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Hybrid Assembly and Improved Head-dropping Scheme for Service Differentiation in Optical Burst Switching*

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Abstract To support QoS and decrease the disorder of packet arrivals, a new hybrid assembly scheme, in which the low and high packet classes are aggregated into one burst simultaneously, is presented for optical burst switched (OBS) networks. Once contention occurs, an improved head-dropping policy, which can overcome the limitations associated with the tail dropping policy, is adopted to drop the overlapping packets. Simulation results demonstrate that hybrid assembly scheme, together with the improved head-dropping policy, can be well used in OBS networks with QoS requirement.

Keywords Optical burst switching; Segmentation; Hybrid assembly; Head-dropping; QoS

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0 Introduction

In optical burst switched (OBS) networks, when two or more incoming bursts are directed to the same output port at the same time, contention occurs[1,2]. If burst segmentation is adopted, either the head or the tail part of the overlapping packets will be dropped. Presently, dropping policy used in most literatures adopt tail-dropping. The main reason to do so, according to[3,4], is that there will be a better chance to keep the packets to arrive at the destination in right order.

As a matter of fact, a serious limitation of tail-dropping solution has been neglected. As we know, a key and fundamental characteristic of the OBS technique, is that burst payload and its associated header are transmitted separately. Each time a burst will be transferred, its associated control packet will be transmitted firstly on a different control channel with the objective to reserve the wavelength resources, more accurately, if the wavelength resources have been reserved for a specified burst, these resources cannot be released or difficult to be changed even if the partial of the burst contained in the burst have been lost. Therefore, downstream nodes cannot know that the burst has been truncated, and it is possible that the previously truncated tail segments will continue contending with other bursts, even though these tail segments have already been dropped at a previous node.

In addition, once burst segmentation is adopted, how to guarantee the dropped packets do not involve in high pack classes, given that different traffic have different QoS requirements, is still an open problem.

In this paper, we adopt hybrid assembly, in which low and high packet classes are aggregated into one burst simultaneously, and by employing the improved head-dropping policy, to overcome the limitations associated with tail-dropping policy, and, to support service QoS.

1 Tail-dropping or head-dropping?

To have a better understand of the limitations associated with tail-dropping policy, an example is given to illustrate the infeasibility of this scheme. Without loss of generality, consider two bursts, A and B, will contend with each other at a particular node, C. Suppose: 1) Both A and B are originally made up of two parts, A_1, A_2 and B_1, B_2. A_1 and B_1 are, respectively, in the foreside of their associated bursts; 2) A and B are all wish to pass through node C on the same output port; 3) The tail of A (as shown in Fig. 1, the shaded area A_2), has been discarded at previous node(s); 4) t_{os}, t_{oe}: The starting, ending time of the resources reserved for original burst by control packets; 5) t_{cs}, t_{ce}: The starting, ending time of the resources reserved for contending burst by control packets; 6) t'_{ce}, t'_{oe}: The actual ending time of the contending, original burst.

Now we can find two limitations are associated with tail-dropping policy.

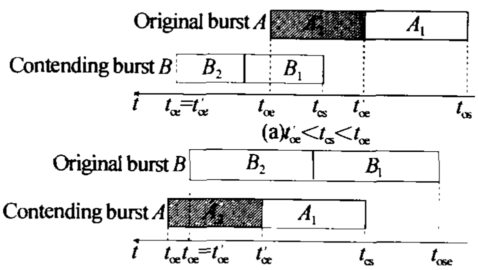

Fig. 1 An illustration of the limitations associated with the tail-dropping policy

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1) Nominal contention: As shown in Fig. 1 (a), suppose burst A will arrive at node C in advance of burst B, and node C has reserved the output port according to the control packets of burst A. Note that resource reservation includes the duration and the starting time of the occupation. Now we consider a general case of arrival of burst B. If the arriving time of burst B, t_{cs}, is just overlapped with the tail of burst A (A_2), i. e., $t'_{oe} < t_{cs} < t_{oe}$, then a nominal contention will occur, and node C has to resolve this contention. In fact, this contention is nonexistent at all. Note that this contention cannot be avoided due to the fact that the occupying duration of the output port has been determined, and node C cannot obtain any information occurred at the previous node(s), thus node C cannot adjust the duration of the occupation. Of course, if a trailing control message associated with burst A is retransmitted to node C to indicate that there has occurred a contention and this message demand that node C should adjust the ending time of the reservation before the arrival of burst A, this nominal contention can be avoided[3]. However, this contradicts with the original intention of the OBS technology, i. e., simplicity, moreover, the nominal contention will continue occurring if the trailing control message arrives at node C behind the arrival of the control packets of burst B.

2) Deterioration of the packet loss probability: Although the nominal contention illustrated in Fig. 1 (a) makes the scheduler to spend extra time to handle contention, it does not worsen the packet loss probability, because the contention occurred at node C does not in factually result in the packet losses. However, another example shown in Fig. 1 (b) can be very different, in this case burst B will arrive at node C in advance of burst A, and node C has reserved the output port according to the control packets of burst B. When burst A arrives at node C, if a contention occurs such that $t'_{ce} < t_{oe} \leqslant t_{ce}$ (Note that in this case burst A is the contending burst), then according to the tail-dropping policy, node C will discard the overlapping packets contained in burst B, specifically, if measured in time scale, the dropping packets of burst B are from t_{cs} to t_{oe}. In fact, the overlapping part of both bursts are from t_{cs} to t'_{ce}, wherein $t'_{ce} < t_{oe}$, so an extra part of burst B has to be discarded, which worsen the packet loss probability.

For head-dropping policy, the situation is very different. Because at a particular upstream node, the resource reservation message sent to the downstream nodes can be sent right after the processing of the burst at this upstream node, or, head-dropping policy has enough time to update the control message already sent to the downstream nodes before the burst is transmitted to the downstream nodes. In one word, the control message received at the downstream nodes is accurate, thus the limitations associated with the tail-dropping policy are no longer in existence.

As for the disorder of the arriving packet, as packets with same source/destination may reach the destination through different paths with different transmitting latency, any destination node can not avoid the operation of sorting the received packets. So, with respect to tail-dropping policy, the increase of the disorder of the packet arrivals for head- dropping policy is trivial. In addition, as mentioned below, we can also adopt hybrid assembly to reduce the disorder of packet arrivals.

2 Hybrid-assembly and improved head-dropping with service differentiation

2.1 Hybrid-assembly scheme

We assume bursts are generated at the network edge with fixed-size, according to their destinations. In other word, packets with different QoS types but with the same destination can be aggregated into a burst simultaneously, we call this hybrid assembly. Fig. 2 shows an example of hybrid assembly versus traditional assembly, in which three kinds of packet classes are considered, where class A, B and C, corresponding to high, medium and low packet classes, are all with the same destination. We can see that the bursts generated in two assembly schemes are very different, i. e., for a considered source destination pair, packets with different QoS types in traditional assembly scheme are aggregated into three kinds of bursts, while for hybrid assembly scheme, just one kind of burst is generated. Moreover, in hybrid assembly scheme, each packet class is grouped into a segment with separate correlative information of it' s own, including the length, number of packets, location of packets and the check sum etc. The number of segments is the priority number that OBS network supports. The priority of the segment is corresponding to the priority of the packets. All segments in a burst are initially transmitted as a single unit. In a burst, segments are arranged in ascending order from burst's head to tail, i. e., the high priority segment is placed at the tail part, while the low priority segment is placed at the head part.

In Fig. 2, notation L denotes burst length, L_A, L_B and L_C denote in hybrid assembly scenario, the corresponding proportion of high, medium and low packet classes, wherein the proportion of each packet class is proportional to its associated traffic load.

Obviously, with respect to the conventional assembly scheme, the waiting time of the hybrid assembly will be reduced and the burst utilization will be higher due to the fact that in hybrid assembly scenario, the average packets arriving rate for a single burst is much higher than that of the conventional counterpart, thus a burst will leave less space to be filled by useless packets. The improvements are much distinctive for low traffic load. In addition, in hybrid assembly scheme, as a single burst is grouped, according to the QoS level, into several relatively independent segments, each segment has its own assembly information, thus if the head of the burst is dropped, the other packets that do not belong to the associated segment will not lose their assembly information, thereby the disorder of the packet arrivals can be minimized.

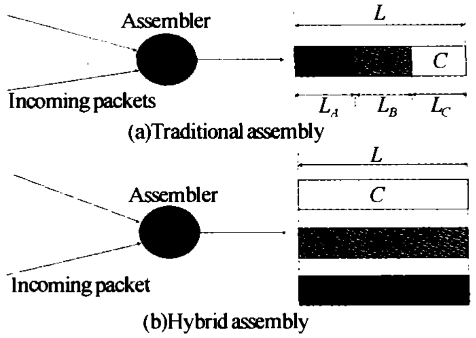

Fig. 2 Comparison of different burst assembly schemes

2.2 Improved head-dropping policy

Based on the principle of the hybrid assembly scheme, it is natural that head-dropping policy must be used to guarantee service QoS. Here we would like to make clear that in OBS networks, a burst that reserve the resources earlier might not imply this burst will arrive at the specified node earlier, because control packets are separated from the burst payload, so, in the following analysis, the contentions are corresponding to the concrete bursts, not the associated control packets. Without loss of generality, we just illustrate that two bursts are involved in the considered contention , and , the switching time of the switch matrix is ignored. For the convenience of the following description, define:

Δ_c: The overlapping length between two bursts; L_c: The total length of the contending burst; t_{os}: The arriving time of the original burst; t_{cs}: The arriving time of the contending burst.

Now, the concrete implementation of contention resolution can be described as:

1) If $\Delta_c < L_c$, goto step 3. Otherwise goto step 2. 2) Drop the entire contending burst (Fig. 3(c)), goto step 4. 3) If $t_{os} \leqslant t_{cs}$, drop the head part of the contending burst, (Fig. 3(a)); Otherwise drop the head part of the original burst (Fig. 3(b)). 4) Update the control packets of the burst that has been truncated.

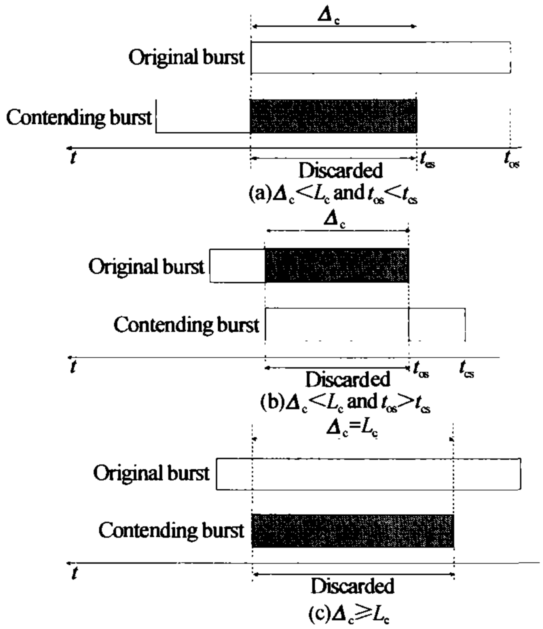

Fig. 3 Concrete implementation of head-dropping policy, wherein the shaded areas are the dropped parts

3 Simulation experiment

The following has been assumed to obtain the results of an OBS core node: 1) The input processes have the same statistic and an arriving burst has the same probability to be directed to any other egress node; 2) The original length of all bursts is fixed to $L_0 = 2500$ bytes (at ingress node). The incoming burst size of the OBS node studied follows negative exponential distribution with the mean length of $\mu = 1500$ bytes; 3) Burst arrivals to each ingress node according to an ON/OFF process, where ON equals to the burst length. OFF is in exponential distribution with the mean value of $L_{off} = L_0(1-R)/R$, wherein R is the traffic load; 4) Switching size of the node is 16 × 16 and switching time is ignored; 5) Three traffic classes, A, B and C, corresponding to high, medium and low packet classes, are considered; 6) The ratio of proportion of three kinds of traffic, from high to low, is 3:2:1; 7) The transmission rate is 10 Gbps.

We compare the number of contentions occurred at the nodes for two different dropping policies, where, the burst is aggregated with hybrid assembly policy. Simulation results are shown in Fig. 4. As the improved head-dropping scheme can, effectively, eliminate the nominal contentions which are inevitable in the tail-dropping scheme, thus as shown in Fig. 4, the number of contentions occurred for the developed dropping policy is much lower than that of the tail - dropping

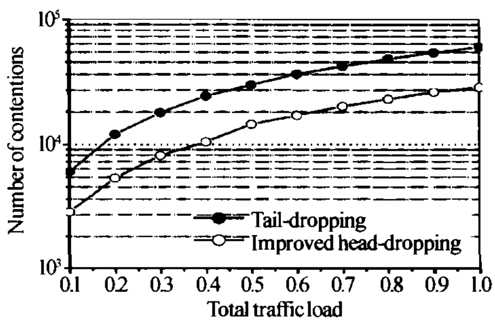

Fig. 4 Comparison of the number of contentions for two different dropping schemes

scheme . This also means that the improved head - dropping scheme can obtain a better packet loss probability. As shown in Fig. 5, we observe that the packet loss probability for the improved head-dropping policy is much lower than that of the tail-dropping policy.

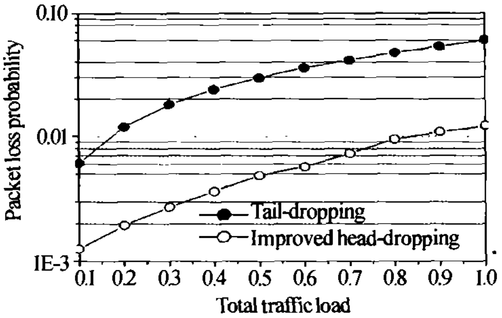

Fig. 5 Comparison of the packet loss probabilities for two different dropping policies

We also investigate how hybrid assembly and improved head-dropping scheme can support service differentiation. For the traffic conditions assumed above, the corresponding simulation results are plotted in Fig. 6. We can see that with a relatively low traffic load, the average packet loss probability for packet class *B* is nearly 10 times higher than that of class *A*, and nearly 10 times lower than that of class *C*, with the

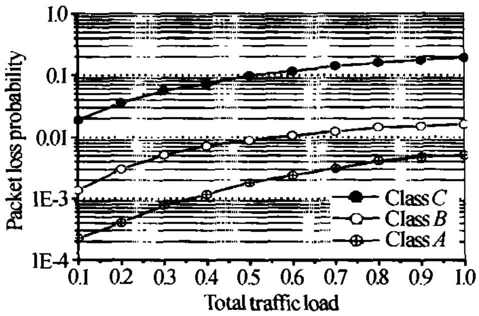

Fig. 6 Comparison of the packet loss probabilities for services with different QoS requirements

increase of the traffic load, the difference between medium and high packet classes is varying, while, even for the maximum traffic load, 1. 0, the packet loss probability for medium packet class is still over 5 times higher than that of the high packet class, and, much lower than that of the low packet class.

4 Summary

In hybrid assembly, burst assembled at the edge node contains the low and high packet classes simultaneously, in which the packets with a relatively high level of QoS requirement are assembled at the relatively backside of the burst. As a single burst is grouped, according to the QoS level, into several relatively independent segments, each segment has its own assembly information, it is helpful to alleviate the disorder of packet arrivals. Moreover, head-dropping can guarantee the downstream nodes to receive the correct control packets, which is inherently difficult to be achieved in tail-dropping scheme, thus it can, effectively, eliminate the nominal contentions, improve the packet loss probability and support QoS.

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光突发交换中支持区分业务的混合封装和改进的头部丢弃策略

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摘 要 介绍一种在光突发交换网中支持业务 QoS，并减少分组到达乱序的突发包混合封装机制．通过将不同级别的分组组成相对独立的段，并进而封装到同一个突发包里，可减少分组到达乱序．结合改进的头部丢弃策略，可克服尾部丢弃法中存在的虚假冲突问题，能真正改善分组丢弃率．仿真结果表明，混合封装在结合改进的头部丢弃法之后，能很好地应用于具有 QoS 要求的光突发交换网中．

关键词 光突发交换；分段；混合封装；头部丢弃；服务质量

Zhang Zhizhong was born in Oct. 1972, in Hubei Province. He received his Ph. D. degree from University of Electronic Science and Technology of China in 2002. He has published and coauthored more than fifty papers in technical journals and conferences, and conducted more than 10 projects. Currently, he is with the center for broadband optical networking technology, Shanghai Jiaotong University. His research interests include wireless networks, photonic switching, resilient packet ring and metro Ethernet networks.