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# Impact of Fuzzy Offset Time on Delay and Burst Loss Ratio for Optical Burst Switching Networks

**Ibrahim Khider Eltahir, Laila A. Wahab Abdullah Naji, Hadeil Haydar Ahmed Elsheikh**

***Abstract: Optical burst switching (OBS) is an optical switching technology; it uses an optical fiber's high bandwidth potential to transfer huge amounts of data in the form of huge packets, which are more commonly referred to as bursts. High burst loss brought on by numerous burst contentions is a significant problem in OBS. An intelligent fuzzy offset time algorithm (FOT) algorithm is suggested to overcome this problem. This study proposed Intelligent Fuzzy Offset Time (FOT) algorithms that adjust offset time (OT) in accordance with network and traffic conditions. The fuzzy input for FOT is made up of three parameters: burst size, distance, and time that burst spent in queuing. The suggested algorithm is assessed versus the Intelligent OT algorithms using the Five defuzzification techniques (Centroid (CM00), Bisector (BM04), largest of maximum (LM02), smallest of maximum (SM03), and mean of maximum (MM01) when Maximum (M) accumulation technique is used, when using Algebraic Sum (S) aggregation methods (Centroid (CS00), Bisector (BS04), largest of maximum (LS02), smallest of maximum (SS03), and mean of maximum (MS01). Simulation results have shown that FOT LM02, FOT LS02, FOT SM03 and FOT LS02 have effects on reducing BLR (burst loss ratio) and E2E (End-2-End) delayed respectively when compared to other defuzzification techniques algorithms. FOT LM02 and FOT SM03 can be used to intelligently adjust the offset parameter using the incoming traffic load and the three parameters.***

***Keywords**: FOT, OBS Networks, Fuzzy Logic, average burst E2E delay, BLR*

## I. INTRODUCTION

Wavelength division multiplexing (WDM) was presented as a viable option to fulfill the rising bandwidth needs due to the proliferation applications of multimedia that are sensitive to bandwidth (BW) [1–5]. In a data transportation system, OBS combines Optical Circuit and Packet Switching [6]. OBS Network composes of the following main nodes, Core nodes, and edge nodes (ingress and egress). Core nodes serve as intermediary nodes and are intended to decrease the processing also reducing storing of an optical data burst (DB) by employing burst header packets (BHP) that include definite information (BHPs) [7]. The important tasks of ingress nodes are bursts assembling, route wavelength assignment (RWA), signalling, BHP generation, and OT setting, Conversely, the purpose of an egress node is to separate DB to its original packets and forward them to their destination on a network (see fig.1) [8].

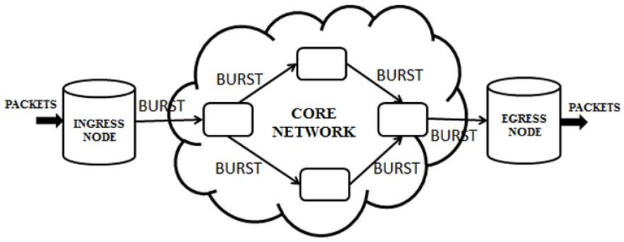


**Fig. 1. OBS Network [8]**

In OBS bursts are generated from several IP packets (IP, SONET, and ATM) [9]. Transmitting the burst is after a BHP allocates the necessary wavelength resources. In this case, the control packet uses delayed or direct reservation protocols to reserve wavelength resources. Thus, after the BHP is processed using the direct reservation method the wavelength resources are reserved [10]. Wavelength resource reservations allocated in the delayed reservation technique [11] are made for the period of the DB transmission. Due to the development of signal processing technology, methods have also been proposed to reduce switching-time [12] and processing-time [13–15]. The burst is lost, if the BCP (burst control packet) is unable to allocate a wavelength between the ingress and the egress node [16].

Prior to sending a burst, a BHP containing the properties of the burst like destination, number of hops and burst size. In core nodes, scheduling the burst is done by using either horizon or filling-void algorithm. An appropriate choosing an OT is necessary for DB arrival and data losing reduction [17]. The following structure is used for this paper: Algorithms for offset time are discussed in section II. The proposed Fuzzy-Offset Time Algorithm (FOTA) is reported in section III. The results' simulations are explained in section IV, the conclusion of this study in section V.

## II. REVIEW OF OFFSET TIME ALGORITHM

BHPs are generated and forwarded before sending DB through OBS networks, and then DB is sent after delay called Offset Time. Transmitting the BHP after an offset time is necessary for the nodes to set up the switches through the path. [17–18].

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Additionally, it permits the Header Control Packet (BHP) to allocate the band width needed at the inter-mediate nodes (core nodes) to send the burst. In order to reserve the wavelength, each core node converts the BHP first from optical–electrical-optical (OEO) signal. The burst is sent optically throughout the path without OEO conversion [19]. Fig. 2 displays an OT scheme in OBS networks.

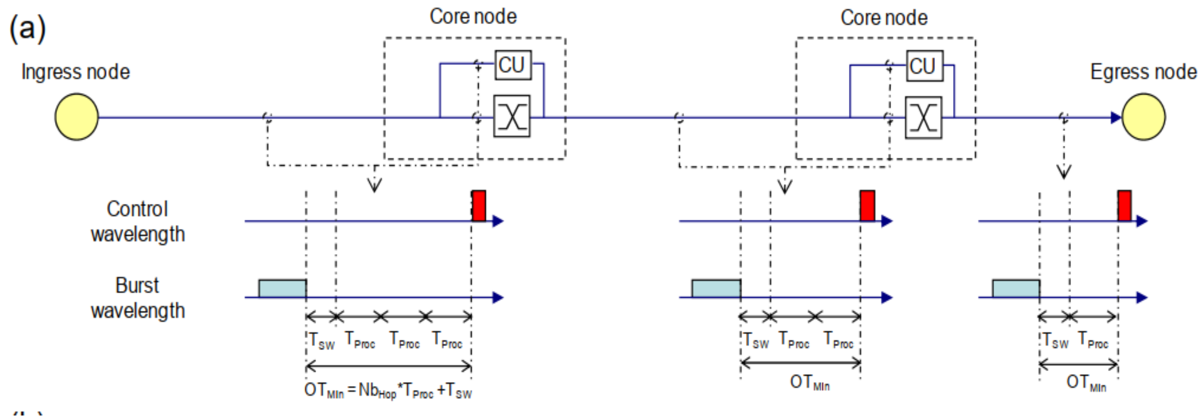


**Fig. 2. OT Scheme in the Network [20]**

Due to the configuration and reservation time spent at the core nodes, then OT is longer than the total amount of time required for BHP processing across all nodes. If the OT is less than the time of processing, then DBs is rejected before the arriving BHP. As a result, the burst loss probability is used to evaluate the OT algorithm's effectiveness.

Fixed OT scheme is derived from [21] the just-enough-time signaling protocol (JET).

OT for JET protocol is constant and is the summation of times of processing for all hops and the time of switching configuration. To estimate the OT, it is required to know how many hops there are between the source and destination nodes. The edge node often provides this information. In a fixed OT scheme, switching and processing times at each node are equal. Due to waiting delays in the control channel, these times may vary between nodes. A fixed OT method is used in Fig. 3 to depict the allocation procedure.

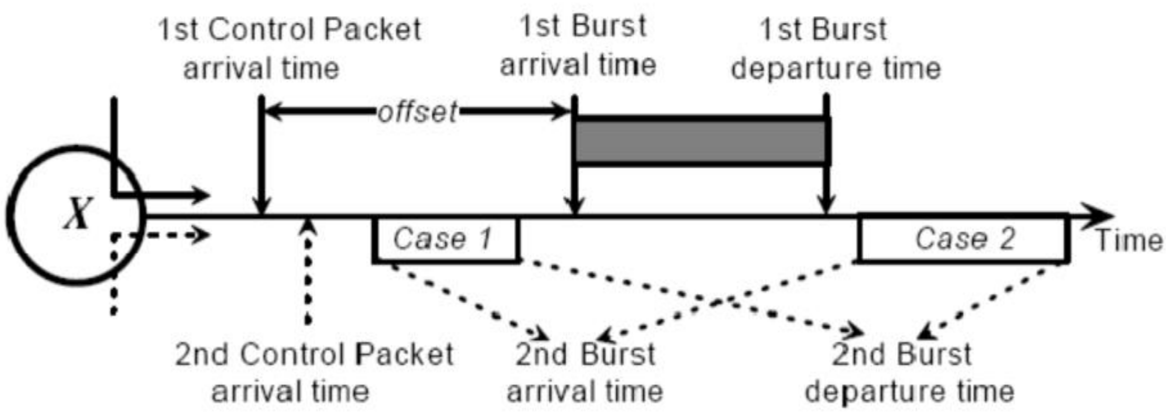


**Fig. 3. Fixed OT**

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.

To achieve a high degree of isolation between bursts of varying sizes, the Adaptive offset-time scheme gives larger bursts more offset time [22]. 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 OT differentiation to avoid congestion is shown in Fig. 4 with $T_1$ representing OT of Burst I, $T_2$ representing an OT for Burst j ($T_i$>$T_j$), and $B_j$ representing the period of burst$_j$. The scheme's drawback is that longer delays and subsequently higher loss penalties will result from the additional offset time. 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.

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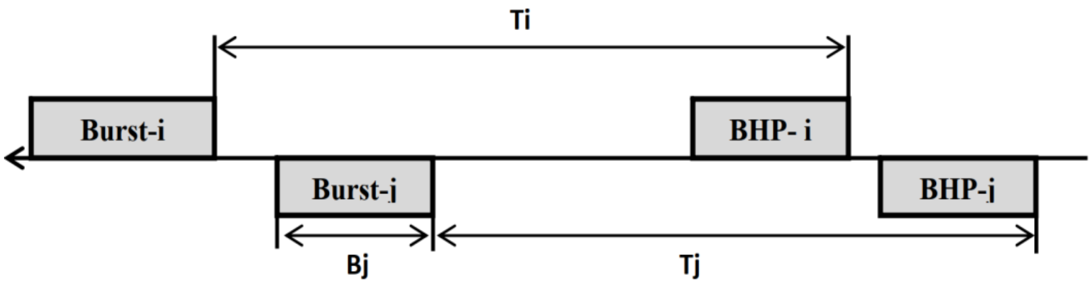


**Fig. 4. OT Differentiation to Avoid Congestion**

When the period of burst assembly is less than the OT, this method reduces the OT by transmitting the CP containing an estimate of the burst length just before the period of assembling the burst expires. This method is because it transmits bursts faster than the conventional approach and does not add additional offset time delay

However, the retransmission time (in the transmission control protocol TCP) should be calculated using the Jacobson-Karels algorithm, and the length of the burst should be predicted and then added in the header of the BHP, so BHP can be sent before the time of burst assembling expires [23]. Inaccurate estimation causes an increase in burst loss.

Hirata and Kawahara's [24] suggested algorithm prevents congestion of multiple transmitting bursts through giving priority to multiple transmitting bursts and giving extra offset-times to uni transmitting bursts. By giving priority to multiple transmitting bursts, deflection routing prevents conflict between uni transmitting bursts. Hence, burst loss has decreased in both cases.

[25] Offers a method to obtain a moderate OT that satisfies the requirements of the insufficient OT (IOT) drop ratio while maintaining a tradeoff between the two. To achieve this equilibrium, the probability of the burst loss which is employed as a monitoring variable is used to allocate offset time dynamically. The OT is dynamically set once the core nodes' background traffic is measured.

In contrast to traditional scheduling algorithms, the novel burst scheduling methods published in the past tenses are geared along with optimizing the usage of local networks. For instance, the technique that is suggested in [26] aims to use local networks without raising the burst loss rate. By connecting upcoming bursts with already-existing bursts, the gap between bursts is decreased. In place of defining an offset-time value, both minimum and maximum OT limitations are established, allowing for a variable OT value. The bursts can alternatively be aligned at the start or finish of the chosen vacuum. No evidence of how this technique affects the value of offset-time, though.

Also [27] suggested an incorporated algorithm that serves to maximize resource utilization while minimizing loss. The proposed algorithm needs the nodes whose information of routing is shared through nodes in the OBS Networks to have wavelength of full conversion capabilities. The edge nodes determine the optimum routes depending on the typical availability of the links. Both the average traffic load and the average link availability are updated. Although utilization findings under low-load situations were less important than burst loss results, this method performed better than the other algorithms that were tested.

The authors of [28] addressed how offset time affected burst loss ratio to confirm that there is no BLR; OT was employed as the adjusting parameter. The researchers suggested a control of closed-loop feedback approach for an adaptive offset time. Adaptively changing offset-time is done due to the receive feedback. The model also makes care to supply the BHP prior to its related burst using the shortest offset time value possible. In [29], a BHP processing paradigm was suggested at the switch-control-units (SCU) of the OBS ring network (OBSR). The receiving, forwarder, scheduler and sending unites all are components of the OBSR network architecture. Substantial deviation, phase-type distribution theorem-based, and central limit are three methods to the distribution model that were proposed. These methods are used to obtain the overall processing time of the BHP for the distribution function, and OT is configured according to with the resulting of function of distribution and the allowable BLR in the event that OT is insufficient. The suggested methods lower BLR for insufficient-OT to the permitted range. The work [21] is modified by [30], where they developed the idea of the Just-Enough-Time-Protocol (JET) based prioritized OBS protocol named pJET. In work [31], where they suggested using a randomized offset time technique to shape traffic. The pJET protocol classifies the burst into classes according to its resolution of interclass conflict; however, it does not address inter-class contention in the event that two bursts belonging to the same class collide. However, a randomized offset time method [31] is suggested for decreasing the probability of blocking produced by bursts of the same class conflicting. In contrast, the stochastic OT algorithm has been proposed as a means of decreasing the probability of blocking when bursts collide with an identical class. However, inter-class conflicts are not resolved, and the value of stochastic OT might be limited. [30] Presents a random OT for intra-class conflicts is introduced in every class in this approach has two OTs; a fixed OT and a random OT. However, it does not overcome conflicting between classes and the value of randomized OT may be limited. When there is inter - class contention, the randomized OT is used, while the fixed OT is utilized when there is inter-class contention. In order to guarantee the transmitting of burst prior to its BHP, the randomized OT is adjusted by giving a value rather than removing it from the fixed OT. The disadvantage of this approach is that, despite increasing the probability that bursts will be blocked, lengthening the randomized offset time causes an increase in E2E.


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The variable OT for composite burst assembly with Segmentation (VCS) technique, which was proposed in [32], similarly addressed the problem of choosing an appropriate OT. High priority packets are sorted out by the proposed VCS algorithm and then placed at the burst' tail. The OT is decided by how many packets at high priority are at every burst. Additional offset time is added when the number of high-priority packets increases to ensure their arrival. When congestion happens at the inter-mediate nodes, the header of the burst is dropped. The bursts are delivered as usual if segmentation was successful. If the contention was not successfully resolved during the segmentation process, the contesting burst is terminated. When compared to traditional variable and composite algorithms, the BLP is higher in. However, the delay is improved over the variable offset time method.

In [17] the authors prove that the intelligent offset time is better than conventional and adaptive offset-time in terms of E2E delay and BLR.

## III. PROPOSE FUZZY-OT ALGORITHM

A new algorithm is suggested to avoid either introducing a delay that increases the E2E delay or setting a fixed value of OT that would not be enough for the BHP to set up the switches and assign the wavelengths (resources).

The control variables used in this algorithm to generate the Fuzzy OT are B. Size parameter, Q. Delay (the total time the burst will spend in queuing before being forwarded to the core nodes), and Distance (hops number) are used as inputs to the FLC, while the output parameter control variable is OT. The new value of OT is essential for the BHP to allocate the necessary wavelengths required for transmission successfully. The new value for the Fuzzy OT (FOT) algorithm is calculated using the input's fuzzy control variables and fuzzy rules. Thus, the Fuzzy OT algorithm is a multiple input single output (MISO) FLC process. Fig. 5 shows Block diagram of the Fuzzy OT Algorithm.

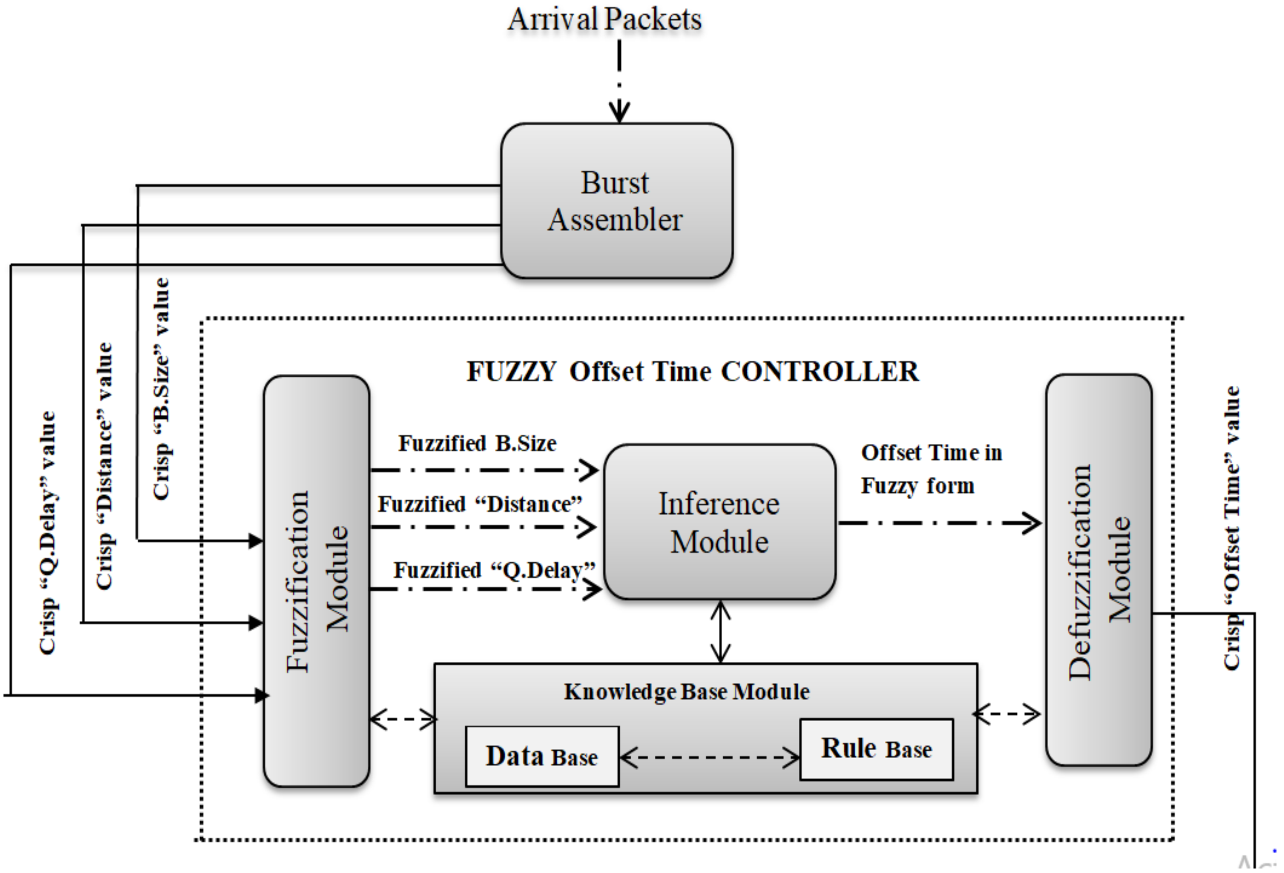


**Fig 5: Block Diagram of the Fuzzy OT Algorithm**

Three steps that fuzzy logic control process consists; Fuzzification, Inferencing and Defuzzification processes. All inputs and outputs control variables are defined and fuzzified in the fuzzification module**.** In Fig. 5, the control variables B. Size, Q. Delay and Distance are inputs to FLC while FOT is the output control variable of FLC. The number of fuzzy partitions that act as fuzzy values for the FLC must be defined for each fuzzy variable in order to complete the fuzzification process. In this study, each fuzzy variable is divided in to three fuzzy partitions each of which has a name, as shown in Table. 1. Determined the type of Membership Function that used to each Fuzzy Partition. A triangular Membership Function is used for each fuzzy partition of the fuzzy control variable, making this stage compatible with the final stage of the fuzzification process.

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**Table-1: Fuzzy Input Variable with Operation Range**

| | Fuzzy variables | Universe of Discourse | Partition label (T) | TMF Definition T(u; a,b,c) |
|---|---|---|---|---|
| Input | B. Size | [0 , 60] | Small | Small ( B.Size; 0,15, 30 k) |
| | | | Medium | Medium ( B.Size; 15,30, 45k) |
| | | | Big | Big ( B.Size; 30,45, 60 k) |
| | Distance | [0 , 8] | Short | Short (Distance; 0, 2, 4 hop) |
| | | | Middle | Middle (Distance; 2, 4, 6 hop) |
| | | | Long | Long (Distance; 4, 6, 8 hop) |
| | Q. Delay | [0 , 400 µs] | Low | Low (Q.Delay; 0 ,100, 200 µ) |
| | | | Average | Average (Q.Delay;100,200,300 µ) |
| | | | High | High (Q.Delay; 200,300,400 µ) |
| Output | FOT | [0 , 100 µs] | Little | Little (FOT; 0 ,25,50 µ) |
| | | | Moderate | Moderate (FOT; 25,50,75 µ) |
| | | | Large | Large (FOT; 50,75,100 µ) |

In fuzzy inferencing process of this algorithm, rule base for FOT Fuzzy logic are 27, which used for evaluation this algorithm as shown in Table. 2. The activated fuzzy rules are then added together to create a single, variable output crisp for the third step. The inference engine used in this study is Mamdani technique. The rules used in determining the output of the fuzzy system produced are in the form of IF (input$_i$) is $A^k{}_1$ AND (input$_j$) is $A^k{}_2$ AND (input$_l$) is $A^k{}_3$ THEN (output) is $B^k$.

**Table-2: The Relationship of the Three FOTA Rule Sets**

| No. | B. Size | Distance | Q. Delay | FOT |
|---|---|---|---|---|
| 1 | Small | Short | Low | Little |
| 2 | | | Average | Little |
| 3 | | | High | Moderate |
| 4 | | Middle | Low | Moderate |
| 5 | | | Average | Moderate |
| 6 | | | High | Moderate |
| 7 | | Long | Low | Large |
| 8 | | | Average | Large |
| 9 | | | High | Large |
| 10 | Medium | Short | Low | Little |
| 11 | | | Average | Little |
| 12 | | | High | Little |
| 13 | | Middle | Low | Moderate |
| 14 | | | Average | Moderate |
| 15 | | | High | Moderate |
| 16 | | Long | Low | Moderate |
| 17 | | | Average | Moderate |
| 18 | | | High | Moderate |

| No. | B. Size | Distance | Q. Delay | FOT |
|---|---|---|---|---|
| 19 | Big | Short | Low | Moderate |
| 20 | | | Average | Little |
| 21 | | | High | Little |
| 22 | | Middle | Low | Moderate |
| 23 | | | Average | Little |
| 24 | | | High | Little |
| 25 | | Long | Low | Large |
| 26 | | | Average | Large |
| 27 | | | High | Large |

The last step is defuzzification stage that converts the output fuzzy value to an output crisp value

Omnet++ version 4.2.2 was used to evaluate the proposed algorithm [33]. The simulation environment was built using OBS Modules Master [34] and fuzzylite version 5.0 [35]. A network environment that is comparable to OBS can be created using OBS modules. The library of the fuzzy logic control (FLC) that is required for this simulation is provided by Fuzzylite. Table. 3 lists the settings for the parameters used to simulate the OBS network.

**Table-3: OBS Network Simulation Parameters**

| Parameters | | Values |
|---|---|---|
| network topology | | NSF-NET |
| number of channels/link | | 4channel (3data and1 control) |
| bandwidth per channel | | 1 Gb/s |
| Packet Size | | 1250 byte |
| BHP's processing time (µs) | | 10 µs |
| Propagation delay | | 1 µs |
| Packet interval time | | Exponential |
| Scheduling Scheme | | LAUC |
| Timeout(s) | | $(5x10^{-4})$ |
| Burst threshold (bytes) | minimum | 1500 |
| Burst threshold (bytes) | maximum | 60000 |
| Incoming Traffic (Load) | minimum | 0.1 |
| Incoming Traffic (Load) | maximum | 1 |
| Incoming Traffic (Load) | Increment | 0.1 |
| Signaling Scheme | | JET |
| Wavelength Conversion | | ON |

The NSFNET, consist of 14 bidirectional links, uniform traffic distributed across all source/destination pairs and one wavelength is allocated as control packet channel on every link. The network offered load was created by traffic with exponential inter-arrival time and it increased from 0.1 until it reaches 1.0, where 1.0 denotes the maximum network offered load.

The new design algorithms is compare with the Intelligent offset Time (IOT). The two important evaluation metrics in this study are BLR and E2E delay.

## IV. RESULT AND DISCUSSION

Figure 6 display the BLR versus offered load of FOT algorithms. From figure it is clear that FOT LM02, FOT MM01 and IOT CM00 have small burst loss ratio as in comparison to FOT BM04 and FOT SM03. The burst loss ratio of FOT MM01 and IOT CM00 are closer to each other 0.035, 0.04 respectively. Increasing in incoming traffic the BLR will increase. The lowest BLR in FOT LM02 is due to its ability to use the Largest of Maximum defuzzification and Maximum aggregation technique in the FLC to produce optimum value of OT between the BHP and the DB, thus reducing the network's congestion level and minimizing burst loss contention and losses. However, FOT LM02 configuration provides better network performance than other configuration under heavily load

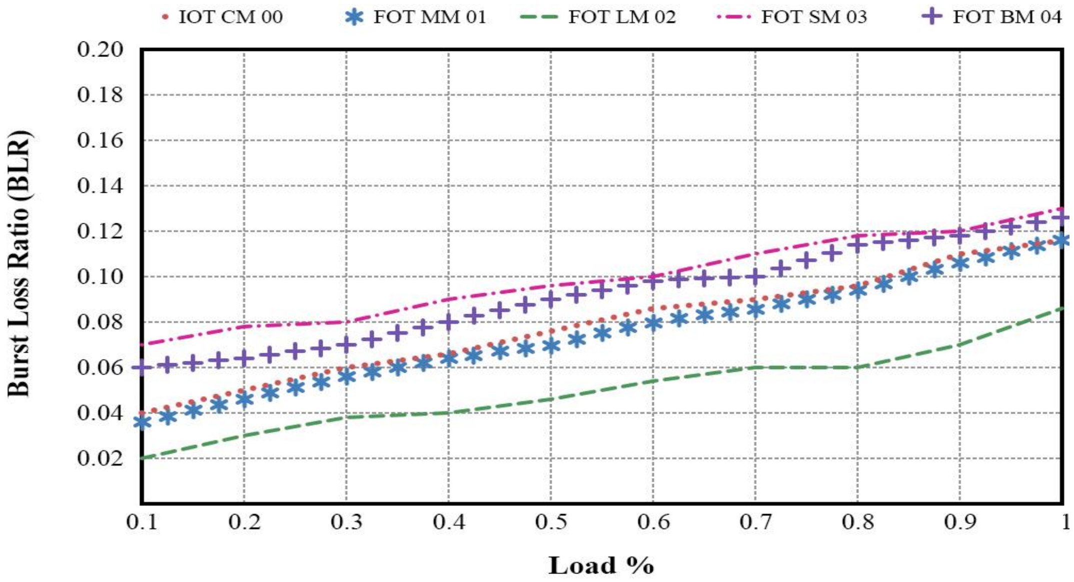


**Fig. 6. BLR Versus Offer Load for Different Defuzzification Techniques and Maximum Aggregation Technique.**

As shown in Fig.7 that, FOT SM03 has better performance in term E2E delay than the three (3) configurations of FOT algorithm and IOT algorithm. From 0.1 to 0.4 IOT CM00 is better than FOT MM01 and FOT LM02 in term of end to end delay. FOT LM02 has highest delay due to the large burst generation which tends to longer transmission time although of this, it has less burst loss ratio. FOT SM03 has high burst loss ratio because it generates high number of busts which cause high contention. In return, it has the best network performance because it produces less E2E delay ratio due to the generation of small bursts. However, despite the increase in burst size and high traffic load, FOT SM03 maintains a constant average delay value.

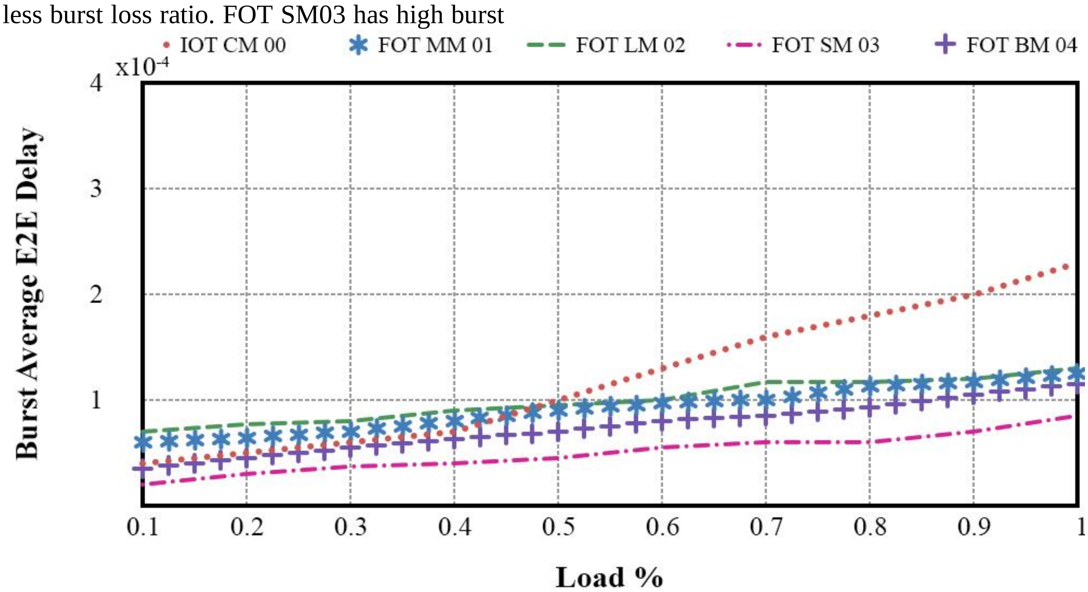


**Fig. 7: Burst Average E2E Delay Versus Offer Load for Different Defuzzification Techniques and Maximum Aggregation Technique**

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Fig.8 explains the effect of five defuzzification techniques and Algebraic Sum(S) aggregation technique on the set of fuzzy rules and their overall effect on BLR. From fig. 8, shown that an increase in the burst loss ratio for all FOTA while IOT CS00 still without change on both BLR and E2E delay that means; IOT CS00 has no affect while changing the aggregation from maximum to algebraic sum. FOT LS02 displayed the best BLR when compared with FOT MS01 FOT BS04, FOT SS03 and IOT, and in return IOT CS00 is better than FOT MS01 FOT BS04, FOT SS03, this is due to that, the B. Size produced of these four configurations are not large to reduce the number of bursts assemble at the assembler to minimizing offset time delay. However, the fuzzy rule used by the configuration FOT LS02 is effective in reducing burst loss ratio at all offered loads.

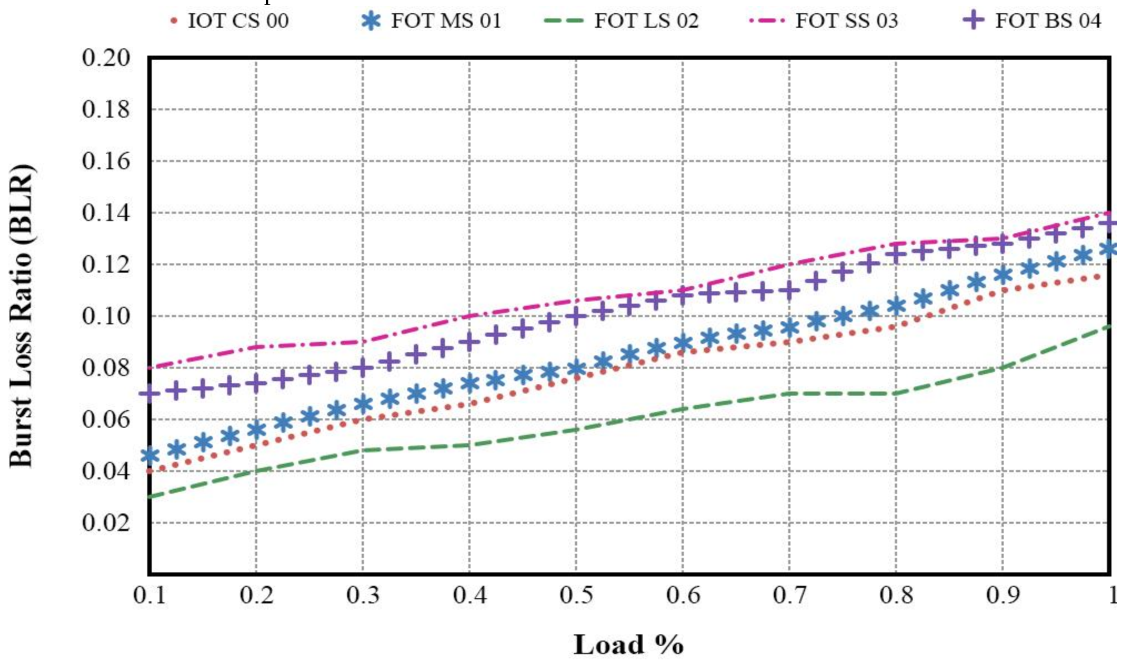


**Fig. 8. BLR Versus Offer Load For Different Defuzzification Techniques and Sum Aggregation Technique.**

Fig.9. elaborate the E2E delay, it's clear that FOT SS03 has the best performance outperforms all configurations and IOT algorithms which is due to the generation of short size of bursts that suffer the lowest delays and also the least transmission delays over the OBS network. In relation of burst E2E delay, FOT SS02 has the best performance due to the fact that its FLC configuration prefers it to produce optimum offset values due to the generation of very short bursts. However, the fuzzy rule used by the configuration FOT SS02 is effective in reducing E2E delay at all offered load.

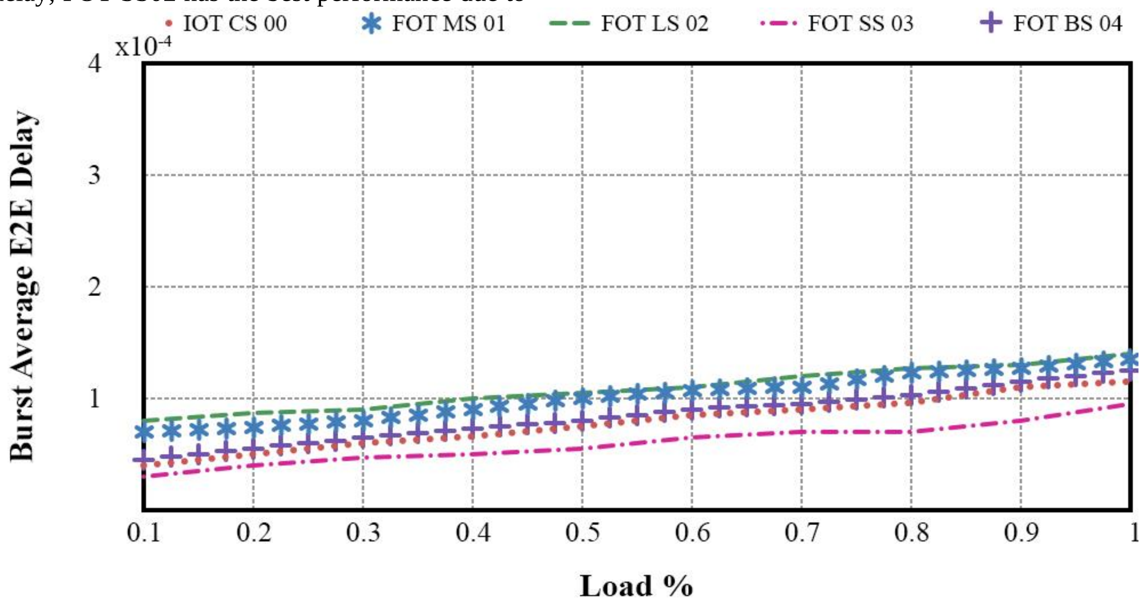


**Fig. 9. Burst Average E2E Delay Versus Offer Load for Different Defuzzification Techniques and Sum Aggregation Techniques.**

## V. CONCLUSION

In this research paper, we presented an effective Fuzzy Offset Time algorithm (FOTA) using fuzzy logic to reduce E2E delay and BLR in OBS Networks. This study has performed very well in terms of BLR when using largest of maximum defuzzification method and maximum aggregation technique (FOF LM 02) while in case of E2E delay the smallest of maximum (FOT SM03) perform the best. For future works, different aggregation methods will be applied on this proposed method.

## DECLARATION

| | |
|---|---|
| Funding/ Grants/ Financial Support | No, I did not receive. |
| Conflicts of Interest/ Competing Interests | The authors say they have none. |
| Ethical Approval and Consent to Participate | No, the article does not require ethical approval and consent to participate with evidence. |
| Availability of Data and Material/ Data Access Statement | On request, the data used to back up the study's conclusions can be provided by the corresponding author. |
| Authors Contributions | Writing the initial draft, as well as writing the review and revising. For instance: Formal analysis, editing, reviewing, and supervision of writing. The manuscript's published form was approved by all authors after they had read it. |

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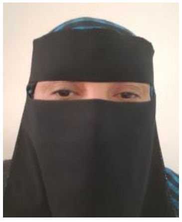

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