High Performance Burst Transmission in OBCS Networks

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Abstract— Optical burst switching is a promising solution for all optical WDM networks. It combines the benefits of optical circuit switching and optical packet switching. In OBS the user data is collected at the edge of the network, sorted based on the destination address and grouped into variable size bursts. The OBS framework has been widely used in past years, for recent work use Optical Burst Chain switching (OBCS) to achieve high performance. Here switching unit is burst chain it consist of non-periodic bursts in one wavelength. We present extensive simulation result for throughput, delay and energy to demonstrate its superior performance over OBS networks.

Key words: OBCS; OBS; Energy consumption

I. INTRODUCTION

OBS network is a hybrid approach between OCS and OPS which tries to combine the advantages of both approaches and avoiding most of their drawbacks. In an OBS the edge routers and core routers connect with each other with WDM links. The edge nodes are responsible for assembling packets into bursts and de-assembling bursts into packets. The core nodes are responsible for routing and scheduling based on the burst header packets, for that some control information are needed.

To achieve this, some control information containing reservation requests is necessary ahead of every burst's transmission time. There are several possibilities how to perform reservation of data channel bandwidth. These reservation concepts are based on a strong separation of control information and data. A reservation request is sent in a separate control packet on a different channel while the actual transmission of the data burst is delayed by a certain basic offset. Optical burst switching is designed in order to provide high-bandwidth transport services for bursty traffic over an optical network in a flexible, efficient as well as feasible way. OBS is designed to improve the utilization of wavelengths.

For high speed switching, the OBS uses several architecture, in that wavelength division multiplexing (WDM) networks to carry huge amount of traffic in optical backbone networks. However, in current OBS network architecture, edge nodes assemble bursts and send them to core networks arbitrarily at any time, which leads to inevitable collisions in the core networks with limited or no buffers, thus leading to low network utilization.

The name OBS comes from the fact that the data are transported in variable size units, called bursts. The length of these bursts can range from one to several packets to a (short) session using one control packet, thus resulting in a lower control overhead per data unit in comparison with OPS.

To reduce these collisions, wavelength converters and fiber delay lines (FDLs) can be used at each node as remedies. To achieve a desirable performance on network either a large number of wavelength converters or FDLs are needed in OBS networks .However, optical wavelength converters and FDLs remain quite expensive, which would be the critical factors affecting the practical deployment of OBS networks.

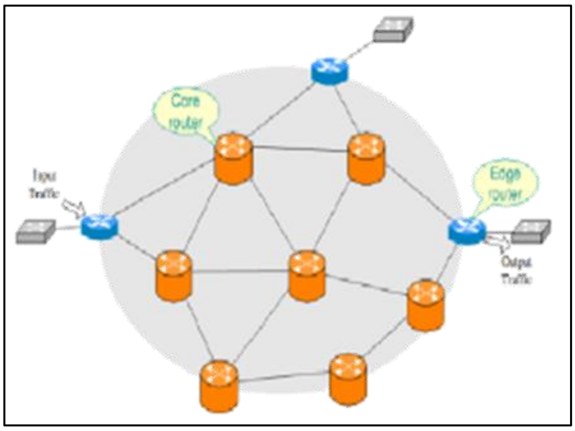

Fig. 1: Architecture of OBS Network

In view of this, we address the basic problem on how to eliminate the requirement of wavelength converters and how to reduce the usage of optical FDLs without sacrificing performance for bursty traffic in optical networks. In this paper, we propose a novel optical burst chain switching (OBCS) mechanism, which combines the merits of OCS and OBS to support high performance transmission for bursty traffic. In the proposed mechanism, the switching unit is a burst chain which consists of multiple non-consecutive and non-periodic bursts in a wavelength. High performance burst transmission is achieved by end-to-end reservation for burst chains.

A. *The Key Contributions:*

- The proposed scheme can eliminate the use of wave-length converters using optical burst chain switching.
- The proposed scheme can significantly reduce the usage of the expensive optical buffers at the core nodes with the use of the electronic buffers at the edge nodes.
- The proposed scheme can achieve significantly better performance than OBS scheme. We also analyze the throughput, delay, reservation of burst and energy.

The energy consumption of the OBCS network is achieved by load balancing algorithm. These algorithm decides the load based on the hop count value, OBS scheme consume more energy between source and destination, in OBCS it can be avoided in order to decreasing the hop count value.

The organization of the paper is as follows. In Section II, we review some related works. In Section III, we propose the optical burst chain switching mechanism to achieve high

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performance burst transmission. In Section IV some simulation results are discussed. Finally we conclude the works in OBCS networks.

II. RELATED WORKS

A time sliced OBS (TSOBS) architecture has been proposed in [5] to replace switching in wavelength domain with switching in time domain, thus eliminating the use of wavelength converters in OBS networks. They focus on the design of an Optical Time Slot Interchanger (OTSI). In [10], a similar time-slotted OBS network architecture has been proposed. A device called Sequencer, a simplified form of OTSI, is used in [10] to map/delay incoming time slots to outgoing time slots.

However, the Sequencer still needs large number of FDLs in each node since the Sequencer needs to delay an incoming burst to any position within one frame. Another related work [11] proposed a time slot scheduling algorithm which can help to improve the loss probability of TSOBS network proposed in [5].

A recent work [24] proposed a hierarchical time sliced OBS architecture, which uses hierarchical frames to support multiple classes of traffic with different bandwidth granularities and loss-delay requirements. Another similar time slotted based OBS (SOBS) scheme has been presented and evaluated in [17][19][21]. In this scheme, control burst and data burst are transmitted on the starting edge of each time slot.

Another difference is that, in SOBS, a single data burst consumes several consecutive time slots at a wavelength. In [22], the authors discussed the optimal time slot size selection for SOBS. In [20], a centralized time slot allocation scheme is evaluated for SOBS.

In [23], the authors proposed a round- robin burst scheduling algorithm to address the fairness issue in SOBS with full wavelength conversion ability.Some time division multiplexing (TDM) based schemes [6][7][12][16] have been proposed to achieve fine bandwidth granularity by WDM circuit switching networks. In [16], dynamic traffic is considered in multi fiber networks using forward reservation with continuous slot constraints. In all these related works, the switching unit is still a burst. The reference scheme in [25] consider OBCS network without optical buffer and converters, but there is no consideration in energy consumption. This paper is quite different from these works in terms of switching unit and bandwidth reservation mechanism as discussed in the next section.

III. OBCS

In the proposed optical burst chain switching (OBCS) scheme, the source node of each connection between a source and destination pair regularly measures the arrival rate for the connection, which is used as the predicted bandwidth demand. This predicted bandwidth demand will be attached to a PROBE packet, which collects the time slot availability information at a wavelength along the end-to-end path.

Once the probe packet reaches the destination, the probe packet will have the latest information on the time slot availability along the end-to-end path. Now the destination node will choose sufficient slots to meet the predicted bandwidth demand. After that, a RESERVE packet will be sent back to reserve the chosen time slots along the same path, and the time slot avail- ability will be updated at each node along the backward path accordingly after reservation. In traditional OCS, a lightpath is defined as an end-to-end optical connection over a wavelength at each intermediate link [18].

Unlike the traditional lightpath in OCS, we call the reserved connection associated with each reserved time slot as a time-slotted lightpath as defined in [6]. As shown in Fig. 1, the time-slotted lightpath refers to the reserved time slots at different nodes along the end-to-end path (The time slots may appear in different positions at each node due to propagation delay and the delay incurred by FDLs). Since we reserve multiple time slots at each intermediate node at a time, we actually reserve multiple time-slotted lightpaths at a time.

Due to simultaneous reservation process of crossing traffic, the successfully reserved slots by a two way reservation process at each intermediate node will be non-consecutive and non-periodic. As shown in Fig.1, we call a chain of these slots at the same node a burst chain.

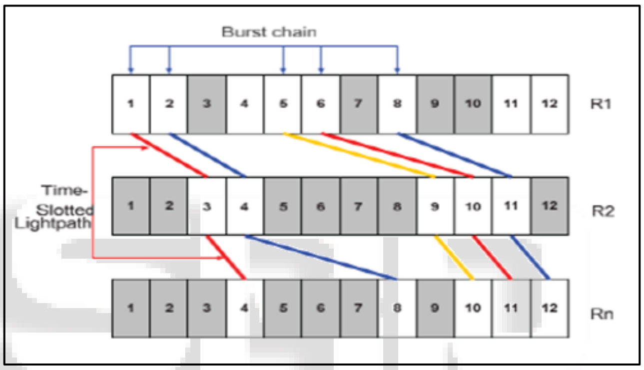

Fig. 2: Burst chain and time slotted light path

In OBS, each burst is associated with a control packet and there is a time gap (offset) between the burs and the control packet. In the proposed scheme, there is also a time gap (offset) between the reservation and the actual burst sending time.

The burst chain will be switched inside the core nodes as a whole unit without collision, thus leading to high performance transmission without any wavelength converters and large amount of optical buffers (FDLs). Note that the burst chain is valid for burst transmission only for one frame (the subsequent frame). The same process will repeat to build burst chains for subsequent frames, thus enabling dynamic bandwidth allocation for each source for bursty traffic.

The proposed scheme consists of the following four phases.

- Probing Phase
- Time Slot Searching Phase
- Backward Reservation Phase
- Burst Chain Building and Sending Phase

A. *Probing Phase:*

The PROBE packet will collect information on the time slot availability for a wavelength in each node along the end-to-end path. The measured average arrival rate by the edge node will be used as the predicted traffic arrival rate for this probing and reservation process. The number of requested

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slots for the initial frame is determined by the traffic waiting in the buffer at edge nodes. Assume each node knows the propagation delay on each of its links. Due to the propagation delay, the slot position number in the first node needs to be converted to the time slot position number in the second node using following formula

$$T_{i+1} = (T_i + d_{i,i+1}) \bmod F \text{ ……(1)}$$

Where,Ti is the time slot number in the node I,F is the frame size,di and i+1 is the propagation delay between the two consecutive nodes I and i+1.

B. Time Slot Searching Phase:

Once the PROBE packet reaches the destination, the destination will start searching for enough time slots according to the information collected by the PROBE packet as shown in Fig. 1. The searching process will start from the first slot in the first frame for the first node.Once a slot i is found to be available, the algorithm will check whether the reserved bandwidth does not exceed the predicted bandwidth requirement for the time period from the beginning of the frame to time slot i so as to satisfy the following inequality

$N_{req}/F >= N_{resv}/I$ …..(2)

Where, Nreq is the requested number of time slots, Nresv is the number of time slots which has been already reserved before time slot i within the same frame for the same request. If the above condition can be met, then time slot i will be reserved. Note that this checking is required for the first node only.

As shown in Fig. 1. The white slots mean available slots. Suppose that slot 1 in R1 is available and it meets the above condition, and slot 1 in R1 is reserved. Then, the searching process will check whether that particular slot (slot 1) is also available in the second node (R2).

If the slot is not available means, the algorithm will search at the second node for the first available time slot within a feasible range, which is determined by the maximum number of FDLs provided at each wavelength at each node. If the algorithm can find such available time slot (slot 3) in the second node (R2), then such slot (slot 3) will be reserved and the same process will repeat for the next node (R3) until the last node. Thus, (1->3->4) is found for this connection. We call (1->3->4) a time-slotted light path.

Next, the searching process will check the next available slot (slot 4) in R1. Since the algorithm cannot find an available slot in R2 within a feasible delay range, which is determined by the maximum number of FDLs, for the time slot 4 in R1, the algorithm will release the unfinished light path originating from the time slot 4 in R1, and go back to the first node (R1) to search for next available slot, and begin another searching process until all the required slots are reserved, or the searching process reaches the end of the frame in the first node. Thus, several time slot light paths will be set up by the PROBE packet. Then, we can build the burst chain at R1 by time slots (1, 2, 5, 6, 8) and this burst chain will be switched as a whole unit to the burst chain (3, 4, 9, 10, 11) at R2.

C. Backward Reservation Phase:

A RESERVE packet with the burst chains determined above at the destination node will be sent back to reserve the chosen time slots and configure the time slot switching along the backward path. During this phase, if the chosen time slots are still available at an intermediate node, the time slots will be reserved.

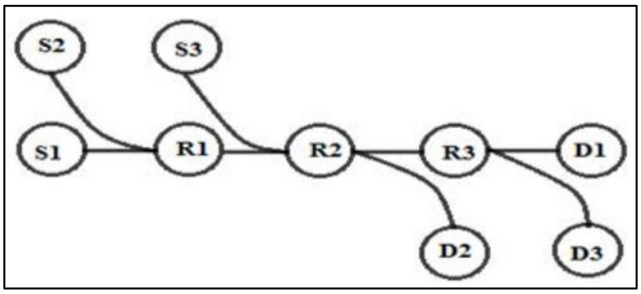

Fig. 3: Network Topology

If some chosen time slots at an intermediate node have been reserved by other RESERVE packets arriving earlier, the corresponding time-slotted lightpath needs to be released. The corresponding time-slotted lightpath will also be deleted from the RESERVE packet and continue its journey until it reaches the source.

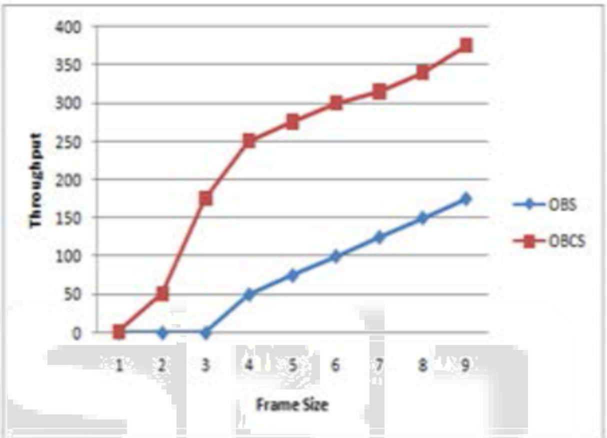

Fig. 4: Throughput comparison under different frame sizes in OBCS.

D. Burst Chain Building and Sending Phase:

The source will assemble the incoming IP packets to bursts with the same size as a time slot. At the beginning of each slot, if the current slot is reserved by the burst chain, one burst waiting in the source buffer will be sent to the destination. If there is no burst waiting in the buffer at that time, that particular slot will be wasted.

IV. SIMULATION

A. Simulation Setup:

Simulate the OBCS network using NS-2.

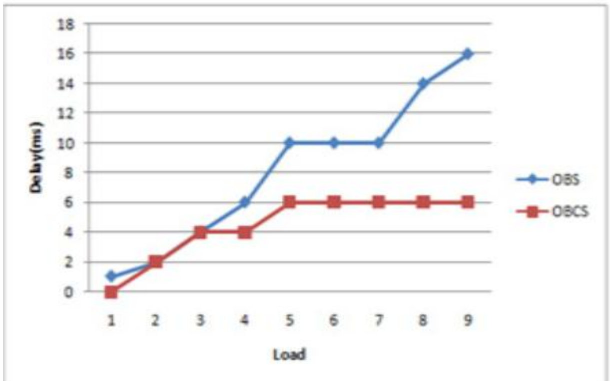

Fig. 5: Delay comparison under different load condition in OBCS.

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There are 3 source and destination pairs (Si,Ri,Di= 1, 2, 3) described in fig.3. All connections have the same offered load with Poisson distribution.

B. Simulation Results:

1) Throughput Comparison:

In the first experiment, the one slot is 1. The offset for a burst chain is 500 slots. The maximum number of the probing retries in each frame is set to be 5, and the buffer size is set to be 70 slots. We compare the proposed OBCS scheme with OBS scheme.

To make a fair comparison, the burst size for OBS schemes is also fixed and set to be 1 time slot. Figure 4 shows the throughput comparison under the proposed time-slotted OBCS. If frame size is increased means the throughput of the proposed OBCS network also increased.

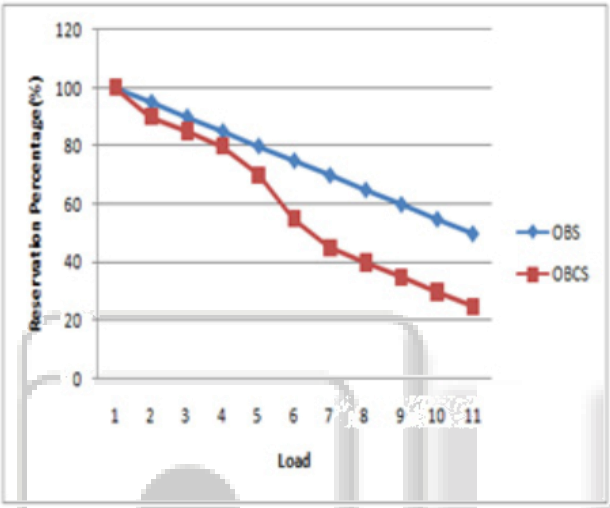

Fig. 6: Reservation percentage under different loads in OBCS.

2) Impact of Load Condition:

In addition, we also collect the results for average end-to-end delay under different loads as shown in Fig.6. In this experiment, the frame size is 1000 slots and one slot is 1 . The offset for a burst chain is 500 slots. The buffer size is 70 slots. Load decides the delay for proposed and existing mechanism.

3) Impact of Frame Size:

Subsequently, we evaluate the impact of different frame sizes on throughput and delay under the same slot size (100), buffer size (70 slots), load (1.05), and maximum probing retires (5). the frame size is small, the delay is high. This is because there are a lot of burst lost. The frame size is small, the delay is high. This is because there are a lot of burst lost. The delay decreases as the frame size increases and it will stabilize as the frame size increases to a certain level. While delay keeps increasing as load increases at normal and high load level as shown in Fig. 6.

4) Impact of Maximum Number of Probing Retries:

We also verify the effect of the maximum number of probing retries in each frame on the performance of the proposed scheme.

5) Impact of Energy:

The energy consumption E of an equipment depends on the power consumption P of the equipment which varies over time t . For a given time period with a length equals to T, the energy is given by

We only consider as consuming equipments the facilities that are plugged in and consume electricity. That is to say that the links are not considered as consuming equipments. However, their “cost” is reflected in the equipments they link.

For load balancing algorithm, ultimate measure is taken for how much performance is sacrificed versus how much energy saving is achieved. We note in Fig.8 at high load important operating region for energy consumption of 50 Erlang the energy saved is 40 % while the increase in blocking probability and delay are only 9% and 11% respectively which is a good gain that can be further optimized using our framework.

V. CONCLUSION

In this paper, an optical burst chain switching mechanism which combines the merits of optical circuit switching and optical burst switching, is proposed to achieve high performance burst transmission in time-slotted optical networks. The proposed OBCS scheme eliminates the use of wavelength converters and reduces the use of optical buffers, and achieves significantly better performance than OBS scheme .Various simulation results show its superior performance and energy consumption over conventional OBS.

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