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Enhancing Fairness in OBS Networks

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***Abstract*— Optical Burst Switching (OBS) is a promising solution for all optical Wavelength Division Multiplexing (WDM) networks. It combines the benefits of both Optical Packet Switching (OPS) and Optical Circuit Switching (OCS). In this switching, data are transmitted in the form of bursts. Fairness is the main constraint in high-performance OBS network. In order to improve the fairness, a method known as hop-based burst-cluster transmission is used. In this method, bursts are assembled from smallest to largest number of hops, and transmitted along with the control packets, that are used to reserve the wavelengths. Bursts with larger number of hops have more chances of wavelength reservation than those with smaller number of hops. This results in the decrease of overall burst loss probability and fairness is also improved. Finally the performance of hop based burst-cluster transmission for 14-node NSFNET is evaluated.**

***Keywords*— OBS, Fairness Improvement, Burst Loss Probability, Wavelength Division Multiplexing.**

I. Introduction

Optical Burst Switching (OBS) is an optical data transport technique, for ensuring efficient use of bandwidth in WDM networks [1], in which a large amount of data is transmitted as various size units called bursts [2]. These bursts are the basic switching entity. Burst is a variable length data packet, assembled at an ingress router by aggregating a number of IP packets, which may be received from a single host or from multiple hosts belonging to the same or different access networks. An optical burst-switched network is composed with OBS nodes that are interconnected via optical fiber link. Fig.1 shows the architecture of an OBS network. OBS network consists of two nodes: edge node and core node. Edge nodes are at the interface between the electronic and optical domain. Edge nodes can be an ingress or egress node. A core node is mainly composed of an optical switching matrix and a switch control unit which are responsible to forward payload/ data burst. A node in OBS network consists of both optical and electronic components. Figure.2. shows the functional block diagram of OBS. The ingress node is responsible for burst assembly routing, wavelength assignment, scheduling of burst at edge node.

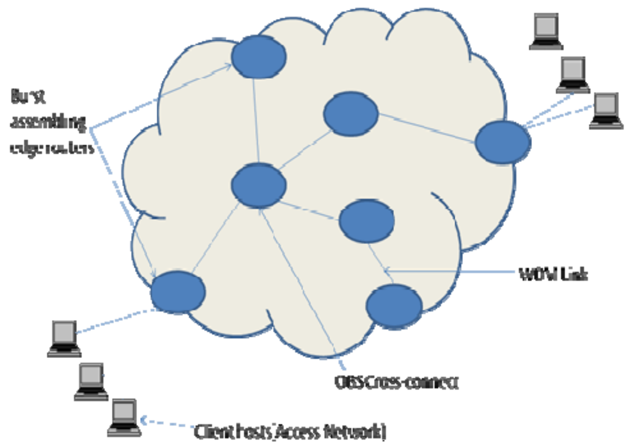

Fig. 1 The OBS network architecture

The core node is responsible for signaling, scheduling, resolving contention. The egress edge node is responsible for disassembling the burst and forwarding the packet to higher network layer. Data bursts are transmitted on separate set of data wavelength channels that are all-optically switched at intermediate nodes [3].

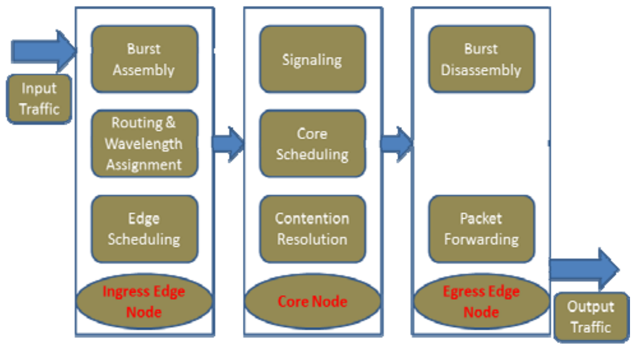

Fig. 2 Functional block diagram

Only control packets that are carried on one or more control wavelength channels undergo optical-electrical-optical (O/E/O) conversion at each intermediate node. OBS combines the transparency of OCS with statistical multiplexing gain of OPS.

II. REVIEW OF LITERATURE

A. *Fairness Improvement*

Fairness is an important issue in high-performance OBS networks. In order to solve the problem of unfairness, some methods have been proposed already. They are balanced just-in-time(BJIT), prioritized random-early-discard(PRED) schemes and preemption mechanism [4]. In BJIT, as a burst is transmitted from one hop to another hop, the number of wavelengths available for the transmission of burst increases, thus improving the fairness. But, sometimes burst with less number of hops may be rejected. Due to this overall burst loss probability increases. In PRED, a proactive burst dropping with discarding probability mechanism is used. As the burst-hop number increases, the discarding probability decreases, thus improving the fairness. To be more effective, this method depends on parameter settings. But, for some parameter sets, it cannot improve the fairness and also increases the overall burst loss probability. In preemption mechanism, a burst with large number of hops can preempt a burst with small number of hops, when the number of transmitting hops is greater than or equal to the pre-specified threshold. Thus, the fairness can be improved [5], but the overall burst loss probability increases. In deflection routing method, burst is deflected to an alternative port in case of contention on the primary port. However, the deflection routing results in several side effects including burst transmission delay and out-of-order packet arrival at the destination. In burst segmentation, when the contention occurs the burst is divided into two segments. One segment is dropped while other is transmitted. Dropped segment can then be retransmitted. Three more methods are used to improve fairness, they are hop-by-hop routing using forward channel reservation(Hop-FCR), hop-by-hop routing using link connectivity(Hop-LC), hop-by-hop routing using neighbourhood forward channel reservation(Hop-N-FCR).

B. ***Burst-Cluster Transmission***

In this method, bursts are arranged in order from the lowest to the highest service class [6]. Thus, the burst-cluster is generated and transmitted from ingress node to the egress node along with multiple control packets. Each control packet reserves a wavelength for transmission of burst. A burst with a higher class has more chances in wavelength reservation. Therefore, this method provides a small (large) burst loss probability for high (low) priority class. It is more effective for immediate reservation protocol as it reduces the redundant wavelength utilization time. This method decreases the overall burst loss probability.

III. HOP-BASED BURST-CLUSTER TRANSMISSION

A. *Edge Node Architecture*

The architecture of an ingress edge node for hop-based burst-cluster transmission is shown in Figure.3. The ingress node has a classifier, burstifier, scheduler and OBS switch. At the ingress node, the arriving IP packet is forwarded to its burstifier and then stored in queue corresponding to its egress node by a classifier.

Consider a high-performance OBS network where immediate reservation is utilized. In this network, there are N nodes and focus on an ingress node which has some egress nodes, as shown in Fig. 4.

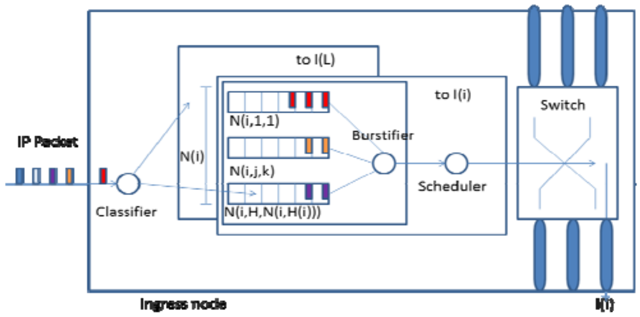

Fig. 3 Edge - Node architecture

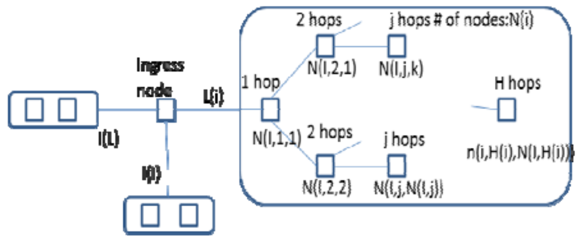

Fig. 4 Input and output links

This node has L output links (L≤N-1) and the ith (i=1,…,L) output link is denoted as l(i). The ingress node transmits bursts to the egress nodes with the L output links. N(i) denotes the number of egress nodes where bursts are transmitted with l(i),where $\sum_{i=1} N(i) \leq N-1$. H(i) is defined as the maximum number of hops among the N(i) egress nodes. Moreover, let N(i,j) denote the number of egress nodes to which bursts are transmitted through j hops, where $\sum_{j=1} N(i,j) = N(i)$ is satisfied.

B. *Burst Assembly and Transmission Algorithms*

In this method, N(i) burst are assembled simultaneously according to a Timer/Threshold-based burst assembly [7]. N(i) burst are assembled when the timer becomes threshold T_{max} or the total amount of packets stored in the N(i) queues becomes threshold B_{max}. With the N(i) assembled bursts, a hop-based burst-cluster is generated. Here, the burst are arranged from smallest number of hops to the largest one. The burst whose egress node is n(I,1,1) is ahead of the burst whose egress node is n(I,2,1), as shown in Figure.4. When the number of burst with j hops is larger than one i.e., N(i,j)>1, the order of bursts is determined at random. Then, the generated hop-based burst-cluster is forwarded to the scheduler and it determines when the N(i) SETUP message and the hop-based burst-cluster containing N(i) burst are sent into the network. SETUP and RELEASE messages are represented as S_m and R_m, respectively, for mth burst and Δj is the offset time between a burst and its control packet when the total number of hops is j. Consecutively the N(i) burst are transmitted from the scheduler along with the N(i) SETUP message. So, the burst whose number of hops is smaller is transmitted first and then the larger one.

C. Processing Mechanism of the Control Packet

Control Packets (CP) are processed by a mechanism that makes use of the S_m and R_m messages for wavelength reservation. The call reference value, V_m is used here [8]. S_m has information about these values V_1 to V_{m-1}. S_m is transmitted to reserve wavelength for the burst and S_m reserves a wavelength and V_m is allocated to the wavelength which is shown in Fig. 5(a).

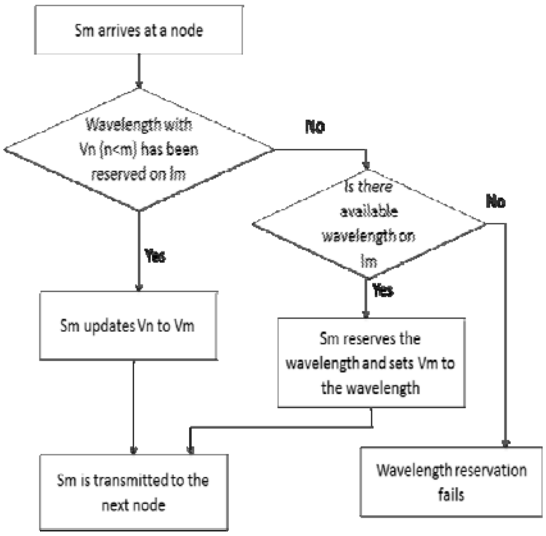

Fig. 5(a) Processing mechanism of the control packets-SETUP message

When S_m arrives at the node, it checks the call reference value for a wavelength with V_k (k<m) and if it is available, S_m updates V_k to V_m and is just sent to the next node without wavelength reservation; if not, S_m reserves wavelength and V_m is allocated to the wavelength [9] and S_m is sent to the next node.

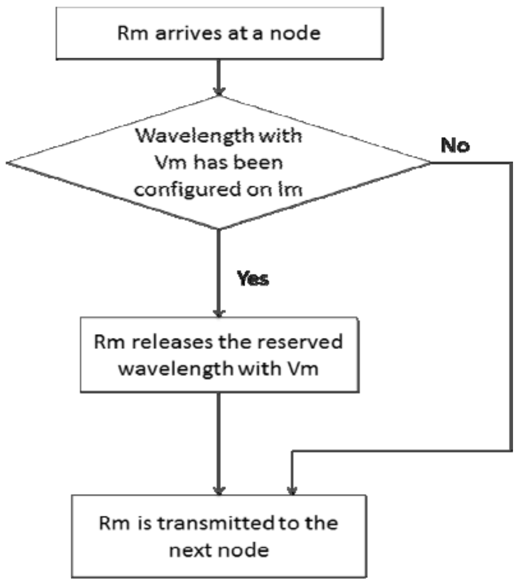

Fig. 5(b) Processing mechanism of the control packets-RELEASE message

Here, the rear burst has more chances in wavelength reservation than the front burst, as it can be transmitted on the wavelength. Thus, the fairness is improved as the burst loss probability of more hops decreases. The reserved wavelength is released by the use of R_m and when it reaches the node, it checks the call reference as shown in Fig. 5(b). If there is wavelength with V_m, R_m releases the wavelength; or else, R_m does not release the wavelength and is sent to the next node. This processing of CP can avoid redundant wavelength utilization.

D. Impact of a Void on Wavelength Reservation

Voids are used when two adjacent bursts are to be transmitted to different output links.

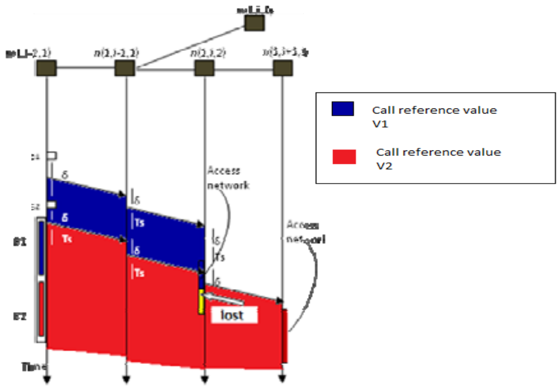

Fig. 6 (a) Burst-cluster transmission without void.

They are used in order to avoid preemption [10] of adjacent bursts, as shown in Fig. 6(a). Here, δ is the processing time of a control packet and Ts is the switching time of an optical switch. Consider a case, where two adjacent bursts are forwarded without void.

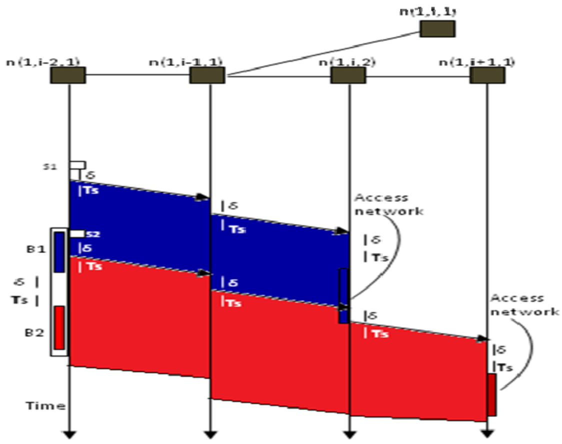

Fig. 6(b) Burst-cluster transmission with void.

One burst may preempt the other and thus, there may be loss of bursts. So, a void of size δ+Ts has to be inserted between them, as given in Fig. 6(b). In some cases, the size must be larger than 2δ+Ts. And the time interval between the SETUP message and the burst is given by r_mδ+Ts and also larger than that for some cases. Thus, the burst loss probability is reduced by the use of void.

IV. NUMERICAL EXAMPLES

The performance of hop based burst cluster transmission in the 14-node NSFNET is evaluated, shown in Figure.7. In this network, the number of wavelength at each link is W and transmission speed is equal to 10Gbps. The distance between each adjacent nodes is from 300km to 2800 km.

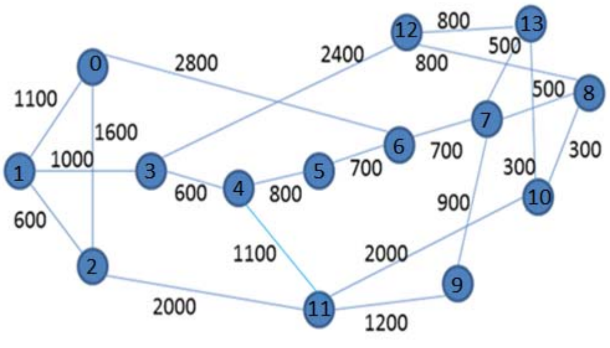

Fig .7 The 14-node NSFNET

In hop based burst cluster transmission a hop based burst cluster is generated according to timer/threshold algorithm with thresholds T_{max}=10[ms] and BC_{max}=10[ms]. The transmission of hop based burst cluster starts only after a waiting period which is selected between [0,T_{max}]. Here the overall burst loss probability is derived and also evaluate fairness, using fairness index.

A. *Impact of the Arrival Rate of IP Packets*

The arrival rate λ of IP packets affect the performance of hop-based burst-cluster transmission and the conventional method. Figure.8. shows the plot of overall burst loss probability against arrival rate λ (packets/μs) for the two methods. From this Figure, it is concluded that the overall burst loss probability of the proposed method is smaller.

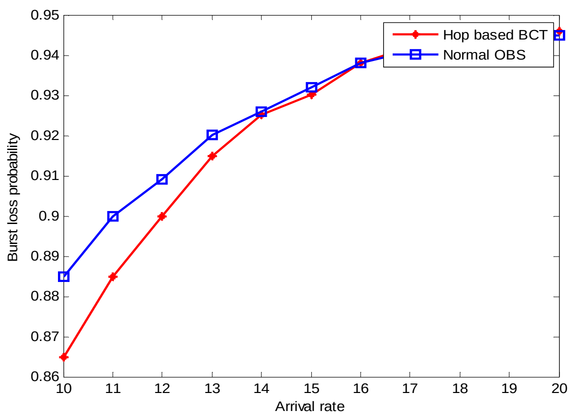

Fig. 8 Burst loss probability versus arrival rate of IP packets

In Fig 9, we can find that the fairness index of hop based burst cluster transmission is improved than that of normal OBS transmission.

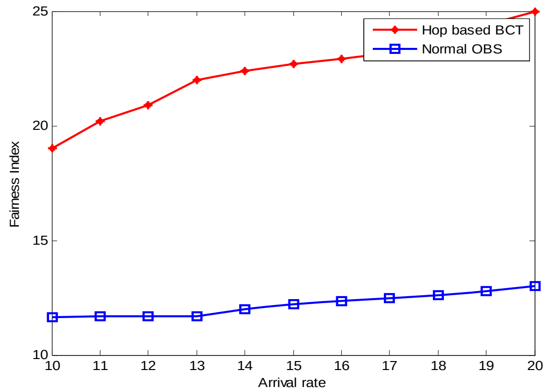

Fig. 9 Fairness index versus arrival rate of IP packets

B. *Impact of the Processing time of the Control Packets*

The processing time of the control packet δ affects the effectiveness of hop-based burst-cluster transmission. Fig.10 shows the overall burst loss probability verses processing time of control packets. From the graph, in hop-based burst-cluster transmission, the overall burst loss probability is smaller compared to that of normal OBS.

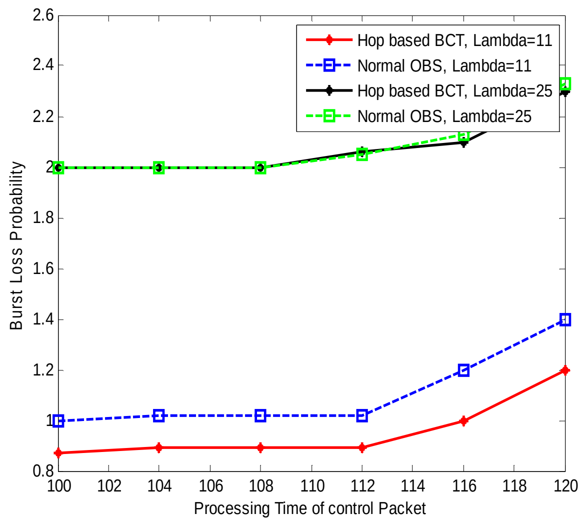

Fig. 10 Burst loss probability versus the processing time of control packets

V. CONCLUSIONS

The performance of hop-based burst-cluster transmission in the 14-node NSFNET is evaluated with simulation. Also, calculated the arrival rate of IP packets, processing time of a control packet, switching time of an optical switch and the number of wavelengths. It is observed that the fairness is improved and the overall burst loss probability is decreased. In addition, this method is more effective when the number of wavelengths is large and is decided based on better network planning and design. Also percolation theory is used to improve fairness in OBS network. In this method the connectivity of the node is identified. The node is connected only if the capacity of the channel is greater than the arrival rate. Then percolation mean value is calculated and it is compared with the percolation threshold value. If the mean value is greater than the threshold value, fairness of the network is improved.

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