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Impact Of Using Fiber Delay Scheme On Burst Loss Ratio And Delay Using Offset Time Algorithm For Optical Burst Switching Networks

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Abstract

The optical burst switching (OBS) paradigm is an intermediate optical switching solution between optical packet switching (OPS) and optical circuit switching (OCS). In addition, OBS has enormous bandwidths that can satisfy the requirements of bandwidth applications and the growing number of end users. OBS, suffer from burst contention due to a lack of optical buffers. This problem results in a high burst loss ratio and increased end-to-end delay, thus degrading the performance of the OBS network. This study has proposed a Fuzzy Offset Time algorithm (FOTA) to address the above issues. The fuzzy input comprises three parameters: B.Size, Distance, and Q.Delay. In this study, Five defuzzification techniques are used Centroid, bisector, largest of maximum, smallest of maximum, and mean of maximum (CM00, BM04, LM02, SM03, MM01, respectively) applying to both maximum and algebraic sum accumulation techniques using fiber delay schemes. The results of FOTA show the defuzzification (LM02 and LS02) have effects in reducing BLR (burst loss ratio) while the defuzzification (SM03 and LS02) have effects in reducing end-2-end delayed, respectively.

Keywords: OBS Networks, FOTA, Fuzzy Logic controller, average e-to-end delay, BLR

1. INTRODUCTION

In the latest years, the interest in the internet has been growing. Still, today, users rely heavily on the Internet of Things (IoT), artificial intelligence (AI), multimedia applications, and other internet technologies such as marketing and banking online. These technical advancements need a large amount of bandwidth to be implemented. The optical fiber may be offered to solve to match the huge requirement of raw bandwidth. A single optical fiber can give a bandwidth of up to 50 THz, so wavelength division multiplexed (WDM) is one solution that matches the requirement of huge raw bandwidth [1]. WDM technology is widely used to meet the significant increase in the demand for channel capacity due to the rising customer and to face the challenges [2] and gives a large amount of bandwidth [3]. Optical burst switching allows dynamic sub-wavelength data switching, eliminating throughput constraints and maximizing bandwidth utilization. Different user data types are merged at the OBS network's edge node before being sent as data bursts. Every burst has a control packet with its information in it. A separate control channel has been designated for the transmission of this packet. Due to its smaller size, this control packet can contain information for hundreds of data channels. At each intermediate OBS node, the control packet undergoes an O/E/O conversion and is electrically switched to obtain a configuration with the switch. The network is establishing an offset time. Before the core can allocate resources to the upcoming burst, offset time is the amount of time it takes to process the information in the control packet; it is referred to as the processing configuration delay. The data burst can immediately switch in an optical domain with the appropriate offset time. At the intermediate nodes, optical RAMs or FDLs (Fiber delay lines) will be less necessary due to this.[4]

OBS is an attractive and preferable choice over Optical Packet Switching (OPS) and Optical Circuit Switching (OCS), as it can handle the dramatic increase in multimedia applications' traffic [2]. Unlike OCS and OPS, data is transmitted in bursts instead of packets. The bursts are grouped and sent based on their destination. Table1: gives a comparison between the three-switching technology. [5][6][7]

Table 1: Comparison of the three techniques of optical switching

Characteristics / Properties	Bandwidth	Set-up	Optical buffer	Overhead Processing	Traffic Adaptability	Speed's Switching	Complexity Processing	Signalling Scheme
Circuit	Low	High	Unwanted	Low	Low	Slow	Low	Two ways
Packet	High	Low	Wanted	High	High	Fast	High	One Way
Burst	High	Low	Unwanted	Low	Low	Moderate	Medium	One way

OBS network architecture consists of edge and core nodes (ingress and egress nodes). All IP packets from different access networks are aggregated in the form of bursts by the ingress node[8]. See Figure1 [9].

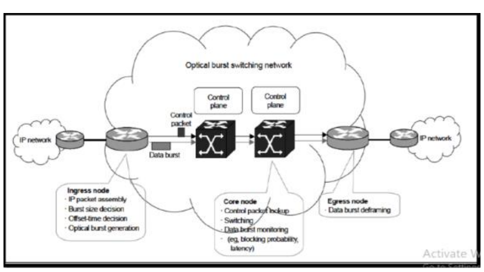

Figure 1: OBS network architecture

The main functions of an ingress node are: aggregating the bursts, generation of the burst header packet (BHP), determination of the offset time, determining the routing and wavelength assignment (RWA), wavelength reservation, and signaling. The signaling process is facilitated by combining the packets into a single data burst, which reduces the number of requests at the core nodes [9]. Also, the main processing of the core nodes is, switching all-optical data bursts from one input port to another depending on the information in the BHP. The core node resolves contention between bursts by deciding the routing of the burst. The egress node's main functions are to disassemble the large bursts to the original packet and route them to their respective final destinations forwarding [10].

The following structure is used for this paper: Section II discusses the related works on offset time. The proposed Algorithm of Offset Time is reported in section III. The results' simulations are explained in section IV, and the conclusion of this study is in section V.

2. RELATED WORKS OF OFFSET TIME ALGORITHM

The time data bursts following its control packet after some time is known as offset time. The offset time allows the switch to handle the control packet. This includes getting the needed resources and setting up the optical switch at transitional OBS nodes so that the next burst can pass through each transitional OBS node without waiting for the resources or the switching fabric. The offset time is set to complete all these operations before the data burst arrives. Different offset times can isolate different traffic classes, allowing for service differentiation. [11].

The offset time should be longer than the total BHP processing times at all nodes because of the configuration and reservation time spent at the core nodes. The burst will be discarded if the offset time is shorter than the processing time because it will arrive before the BHP. Thus, the burst loss probability and end-to-end delay are used to evaluate the efficiency of any offset-time method [9].Figure2 displays an OT scheme in OBS networks [12].

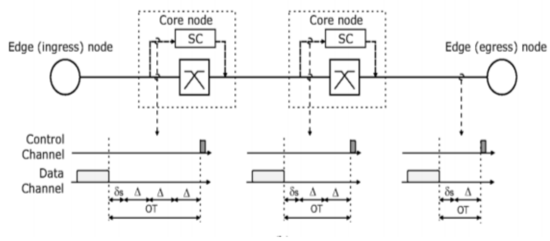

Figure 2 Displays an OT scheme in OBS networks.

Due to the processing delay of the CP at all nodes from ingress to egress, it is challenging to have all bursts with the same offset time [13]. The Virtual Fixed Offset Time (VFO) was presented as a solution to the issue of processing delays that vary from one to another. VFO processes bursts in accordance with the burst arrival time rather than the CP arrival time. The burst with the earliest arrival time is scheduled after the CPs have been sorted by their burst arrival time. However, fiber delay lines (FDLs) utilize the burst offset time at each node to delay bursts and ensure that no other bursts arrive before the earliest burst scheduled. The VFO scheme sends the smaller bursts directly but increases the delay time for larger bursts; this operation causes the problem of unfairness between bursts, even though it delays the larger bursts in each node using FDLs beside this, it is the using of FDLs is costly.

Fixed OT scheme is derived from [14] the just-enough-time signaling protocol (JET). OT for JET protocol is constant and is the summation of processing times for all hops, and the time of switching configuration, switching time, and processing times at each node are equal. Estimation OT must know how many hops there are between the source and destination nodes. Due to waiting delays in the control channel, these times may vary between nodes. Having a defined offset time has the disadvantage of allowing small bursts to be sent sooner and without delay. In contrast, there won't be enough time to send large bursts.

[15], also proposed an algorithm that maximizes resource use while reducing loss. The suggested algorithm requires wavelength of full conversion capabilities from the nodes whose routing information is provided through nodes in the OBS Networks. The edge nodes choose the best routes based on the typical link availability. Updates are made to the average traffic volume and link availability. Although burst loss results were more significant than utilization outcomes under low-load conditions, this technique outperformed the other examined algorithms.

To achieve a high degree of isolation between bursts of varying sizes, the Adaptive offset-time scheme gives larger bursts more offset time [16]. Additionally, if the isolation of OT is equal to the size of the burst, a degree of separation of one can be attained. As a result, the network's overall performance is enhanced, and the blocking probability is decreased when the additional OT is applied to a larger burst. The scheme's drawback is that the additional offset time will result in long delays and higher loss penalties. Furthermore, the adaptive OT system is better appropriate for usage in long-distance networks with high real-time traffic, making the offset time insignificant in comparison to the delay of transmission.

In the Jacobson-Karels algorithm, when the period of burst assembly is less than the OT, this method reduces the OT by transmitting the control packet containing an estimate of the burst length just before the period of assembling the burst expires. This method transmits bursts faster than the conventional approach and does not add additional offset time delay. The retransmission time (in the transmission control protocol TCP) should be calculated using this algorithm, and the burst length should be predicted and then added in the header of the BHP, so BHP can be sent before the time of burst assembly expires. Inaccurate estimation causes an increase in burst loss17].

A method is provided by [18] for obtaining a moderate OT that fits the insufficient OT drop ratio criteria while preserving a tradeoff between the two. The burst loss probability, which is used as a monitoring variable, is used to allocate offset time dynamically to reach this equilibrium. After measuring the background traffic on the core nodes, the OT is dynamically set.

The burst scheduling techniques published in the previous tenses, in contrast to conventional scheduling algorithms, are focused on maximizing the utilization of local networks. For instance, [19] proposes a method that uses local networks without increasing the burst loss rate. The gap between bursts is reduced by connecting upcoming bursts with existing bursts. A variable offset-time value can be achieved by establishing minimum and maximum OT limits instead of defining an offset-time value. Alternately, the bursts can be aligned at the beginning or end of the selected vacuum. However, no evidence exists that this method changes offset time's value.

The authors [20] examined how offset time affected the burst loss ratio. As the adjusting parameter, OT was used. The researchers suggested controlling the closed-loop feedback method for an adaptive offset time. As a result of the feedback that was received, the offset time is changed adaptively. The model supplies the BHP using the shortest offset time value before its associated burst.

In [21], the intelligent offset time is better than conventional and adaptive offset time in terms of E2E delay and BLR. The authors used in this algorithm a fuzzylite program and Omnet++ simulation to perform this algorithm using centroid defuzzification to evaluate these two matrices.

3. THE PROPOSED ALGORITHM OF OFFSET TIME

The contention is the main problem in the core network of OBS networks which causes drop bursts; so many researchers try to avoid contention at the edge node by using different techniques to minimize contention. Controlling the offset time delay has been proposed in this study, so the size of the burst, the time of assembled burst wait at the assembler, and the distance from ingress to the egress node is the main parameter in this study to minimize the contention. In this proposed algorithm, the main input parameters to the fuzzy logic controller are B. Size, Q.Delay (the time spent by burst in queuing before being directed to the core nodes), and distance (hops number), while OT is the output control variable. The new output value is a Fuzzy offset time (FOT) used for the burst header packet BHP to reserve the resources (wavelengths) needed for successful transmission. This algorithm is multi-input single output and has 27 rules to evaluate it.

The design of FOT algorithms consists of two main components:

1. Design the fuzzy logic controller of fuzzy Offset Time, where its component is:
    - Identification of control variables: The control variables used in this algorithm to generate the Fuzzy Offset Time are the Burst Size, Q. Delay, and distance. These control variables are used as inputs to the FLC. The last control variable is Offset Time, the output parameter where the three inputs are used to calculate the adaptive value of offset time.
    - Fuzzification of control variables: Here, the input and output control variables are converted into fuzzy forms using triangular membership functions (TMF).
    - Knowledge base formation: In this stage, a set of rules are formulated by the Fuzzy Logic Controller (FLC) where four (three inputs and one output) sets of fuzzy rules are defined for FLC.
    - Fuzzy Inference Engine formation: a Mamdani fuzzy inference engine was chosen.
    - Defuzzification of Fuzzy Output variables: The output control variable is in the form of fuzzy to convert into its crisp value. In this phase, a defuzzification process produced an output that achieves the objective of this study.
2. Designing the algorithm and integrating it with the FLC: Here, the FLC and the FOTA procedure are integrated to explain the FOT algorithm in this stage.

The OBS paradigm was simulated on the Omnet++ simulation framework version 4.2.2 platform. Omnet++ was chosen for this study due to its many useful features. A few of its beneficial attributes are open source, free for academic research, and ease of programming due to object-oriented programming basics. Omnet++ simulation framework was selected because it has a well-developed OBS simulation model (component or plug-in).

In this study, each control variable is divided into three partitions, each witha label name, as shown in Table2. A triangular membership function is used for every partition, which is the final stage of the fuzzification process.

Table 2: Fuzzy input variable with operation range

	Fuzzy variables	**Universe of Discours**	**Partition label (T)**
Input	B. Size	[0, 60] k bytes	Small
			Medium
			Big
	Distance	[0, 8]	Short
			Middle
			Long
	Q. Delay	[0, 400] μs	Low
			Average
			High
Output	FOT	[0, 100] μs	Little
			Moderate
			Large

In this phase, the simulation results obtained from the experiment were analyzed, assessed, and discussed. Burst loss ratio (BLR) and burst end-to-end delay, which are the two-performance metrics, were used to assess all of the study's finding results in this study. They were chosen to ensure the algorithms are appropriate for BLR and end-to-end delay-sensitive applications. More important, the results of the analysis and evaluation are as the following:

Proposed Fuzzy Offset Time algorithm versus the existing intelligent offset time algorithm:

A. Applying different defuzzification processes such as Bisector, Largest of Maximum, Smallest of Maximum, and Mean of Maximum "with FDL" versus Centroid using maximum as the aggregation type.

B. Applying different defuzzification processes such as Bisector, Largest of Maximum, Smallest of Maximum, and Mean of Maximum "with FDL" versus Centroid using Algebraic sum as the aggregation type.

The parameters used for the Omnet++ simulation framework's OBS modules plug-in is shown in Table 3

Table 3: Parameters and setting of OBS Simulation

Parameter	**Value**
Network	NSFNET
Number of	4 (3 data
Bandwidth	1
Packet Size	1250
Control	10
Propagation	1
Packet	Exponential
Scheduling	LAUC
Timeout (s)	0.0005
Burst	1.5K
Burst	60K
Load (min)	0.1
Load (max)	1
Load	0.1
Signalling	JET
Optical	ON

The network is NSFNET, consisting of 14 bidirectional links, uniform traffic distributed across all source/destination pairs, and one wavelength allocated as a control packet channel on every link. The algorithm design compares with the Intelligent offset Time (IOT). The two important evaluation metrics in this study are BLR and end-to-end delay.

4. RESULT AND DISCUSSION

From Figure 3, it is clear that there is an increase in the burst loss ratio for all defuzzification methods when FDLs are employed as optical buffers. FOT LM02 is the best in the case of BLR due to the low burst loss ratio exhibited by FOT LM02, which is due to its ability to use its rules in the fuzzy logic controller to produce an adequate value of offset time between the BHP and data burst of suitable sizes. As a result, FOT LM 02 generates bursts of large sizes that lower the network's level of congestion and hence minimize burst contention and their loss. However, the FOT LM02 configuration provides better network performance than other configurations under heavy load.

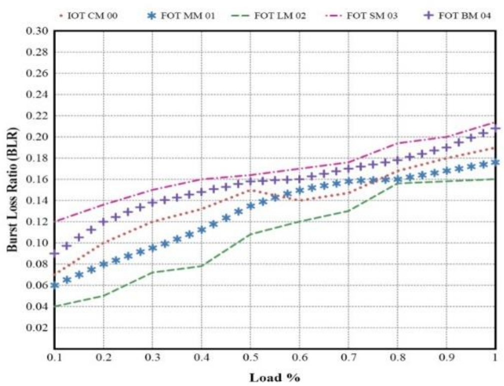

Figure 3: Burst Loss Ratio versus offer load for diffèrent défuzzification techniques and Maximum aggregation method with FDLs.

As shown in Figure 4, FOT SM03 has better performance in terms of end-to-end delay than the three configurations of the FOT algorithm and IOT algorithm due to the small burst size. However, despite the heavy traffic load and growing burst size, FOT SM03 has a constant average delay value from 0.8 to 1.0. FOT LM02 has the highest delay due to the large burst generation, which tends to have a longer transmission time, although, of this, it has less burst loss ratio. When the burst size is small, BHP does not need a large processing time and is directed to the destination without any loss and will not take time in buffering during processing BHP. Unlike when the burst size is large, it needs buffering for a fixed and predetermined duration which is limited by fiber length, so when there is a large burst in queuing, this causes the burst to drop and hence increases the BLR because the FDL process a FIFO system.

FOT SM03 has a high burst loss ratio because it generates many large bursts, which causes high contention. In return, it has the best network performance because it produces less end-to-end delay ratio due to generating small bursts.

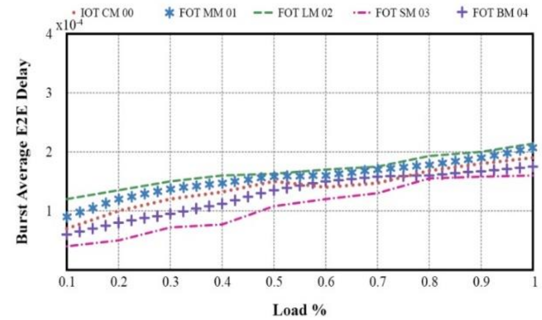

Figure 4: Burst average end-to-end delay versus offer Load for different defuzzification techniques

and Maximum aggregation method with FDLs

Figure 5 shows an increase in the burst loss ratio for all FOT LS02 while IOT CS00 still without change on both burst loss ratio and end-to-end delay means; IOT CS00 has no effect while changing the aggregation from maximum to algebraic sum. From 0.8 to 1.0, it is noticeable that IOT CS00 and FOT MS01 have the same end-to-end delay due to generating equal data burst size and causingan equal burst loss ratio.FOT LS02 displayed the best burst loss ratio when compared with other defuzzification techniques, and in return. At the same time, IOT CS00 is better than both FOT MS01 FOT BS04 and FOT SS03, as FOT LM 02 generates bursts of large sizes that lower the network's level of congestion, so it minimizes burst contention and reduce loss of burst. However, the FOT LM02 configuration provides better network performance than other configurations under heavy load. However, the fuzzy rule the configuration FOT LS02 uses effectively reduces the burst loss ratio at all offered loads.

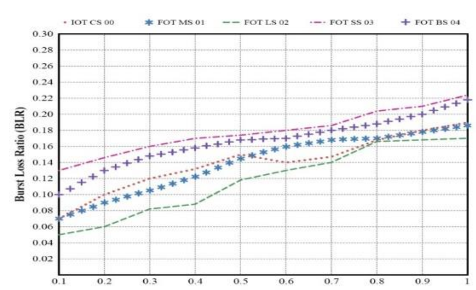

Figure 5: Burst Loss Ratio versus offer load for different defuzzification techniques
And Sum aggregation method with FDLs.

As shown in Figure 6, FOT SM03 has better performance in terms of end-to-end delay than the three configurations of the FOT algorithm and IOT algorithm due to the small burst size. However, despite the heavy traffic load and growing burst size. From 0.1 to 0.4, IOT CM00 is better than FOT MM01 and FOT LM02 regarding end-to-end delay. FOT LM02 has the highest delay due to the large burst generation, which tends to have a longer transmission time, although, of this, it has less burst loss ratio. When the burst size is small, BHP does not need a large processing time and is directed to the destination without any loss and will not take time in buffering during processing BHP. Unlike when the burst size is large, it needs buffering for a fixed and predetermined duration which is limited by fiber length, so when there is a large burst in queuing, this causes the burst to drop and hence increases the BLR because the FDL process a FIFO system. FOT SM03 has a high burst loss ratio because it generates a high number of busts which causes high contention. In return, it has the best network performance because it produces less end-to-end delay ratio due to generating small bursts.

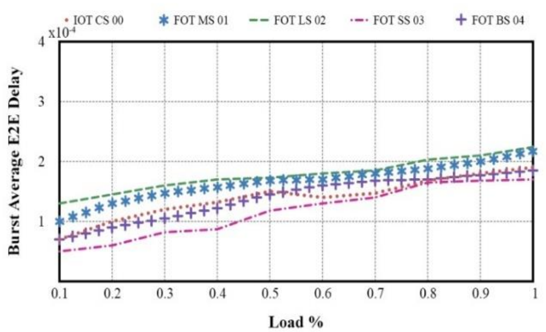

Figure 6: Burst average end-to-end delay versus offer Load for different defuzzification techniques and Sum aggregation method with FDLs.

5. CONCLUSION

This study presents an algorithm using the fuzzy offset time (FOTA) to reduce the burst loss probability (BLR) and end-to-end delay in optical burst switching networks. Adding FDLs increases the burst loss ratio, as in Figures 3 and 5; in contrast, end-to-end delay performs the best in Figures 4 and 6. Compared to different defuzzification, FOT LM02 performs the best loss ratio, while FOT SM03 performs the best on end-to-end delay. In future research, it is recommended to explore alternative aggregation methods beyond the ones utilized in this study, such as different techniques apart from maximum and algebraic sum aggregation. Additionally, considering the use of a greater number of partitions for each fuzzy control variable can be proposed to enhance the precision and accuracy of the findings.

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