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A Review Burst Assembly Techniques in Optical Burst Switching (OBS)

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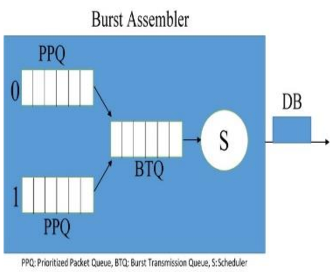
Graphical abstract



Abstract

Optical Burst Switching (OBS) is perceived as the most favorable switching method for the next generation all optical networks to support the growth of the number of Internet users and to 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. Currently, there is only one review paper for burst assembly; the paper is limited in number of techniques reviewed. In this paper, we have undertaken a comprehensive review of burst assembly techniques proposed for OBS where techniques are reviewed by category. The aim is to identify strengths and weaknesses of these techniques. The analysis of the paper will assist researchers in finding problems; thus, a significant amount of time will be saved which can be used in developing appropriate solutions for OBS networks.

Keywords: OBS; burst assembly; traffic prediction; QoS; delay; loss

1.0 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.

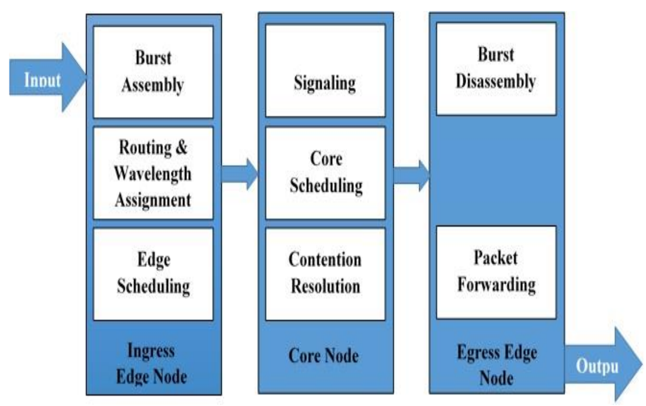


Figure 1 OBS function diagram

2.0 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.

To enhance the performance of OBS and make it more competitive, many methods have been proposed such 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].

Table 1 Comparison between the three optical switching methods

Characteristic	Circuit	Packet	Burst
Bandwidth Utilization	Low	High	High
Setup Latency	High	Low	Low
Optical Buffer	Not Required	Required	Not Required
Signaling Scheme	Two ways Out-of-Band	One way In-Band	One way Out-of-Band

To enhance the performance of OBS and make it more competitive, many methods have been proposed such 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 pre-determined 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.

3.0 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.

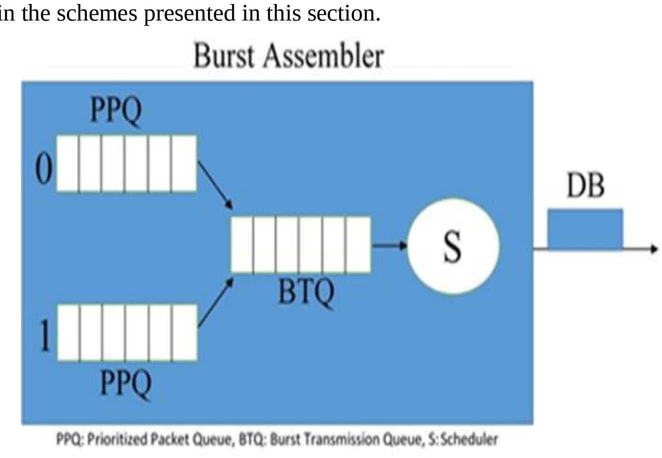


Figure 2 Burst assembler processing

4.0 BURST ASSEMBLY SHEMES

In the following subsections, twenty burst assembly algorithms are reviewed. These algorithms are categorized into six categories; Time based [16], threshold based [17], hybrid based [18], prediction based [21-27], QoS based [28-38], and General schemes [39-41].

4.1 Time-based Schemes

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 Schemes

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.

4.3 Hybrid Time and Threshold-based Schemes

Both time-based and threshold-based schemes were combined in this scheme. In this scheme [18, 19], 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 increases the end-to-end delay.

4.4 Traffic Prediction Schemes

Mixed-length and time threshold burst assembly algorithm based on traffic prediction (MTBA-TP) [20] 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. However, Poor resource utilization may occur if he generated burst size is less than the predicted length.

Burst assembly algorithm based on burst size and assembly time prediction (BASTP) is proposed by [21]. 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. However, the prediction process increase the offset-time because of the elapsed time between the time of sending burst control packet. So the delay will increase. In addition, Poor resource utilization may occur if he generated burst size is less than the predicted length.

With the goal of minimizing contention and providing better proportional differentiated services, traffic prediction based burst assembly mechanism is proposed by [22]. 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.

In order to improve prediction process for the traffic data rate [23], 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.

The authors in [24, 25] used a linear prediction filter with four different criteria. The general concept of this technique is to assemble the packets into frames that have equal duration. The packets with the same destination address and QoS requirements are assembled together. The prediction method is applied in order to estimate the number of packets that is expected to arrive in the following frame. The burst length and acceptable burstification delay might differ from a scheme to another depending on the criteria chosen. In general, if the packets expected to arrive are sufficient and meet the specified criteria, the burstification process continues since increasing the number of packets in a burst compensate the extra burstification delay. However, if the expected number of packets does not meet the requirements, the burst is launched without further delay and a new burst is to be assembled.

The Adaptive-Threshold with Fixed Maximum Time Limitation (ATH-FMTL) algorithm proposed in [26] 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.

The previous prediction algorithms are efficient in term of reducing end-to-end delay by utilizing the packet burstification time. The prediction process also helps in aggregating bigger bursts, thus; the number of bursts and their associated processing overhead at the core nodes is reduced. Nonetheless, aggregating a burst that is bigger or smaller than the predicted size might result of burst loss.

4.5 QoS-based Schemes

In Burst-assembly algorithm with service differentiation scheme, the time-based method to assemble the packets in one burst is used [27]. 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.

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 [28]proposed a method that can reduce end-to-end delay. The researchers claimed that the algorithm has achieved 12-23% delay reduction for of 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. 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.

New Burst Assembly and Scheduling technique (NBAS) in [29], showed improvement in terms of QoS parameters such as burst delay and delivery ratio. In [30] 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 [31], 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 T_{out} 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.

Burst Assembly with CBR traffic Delay Requirements (BACDR) [32] is a scheme that uses Constant Bit Rate (CBR) real time traffic over OBS network. In BACDR scheme, CBR traffic delay requirements are guaranteed over OBS network under various conditions such as traffic load, value of maximum packet transfer delay, or network topology. The main concept for this technique is to keep end-to-end delay under or equal to the CBR parameter, which is MaxCTD value, by adjusting the assembly time (T_{out}). Thus, BACDR guarantees the reduction of end-to-end delay which highly contributes to the improvement of QoS for the real time traffic over the Internet. Though, end-to-end delay is reduced, burst loss is not taken into consideration.

Burst assembly process and offset-time create extra delay in OBS networks. To make OBS suitable for real time applications, this extra latency needs to be controlled. The solution proposed in Hybrid Offset-Time and Burst Assembly algorithm (H-OTB) [33] consists of burst assembly and offset time techniques. The objective of this scheme is achieved by controlling maximum burst transfer delay (MaxBTD) parameter of Constant bit rate (CBR) real time traffic. Similarly to [32] this scheme controls end-to-end delay with assembly time (T_{out}) but with addition of offset-time Deductive Value (ODV). Although, the advantage of this scheme, which is end-to-end delay reduction especially with low load traffic, the burst loss rate still the same like traditional algorithm.

Different assembly schemes have been proposed to reduce packet loss probability and end-to-end delay. A novel priority-based composite assembly scheme [34] is applied by aggregating the packets in a burst according to priority. The high priority packets are placed in the middle of the burst while the low priority packets are placed in the head and tail of the burst. If contention occurs, segmentation mechanism can be applied at the head and tail of the burst that contain the low priority packets. Though this mechanism is advantageous in term of delay and packet loss, the computation is complex. The positions of the high and low priority packets need to be specified in the assembler so the segmentation mechanism can be carried effectively [35].

Adaptive Classified Cloning and Aggregation scheme (ACCS) [36] is a scheme proposed for high priority traffic. This scheme is aimed at reducing both the loss and end-to-end delay. The adaptation process is done based on the collected information from the network about the loss rate. Once the needed information is collected, the hybrid burst assembly thresholds are adjusted accordingly by aggregating short bursts in case of high loss rate and long bursts in case of low loss rate. Since this scheme assigns importance for high priority packets, less priority packets are dropped. Another drawback of this scheme is that it does not perform well with high loads due to the bandwidth limitations.

Novel Assembly Mechanism based on Control channel availability and Traffic type (NAAM-CT) in [37] classifies the packets into different types according to the QoS requirements. To create the burst its control packet has to be transmittable. The L_{step}, which is the variation of the size threshold, represents the best value based on the different traffic type as it makes the assembly algorithm more self-adaptive. In spite of the advantages of this algorithm, which are packets loss rate and end-to-end delay reduction, end-to-end delay is not controlled in case of heavy traffic.

4.6 General Schemes

This Section discusses schemes that are not classified under the six categories mentioned in Section 4.0.

Learning-based Burst Assembly (LBA) is an adaptive burst assembly scheme proposed to reduce burst loss [38]. In this algorithm, the burst assembly is adapted according to the loss pattern experienced in the network itself. By using learning automata algorithm, 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. Although this scheme seems to reduce burst loss ratio it does not consider end-to-end delay.

Reducing the average delay during burstification process is achieved through reducing blocking probability, congestion control and utilizing bandwidth better. Optimal burst assembly approach employing traffic shaping (OBATS) for OBS networks proposed in [39] improves burst drop, resource contention and delay in the network. The packets are grouped according to their destination and burst is created once the size or time limit is reached. By the arrival of the first packet, an average delay estimator (t_{ADE}) starts computing until the threshold value (t_{TH}) is reached. The transmission is for the first arriving packet allows sending bursts to the same destination while delivery sequence is maintained.

Another burst assembly technique is adaptive hybrid burst assembly, which is named variable time burst assembly (VT-BA) algorithm [40]. This technique adjusts the threshold values of timer and size with the use of the congestion information of links incident to the ingress node. The performance of this technique with different scheduling techniques is good especially with CTBR (constant time burst re-sequencing) and Min-SV (minimum starting void) schedulers. The evaluation of this technique pointed out the reduction in the overall burst loss. End-to-end delay is not reduced but kept within reasonable level.

■5.0 CONCLUSION

This paper has presented general concepts of optical burst switching. A comprehensive review of burst assembly algorithms was carried out. The review findings as shown in Table 2, illustrate that most of the current techniques are based on either QoS (40%) or prediction (30%). Also, the results demonstrate that most of the methods are concerned about end-to-end delay (90%). Therefore, new burst assembly solutions for OBS should take delay into consideration in the design phase. Delay is the most important characteristic of real time applications which are in continuous growth. Based on our findings, it is obvious that there is a real need for more adequate solutions to address burst assembly in OBS. The future work include among others consideration of reliability, security and energy efficiency aspect in the review analysis; current review papers do not consider these parameters.

Table 2 Classification of burst assembly algorithms

No	Ref.	Burst Assembly Based						E2E delay	Burst Loss	Year
		Time	Threshold	Hybrid	PT	QoS	Other			
1	16	✓						✓	✗	2000
2	17		✓					✗	✓	2002
3	18			✓				✓	✓	2003
4	39						✓	✗	✓	2007
5	28					✓		✓	✗	2007
6	25				✓			✓	✗	2007
7	29					✓		✓	✓	2009
8	38					✓		✓	✓	2009
9	27				✓			✓	✓	2011
10	24				✓			✓	✗	2011
11	37					✓		✓	✓	2011
12	21				✓			✓	✗	2012
13	22				✓			✓	✗	2013
14	23				✓			✗	✓	2013
15	30					✓		✓	✗	2013
16	40						✓	✓	✓	2013
17	41						✓	✓	✓	2013
18	33					✓		✓	✗	2014
19	34					✓		✓	✗	2014
20	35					✓		✓	✓	2014
Subtotal		1	1	1	6	8	3			
Total								**20**		

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