Burst Assembly Techniques in Optical Burst Switching (OBS)

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Abstract

Optical Burst Switching (OBS) is seen as the most favorable switching method for the next generation all optical networks to support the growth of the number of Internet users and satisfy bandwidth demands for greedy-bandwidth applications which are in continuous growth. OBS consists of an edge node and a core node. The edge node is responsible for burst assembly which is the first process in an OBS network. In this paper, burst assembly mechanism in OBS will be described along with some current assembly methods. The aim is to assist new researchers in understanding the function of burst assembly in OBS.

Keywords. OBS; burst assembly

1. Introduction

The increased demand for a network that can handle traffic of multimedia applications and others has made Optical Burst Switching (OBS) network more attractive than other wavelength division multiplexing (WDM) networks namely Optical Packet Switching (OPS) and Optical Circuit Switching (OCS) [1, 2]. OBS has some interesting characteristics such as high speed data transmission and huge bandwidth since an optical fiber can support as much as 50THz [3]. The data is transmitted into bursts that have the same destination. The assembly of packets into bursts is done in the ingress node and the bursts are separated into the egress node [4]. The data burst is preceded by control packet (CP) that include the destination and size of the corresponding burst. In the core nodes, bursts are scheduled based on either void-filling or horizon techniques [5]. Burst assembly process is crucial since it determines bursts characteristics, which affects the performance of OBS network. This paper compares the existing burst assembly time schemes and is organized into several sections.

The remaining paper is organized as follows: Section 2 introduces OBS network. Burst assembly and its role are presented in Section 3 which is the core section of this paper. Section 4 provides a description of the existing burst assembly schemes. Finally, Section 5 concludes the paper.

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2. OPTICAL BURST SWITCHING

OBS is a telecommunication technique that allows dynamic sub-wavelength switching of data. The assembly of packets into bursts is done in the ingress node and the bursts are separated into the egress node. The data burst is preceded by control packet (CP) that includes the destination and size of the corresponding burst. Recent researches are concerned with finding a solution that can reduce the delay and burst loss via threshold-based technique and adaptable traffic. Burst assembly process is crucial since it determines bursts characteristics, which affects the performance of OBS network. Each burst is assigned a control packet which is delivered to a core switching node with some offset-time prior to the burst payload. The offset-time allows the control packet to be processed and the switch to be set up before the arrival of the burst to the intermediate nodes, so no electronic or optical buffering is necessary at the intermediate nodes[6, 7].

As shown in Table 1,Few advantageous characteristics are combined in OBS in order to overcome the drawbacks of both OCS and OPS[8]. OCS has a very low link utilization since a wavelength can only be used a pair of nodes, unlike OCS and OBS, that traffic between multiple pairs to share the same bandwidth due to statistical multiplexing[9]. OBS has also avoided the setup latency of OCS which use two-way signaling scheme for resources reservation. The wavelengths in OBS are released after a previously defined offset time instead of waiting a signaling message from the egress (destination) node. Moreover, OBS and OCS share the fast switching speed compared to OPS that switch small packets using high speed switches. In OBS, bursts are sent instead of packets and medium-speed switches can be used. In terms of processing complexity, OBS falls in the middle between OCS and OPS. The control packet is separated from the burst in OBS, unlike OPS, which reduces the processing complexity in the core nodes. However, the complexity level in OCS network is the lowest. Another advantage that combines both OPS and OBS is traffic adaptively since they support statistical multiplexing in contrast to OCS that is not adaptive due to its high setup latency.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Circuit</th>
<th>Packet</th>
<th>Burst</th>
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<tbody>
<tr>
<td>Bandwidth Utilization</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Setup Latency</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Optical Buffer</td>
<td>Not Required</td>
<td>Required</td>
<td>Not Required</td>
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<tr>
<td>Signaling Scheme</td>
<td>Two ways</td>
<td>One way</td>
<td>One way</td>
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<td></td>
<td>Out-of-Band</td>
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To enhance the performance of OBS and make it more competitive, many methods have been proposed such as fiber delay lines [10], deflection routing [11], wavelength conversion [12], and burst segmentation [13]. A review of routing strategies as means to reduce contention in OBS can be found in [9].

In OBS network architecture, there are two kinds of nodes in OBS networks as shown in Figure 1, i.e. edge nodes and core nodes. The edge side consists of two nodes which are the ingress node (source) and ingress node (destination). In the core node, optical burst are switched or routed from a fiber link to another [6].

An ingress node can receive different types of client networks such as IP, ATM, GbE, SONET or other network. It has multiple functions as shown in Figure 2 which are initially assembling burst, scheduling the transmission, and setting up a basic offset-time. The assembled burst consists of packets that are sent for a specific destination [14].

After burst assembly, the transmission is scheduled by using a scheduling or wavelength assignment algorithm. The bursts and their control packet are transmitted at predetermined times where there is a value of an initial offset between these bursts and their control packet [6, 15]. Burst assembly and Offset-time and their schemes are discussed in details in the following sections.

In a core node, signaling protocols and related forwarding and control functions are implemented. The switching of burst from input to output ports is also performed by the optical cross connect (OXC) [15].

The egress node is the receiver of the burst where burst are separated into packet by the burst disassembler. After disassembling the burst, packets are sent up to the higher network layer.
3. **BURST ASSEMBLY**

Burst assembly is the first process in OBS network where packets are aggregated into data bursts. Burst assembly is done in the ingress node where the packets are sequenced in different destination queues as shown in Figure 2. After burst aggregation, the ingress node sends the data burst to the core nodes. Gathering the packets into one data burst is very useful since it makes the signaling process easier by reducing requests at the core nodes. Assembling the burst can be based on size, time or both, adaptive or non-adaptive differentiated, or predicted as will be illustrated in the schemes presented in this section.

4. **BURST ASSEMBLY SCHEMES**

In the following subsections, twelve burst assembly schemes are reviewed. Some of the traditional schemes are time-based scheme [16], threshold-based scheme [17], Hybrid Time-and-Threshold-based Scheme [18, 19], Learning-based Burst Assembly (LBA) [20]. Service differentiation was the main criterion in the schemes proposed by [21, 22]. However, the common criterion of current schemes is traffic prediction such as in mixed-length and time threshold burst assembly algorithm based on traffic prediction (MTBA-TP) [23], burst assembly algorithm based on burst size and assembly time prediction (BASTP) [24], traffic prediction based burst assembly mechanism for OBS [25], and efficient burst assembly algorithm with traffic prediction [26].
4.1 Time-based Scheme

Time-based scheme [16] depends mainly on setting an interval time (T) in creating the data bursts. When the packets arrive in this interval time T, they will be aggregated into a burst. In this scheme, there are queues set according to the destination and each queue has its own timer staring from 0. All packets will be kept in queue based on the destination until the timer arrives at the T. After that, the data burst will be created in order to be sent to its destination.

However, setting a specific interval time will creates some drawbacks. For example, if the traffic is too high, the burst will be too long which creates problems in the core nodes such as increasing the loss rate. But when the traffic is low, the interval time will reach the T before aggregating enough packets in the burst.

4.2 Threshold-based Scheme

Threshold-based scheme [17] is a method that uses a parameter called burst minimum size (B_{min}). Using the B_{min} parameter means that the data burst will be created when a minimum number of bytes is reached. Setting the burst minimum size have an important disadvantage where the burst assembly can take a long time due to low load traffic and so the delay will increase. As a result, this scheme is not suitable to use in real time traffic since it does not meet the delay requirements.
4.3 Hybrid Time-and-Threshold-based Scheme

Both time-based and threshold-based schemes were combined in this scheme [18, 19]. In this scheme, as shown in figure 3 the burst is created either by reaching the maximum value of the timer or by reaching the T of burst minimum size. Since this scheme combined the benefits of the time-based burst assembly scheme and the threshold-based scheme, it is considered to be the default burst assembly scheme. Nonetheless, the low traffic load problem remains unsolved since the packets still have to wait for reaching the maximum value which affects the real time traffic delay requirements.

4.4 Learning-based Burst Assembly (LBA)

Learning-based Burst Assembly (LBA) is adaptive scheme proposed to reduce burst loss [20]. In this algorithm, the burst assembly is adapted according to the loss pattern experienced in the network itself. By the learning automata algorithm used in this scheme, the loss is checked periodically in order to change the assembly time at the ingress node to more suitable one. The assembly time parameter value chosen is updated using a linear reward-penalty. As mentioned above, this scheme concentrates on reducing the loss in the network without considering the end-to-end delay requirements results from it. Therefore, this scheme may be effective in reducing the loss but it is unsuitable to use in real time traffic.
4.5 Burst-assembly Algorithm with Service Differentiation

In Burst-assembly algorithm with service differentiation scheme, the time-based method to assemble the packets in one burst is used [21]. However, there is only one timer for all traffic types in this scheme which is set based on the value of the maximum delay that should not be exceeded.

![Figure 4: Burst transpiration with proposed method [22]](image)

4.6 Delay aware burst assembly method.

Differentiating loss rates of packets according to their priority/QoS level has been proposed in many schemes but adding extra offset-time to high priority packets leads to higher end-to-end delay. In [22], Yukinobu et al., proposed a method that can reduce end-to-end delay. The researchers claimed that the algorithm has achieved 12-23% delay reduction for high priority packets without almost the same loss rate. In this method, the IP packets that arrive after the control packet is sent are included in the current assembled burst and not delayed to be sent with the new assembled burst as shown in figure 4. In order to reserve wavelengths based on estimated burst size, the release packet is delayed and this method can be applied with JIT and JET protocols. In spite of the significant end-to-end delay reduction, the estimated burst size might not be the same of the actual burst size. If the estimated burst size is larger than the actual size, lower wavelength utilization occurs. In contrast, if the estimated burst size is smaller than the actual size, the overflowing packets are included in the next assembled burst.
4.7 Mixed-length and time threshold burst assembly algorithm based on traffic prediction (MTBA-TP).

Mixed-length and time threshold burst assembly algorithm based on traffic prediction (MTBA-TP) [23] is an algorithm that sets the minimum length threshold and minimum time threshold in order to reduce the end-to-end delay. Moreover, traffic prediction mechanism is used to send BDP in advance by predicting the burst length which further reduces the delay. When the minimum set for length or time threshold is reached, the BCP is initiated. After sending the BCP with the estimated BDP length information, IP packets are also assembled in the current BDP. This algorithm increases the number of transmitted packets, improves wavelength utilization and reduces end-to-end delay. In a comparison between mixed-length and time threshold burst assembly algorithm (MTBA) and (MTBA-TP), MTBA-TP performs better especially in reducing the end-to-end delay.

4.8 Burst assembly algorithm based on burst size and assembly time prediction.

Burst assembly algorithm based on burst size and assembly time prediction (BASTP) is proposed by [24]. In this algorithm, the BCP is sent to its destination by the arrival of the first IP packet into assembly queue with predicted size and time. Size is predicted according to the size threshold while time is predicted through Time Prediction Equation. By reaching size or time prediction condition, the burst will be sent to its destination. Any alternation of traffic load is detected and so the size threshold can be adjusted adaptively by using the step size. Finally, predictive coefficient is used to adjust end-to-end delay adaptively in order to shorten the end-to-end delay at low traffic load and raise the predictive success probability at high traffic load. This algorithm avoids bandwidth wastage and reduces end-to-end delay significantly.

4.9 Traffic prediction based burst assembly mechanism for OBS.

With the goal of minimizing contention and providing better proportional differentiated services, traffic prediction based burst assembly mechanism is proposed by [25]. By using this mechanism, burst loss performance will be improved and the variance of traffic will be reduced. Different queues are initiated according to their destination and the time axis is divided into equal time frames. The bursts are assembled based on their destination and QoS requirements until the end of the frame. After that, a decision, which is taken by using a linear prediction filter, is made either to send the burst or to wait for another frame in order to assemble more packets. If the estimation is smaller than the threshold, the burst is immediately sent; otherwise, the assembly process is continued for another frame. The
delay tolerance of each packet is taken into consideration and the bursts are assembled without violating it. As a result, the average delay is equal to the desired value.

4.10 Adaptive-Threshold with Fixed Maximum Time Limitation (ATH-FMTL)

The Adaptive-Threshold with Fixed Maximum Time Limitation (ATH-FMTL) algorithm proposed in [27] aims at achieving equilibrium where the rate of the arrival packets corresponds with the rate of assembling and transmitting the bursts. ATH-FMTL uses an optimal burst length threshold and fixed maximum time limitation for burst generation. The burst length threshold is increased or decreased according to upper or lower threshold respectively which increases switching efficiency, smoothens the input packet traffic and reduces the burst loss negligibly. For minimizing burst loss, the optimal threshold range is found by improving fixed-based assembly scheme, since its range falls between threshold-based and time-based techniques, using the adaptable burst size decision value.

4.11 Efficient burst assembly algorithm with traffic prediction

In order to improve prediction process for the traffic data rate, [26] used a linear predictor with dynamic error compensation (L-PREDEC), which is applied on time series to predict the future value based on the history of the time series. Since the traffic changes, the burst assembly length is dynamically adjusted. After that, the chosen value is applied to the time hybrid algorithm. In general, this scheme improves the delay more than the traditional hybrid algorithm. However, it increases the delay under uniform traffic.

1.4 New Burst Assembly and Scheduling technique

(NBAS) in [28], showed improvement in terms of QoS parameters such as burst delay and delivery ratio. In [29] the Redundant Burst Segmentation (RBS) is implemented in the assembly phase by constructing a new burst that contains redundant data of the other bursts which reduces the burst loss. In the scheduling phase, the scheduling algorithm is used to switch burst payload to its target output fiber by managing the output wavelength and contention-free fiber delay lines. Even though the RBS technique was previously shown improved results in [30], the NBAS outperformed RBS by achieving average of 18.8% lesser burst delay which improves further the QoS parameters.

The main drawback for this method is that the OBS delay is only the Tout timer value which is not precise since there is other delay that can be experienced in OBS network. Choosing the maximum delay which is the Tout timer value limits the quality of this method highly along with more process complexity. Moreover, the performance of this algorithm is affected due to the small size bursts created. Hence, a scheme that counts other
delay than the Tout timer value, simpler and suitable to be used with real time traffic is needed.

5. Conclusion

This paper has presented general concepts of optical burst switching. Burst assembly algorithms were reviewed. In summary, one can conclude that there exist quite number of burst assembly algorithms for OBS with different performance objectives. However, most of the solutions studied in this paper do not take into account QoS requirements especially for real time applications. Therefore, it is essential that future research in this area propose adequate assembly solutions for real time traffic.

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