A novel differentiated services supporting scheme for optical burst switched networks

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In this letter, we analyze the drawback of tail-dropping contention resolution in optical burst switched networks. Once contention occurs, we adopt modified head-dropping policy to resolve contention. This policy drops the head of the contending burst only if the overlapping region of the two bursts is less than the whole contending burst size, otherwise drops the whole contending burst. In order to have a better support of differentiated service, a new burst assembly policy, namely, Priority-based proportional mixed burst assembly, is proposed. Simulation results show that the proposed scheme performs very well in terms of performance metrics such as the times of contention and packet loss probability.

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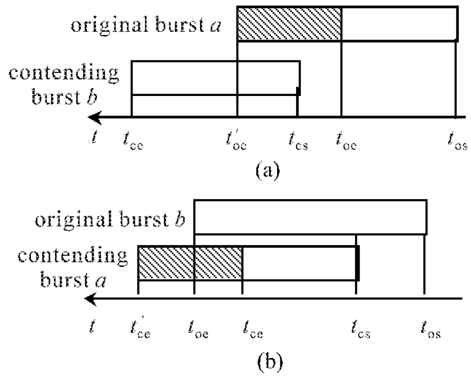
Optical burst switching (OBS)[1,2] has been proposed as an efficient switching technique to exploit the capacity provided by dense wavelength division multiplexing (DWDM) transmission technology for the next generation optical Internet. The idea underlying OBS technology is to decouple the data-path from the control-path. But the contention for resource between two bursts is inevitable, so something must be done to resolve it for supporting QoS. The conventional contention resolution options include wavelength domain, time domain and space domain, which mean wavelength conversion, fiber delay line (FDL) buffering and deflection routing respectively. Many efforts have been done to these schemes[3]. These resolutions are all to find a vacant out-port to pass through the whole burst. Recently a new notion segmentation is proposed in literatures to resolve the contention, which only discards one of the overlap parts of the bursts in order to reserve the wavelength as soon as the wavelength becomes free on the output port. For example, Vokkarane *et al.* chose to discard the tail part of the burst arriving first, which we call the original burst, to resolve the contention[4]. Detti *et al.* adopted conventional burst assembly, in which a burst was composed of same class packets, and chose to drop the head of later arrival burst, named contending burst, when there was a contention[5]. In the following sections, we firstly analyze the drawback of the methods introduced in Refs. [4] and [5], and then present a modified head-dropping scheme to resolve contention in OBS networks. In order to have a better support of QoS, a new burst assembly policy, priority-based proportional mixed burst assembly (PPMBA), is also proposed. Simulation results confirm the validity of the proposed burst assembly policy and the corresponding contention resolution scheme.

It is well known that the contention will occur when two or more incoming bursts are directed forward the same out-port at a same time slice. If the tail of the original burst is dropped in the contention resolution as described in Ref. [4], some serious issues will arise in downstream nodes. After finishing the out-port reserving, the control packet of the original burst leaves this node with burst information to reserve the resource of the next node, which includes the original size and arriving time of this burst. But when the contending burst came for the same out-port before the previous reservation expired, the tail of first burst would be discarded. In fact, after the conflict is resolved, the burst size of the original burst has been changed for the segmentation while its associated control packet does not know. We call the burst, one part of which was dropped, truncated burst.

We illustrate these with a simple example. Suppose that burst a comes from node A and burst b comes from node B. Both a and b will go to node D through node C, and the tail part of burst a has been discarded at node A. Figure 1 shows two typical kinds of contentions may happen at node C. t_{os} and t'_{oe} denote the resource starting time and the expiring time reserved by control packet, t_{cs} and t'_{ce} denote the reserved starting time and expiring time of the contending burst, t_{ce} and t_{oe} denote the actual end time of the truncated original burst and contending burst, respectively.

The dashed area in Fig. 1 is the part which has been discarded before arriving at node C. Figure 1(a) shows the situation when the truncated burst a arrives earlier than burst b at node C. Burst a will actually end at t_{oe} for the tail dropping at node A, while its control packet has reserved the expiring time t'_{oe} before it comes. So there is a contention arising only if $t_{\mathrm{cs}} < t'_{\mathrm{oe}}$. If $t_{\mathrm{cs}} < t_{\mathrm{oe}}$, there will be a statistic error of contention



(a)

(b)

Fig. 1. Two cases when tail-dropping used to resolve contention. (a) when $t_{\mathrm{oe}} < t_{\mathrm{cs}} < t'_{\mathrm{oe}}$; (b) when $t_{\mathrm{ce}} < t_{\mathrm{oe}} \leq t'_{\mathrm{ce}}$.

because of the longer overlap between burst *a* and burst *b*. If $t_{\rm oe} < t_{\rm cs} \le t_{\rm oe}$, a nonexistent contention has to be coped with, which will add the process burden of node. Figure 1(b) shows the situation when the truncated burst comes as the contending burst. There comes a contention if $t_{\rm oe} < t'_{\rm ce}$. Especially when $t_{\rm ce} \le t_{\rm oe} < t'_{\rm ce}$, the tail of original burst will be discarded and the bandwidth will be made way for a vacancy from $t_{\rm ce}$ to $t_{\rm oe}$. It is because the control packet did not know the dropping information before it left node A, and node C did not receive the updating information about dropping in time that results in resource waste. Sending an extra control packet is recommended in Ref. [4] after resolving contention in order to update the dropping information, but when the extra packet reaches node C after contending burst, this kind of waste is still unavoidable.

In Ref. [5], authors adopted conventional assembly scheme. The differentiated services is not supported well in this scheme. Firstly, vacancy will be filled with useless message if the packets are not enough to form a threshold-based or timer-based burst in conventional burst assembly scheme, so the waiting time at edge node will be much longer if the traffic load is low. Secondly, when contention occurs between two same class bursts at core node, if unfortunately the bursts are consisted of high priority traffic, the high priority packets will be discarded.

To improve the performance of networks to guarantee the QoS requirement, it is essential to achieve better bandwidth utilization and reduce the packets loss probability and the end-to-end delay. In order to provide better performance, we propose to employ modified head-dropping contention resolution, an extended segmentation, with priority-based mixed burst assembly in OBS networks. In this section, we will give an explanation to our scheme in details.

Our resolution is the modified head-dropping policy when determining how to resolve contention. In this policy, only when the contending burst is later than the original burst to arrive at one node, and the contending region Δ_c is less than the whole contending burst size L_c, the head of the contending burst will be dropped, otherwise, the whole contending burst will be dropped. Figures 2(a) and 2(b) show the two scenarios of contention respectively, in which the switching time Δ_s means the time cost for the switch to transfer from one output port to another one. If the switching time is non-negligible, additional packets may be lost when the output port is switched from one to another.

In order to provide QoS more better, we propose a new burst assembly mechanism, namely PPMBA. At the edge node of OBS networks, the incoming data packets are assembled into data bursts. Yuang *et al.* suggested cramming a burst with packets of all sort priorities on weight basis[6]. They proved with simulation that this method supported differentiated services in terms of delay. In order to support differentiated service on both delay and packets loss probability, we present a kind of PPMBA in which different classes packets are assembled in a burst with an assigned proportion respectively, and the priorities are lined in an ascending order in a burst from head to tail. Figure 2(c) gives an illustration of a burst with three classes, in which the proportion of class A, B, C is $W_{\rm A} : W_{\rm B} : W_{\rm C}$, and A is the highest priority, B is the second and C is the lowest one. The ratio of each priority is adjusted dynamically to its density. The denser the traffic is, the larger its ratio will be. But it also complies with that the ratio of relatively higher priority traffic is higher than that of relatively lower priority. Obviously, PPMBA can save more waiting time and improve the utilization of the burst when assembling a burst at edge node in case of low traffic load than the conventional assembly, in which a burst consists of one class packet, because the total packets of all sorts priorities are always more intense than any one priority packet.

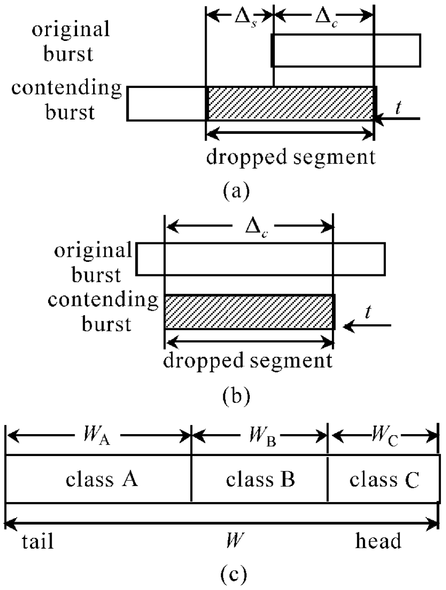


Fig. 2. Our burst assembly and contention resolution scheme, (a) when $\Delta_c < L_c$; (b) when $\Delta_c = L_c$; (c) mixed assembled burst.

Not only can our scheme resolve contention effectively, but also it can deal with control packet well after resolving contention. When the head of contending burst is dropped, the values of the burst arriving time at next node and the burst length can be updated in time according to the fact of discarding before control packet leaves for the downstream node. If the whole contending burst is dropped, the corresponding control packet will be discarded to alleviate the network burden. This approach reduces the probability of a long burst preempted by a short one and minimizes the number of packets loss during contention.

The most impressed improvement is that it can update the burst information for reserving resource in the control packet in time before the control packet leaves for the downstream node, if the modified head-dropping scheme is adopted to resolve contention at core node. So the errors due to tail-dropping mentioned above will be avoided and the process burden will be alleviated effectively. It is just because the control packet will reserve the resource according to the real parameters of the coming burst. That the second improvement of this policy for contention resolution lies in the differentiated services will be potentially supported. Due to PPMBA which arranges the high priority packets at the tail of the burst while the low priority packets at the head, the dropped part will be always the relative low priority packets when contention occurs. Then the QoS of high priority traffic will be guaranteed more than that of low priority traffic. We will approve it through the following simulation results.

We evaluate the performance of an $N \times N$ optical switch node which is located in OBS network. To obtain the results, the parameters of networks have been assumed as following:

1) The traffic is symmetric, i.e., the input processes have the same statistic characteristic and any arriving burst has the same probability to be directed to any output wavelength channel.

2) The original length of all bursts is fixed to L_0 for the assembly of ingress node. The incoming burst size of each OBS node follows negative exponential distribution with the mean length of μ.

3) Burst arrivals to each input wavelength channel according to an ON/OFF process, here ON duration equals to burst length, and OFF is in exponential distribution with the mean of $L_{\text{off}} = L_0(1 - R)/R$, where R is the traffic load on each wavelength channel of the networks.

4) Switching size $N = 16$ and the switching time can be ignored.

5) There is three classes traffic, namely class A, class B and class C, in the networks, and class A is the highest class, class B is the second one and class C is the lowest one.

We choose the parameters of N, L_0 and μ as 16, 2500, 1500, respectively. In this letter, we study our contention resolution scheme with the differentiated service and compare its contention times and average packet loss probability with tail-dropping resolution among 1000,000 bursts. Through the simulation, we get the curves as in Fig. 3. Figures 3(a) and 3(b) show the comparison of contention times and average packet loss probability between the tail-dropping and modified head-dropping scheme. From the figures, we can say that both the contention times and the average packet loss probability of the modified head-dropping scheme are all lower than that of the tail-dropping scheme. Figure 3(c) shows our scheme, modified head-dropping along with proportional mixed burst assembly, supporting differentiated services in which the packet loss probability of the high priority traffic is much lower than that of the low priority traffic. The results match our expectation well.

Because not only can our scheme resolve contention effectively, but also it can deal with control packet well after resolving contention, we get above results. When the head of contending burst is dropped, the real information of burst in control packet can be updated in time before the control packet leaves for downstream node. If the whole contending burst dropped, the corresponding control packet will be discarded. This approach reduces the probability of a long burst preempted by a short one and minimizes the number of packets loss during contention. It is the burst assembly, PPMBA, who makes the low priority packets dropped more than the high priority packets.

We analyze the shortage of tail-dropping scheme with two cases and propose a new burst assembly scheme as well as a contention resolution of the modified head-dropping. From the simulation results, we conclude that our scheme will support differentiated service well and has lower packet loss probability than tail dropping contention resolution scheme, confliction times is fewer and the contention resolution is simpler than tail-dropping scheme as well.

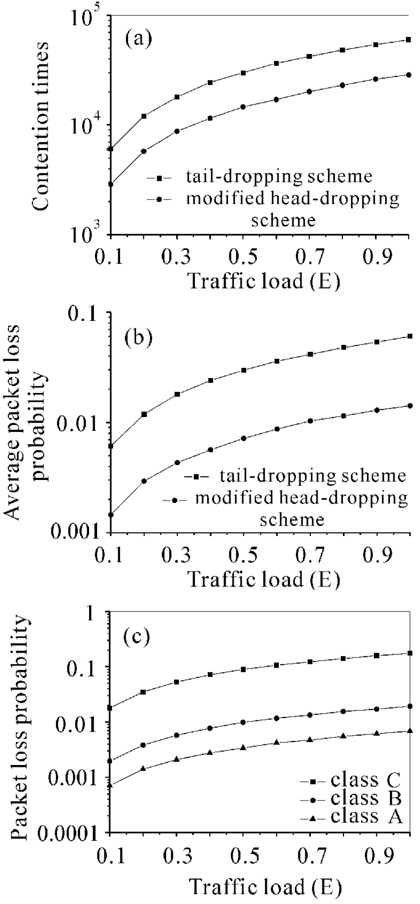


Fig. 3. The simulation experimental results. (a) The contention times comparison between the tail-dropping and our scheme; (b) the average packet loss probability comparison between tail-dropping and our scheme; (c) the packet loss probability of different class traffic with our scheme.

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