Traffic Tree Based Burst Scheduling in Optical Burst Switching Network

Wei Dai, Guiling Wu, Jianping Chen, Xinwan Li, and Yahong Yang

***Abstract*—Serializing bursts at the ingress node is an effective method to reduce burst loss in OBS networks. One of the key issues in the scheduling scheme is home channel assignment. In this letter, serialized burst traffic load (SBTL) is defined to evaluate the burst serializing degree according to the traffic tree model. A home channel assignment algorithm based on the optimization of total SBTL is proposed. Simulation is performed to verify the efficiency of the burst scheduling scheme for the proposed algorithm. The results show that the performance of the proposed algorithm is better than that obtained by greedy algorithm.**

***Index Terms*—Optical burst switching, home channel, burst scheduling, traffic tree.**

I. INTRODUCTION

RECENTLY, optical burst switching (OBS) has been proposed as a promising solution for IP over WDM [1], [2]. Despite its merits like smaller granularity and higher flexibility, the bursts are relatively easy to be lost in the OBS network for the random contention caused by the absence of optical buffer. Much work has been done to reduce the burst loss ratio in the OBS network by improving the burst scheduling strategy [3]. One of them is burst serialization. The basic idea is to serialize bursts on the corresponding home channel at the OBS ingress nodes so that the possible burst collision in the OBS core network can accordingly be reduced. J. Li and C. Qiao in [4] proposed BORA-FS-VF and BORA-DS-VF to serialize the bursts at the OBS ingress edge node. F. Farahmand et al. in [5] proposed a scheme where several sub-bursts of different destinations are groomed together at the OBS ingress nodes and split on the relevant OBS core node. Home channel assignment, however, for the serialization based scheduling scheme is still an open problem.

In this paper, a metric, named serialized burst traffic load (SBTL), is defined to evaluate the burst serializing degree based on the traffic tree model. Then we use two home channel assignment algorithms to seek the maximum total SBTL, one is proposed by us and the other is the modified greedy algorithm. The performance of the corresponding OBS burst scheduling scheme is evaluated and compared in terms of burst loss ratio.

II. BURST SCHEDULING SCHEME BASED ON TRAFFIC TREE

Assume that the burst traffic from an OBS ingress node is sent to a set of egress nodes $K = \{node_i | 1 \le i \le N\}$, and SPF (shortest path first) routing protocol is adopted. The distribution of the traffic from the ingress node can be described by a traffic tree from the ingress node to N egress nodes through the shortest paths as shown in Fig. 1(a). The sub-tree from the ingress node to a subset k, $k \subseteq K$, named traffic sub-tree, is used to describe the distribution of traffic from the ingress node to the corresponding egress nodes as shown in Fig. 1(b). The traffic load on each link in a traffic sub-tree is the by-pass traffic load from the ingress node to the egress nodes in the corresponding traffic sub-tree.

Based on the above traffic tree concept, the home channel selection problem can be modeled as the selection of traffic sub-trees from the entire traffic tree and the assignment of different home channels to them. The bursts on each link in a selected traffic sub-tree can be classified into serialized bursts and non-serialized bursts. The serialized bursts on a link are defined as bursts which are scheduled to the corresponding home channel at the ingress node after some delay for the presence of other bursts that will bypass the same link.

Let n be the allowed maximum number of bursts waiting in the queue at the ingress node; λ_i be the traffic load on link i in the traffic sub-tree; λ_{in} be the total traffic load sent from the ingress node in the traffic sub-tree; B is the bandwidth of the data channel. The possibility that a burst is serialized on link i can be expressed as:

$$\begin{aligned}
P_i &= \sum_{j=1}^{n-1}\left(P(L_{\lambda_i}=j)\times\sum_{k=j}^{n-1}P(L_{\lambda_{in}}=k|L_{\lambda_i}=j)\right)\\
&= \sum_{j=1}^{n-1}\Bigg(P(L_{\lambda_i}=j)\times\\
&\qquad \sum_{k=j}^{n-1}P\left(L_{\lambda_i}+L_{\lambda_{in}-\lambda_i}(t_{\lambda_i})=k|L_{\lambda_i}=j\right)\Bigg)\\
&= \sum_{j=1}^{n-1}\Bigg(P(L_{\lambda_i}=j)\times\\
&\qquad \sum_{k=j}^{n-1}P\left(L_{\lambda_{in}-\lambda_i}(t_{\lambda_i})=k-j|L_{\lambda_i}=j=t_{\lambda_i}\cdot\lambda_i\cdot B\right)\Bigg)\\
&= \sum_{j=1}^{n-1}\Bigg(P(L_{\lambda_i}=j)\times\\
&\qquad \sum_{k=j}^{n-1}P\left(L_{\lambda_{in}-\lambda_i}\left(t_{\lambda_i}=\frac{j}{\lambda_i\cdot B}\right)=k-j\right)\Bigg)
\end{aligned}\tag{1}$$

where, $P(L_{\lambda_i}=j)$ is the possibility that there are j serialized bursts on the corresponding home channel at the ingress node when the ingress node only sends bursts bypassing link

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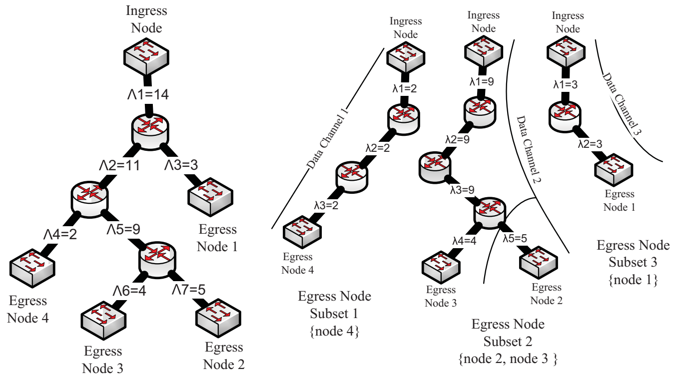
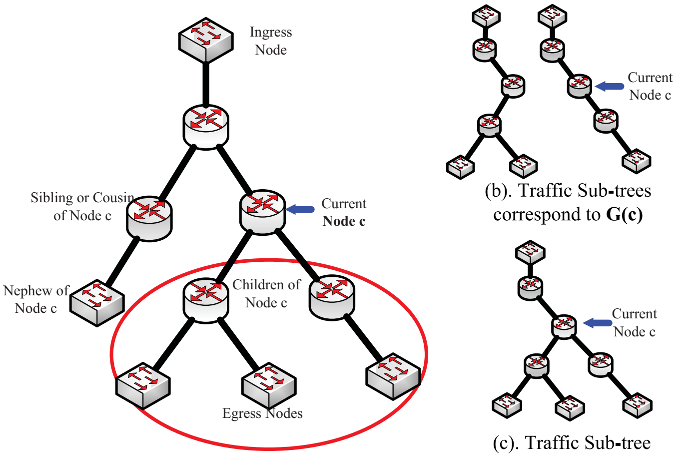


(a) Traffic tree for OBS network

(b) Assignment of home channels for relevant traffic sub-trees

Fig. 1. Traffic tree structure.



(a). Node Set **S(c)**

(b). Traffic Sub-trees correspond to **G(c)**

(c). Traffic Sub-tree corresponds to **F(c)**

Fig. 2. Graphic illustration for split algorithm.

i. $P(L_{\lambda_{in}} = k | L_{\lambda_i} = j)$ is the possibility that there are k serialized bursts on corresponding home channel at the ingress node under the condition of $L_{\lambda_i} = j$. $L_{\lambda - \lambda_i}(t_{\lambda_i})$ is the number of the arrived bursts that would not bypass link i at the ingress edge node during the time to serialize j bursts bypassing link i (namely $t_{\lambda_i} = j/(\lambda_i \cdot B)$).

Assuming the burst traffic at ingress nodes is Poisson traffic, and the length of the bursts follows exponential distribution, burst scheduling process on a home channel can be analyzed using M/M/1/n queuing model, we have:

$$P(L_{\lambda_i} = j) = \frac{1-\lambda_i}{1-\lambda_i^{n+1}}\lambda_i^j \tag{2}$$

$$P\left(L_{\lambda_{in}-\lambda_i}\left(\frac{j}{\lambda_i \cdot B}\right) = k-j\right) = \begin{cases} \frac{((\lambda_{in}-\lambda_i)j/\lambda_i)^{k-j}}{(k-j)!}e^{-(\lambda_{in}-\lambda_i)j/\lambda_i}, & \lambda_{in} \neq \lambda_i \\ 1, & \lambda_{in} = \lambda_i \; and \, k = j \\ 0, & \lambda_{in} = \lambda_i \; and \, k \neq j \end{cases} \tag{3}$$

So the burst serializing degree of a traffic sub-tree can be evaluated by a metric, named Serialized Burst Traffic Load (SBTL):

$$\lambda_{serialized,k} = \sum_{i=1}^{M} \lambda_i P_i \tag{4}$$

where, M is the total number of links in the sub-tree. The total SBTL of a traffic tree is as follows:

$$\lambda_{serialized,total} = \sum_{l=1}^{L} \lambda_{serialized,l} \tag{5}$$

where, L is the total number of the traffic sub-trees selected from the traffic tree.

Based on the defined SBTL, a corresponding burst scheduling scheme is presented. It includes two steps:

1). Assigning home channels so as to seek the maximum total SBTL of OBS network;

2). Scheduling bursts to the corresponding home channel at the ingress node as soon as the maximum allowed delay is not exceeded. Otherwise, the burst will simply be scheduled based on LAUC-VF algorithm [6].

A conventional greedy algorithm for the tree structure can be used to find home channel assignment with the maximum total SBTL. It works as follow:

1). Compute the SBTL of each traffic sub-tree in the current traffic tree.

2). Assign an empty home channel to the traffic sub-tree with the maximum SBTL. If no home channel can be assigned. The process is ended.

3). Remove the selected traffic sub-tree from the current traffic tree. If the current traffic tree becomes null, the process is ended. Other wise, return to step (1).

The greedy algorithm is simple and easy to apply. However, it cannot always get the global optimal results since it is a locally optimal algorithm [7]. In order to overcome the shortage, we propose a split algorithm, which gradually optimizes the home channel assignment by splitting traffic tree from up to down and considers the result of the former home channel assignment. It works as follow:

1). Initialize the ingress node as the current node c, and assign a common home channel to all the egress nodes in set S(c), which contains nodes that share the common ancestor node c.

2). If node c is the leaf node, or the number of empty home channels is smaller than that of the children of node c, goes to step (4); else calculate both F(c) and G(c). F(c) is the SBTL of the traffic sub-tree corresponding to S(c). G(c) is where node j is the children of node c.

3). If the G(c) is larger than the F(c), cancel the home channel assignment for S(c) and assign a different home channel to each S(j), respectively. And mark each child of node c.

4). If all marked sibling and cousin nodes of node c have been processed, take one marked child or nephew node of node c as the current node c; else take an un-processed marked sibling or cousin node of node c as the current node c. Return to step (2).

5). If no marked sibling, cousin, child or nephew of node c can be taken as the current node, the process is ended.

For example in Fig. 2, Node c is current node. Corresponding S(c) is the set of nodes inside the circle of Fig. 2(a); the traffic sub-tree used to calculate F(c) is shown in Fig. 2(c); Fig. 2(b) shows the traffic sub-trees corresponding to two children

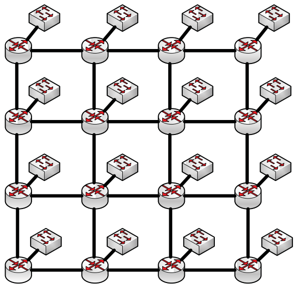
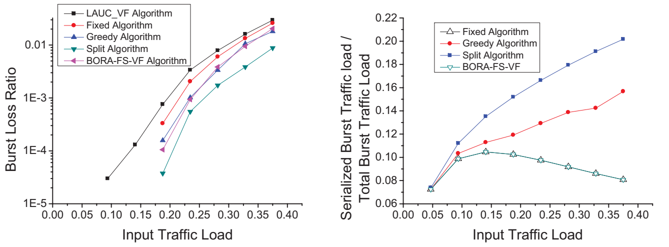
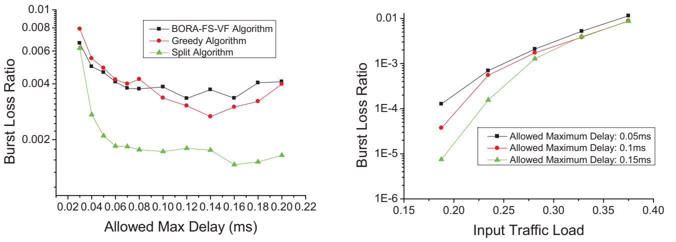


Fig. 3. OBS network for simulation.



(a) Burst loss ratio vs. traffic load under different algorithms

(b) The percentage of total SBTL vs. traffic load under different algorithms



(c) Burst loss ratio vs. allowed maximum delay when the input traffic load is 0.28

(d) Burst loss ratio vs. traffic load under different allowed maximum delay for split algorithm

Fig. 4. Performance comparison under different algorithms and allowed maximum delay.

of node c, which are used to calculate F(j)s for G(c). If the G(c) is lager than the F(c), the traffic sub-tree in Fig. 2(c) will be split. In this case, the total SBTL will be enlarged after splitting traffic sub-tree in Fig. 2(c) into two traffic sub-trees in Fig. 2(b) and assigning one home channel for each of them, respectively.

III. SIMULATION RESULTS

The topology of the simulated OBS network is shown in Fig. 3, where each link is duplex WDM link with 2 control channels and 8 data channels, each OBS core node uses wavelength converters. The allowed maximum delay for each burst at the OBS edge node is 0.1ms. Each OBS edge node sends Poisson traffic to every other edge node respectively.

The dependence of burst loss ratio (BLR) on the input traffic load under different algorithms is shown in Fig. 4(a). The results about BORA-FS-VF [4] and fixed algorithm are also given for the purpose of comparison, where fixed algorithm is to assign a fixed home channel to all egress nodes in the network. We can find that any algorithm that seeks to serialize bursts at the ingress node performs better than LAUC-VF algorithm. Besides, split algorithm performs best among these algorithms, while the result of greedy algorithm is similar to that of BORA-FS-VF.

Fig. 4(b) shows the relationship between the percentage of the total SBTL and the input traffic load. We can see that split algorithm has the largest percentage of the total SBTL, which consists with Fig. 4(a). We can also see that BORA-FS-VF and fixed algorithm have the same percentage of the total SBTL since they have the same home channel assignment. However, BORA-FS-VF has lower BLR than fixed algorithm in Fig. 4(a) since it can serialize more bursts on data channels besides the home channel by ”fixed order search”.

Fig. 4(c) shows the dependence of BLR on allowed maximum delay when the input traffic load is 0.28. The results shows that as the allowed maximum delay increases, the BLR will decrease sharply at first, and then gradually become stable. It can be explained as follows. At first, collision caused by non-serialized bursts is a main reason of burst loss, and serializing bursts can obviously reduce BLR. As the allowed max delay increases, the total SBTL and the effect of serialization access an upper limit gradually. BLR reaches stabilization since burst loss caused by other factors such as bandwidth shortage can not be avoided by serialization.

Fig. 4(d) shows the relationship between BLR and the traffic load under different allowed maximum delay for the split algorithm. We can see that as allowed maximum delay increases from 0.05ms to 0.1ms, BLR under all simulated traffic loads are accordingly reduced. However, BLR under 0.15ms is lower than the BLR under 0.1ms only when the input traffic load is light. This is because bandwidth shortage become a main factor of burst loss when the input traffic load is high, which can not be solved by serializing bursts.

IV. CONCLUSION

In this letter, a home channel assignment algorithm that seeks to maximize the total SBTL according to the concept of traffic tree is proposed. The performances of burst scheduling schemes based on different home channel assignment algorithms are compared by simulation. The results show that the scheduling scheme based on the proposed split algorithm has the largest SBTL and lowest burst loss ratio. The effect of allowed maximum delay is also analyzed. The results show that the burst serializing degree increases fast at first with the allowed maximum delay, and then reaches an upper limit after the allowed maximum delay exceeds a certain value.

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