Performance analysis of optical burst switching under bursty traffic

Chunhan Chen (陈春汉), Mingcui Cao (曹明翠), and Zhixiang Luo (罗志祥)

State Key Lab of Laser Technology, Huazhong University of Science and Technology, Wuhan 430074

Received September 16, 2003

The performance of the algorithm of the data channel scheduling algorithm of latest available unscheduled channel with void filling (LAUC-VF) under bursty traffic is presented firstly. A bursty traffic model for optical burst switch performance simulation is also introduced.

OCIS codes: 060.4250, 060.4510.

The rapidly growing internet is driving the demands for Tb/s transmission and IP routers. With the dense wavelength division multiplexing (DWDM) technology, the Tb/s transmission can be achieved easily. Now the high-speed network bottleneck lies in IP routers. Currently, the optical burst switching (OBS) is the most promising technology to achieve Tb/s IP routers in the near future[1,2].

An optical burst switching system consists of edge routers and core routers connected by WDM links. Packets having the same egress address and some common attributes, such as quality of service (QoS) requirements are assembled into bursts at ingress edge routes, which are then routed through the OBS core network and disassembled back at egress edge routers to their next hops (e.g., conventional IP routers).

A general core routers architecture is shown in Fig. 1. Here we consider an ideal nonblocking $N \times N$ optical switch matrix. The number of data channels is $(K - k)$, in which K represents all optical channels and k represents control channels. Each optical buffer has B fiber delay lines (FDLs) with ith FDL being able to delay $Q_i = i \times D$, where D is the basic delay unit time. The scheduler schedules the input data bursts from the matrix to output data channels.

The scheduler is an important part in optical burst switching. Now there are main two algorithms to schedule burst, which are latest available unscheduled channel (LAUC) and latest available unscheduled channel with void filling (LAUC-VF) algorithms. The burst loss probability of LAUC-VF algorithm is much less than LAUC. The performances of LAUC and LAUC-VF are analyzed in Ref. [3]. But it does not consider the competition of FDLs and bursty traffic. On the one hand, we present the performance of LAUC-VF, in which the competition of FDLs is taken into account and the competition is resolved also by LAUC-VF algorithm. On the other hand, a bursty traffic model for OBS performance simulation is given for the first time. The performance of LAUC-VF algorithm under bursty traffic is also presented.

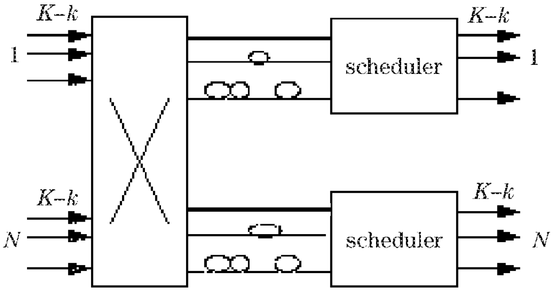

Fig. 1. A general architecture of core routers.

The simplified conventional algorithm of LAUC-VF is shown in Table 1[3], in which line 3+ is not included. In the algorithm a proper data channel is searched with $ch\_\mathrm{search}(x)$ from 0th to Bth FDLs to output the arriving data burst. The function of $ch\_\mathrm{search}(x)$ in line 4 is to search a proper channel to output the arriving burst with LAUC-VF algorithm. From the algorithm in Table 1, we can see that in conventional algorithm it is assumed that the FDLs are available at any time or the algorithm do not consider the competition of FDLs. In fact, the FDLs are also important resources in the system. So the line 3+ is added in our algorithm. Like $ch\_\mathrm{search}(x)$, the function of $fdl\_\mathrm{search}(i, t)$ in line 3+ is to check whether the current FDLs (ith FDLs) are available with LAUC-VF algorithm.

The performance comparison of the conventional and our algorithm is shown in Fig. 2.

The traffic model is the same as Ref. [3]. The packet stream from a IP router to the edge router is modeled by the fractional Gaussian noise (FGN) self-similar traffic[4] with Hurst parameter $H = 0.8$. The average packet length is 389.5 bytes. Let L_p be the packet length in bytes. We have the packet length distribution

Table 1. Algorithm of LAUC-VF

```
1    laucvf_channel_search($t$) {
2        $x = t$; /* $t$ is the burst arriving time */
3        for ($i = 0$; $i < B$; $i$++) {
3+           if ($fdl\_\mathrm{search}(i, t) == 1$) {
4                if ($ch\_\mathrm{search}(x) == 1$) {
5                    return success;
6                } else
7                    $x = x + i * D$;
8            }
9        }
10       return failure;
11   }
```

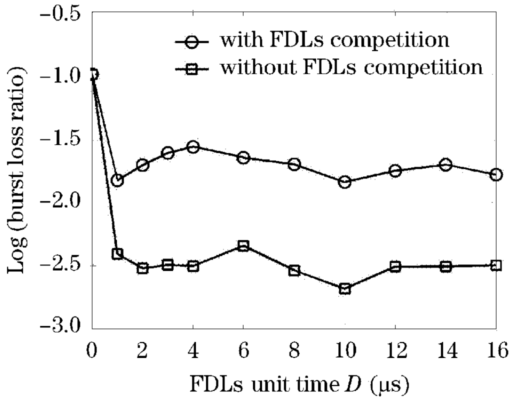

Fig. 2. Burst loss ratio under nonbursty traffic.

$$P(L_p = 44) = 0.5, P(L_p = 552) = 0.05,$$

$$P(L_p = 576) = 0.03, P(L_p = 1500) = 0.12,$$

$$P(45 \le L_p \le 551) = 0.25,$$

$$P(553 \le L_p \le 575) = 0.005,$$

$$P(577 \le L_p \le 1499) = 0.035,$$

$$P(1501 \le L_p \le 4300) = 0.01.$$

We assume the variance ν is equal to the square of its mean μ. In our simulation, we also assume that the number of ports in switch matrix is $N = 8$, the number of data channels $(K - k) = 8$, the number of destinations $G = 8$, the Hurst parameter $H = 0.8$, the channel rate $R = 10$ Gb/s, the data channel utilization $\lambda = 0.86$, the burst assembly time $T_\mathrm{a} = 2$ μs, the basic delay unit time is D, the number of delay line unit is B. Last of all, we also assume that each burst entering the core router will be routed to an outgoing port with probability $1/N$, independent of other bursts, which is nonbursty traffic. In this paper we take the burst loss ratio as the performance of the system.

In Fig. 2 the line with square presents the result when the FDLs competition is not taken into account and the result is all the same as Ref. [3]. The line with circle shows the result with FDLs competition.

From Fig. 2 we can see that when $B = 8$, the burst loss probability is less than $10^{-2.5}$ when FDLs competition is not taken into account. Whereas the burst loss ratio is only about $10^{-1.8}$ when FDLs competition is taken into account. And increasing delay time unit has little effect on burst loss ratio.

The general simulation parameters are the same as above. In nonbursty traffic we assume that each burst entering the core router will be routed to an outgoing port with probability $1/N$, independent of other bursts. In bursty traffic three parameters are defined: average burst intensity B_i, burst last period T_1 and nonbursty period T_2. The input bursts will go to an output port with probability B_i/N within the bursty period T_1. The bursty period T_1 is uniformly distributed with average length L_1. The nonbursty period T_2 is also uniformly distributed with average length L_2. In nonbursty period T_2, if $B_i \le 2$, the input bursts will go to an output port with probability $(2 - B_i)/N$ and L_2 is equal to L_1. If $B_i > 2$, no input bursts will go to an outgoing port and L_2 is equal to $(B_i - 1) \times L_1$. The assumption above keeps the average channel utilization of an outgoing channel is the same as input. If $B_i \le 2$, the total output intensity is

$$N \times \lambda \times \frac{B_i}{N} \times \frac{L_1}{L_1 + L_2} +$$

$$N \times \lambda \times \frac{2 - B_i}{N} \times \frac{L_2}{L_1 + L_2} = \lambda,$$

for $L_2 = L_1$.

And if $B_i > 2$ the total output intensity is

$$N \times \lambda \times \frac{B_i}{N} \times \frac{L_1}{L_1 + L_2} + N \times \lambda \times 0 \times \frac{L_2}{L_1 + L_2} = \lambda,$$

for $L_2 = (B_i - 1) \times L_1$.

Figure 3 gives the relationship of burst loss ratio versus FDLs unit time D and the FDLs number B under bursty traffic, on the condition that the average burst period $L_1 = 10T_\mathrm{a}$ and the burst intensity $B_i = 2$. Unlike nonbursty traffic in Fig. 2, Fig. 3 shows that the burst loss ratio decreases with the increasing of D and B. But when $D \ge 6$ μs, the burst loss ratio changes little relatively. So the simulation below will take $D = 6$ μs.

The burst loss ratio versus average burst period L_1 is shown in Fig. 4, where we assume FDL unit time $D = 6$ μs, the burst intensity $B_i = 2$, and other parameters are the same as above.

The burst loss ratio versus burst intensity B_i is shown in Fig. 5, where FDLs unit time $D = 6$ μs, the average burst period $L_1 = 10T_\mathrm{a}$ is assumed and other parameters are the same as above.

Lastly, we present the burst loss ratio versus input traffic ratio λ under bursty and nonbursty traffic in Fig. 6. In Fig. 6, the average burst period is $10T_\mathrm{a}$, the burst intensity is 2 and the FDLs unit time $D = 6$ μs. The solid lines with circle and square and star present performance under bursty traffic, whereas dotted line with triangle presents nonbursty traffic. From Fig. 6 we can see that if the burst loss ratio $\le 10^{-3}$ is demanded, the input traffic ratio λ that the system can bear under nonbursty traffic is about 0.7, 0.8 and 0.8 when

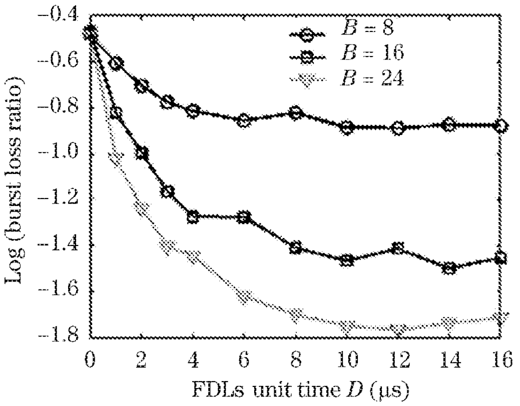

Fig. 3. Burst loss ratio versus B and D ($L_1 = 10T_\mathrm{a}$ and $B_i = 2$).

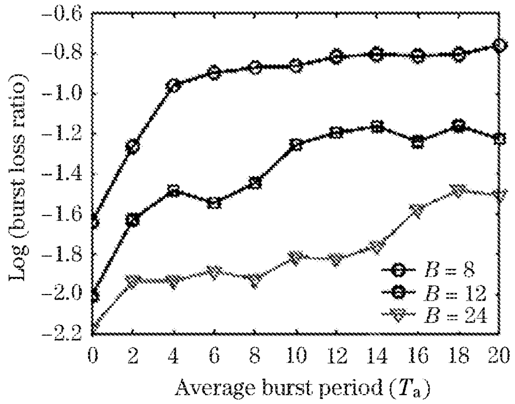

Fig. 4. Burst loss ratio versus L_1 and B ($D = 6$ μs and $B_i = 2$).

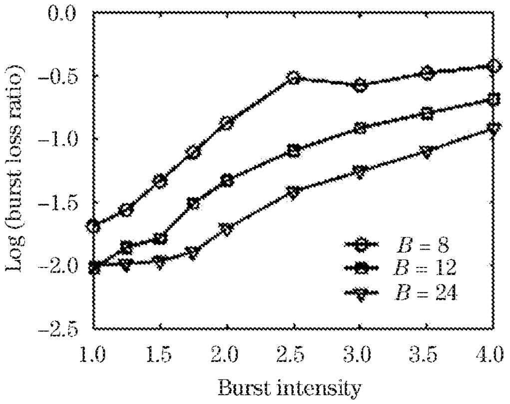

Fig. 5. Burst loss ratio versus B_i and B ($D = 6$ μs and $L_1 = 10T_a$).

$B = 8$, 16 and 24, respectively. Whereas λ is only about 0.45, 0.6 and 0.7 under burst traffic when $B = 8$, 16 and 24, respectively.

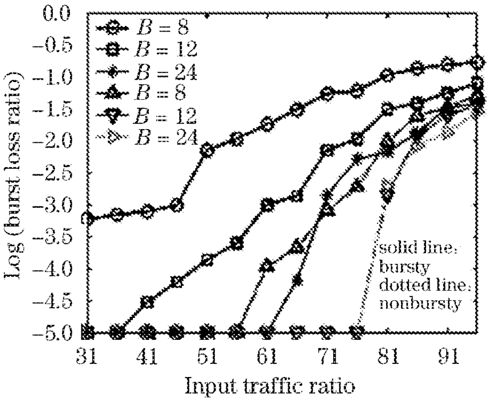

Fig. 6. Burst loss ratio versus λ under nonbursty and bursty traffic.

In conclusion, optical burst switching provides an attractive alternative for realizing Tb/s optical packet/burst switched WDM networks. In this paper, we present our initial work on the performance of OBS network under bursty traffic. A bursty traffic model for OBS network simulation is also introduced. We are sure that this model is not most suitable to present the traffic in the real world. It is only to supply a way to analyze the performance of OBS network under bursty traffic which is more reasonable in the real world.

C. Chen's e-mail address is cchbob@163.com.

References

1. J. S. Turner, J. High Speed Networks **8,** 3 (1999).
2. C. Qiao and M. Yoo, J. High Speed Networks **8,** 69 (1999).
3. Y. Xiong, M. Vandenhoute, and H. C. Canleaya, IEEE J. Sel. Areas in Communications **18,** 1838 (2000).
4. V. Paxson, Technol. Rep. LBL-36750/UC405 (Apr. 1995).