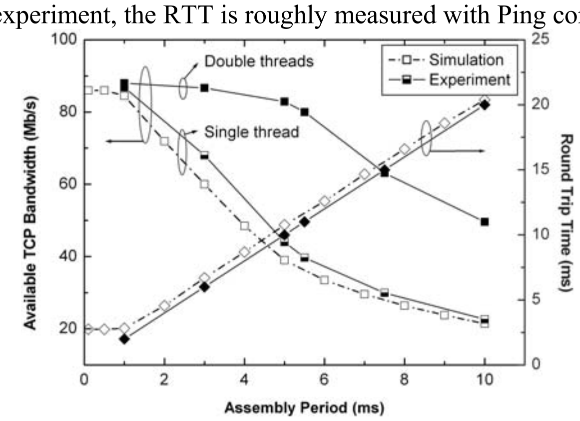
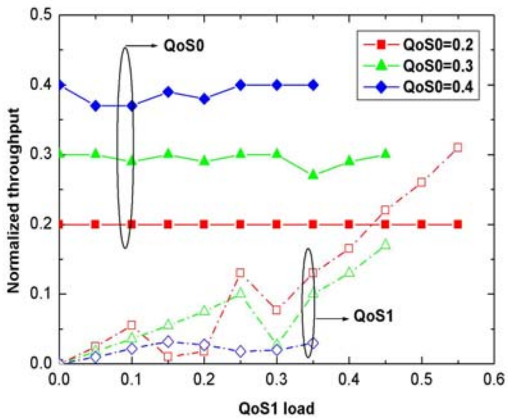


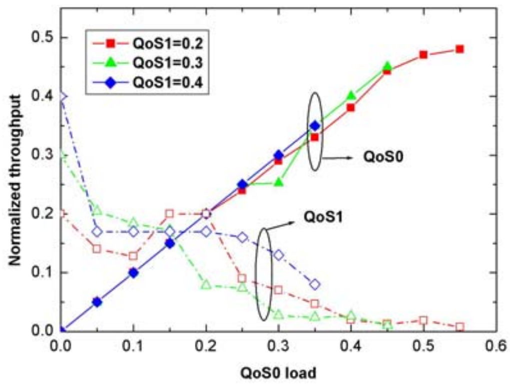
Fig.7. TCP bandwidth decreasing due to delay penalty

5.2 QoS provision

In QoS provision experiment, two classes of QoS traffics are set in IP data quality analyzer, namely QoS0 and QoS1, and QoS0 is a higher QoS class. Transmission performance is recorded for each of traffics, and comparison is given in Fig.8(a) and (b).



(a) Impact of low QoS traffic to high QoS traffic



(b) Impact of high QoS traffic to low QoS traffic

Fig.8. QoS provision transmission in OBS network

In Fig.8(a) the normalized throughput of QoS0 is set to 0.2, 0.3 and 0.4, and then the throughput of QoS1 is increased slowly. Results show that low QoS traffic doesn't affect the throughput of high QoS traffic. On the contrary, it is shown in Fig.8(b) that high QoS traffic will take bandwidth away from low QoS traffics. Results from this experiment show that by configuring to high class QoS, TCP throughput can be guaranteed.

6. Interconnection Experiment between OBS and GMPLS network

Generalized Multi-Protocol Label Switching (GMPLS) is one of enablers to provide flexible control and management for carrier's optical transport networks in near future. In the meantime, Optical Burst Switching (OBS) has become a promising technology for the next generation optical network with advances in ultra-fast switching technologies and optical burst control techniques. Considering such current situations, it is very important to investigate the network architecture interconnected between OBS domains via GMPLS-controlled core transport network [16].

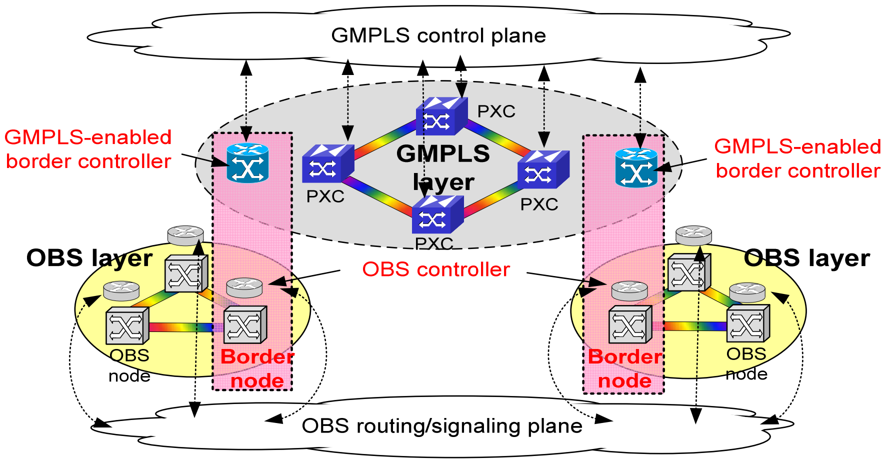


Fig.9. Scenario of interconnection between OBS and GMPLS network [16]

During the submission of this paper, the experiment is still under developing. The result will be reported on the meeting.

7. Conclusions

In this paper, several key technologies of OBS network are addressed. Burst assembling and scheduling are implemented with high-speed FPGA technology with high processing speed. Burst-mode receiver with high receiving sensitivity and fast clock and data recovery time (less than 80ns) is implemented. All other modules are implemented and experimentally verified in this testbed, which means a flexible and scalable OBS testbed is demonstrated and can provide a flexible platform for further research works.

Moreover, the TCP performance over OBS is experimentally investigated on this testbed and multi-QoS traffic transmission on the testbed are demonstrated as well. Experimental results show that the performance of TCP traffic is greatly influenced in the case of 1% burst loss probabilities. With the decreasing of burst loss probabilities to 0.1%, the TCP performance is improved greatly, which means that the TCP performance over OBS can be guaranteed in the case of 0.1% burst loss probabilities. Experimental results verify QoS provision in OBS network which means the TCP throughput of high QoS traffic can be guaranteed. Delay penalty observed in experiment means that the transmission protocols in high layer needs to be modified for a higher transmission bandwidth in OBS network. At last, a joint project of interconnection of OBS and GMPLS network is reported for further investigation.

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