Improvement of TCP Performance over Optical Burst Switching Networks

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Abstract. Transmission Control Protocol (TCP) performance over optical burst switching (OBS) is experimentally investigated on an OBS network testbed. The effect of burst losses on TCP performance over the OBS testbed is studied and the result shows that burst losses will lead to a network wide drop in TCP throughput and there exists an optimal assembly period to maximize the available TCP bandwidth. Then a new assembly mechanism constraining the ratio of acknowledgement (ACK) number to all the segment number in one burst is proposed. Simulation results demonstrate that compared with conventional assembly mechanism, the new one can improve TCP performance over OBS networks to great extent with lower network burst loss probability and higher TCP throughput.

Keywords: optical burst switching, transmission control protocol, assembly, throughput, burst loss probability

1 Introduction

As one of the promising technologies for future Internet Protocol (IP) over wavelength division multiplexing (WDM), optical burst switching (OBS), which combines the best of optical circuit switching (OCS) and optical packet switching (OPS) [1], has attracted considerable research attention recently. Given that Transmission Control Protocol (TCP) is today's prevailing transport protocol and likely to be adopted in future optical networks, so the evaluation and improvement of TCP performance over OBS networks is an important issue [2].

Since in OBS networks data is transmitted and switched in the format of large bursts, which is different from small packets in traditional packet switching networks. Therefore the existing upper-layer transmission protocols such as TCP will exhibit different characteristics, such as delay penalty and correlation benefit, which will influence TCP performance greatly [3].

This paper firstly investigates burst assembly's influence on TCP performance over OBS network testbed experimentally, concluding that there exists an optimal assembly period to maximize the available TCP bandwidth, while burst losses lead to a network wide drop in the bandwidth. Then, a new TCP/ACK-based assembly mechanism is proposed, and simulation results show that the mechanism can improve

I. Tomkos et al. (Eds.): ONDM 2007, LNCS 4534, pp 194-200, 2007.

the performance of OBS networks to great extent, providing lower network burst loss probability and higher available TCP bandwidth.

2 Experiments and Discussion

2.1 Experimental Setup

Fig.1 illustrates the experimental setup and for simplicity only two edge nodes and one core node are utilized. Each edge node is connected with a core node through a fiber link carrying 8×1.25Gb/s channels including a control channel. Both edge and core nodes employ efficient latest available unused channel with void fill (LAUC-VF) scheme to allocate proper output wavelengths for the data bursts, and the maximum processing delays are 2.5us and 10us respectively. Furthermore, the 32×32 optical switching fabric features a switching speed is less than 100ns [4].

In the experiment, we focus on static timer-based algorithm to analyze burst assembly effects on TCP transmission under different burst loss probabilities. Burst losses are obtained through intentional dropping at nodes. As shown in Fig.1, TCP server is connected to one edge node and the client is connected to the other one, by which a TCP connection is set up through the 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.

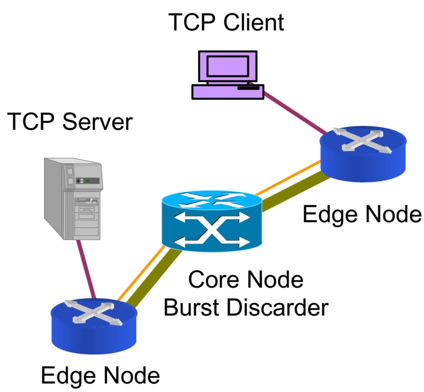


Fig. 1. Experimental setup in OBS testbed.

2.2 Experimental Results and Discussion

In OBS networks, several consecutive packets or segments from different sessions are included in one burst and a burst loss will result in loss of many packets per session.

The continuous packet loss pattern in OBS networks will trigger different retransmission pattern and worsen the network performance [3].

Fig.2 shows that burst losses lead to a network wide drop in throughput. For example, burst loss probability P_b of 0.8% makes the available bandwidth drop by 52%. The figure also shows that higher burst loss probabilities will result in lower TCP bandwidth. So in order to improve the performance of TCP, it is very important to reduce the burst losses in the OBS networks [5].

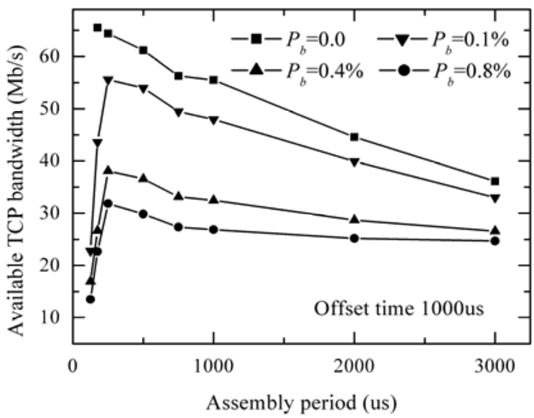


Fig. 2. TCP bandwidth vs. burst assembly period under different burst loss probabilities

Fig.2 depicts that in the case of no burst losses longer assembly period results in lower available TCP bandwidth. Reference [6] has reported the bandwidth is also reduced with the increasing of offset time for the same reason of delay penalty. Therefore, with the increase of assembly period and offset time, the round-trip time (*RTT*) is increased, resulting in delay penalty to decrease the available TCP bandwidth. Here only the instance of P_b=0 is considered because in the case of no burst losses only the delay penalty is in effect, that is to say, the correlation benefit vanishes with extreme value of P_b (i.e., 0 and 1) [7].

As discussed above, the burst assembly process causes delay penalty to decrease the available TCP bandwidth. On the other hand, the assembly process can also introduce a degree of correlation among the loss events for TCP segments interfering with TCP recovery mechanisms [7], and more important, an increase in the assembly period will result in an increase in the TCP bandwidth because of the increase in the number of segments per burst, which is the effect of correlation benefit in OBS networks.

Fig.2 shows that with burst losses introduced, the available TCP bandwidth is increased rapidly and then decreased slowly with the increasing of assembly period because of the combined interaction of the delay penalty and correlation benefit, i.e. there exists an optimal value assembly period 250us to maximize the available TCP bandwidth and the value is independent of burst loss probabilities. The reason is explained in detail as follows. On the one hand, when the assembly period is larger than the optimal value, the available bandwidth is decreased because in this case the delay penalty has greater influence than the correlation benefit. On the other hand, if the assembly period is smaller than the optimal value, similar *RTT* results in similar delay penalty and the correlation benefit becomes the primary factor.

In addition, it can also be seen that the available TCP bandwidth under low burst loss probabilities varies quickly compared with that under high loss probabilities. For example, the bandwidth at 3000us assembly period drops by 40% and 16% for burst loss probabilities of 0.1% and 0.8% respectively, compared to the corresponding bandwidth at 250us assembly period, because for lower burst loss probabilities, the delay penalty effect is the dominant factor to decrease the bandwidth compared with the correlation benefit, while for high loss probabilities the correlation benefit is the primary element.

3 New TCP/ACK-Based Assembly Mechanism

From the above experiment results, it can be seen burst losses lead to a wide drop in TCP throughput. So it is important to reduce burst losses for improving network performance. Furthermore, in the previous studying the ACK loss of TCP connection is either ignored or set to zero using lossless links. However, ACK losses indicate all the correlated data segments have to be retransmitted, causing the network performance to be much worse. Therefore, ACK losses can not be avoided and must be taken into consideration. In this section, we propose a TCP/ACK-based assembly mechanism to constrain the number of ACK packets in one burst by introducing a parameter R to depict the ratio of ACK number to all the segment number in one burst. Therefore, the number of ACK losses due to burst losses can be effectively controlled.

3.1 Principle of the New Mechanism

In the new TCP/ACK-based assembly mechanism, ACKs and other TCP segments are assembled together into one burst, just like the conventional timer-based assembly algorithm. However, the value of R is controlled to be approximately equal to or less than the pre-determined threshold R_{MAX} through the R control algorithm as shown in Fig.3. More details need to be explained about the R control algorithm is that the Extra-Queues are only for ACKs due to the control mechanism, that is to say, if R has never exceeded R_{MAX}, the Extra-Queues are always void and all ACKs are assembled into bursts directly from the Input Queues, as well as other TCP segments. More important, the delayed ACK packets in Extra-Queues are given higher priority than those from the Input Queues to be assembled into bursts, ensuring the delayed ACKs to be transmitted as soon as possible for lower *RTT* and higher TCP throughput [8].

Therefore, with the new TCP/ACK-based assembly mechanism, the number of ACK packets in one burst is constrained to be approximately equal to or less than the threshold R_{MAX}.

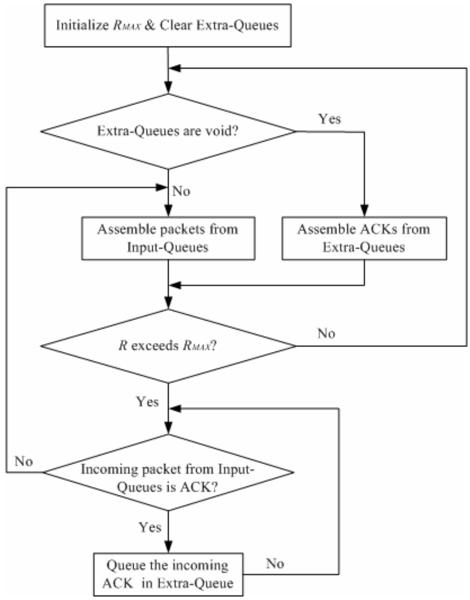


Fig. 3. Schematic description of R decision algorithm.

3.2 Simulation Results and Discussion

Simulation is carried out of the new mechanism on the network scenario as in Fig. 4 with two core nodes (CN) and six edge nodes (EN), assuming a TCP segment size is 512byte, RTT=600ms, the sending window W_m=128, the access bandwidth 200Mb/s, the maximum burst length 200Kbyte, the minimum burst length 30Kbyte and the mean burst size is 100Kbyte.

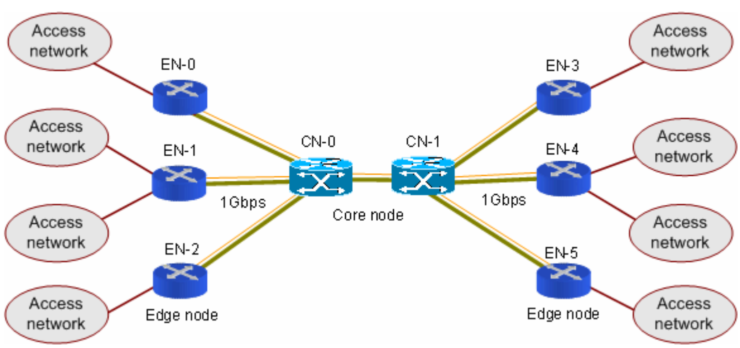
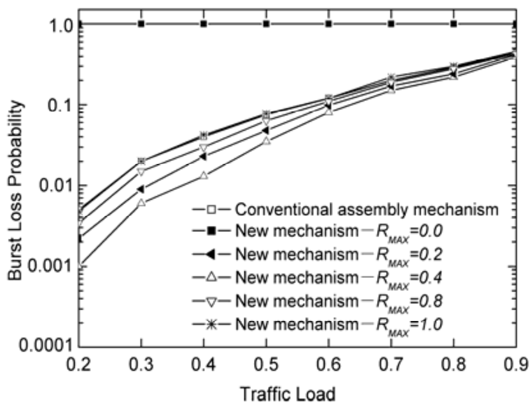
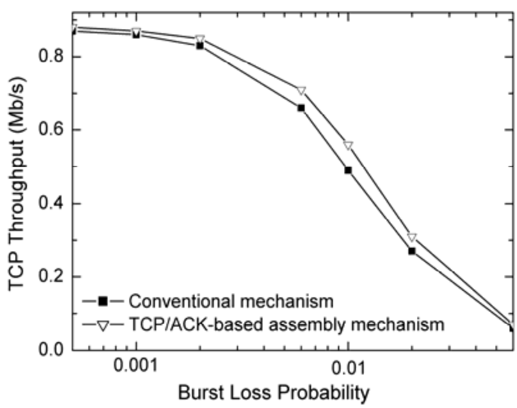


Fig. 4. Network simulation topology with 2 CNs and 6 ENs.

Fig. 5 shows the simulation results compared with the conventional timer-based assembly mechanism that the new mechanism shows better TCP performance than the conventional assembly one with lower burst loss probability and higher TCP throughput.



(a) Lower burst loss probability characteristic of the new mechanism



(b) TCP performance improvement of the new mechanism

Fig. 5. Performance comparison of the new mechanism vs. the conventional mechanism..

It can be seen from Fig.5 (a) that the curve of the new mechanism with R_{MAX}=1 is approximately coincident with the curve of the conventional one because R_{MAX}=1 means that only when all packets in one burst are ACKs (the case seldom happens), the assembly process needs to be adjusted by the *R* decision algorithm. In other words, the new mechanism in this case works as the conventional assembly scheme. On the other hand, in the case of R_{MAX}= 0 (i.e. all ACK packets are queued and only data segments are assembled to be transmitted, which means that no TCP connection is setup), the burst loss probability will always be equal to one. Fig.5 (a) also depicts that with the increasing of R_{MAX} to a certain extent, more ACK packets can be assembled to bursts to improve the network performance. However, the value of R_{MAX} can not be set too large, because with too larger R_{MAX} the function of the new mechanism will be more similar to the conventional ones. Fig.5 (b) demonstrates that the new assembly mechanism improve TCP performance with higher throughput compared with the conventional assembly algorithm.

4 Conclusions

The TCP performance over OBS is experimentally investigated on the OBS testbed. Burst losses lead to a network wide drop in throughput. Then the effects of delay penalty and correlation benefit are taken into consideration, concluding that there exists an optimal assembly period independent of the burst loss probabilities to maximize the TCP bandwidth. To improve the performance of TCP over OBS networks, a new TCP/ACK-based assembly mechanism is introduced. Simulation results demonstrate that compared with conventional assembly mechanism, the new mechanism can improve TCP performance to great extent, such as lower network burst loss probability and higher TCP throughput.

Acknowledgments. This work is supported by Program of Ministry of Education of China (Grant No. 105036 and Grant No. NCET-04-0116).

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