

Segment Technology of Differentiated Services Supporting in Optical Burst Switched networks

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ABSTRACT

Optical Burst Switching (OBS) has been developed as an efficient switching technique to exploit the capacity provided by Dense Wavelength Division Multiplexing (DWDM) transmission technology for the next generation optical Internet. Segmentation is proposed in literatures to resolve contention, a major concern in optical burst switched networks. As far as segmentation is concerned, nearly all the methods introduced in the literatures adopt tail-dropping policy. In this paper, we will demonstrate, however, that tail-dropping policy may not be a feasible solution to resolve contention. Based upon this, a modified head-dropping solution is proposed. In this method, when the overlap part is no more than the entire contending burst arriving late, the head part of contending burst will be discarded, otherwise the entire contending burst will be dropped. In order to alleviate disorder resulted from head dropping and support Differentiated Services well, we also present a priority-based proportional mixed segment assembly technique to encapsulate burst at edge node. A burst consists of several segments, each of which is a group of same priority packets and has its own assembly information. We suggest that the priority-based proportional mixed segment assembly be used integrated with modified head-dropping contention resolution policy in OBS networks. The main objective of our segment scheme is to improve the utilization of resource, decrease the packet loss probability, and afford a better Differentiated Services support as well. Experiment results prove that our integrated segment scheme performs well on decreasing packet loss probability and Differentiated Services.

Key words: Segment, Contention Resolution, Assembly, Differentiated Services, Optical Burst Switching

1. INTRODUCTION

The Internet is evolving from best-effort service toward an integrated or differentiated service framework with Quality-of-Service (QoS) assurances that are required for new multimedia service applications. Given this increasing demand for high bandwidth Internet with QoS assurances in the coming years, an IP/MPLS-based control plane combined with Dense Wavelength Division Multiplexing (DWDM) optical network has been developed as a very promising approach for the realization of future transport networks. The first optical switching paradigm that has been proposed in literature is the optical packet switching (OPS) based on fixed-length packets and synchronous node operation. The drawbacks of this approach mainly consist of the difficulty of implementing the optical synchronizer and of processing the packet headers in the electronic domain. A more promising proposal in this direction, at least in short-medium term, is a new switching paradigm called

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optical burst switching (OBS)^{[1][2]} based on variable length packets (called bursts), asynchronous node operation, and the decoupling of the burst payload from its header with control packets transferred on wavelengths different from the data ones. Optical Burst Switching has been considered as an efficient switching technique to exploit the capacity provided by DWDM transmission technology for the next generation optical Internet.

In OBS networks, bursts of data consisting of multiple packets are switched through the network all-optically. A control packet is transmitted ahead of the burst in order to configure the switches along the burst's route. The data burst follows the header without waiting for an acknowledgement for the connection establishment. The control packet and the data burst are separated at the source, as well as subsequent intermediate nodes, by an offset time. The offset time allows for the control packet to be processed at each node while the burst is buffered electronically at the source; thus, no fiber delay lines are necessary at the intermediate nodes to delay the burst while the control packet is being processed. The control message may also specify the duration of the burst in order to let a node know when it may reconfigure its switch for the next burst, a technique known as Delayed Reservation (DR). In this paper, we will consider an OBS network which uses the DR technique.

Much has been done to OBS network technology such as the signaling protocol^{[1][2]}, node technology including node structure^[3], burst aggregation^[4] at ingress node and contention resolution at core node^[5], and QoS supporting technology^[2]. This paper is dedicated to report our progress on contention resolution and burst assembly technology.

This paper is organized as following: In the second section, we introduce the background of our research on segmentation contention resolution. It is mainly on the analysis to tail-dropping policy. The third part of this paper is to propose our integrated segment scheme in detail. The experiment results are shown with detailed analysis in the following section. Then we make conclusions in the end.

2. RESEARCH BACKGROUND

Contention is the situation that there are two or more bursts which are for a same link at a same time slice. The conventional contention resolution options include wavelength domain, time domain

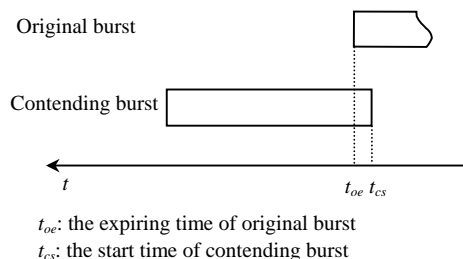


Fig.1 contention between two bursts

and space domain, which mean wavelength conversion, Fiber Delay Line (FDL) buffering and deflection routing respectively. Many efforts have been done to these approaches^[7]. We call the burst which reserved the output port first as original burst, and the burst that also wants to reserve the same output port but still has not got it as contending burst. All these approaches are trying to find a spare output to pass through the entire contending burst without utilizing some spare fragment to forward some parts of burst. So if contention cannot be resolved through these conventional approaches, the contending burst will be dropped in it's entirely, even though the overlap between the two bursts may be minimal just as the situation of $t_{oe} \approx t_{cs}$ in Fig.1. Recently, a new notion of segmentation is proposed to utilize the fragmentary resource to pass packets as many as possible. In burst

segmentation^{[6][8][9]}, rather than dropping the entire burst during contention, the burst may be broken into multiple segments, and only the overlapping segments are discarded. When the contending output port is free, the left of the truncated burst will be transmitted continuously. We adopt this kind of solution is to make the best use of resource and decrease the packet loss probability. There are two kinds of segment dropping policies, namely, head-dropping and tail-dropping. Tail-dropping is to discard the overlap of original burst, the tail part of original burst, to give way for the contending burst. While head-dropping is to discard the overlap part of the contending burst, the head part of the contending burst, to pass through the whole original burst. The tail-dropping policy is the most studied one because it will not disorder the left packets because of the discarded part.

As a matter of fact, a serious drawback of tail-dropping solution has been neglected, which is that it will leave some confusion for the downstream nodes. Because the control packet of the truncated burst has been forwarded before the segmentation occurs, which still contains the original information such as burst length, downstream nodes do not know that the burst has been truncated. If the downstream nodes are unaware of a burst's truncation, it is possible that the previously truncated tail segments will contend with other bursts, even though these tail segments have already been dropped at a previous node. These may result in unnecessary packet loss. Two cases will be resulted in as follows.

Suppose that burst A and burst B was composed of two parts, say, A1, A2 and B1, B2 from head to tail respectively. Both A and B will go to one same output port of node C, and the tail part A2 of burst A has been discarded at previous node. We will consider two cases that maybe arise as in Fig.2. In Fig.2, t_{os} and t'_{oe} denote the resource starting time and the expiring time reserved by control packet, t_{cs} and t'_{ce} , the starting time and expiring time of the contending burst, t_{oe} and t_{ce} denote the actual end time of the truncated original burst and contending burst respectively.

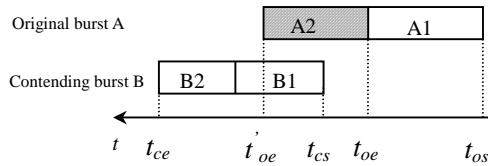


Fig 2.1 Situation when $t_{oe} < t_{cs} < t'_{oe}$

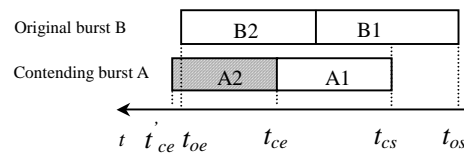


Fig 2.2 Situation when $t_{ce} < t_{oe} \leq t'_{ce}$

Fig 2 two cases maybe arise at node C when tail-dropping used to resolve contention

1. There maybe arise “non-exist” contention to be resolved as in Fig.2.1. Node C has reserved the output port according to the control packet of burst A firstly. The reservation includes the use duration and the start time of use. Then comes the control packet of burst B. If the arriving time of burst B, t_{cs} , is just in the transmission duration of part A2 ($t_{oe} < t_{cs} < t'_{oe}$), there comes a contention. Then node C has to resolve the contention. In fact, this kind of contention is non-existence at all, because the truncated burst A will have been transmitted over before burst B arrives.

2. The resource fragment achieved at the expense of tail dropping at previous node cannot be used well. If when burst A arrives, the output port is in used (burst B has reserved it before burst A) and it will not be free until t_{oe} , node C will discard the overlap of burst B, from t_{cs} to t_{oe} . But in fact, the A2 part of burst A had been discarded, so the duration of part A2 will be wasted as in Fig.2.2. We had hoped to discard A2 part to utilize the output port more efficiently, but it is only in vain in the end. It cannot decrease the packet loss really and only produces a supposititious phenomenon that the resource had been utilized more efficiently.

All above is resulted from the fact that the control packet of the truncated burst cannot be updated before it arrives

at node C. This is inevitable if the tail-dropping policy is adopted to resolve contention in OBS network. Authors in [9] suggested to send a trailing control message to indicate when the truncated burst ends after contention resolution. But it is still not a good remedy because the supposititious phenomenon will arise if the trailing control message arrives at downstream node after the control packet of contending burst.

The aim of segmentation to resolve contention is to decrease packet loss probability, utilize the output port efficiently. The aim of segmentation is to decrease packet loss probability, and utilize the output port more efficiently. But the tail-dropping policy cannot achieve it factually. How to achieve the aim of segmentation is one purpose of this paper. Another intention is to support Differentiated Services besides resolving contention effectively.

3. PROPOSED SCHEME

Almost all literatures adopting tail-dropping policy to resolve contention point that the weakness of head-dropping policy is the disorder of the packets for missing of burst head. Conventionally, the assembling information is placed at the head of burst assembled. If the head is dropped, the latter packets will lose the location information. As a matter of fact, packets with same source/destination maybe reach the destination node through different routes with different latency in IP networks. Whether the location identification of packets in a burst is lost or not, any destination node cannot escape from the operation of sorting to all the received packets. So, whether it will disorder the packets or not should not be the most exclusive criterion to choose the segmentation resolution policy. On the contrary, the most efficient criterion should be that if it reaches the aim of segmentation, i.e., does it improve the resource utilization and decrease the packet loss probability? As analyzed above, there exists a supposititious phenomenon of improving the resource utilization and decreasing the packet loss probability if tail-dropping policy is used, and the remedy cannot eliminate such phenomenon. While, however, such phenomenon doesn't exist in head-dropping policy at all, because it can update control packet before which is sent out for downstream nodes. To lessen the disorder among the latter packets, we propose priority-based mixed segment assembly mechanism.

In order to discuss the modified head-dropping policy, we explain our segment assembly mechanism first, then on which our integrated segment scheme is exploited in detail.

3.1 Priority-based mixed segment assembly mechanism

The conventional assembly is to aggregate the packets of the same priority into a burst. We observe that if this mechanism is adopted to form burst, when two high priority bursts contend for output port, the dropped part is always the high priority packets whichever kind of segmentation policy is used. It is not perfect to support Differentiated Services to employed conventional assembly along with segmentation contention resolution in OBS network. This new burst assembly^[10] is proposed to provide differentiated services and alleviate the disorder because of burst head dropped.

At the ingress node in OBS network, all the packets will be assembled into bursts. It was suggested in literature [6] that packets of different priorities be aggregated in one burst with some weight respectively. The simulation results show that it supports both QoS and fairness well on delay. In order to guarantee the discrimination between priorities in terms of both delay and packet loss probability, we refer to this mixed aggregation. Different class packets with certain proportion are aggregated into one burst, in which each class packets are grouped into a segment with separate correlative information of its own, including the length, number of packet, location of

packet and the check sum. The priority of the segment is the priority of packets. All segments in a burst are initially transmitted as a single burst unit. In a burst, segments are arranged according to the priority in an ascending order from head to tail, i.e., the higher priority segment is placed at the tail part, and the lower priority segment is placed at the head part. The number of segments in a burst is the priority number that OBS network supports. The length of each segment is determined by traffic load of each class. Fig.3 shows a simple example of burst with three classes packets, where class A is the highest priority, B is the second and C is the lowest one. The proportion of three classes is $P_A : P_B : P_C = W_A : W_B : W_C$, W_A , W_B and W_C is the length of segments A, B and C, W is the whole length of the burst. Because of the mixed assembly, all the bursts are equally.

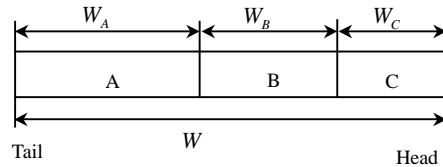


Fig.3 an example burst

Obviously, compared with conventional assembly, the waiting time will be reduced and the burst utilization will be higher with this assembly mechanism. This kind of improvement is much distinctive when in low traffic load. This is because that the total density of all classes load is much denser than any one of them. The most impressive characteristic of such bursts is that same level packets are grouped into a segment, which carries its own assembly information. That means that if the head of a burst is missing, packets belong to other segments at the back of the burst will not lost their assembly information to be disorder.

3.2 Modified head-dropping policy

To date, the operation of head-dropping policy was only introduced in [5], in which the head of the contending burst will be discarded if there arises contention on an output port. Base on this, we modify it as follows.

Fig.4 describes the operation of our modified head-dropping contention resolution^[11]. In optical burst switching, the reserving of output port is achieved due to the control packet arriving ahead of burst, and contention resolution is completed when coping with the control packet of contending burst. The bursts may not arrive when the contention is being resolved. For the sake of visualization, we analyze the instances with bursts. The symbols in Fig.4 is defined as following:

Δ_c : the contention duration between two bursts.

L_c : the equivalent duration of the whole contending burst.

Δ_s : the switching time of the switch matrix.

t_{os} : the arriving time of the original burst.

t_{cs} : the arriving time of the contending burst.

The contention resolution process consists of two steps. The first step is to determine which part will be dropped. The processor of control packet compares the contending duration with the equivalent duration of the whole contending burst, if $\Delta_c < L_c$ and the contending burst is later than the original burst to arrive the node ($t_{os} < t_{cs}$), the head part of contending burst will be dropped and the entire original burst will be delivered. The truncated contending burst will be forwarded continuously after the output port has been released by the original burst. The equivalent duration of the dropped part of contending burst is $\Delta_c + \Delta_s$ just as in Fig.4.1. If $\Delta_c < L_c$ and the contending burst arrives at the node earlier than the original burst ($t_{os} > t_{cs}$), the entire contending burst will be

dropped to guarantee the original burst delivered intact as Fig.4.2. If $\Delta_c \geq L_c$, the entire contending burst will be dropped as Fig.4.3. To summarize, when the control packet of original burst arrives earlier than that of contending burst, it depends on the comparison between the contending duration and the equivalent duration of entire contending burst to determinate to drop the head part or the whole contending burst. When control packet of original burst arrives earlier but the responding burst arrives later, the whole contending burst will be dropped. The second step is to update the control packet of the contending burst due to the resolving issue. If the head part of contending burst is discarded, relative information carried in control packet such as the length of the burst and the arriving time at next node will be changed. If the whole contending burst is dropped, the responding control packet should be dropped too. The second step is very important for correct subsequence link reservation.

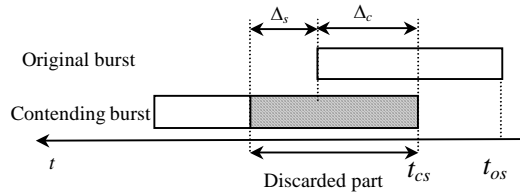


Fig.4.1 $\Delta_c < L_c$ and $t_{os} < t_{cs}$, dropping the head part of contending burst

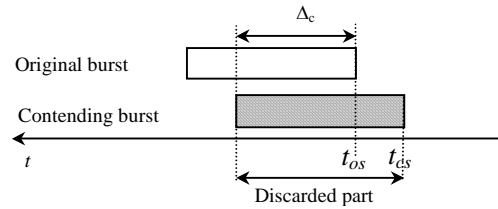


Fig.4.2 $\Delta_c < L_c$ and $t_{os} > t_{cs}$, dropping the entire contending burst

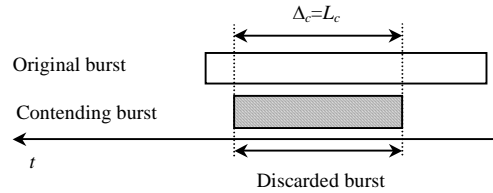


Fig.4.3 $\Delta_c \geq L_c$, dropping the entire contending burst

Fig.4 Modified head-dropping policy

In OBS network, modified head-dropping contention resolution can not only handle conflict on output port of node, but also dispose the control packet well in time. This policy reduces the probability of a short burst preempting a longer burst and minimizes the number of packets lost during contention.

Our scheme is to integrate the priority-based mixed segment assembly mechanism with modified head-dropping policy. We call it integrated segment scheme. The advantages of this scheme are listed as follows.

Firstly, it can correct control packet that is crucial to resource reserving and will not result in resource wasting phenomenon at downstream nodes. So it is impossible to appear such supposititious phenomenon as with tail-dropping policy, the contention times will also be decreased and the process burden will be lessen. All these owes to the ability of updating control packet in time.

Secondly, it can support differentiated services well. In priority-based mixed segment assembly, the high priority packets are placed as one segment at the tail part of burst, and low priority packets are placed as one segment at the head part of burst. When encounter contention, the dropped part will be the relative low priority segment. So

the high priority traffic will attain relative better QoS on packet loss probability.

Another advantage is also related with segment-based assembly. In a burst, packets with same priority are aggregated as a segment with its own assembling attributes. If the head part of a burst is dropped, it will not affect the order of the left packets other than in the segment the dropping point belongs to. The disorder from priority-based proportional mixed segment assembly is much alleviated than that from conventional assembly.

4. PERFORMANCE ANALYSIS AND NUMERICAL RESULTS

We evaluate our scheme in OBS network. To simplify the simulation, we suppose the network parameters as following:

- 1) The traffic is symmetric, i.e., the input processes have the same statistic characteristic and any arriving burst at one ingress node has the same probability to be directed to any output wavelength channel as any other egress node.
- 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 at each ingress node according to an ON/OFF process, where ON duration equals to burst length, and OFF is in exponential distribution with the mean of $L_{off} = L_0(1 - R)/R$, R is the traffic load.
- 4) Switching size of each node is N and the switching time can be ignored.
- 5) The traffic is divided into three levels, namely A, B and C, and level A holds the highest priority, level B holds the second one and level C holds the lowest one. The encapsulating scale is $W_A : W_B : W_C = 3 : 2 : 1$.

We choose the parameters of N , L_0 and μ as 16, 2500B, 1500B respectively. The transmission rate is 10Gbps. What this paper studied is the performance of our integrated segment scheme and the compare between the modified head-dropping policy and tail-dropping policy to resolve contention.

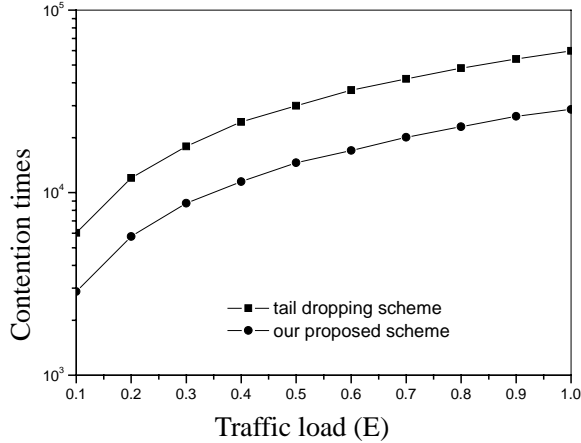


Fig.5 results of contention times of two policies

In order to validate the analysis to tail-dropping policy and the improvement of our scheme, we compare the contention times that should be coped with in network as in Fig.5. In this experiment, the burst is aggregated with priority-based mixed segment assembly. It's obvious that the contention times will be much less when the modified head-dropping policy is adopted instead of tail-dropping policy. As analyzed above, if tail-dropping policy is used to resolve contention, the nodes need to treat some non-exist contention, which is unnecessary for modified head-dropping policy though. Because the downstream nodes can reserve output port for burst according

to the authentic information carried in control packet.

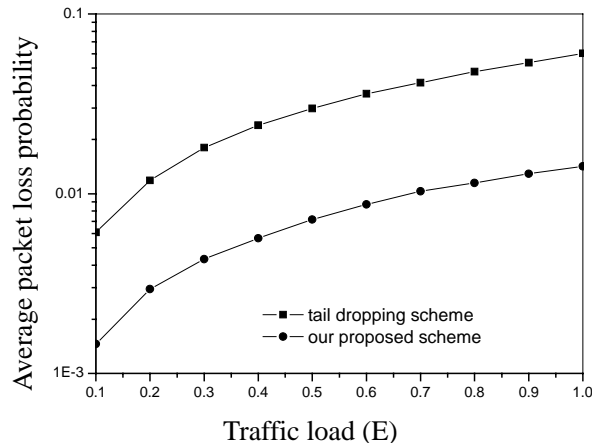


Fig.6 results of average packet loss probability

As for the fragment resource attained at the cost of tail part of burst cannot be able to be utilized well, and the packet loss will not be decrease as our wishes, we hope to improve this instance to achieve the anticipate purpose of segmentation. We simulate the average packet loss probability of these two contention resolution policies and get results as in Fig.6. In this experiment, the burst is also aggregated with priority-based mixed segment assembly. We observe that the packet loss probability when modified head-dropping policy used to resolve contention is much less than that of tail-dropping policy. It's because that the output port will not be occupied sparely in former case, and the resource can be utilized much better to decrease the packet loss probability than in the latter case.

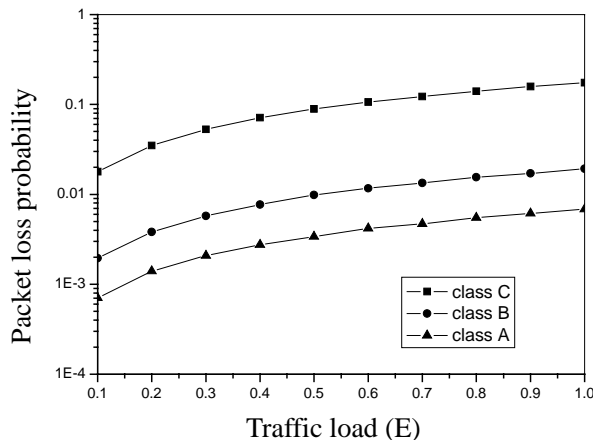


Fig.7 Comparison of packet loss probability among three classes

The purpose that we adopt priority-based mixed segment assembly is to attain two aspects progress. One is to alleviate the disorder for the dropping of burst head part, the other is to support differentiated services for users. Fig.7 plots the packet loss probability of diverse priorities traffic when the integrated segment scheme is employed and the assembly proportion is $P_A:P_B:P_C = 3:2:1$. We observe that the packet loss probability of high priority traffic is lower than that of low priority traffic. The contention is resolved through the comparison of the order of output port reservation and the length of contending burst and the contention region in our modified head-dropping policy. The dropped part is the entire or the head part of contending burst reserving later. The head

part of a burst is always the relative lower priority segments. So the packet loss probability of high priority traffic will be lower than that of low priority traffic. The result matches with our expectation.

It is because that not only our scheme can handle contention effectively, but also can update control packet in time, which will not leave any aftermath to downstream nodes and improve the utilization of link to decrease the packet loss probability really. Because of the use of priority-based mixed segment assembly, the performance of high priority traffic can be guaranteed more than low priority traffic in terms of packet loss probability. From the experiment results above, it can be concluded that our scheme not only achieves the objective of segmentation, but also support differentiated services well.

5. CONCLUSIONS

We analyze the drawback of tail-dropping policy for contention resolution, and demonstrate the feasibility of head-dropping policy. We modified the simple head-dropping policy introduced in literatures to avoid the disadvantages of tail-dropping policy. To alleviating the weakness of head-dropping policy, we propose priority-based proportional mixed segment assembly mechanism. Not only can it advance the burstification efficiency, but also reduce the waiting time during assembly. Most importantly, it can also minimize the disorder effectively and support Differentiated Services. Observed from the experiment results, the integrated segment scheme performs very well on improving the performance and supporting Differentiated Services in terms of packet loss probability.

REFERENCES

- 1 C. Qiao and M. Yoo, "Optical burst switching (OBS)-a new paradigm for an optical Internet" *Journal High Speed Networks*, vol. 8, pp.69-84, 1999
- 2 C. Qiao, "Labeled optical burst switching for IP-over-WDM Integration", *IEEE Communications Magazine*, vol. 38, no. 9, pp.104-114, 2000
- 3 Y. Xiong, M. Vandenhouste, and H.C. Cankaya, "Control architecture in optical burst switched WDM networks" *IEEE JASC*, vol.18, pp.1838-1851, 2000
- 4 M.C. Yuang, et al, "QoS Burstification for Optical Burst Switched WDM Networks" *OFC 2002*, ThGG118
- 5 C. Gauger, et al., "Contention resolution in optical burst switching networks" *Advanced Infrastructures for Photonic Networks: WG 2 Intermediate Report*, pp. 62-82, 2002
- 6 Andrea Detti, V. Eramo and M. Listanti, "Performance Evaluation of a New Technique for IP Support in a WDM Optical Network: Optical Composite Burst Switching(OCBS)" *J. of Lightwave technology*, Vol.20, FEB. 2002 pp.154-165
- 7 S.Yao, B. Mukherjee, et al, "All-Optical Packet-Switched Networks: A Study of Contention Resolution Schemes in an Irregular Mesh Network with Variable-Sized Packets" *Proceedings, SPIE Opticomm 2000*
- 8 M. Neuts, H. L. Vu, and M. Zukerman, "Insight into the Benefit of Burst Segmentation in Optical Burst Switching", *Proceedings of COIN-PS 2002*, Cheju Island, Korea, July, 2002.
- 9 Vinod M. Vokkarane, Jason P. Jue, and Sriranjani Sitaraman "Burst Segmentation: An Approach For Reducing Packet Loss In Optical Burst Switched Networks" *IEEE ICC 2002*, 28 April-2 May 2002 Page(s): 2673 -2677 vol.5
- 10 Jianxin Wang, et al, "Priority-based mixed assembly supporting differentiated service for optical burst switched networks" *OECC 2003* to appear
- 11 Jianxin Wang, et al, "Contention Resolution QoS Supporting for Optical Burst Switched Networks" *ITCOM 2003* to appear