

Adaptive Burst Assembly Algorithm for Reducing Burst Loss and Delay in OBS Networks

¹Bharathi Lakshmanan, ²Sasikala Ramasamy and ³Srinivasan Alavandar

¹Department of Electronics and Communication Engineering, Excel College of Technology,
637303 Komarapalayam, Tamil Nadu, India

²Department of School of Computing Science and Engineering, VIT University,
632014 Vellore, Tamil Nadu, India

³Department of Electrical and Electronics Engineering, Agni College of Technology,
603103 Thalambur, Tamil Nadu, Chennai, India

Abstract: In Optical Burst Switching (OBS), during burst assembly approaches, the burst offset time, Burst Loss Rate (BLR) and dropping probability of bursts are not taken into account which may cause contention issue. In order to overcome these issues, in this study, we propose to design an Adaptive Burst Assembly Algorithm for Reducing Burst Loss and Delay in OBS networks. In this technique, the traffic for next interval is predicted using linear prediction filters. This predicted traffic along with the timer and burst length is then considered as input for fuzzy logic and the new burst length and output values are generated as output. At core routers, the contention is measured based on the BLR and link utilization and then sent as a feedback to the ingress. Based on the measured contention, the new offset time, burst length and timer are determined and used for the next frame. By simulation results, we show that the proposed approach resolves the contention and it reduces the burst delay.

Key words: Adaptive burst assembly algorithm, fuzzy based adaptive hybrid burst assembly, blocking probability, average packet delivery ratio, time

INTRODUCTION

Optical Burst Switching (OBS) is a preeminent technology which unites the greatest characteristics of both circuit switching and packet switching. It carries the Internet Protocol (IP) over the dense Wavelength Division Multiplexing (DWDM). To set up the connection in OBS networks, a control packet is transmitted foremost on a separate signaling channel and it is followed by a data burst. OBS does not wait for an acknowledgement message to establish the path Monther.

The architecture of OBS consists of a broad range of experimental switching paradigms which supports IP over Wavelength Division Multiplexing (IP-over-WDM) in all optical communication networks (Le Vu *et al.*, 2005). The basic data block transmitted in the OBS network is burst. The burst encompass of collection of data packets it has same network egress address, and common attributes, like QoS requirements. Burst can also be termed as super packet or data burst (Xiong *et al.*, 2000).

Before transmission, packets are congregated at the ingress node as bursts and then transferred through the

OBS network. The congregated (assembled) bursts are disassembled back to the packets at the network egress. The same process is repeated in all hops (e.g., conventional IP routers). Assembly/Disassembly functions and legacy interfaces such as gigabit Ethernet, Packet Over SONET (POS), IP/ATM) are provided by the edge routers. On the other hand, a core router consists of an optical switching matrix and a Switch Control Unit (SCU) (Xiong *et al.*, 2000).

Since, OBS networks are connectionless; there are more possibilities for occurrence of contention in the network for resources. This contention gradually leads to packet loss (Vokkarane and Zhang, 2006). When, two or more bursts try to win the same output port on the same wavelength channel of OBS network, then the situation is termed as contention. The network performance is drastically affected by contention for the reason that need of optical memories (Um *et al.*, 2006).

Contention and burst loss are the major issues in OBS networks. The starting pace of contention is classified into two categories such as contention on data channels and contention on control channel.

Segmentation is a method used to resolve contention; it segregates the contended burst into a number of smaller parts referred as segments such that instead of dropping the entire burst some segments are dropped (Aly and El-Biaze, 2011; Patil and Dafedar, 2014).

In burst assembly, burst from various sources are classified and aggregated into optical bursts of varying length according to the destination. In presence of low and high traffic load, the data loss and delay will be more (Odeh *et al.*, 2013). Conventional schemes are unfair about the number of hops for the packet loss probability. For a burst assembly algorithm, selecting the required balance between the burstification delay and burst size depends on the QoS requirements of the users and the processing and buffering capabilities of the backbone nodes (Garg, 2013).

To lessen the overall Burst Loss Rate (BLR) and to improve the link utilization, a soft contention resolution algorithm may also be associated with a scheduling algorithm. When there is an unavailability of an unscheduled channel for transmitting BHP request then the contention resolution algorithm is triggered.

Even after the utilization of different loss minimization mechanisms there is a possibility for Burst Loss. Therefore, loss recovery mechanisms are needed to offer reliable OBS transport network (Vokkarane and Zhang, 2006).

Problem identification: In traffic prediction based burst assembly mechanisms are proposed in which the timer and burst length thresholds are adaptively determined based on the traffic arrival (Garg, 2013; Seklou *et al.*, 2013). In fuzzy logic is used to determine the new timer and burst length values based on current the traffic load (Umaru *et al.*, 2014; Yayah *et al.*, 2016; Ramalakshmi and Thanushkodi, 2014). Though these burst assembly mechanisms, aim to reduce the burst assembly delay, they fail to adjust the burst offset time and address the burst losses due to contentions. The Burst Loss Rate (BLR) and dropping probability of bursts are not taken into account there by raising the contention issues.

Burst contention resolution techniques proposed by Aly and El-Biaze (2011) use the BLR and link utilization metrics to avoid the contention. In Dynamic Contention Resolution Protocol (DCRP) (Aly and El-Biaze 2011), an adaptive decision threshold is determined based on which deflection routing, retransmission and burst delaying strategies decision are taken. But, the retransmission and delaying strategies may not reduce the contention if proper burst offset time and assembly thresholds are used. In order to solve these issues, we propose to design a burst assembly algorithm which reduces the burst delay and resolve contention.

Review of literature: Bikram *et al.* (2011) have presented a multi-layer data loss recovery approach for OBS networks. Their loss recovery approach syndicates ARQ and Snoop for OBS networks. They have implemented RAQ at the lower layer to lessen the data loss caused by random burst contentions. Snoop is employed at the next higher level to eradicate any FTOs/FFRs in the network. At last, TCP retransmits the lost packets at the higher by means of timeouts and fast retransmission mechanism. In their scheme, the Snoop layer operates on a packet-level and utilizes triple duplicates to determine when to attempt recovery while ARQ works on a burst-level and uses explicit requests to attempt recovery. Both of these approaches are independent of one another but complement each other.

Boobalan *et al.* (2011) have suggested two level schemas to reduce Burst Loss Ratio (BLR). Their first algorithm has introduced a closed loop feedback technique in which the destination node senses the data traffic and forwards a feedback to the source node. On the other hand, their second algorithm offers a link protection and restoration mechanism by recommending suitable backup channels using Label-Stacking and Burst-Multiplexing techniques. Their work attains service level objectives in terms of Burst Loss Ratio (BLR) while guaranteeing QoS requirement of each class of bursts.

Abdulsalam and coauthors proposes and evaluates a Hybrid Offset Time and Burst Assembly Algorithm (H-OTBA) to reduce the burst transfer latency occurred in burst assembly process in Constant Bit Rate (CBR) applications. It estimates the burst off-set time and burst assembly time values based on the difference between the end-to-end delay and Maximum Burst Transfer Delay (MaxBTD).

Coulibaly *et al.* (2011) have introduced a Priority-Based Segmented Train Algorithm (PSTA) for Hierarchical Time Sliced OBS (HiTSOBS). It assumes shortest path routing and first fit wavelength assignment algorithms. In PSTA, time slots are allocated in a given level depending on the priority of the burst to be transported.

Garg (2013) developed an efficient burst assembly mechanism with traffic prediction characteristics to reduce the variance of assembled traffic and to improve the burst loss performance. In traffic prediction, the number of packets that will be arrived in the assembly queue in future is estimated. Based on this, it can be decided that whether it would be beneficial for the burst assembly process to wait for these packets or the burst should be sent immediately.

Another research based on traffic prediction was by Seklou *et al.* (2013) in which new burst assembly schemes and fast reservation protocols are proposed. The burst assembly techniques use a linear prediction filter to estimate the number of packet arrivals at the ingress node in the next interval. The fast reservation protocols use prediction filters to estimate the expected length of the burst and the time needed for the burst assembly process to complete.

MATERIALS AND METHODS

Overview: In this research, we propose to design an adaptive burst assembly algorithm for reducing burst loss and delay in OBS networks. In this technique, the traffic for next interval is predicted using linear prediction filters. This predicted traffic along with the timer and burst length is then considered as input for fuzzy logic and the new burst length and output values are generated as output. At core routers, the contention is measured based on the BLR and link utilization and then sent as a feedback to the ingress. Based on the measured contention, the new offset time, burst length and timer are determined and used for the next frame. By simulation results, we show that the proposed approach resolves the contention and reduces the burst delay.

Traffic prediction: The network traffic for next interval is predicted using the linear predictor filter ‘Least Mean Square’ filter.

Let α be the step size which affects the converging process of the adaptive filter towards the unknown system.

Let $y(i)$ be the filter co-efficient. The number of packets received during the n th frame is estimated using the following Eq. 1:

$$\hat{Z}(n) = \sum_{i=1}^q y_z(i)Z(n-i) \tag{1}$$

Where:

$Z(n-i)$ = No. of packets received during the $(n-i)$ th frame
 q = Length of the filter

$$y_z(j) = y_z(j-1) + \alpha e_z(j-1)Z(j-1)$$

Where:

$e_z(j-1)$ = Error between the actual and predicted number of packets received at the

$(j-1)$ th = Frame

The length of the n th burst is estimated using the following Eq. 2:

$$\hat{Q}(n) = \sum_{i=1}^q y_Q(i)Q(n-i) \tag{2}$$

where, $Q(n-i)$ length of the $(n-i)$ th burst.

$$y_Q(j) = y_Q(j-1) + \alpha e_Q(j-1)Q(j-1)$$

Where:

$e_Q(j-1)$ = Error between the actual and predicted length of the

$(j-1)$ th = Burst the time at which the n th burst is assembled is estimated using the following Eq. 3:

$$\hat{X}(n) = \sum_{i=1}^q y_X(i)X(n-i) \tag{3}$$

where, $X(n-i)$ duration of the $(n-i)$ th burst.

$$y_X(j) = y_X(j-1) + \alpha e_X(j-1)X(j-1)$$

Where:

$e_X(j-1)$ = Error between the actual and predicted duration of the

$(j-1)$ th = Burst assembly period.

The time complexity for the co-efficient calculation of the LMS- based approach is $O(q)$.

Fuzzy based burst assembly control technique: We can control the burst assembly process using the Fuzzy Logic Decision (FLD) model. Here the timer, length and load predicted using the linear predictor (Explained in traffic prediction) are provided as the input to the fuzzy logic model and fuzzy decision rules are formed. Based on the outcome of the rules, the new Timer and Length are decided based on which the burst assembly process is controlled. The steps that determine the fuzzy rule based interference are as follows:

- Fuzzification: this involves obtaining the crisp inputs from the selected input variables and estimating the degree to which the inputs belong to each of the suitable fuzzy set.
- Rule Evaluation: the fuzzified inputs are taken and applied to the antecedents of the fuzzy rules. It is then applied to the consequent membership function
- Aggregation of the rule outputs: this involves merging of the output of all rules
- Defuzzification: the merged output of the aggregate output fuzzy set is the input for the defuzzification process and a single crisp number is obtained as output

The fuzzy inference system is shown in Fig. 1.

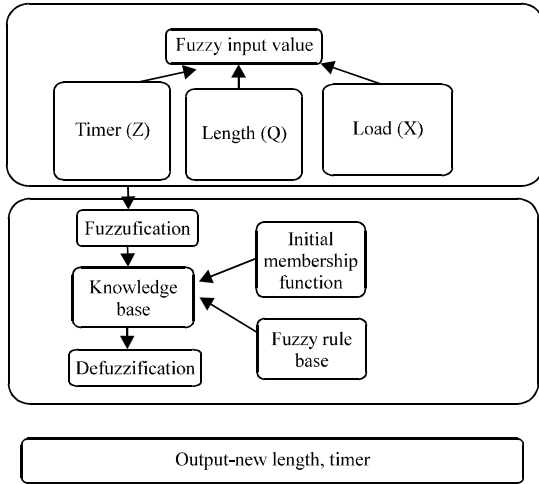


Fig. 1: Fuzzy inference system

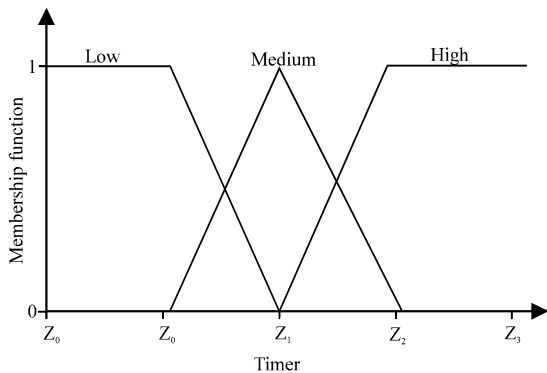


Fig. 2: Membership function of timer

Fuzzification: This involves fuzzification of input variables such as interference among timer (Z), length (Q) and load (X). (Estimated in traffic prediction) and these inputs are given a degree to appropriate fuzzy sets. The crisp inputs are the combination of Z, Q and X. We take three possibilities, high, medium and low for Z, Q and X.

Figure 2-6 shows the membership function for the input and output variables. Due to the computational efficiency and uncomplicated formulas, the triangulation functions are utilized which are widely utilized in real-time applications. Also a positive impact is offered by this design of membership function. In Table 1, Z, Q and X are given as inputs and the output represents the New Length and Timer (Z' and Q').

- Z'_0 and Q'_0 = Very low
- Z'_1 and Q'_1 = Low
- Z'_2 and Q'_2 = Medium
- Z'_3 and Q'_3 = High
- Z'_4 and Q'_4 = Very high

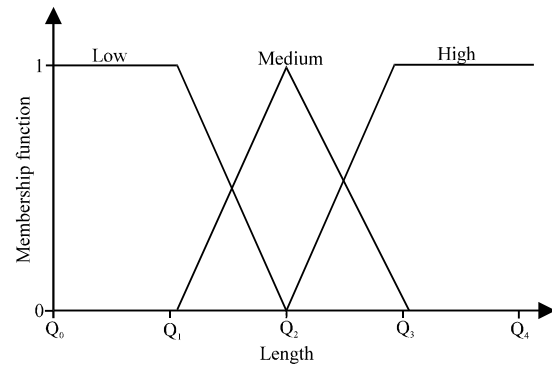


Fig. 3: Membership function of length

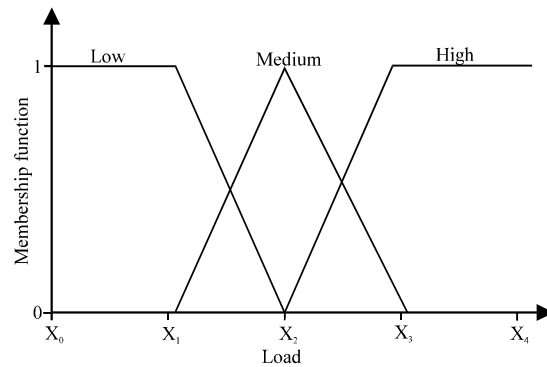


Fig. 4: Membership function of load

Table 1: The fuzzy sets with the combinations

Timer	Length	Load	New Timer	New Length
Low	Low	Low	Z'_0	Q'_0
Low	Low	medium	Z'_0	Q'_0
Low	Low	High	Z'_0	Q'_0
low	Medium	Low	Z'_0	Q'_0
low	Medium	Medium	Z'_1	Q'_1
low	Medium	High	Z'_1	Q'_1
low	High	Low	Z'_1	Q'_1
low	High	Medium	Z'_1	Q'_1
low	High	High	Z'_1	Q'_1
Medium	Low	Low	Z'_2	Q'_1
Medium	Low	Medium	Z'_2	Q'_2
Medium	Low	High	Z'_2	Q'_2
Medium	Medium	Low	Z'_2	Q'_2
Medium	Medium	Medium	Z'_2	Q'_2
Medium	Medium	High	Z'_2	Q'_2
Medium	High	Low	Z'_2	Q'_2
Medium	High	Medium	Z'_2	Q'_3
Medium	High	High	Z'_2	Q'_3
High	Low	Low	Z'_3	Q'_3
High	Low	Medium	Z'_3	Q'_3
High	Low	High	Z'_3	Q'_3
High	Medium	Low	Z'_3	Q'_4
High	Medium	Medium	Z'_3	Q'_4
High	Medium	High	Z'_3	Q'_4
High	High	Low	Z'_4	Q'_4
High	High	Medium	Z'_4	Q'_4
High	High	High	Z'_4	Q'_4

Table 1 demonstrates the designed fuzzy inference system. This illustrates the method and function of the

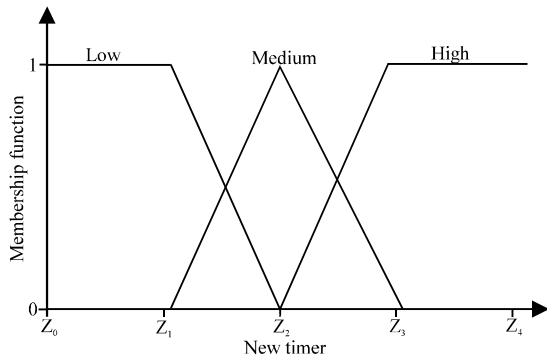


Fig. 5: Membership function of new timer

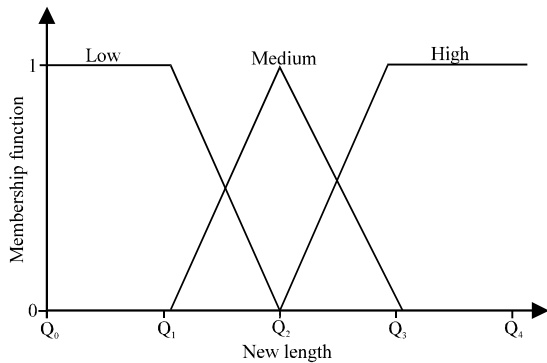


Fig. 6: Membership function of new length

inference engine and method by which the outputs of each rule are combined to generate the fuzzy decision. For example:

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Let us consider Rule 13
If (Z = High and X = Low, Q = High)
Then
    New Timer = Z4, and New Length = Q4
End if
    
```

Defuzzification: The technique by which the crisp values are extracted from a fuzzy set as a representation value is referred to as defuzzification. The centroid of area scheme is taken into consideration for defuzzification during fuzzy decision making process. Equation 6 describes the defuzzifier method:

$$\text{Fuzzy_cost} = \frac{\sum_{\text{allrules}} f_i \times \psi(f_i)}{\sum_{\text{allrules}} \psi(f_i)} \quad (4)$$

Where:

Fuzzy_cost = It is used to specify the degree of decision making
 f_i = The fuzzy all rules and variable
 $\psi(f_i)$ = Its membership function. The output of the fuzzy cost function is modified to crisp value as per this defuzzification method

Contention resolution technique:

- Let S and D be the source and destination node, respectively
- Let PACK and NACK be the positive and negative acknowledgement, respectively
- Let T_o be the offset time

During routing, when there is no contention is the network, the source node selects the primary path. However, in the presence of contention, an alternate contention free route is selected based on the Burst Loss Ratio (BLR) and link utilization.

The success probability that the packet can be forwarded is measured as the probability of the sum of the BLR (ω) and the link utilization (γ) between two consecutive nodes:

$$C (N_i, N_{i+1}) = \pi_{i-1}^R [(\omega_{N_i, N_{i+1}}) + (\gamma_{N_i, N_{i+1}})] \quad (5)$$

Also the offset time should be maximum such that the burst arrives at each switch following the control packet. It is estimated as follows:

$$T_o = T_{ct} + H_i + T_p \quad (6)$$

Where:

- T_{ct} = Configuration time
- H_i = Hop count
- T_p = Processing time

As T_{ct} and T_p are constant values, it is required to accurately predict H_i . But during deflection, long route can be chosen which may increase H_i . The steps involved in this technique are as follows:

- When a control packet is received, the current node is compared to D. If the control packet has reached D then a PACK is sent to S
- If enough T_o is inadequate (estimated in Eq. 6) then the NACK is sent to S and burst packet is retransmitted using the best path after a pre-defined time period
- The best output path is selected which contains the maximum success probability (estimated in Eq. 5)

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If  $C_d ( N_i, N_{i+1} ) < \text{threshold}$ 
Then
    NACK is sent to S
    The burst packet is re-transmitted
End if
    
```

$$\text{Threshold} = W1 * + W2 * \gamma * W3 * \text{delay}$$

where, $W_{1,3}$ Be the weight values of the burst loss ratio, link utilization and delay. If the success probability of the current alternative is less than the threshold, then a NACK is sent to S and the burst is retransmitted. The status of the routing table is updated periodically. The relevant cost value is estimated as follows:

$$CV (NH,D)=1-Z\pi_{i-1}^R [C (N_{i+1}),D]$$

Where:

NH = Next Hop

$C (N_{i+1}), D$ = Route of a given next hop node to D

This reveals that the next hop with high success probability results in low cost. Based on the measured contention, the new offset time, burst length and timer are determined and used for the next frame.

RESULTS

Simulation parameters: We use NS2 (Network Simulator *et al.*, 2014) to simulate our proposed Adaptive Burst Assembly Algorithm (ABAA) protocol. We used the OBS Network. In our simulation, the self simulator rate is varied as 10000, 20000, 30000, 40000 and 50000 for low load case and 50000, 60000, 70000, 80000, 90000 and 100000 for high load case. The burst size is varied as 10000, 20000, 30000, 40000 and 50000. The self simulated traffic is used here for the implementation. The simulation topology and parameters are shown in Fig. 7 and Table 2.

Table 2: Simulation parameters

Variables	Values
No. of edge nodes	7
No. of core nodes	7
Low load	20, 40, 60, 80, 100 Mb
High load	100, 120, 140, 160, 180, 200 Mb
Traffic source	Self similar traffic
Burst size	10-50 kb
Simulation time	50 sec

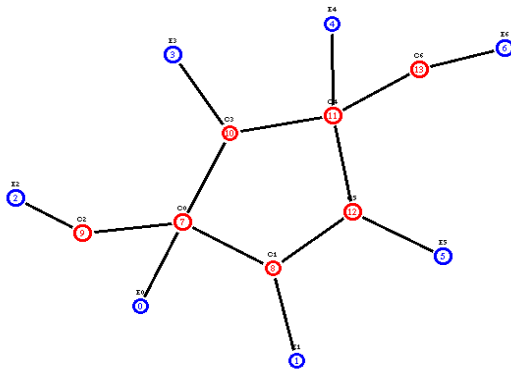


Fig. 7: Simulation topology

Performance metrics: We evaluate performance of the new protocol mainly according to the following parameters. We compare the FAHBA (Umaru *et al.*, 2014) protocol with our proposed ABAA protocol.

Average packet delivery ratio: It is the ratio of the number of packets received successfully to the total number of packets transmitted.

Burst delay: The end-to-end-delay is averaged over all surviving bursts from the sources to the destinations.

Throughput: The throughput is the amount of data that can be sent from the sources to the destination.

Burst drop: It is the number of bursts dropped during the data transmission.

Blocking probability: It is the ratio of the number of rejected requests to the total number of requests.

Results analysis: The simulation results are presented in the next study.

Based on low load: In our first experiment, we are varying the rate as 10000, 20000, 30000, 40000 and 50000.

Figures 8-14 show the results of blocking probability, deliveryratio, burst delay, burst drop, SSIM delay, throughput and bandwidth utilization by varying the rate from 10000-50000 for the traffic in ABAA and FAHBA protocols. When comparing the performance of the two protocols, we infer that ABAA outperforms FAHBA by 50% in terms of blocking probability, 32% in terms of delivery ratio, 25% in terms of burst delay, 50% in terms of burst drop, 25% in terms of Delay, 32% in terms of Throughput and 32% in terms of bandwidth utilization.

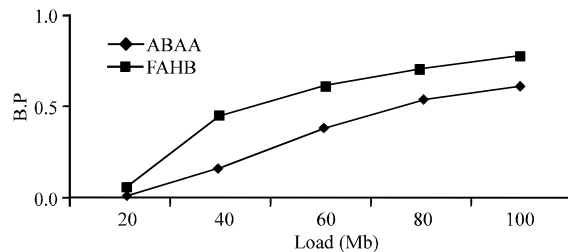


Fig. 8: Load vs blocking probability

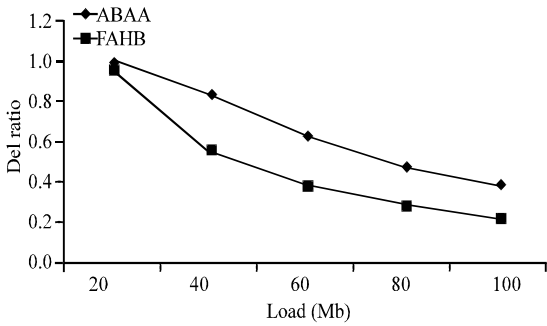


Fig. 9: Load vs delviery ratio

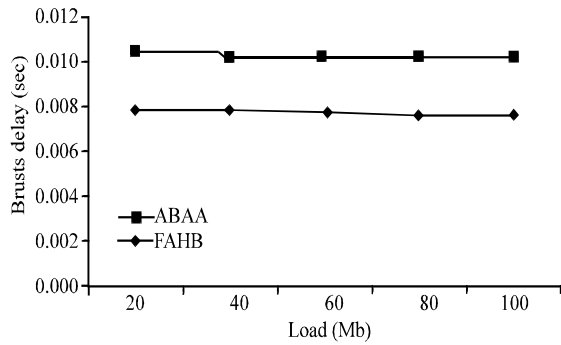


Fig. 10: Load vs burst delay

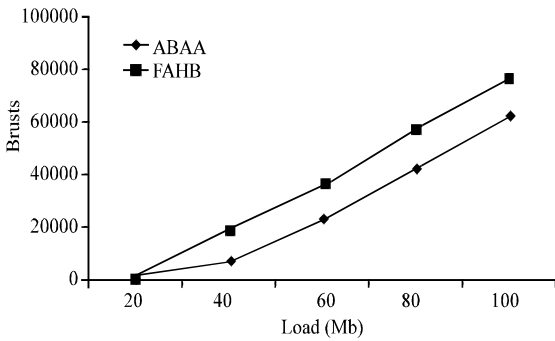


Fig. 11: Load vs burst drop

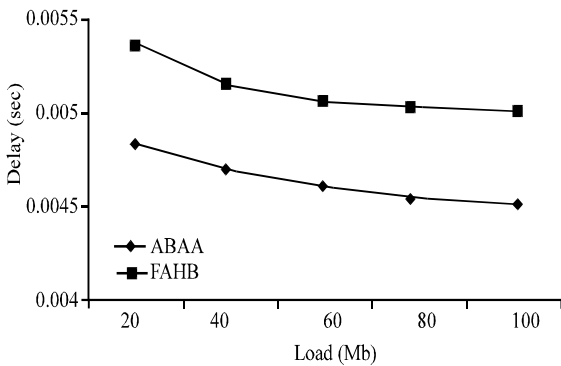


Fig. 12: Load vs SSIM delay

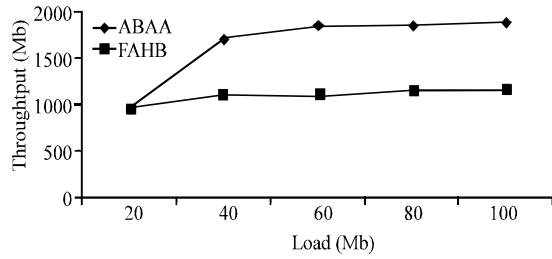


Fig. 13: Load vs SSIM throughput

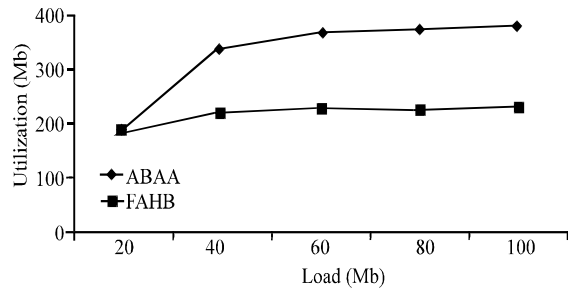


Fig. 14: Load Vs bandwidth utilization

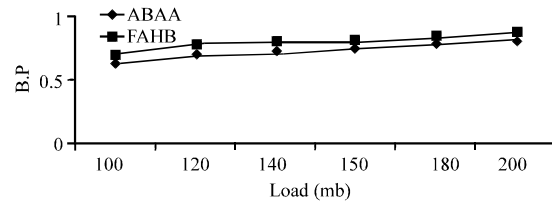


Fig. 15: Load vs blocking probability

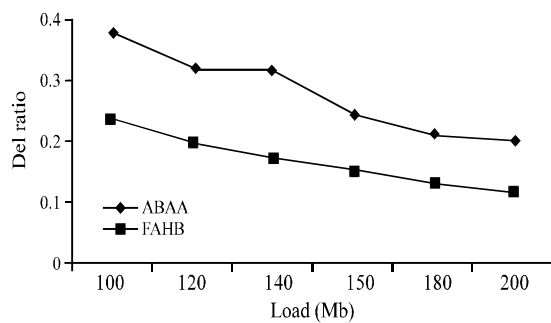


Fig. 16: Load Vs delviery ratio

Based on high load: In our second experiment we vary the high rate as 50000, 60000, 70000, 80000, 90000 and 10000.

Figures 15-21 show the results of blocking probability, delivery ratio, burst delay, burst drop, delay, throughput and bandwidth utilization by varying the load from 100-200 Mb in self similar traffic for ABAA and

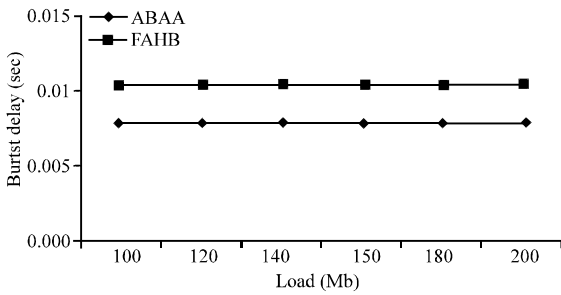


Fig. 17: Load Vs burst delay

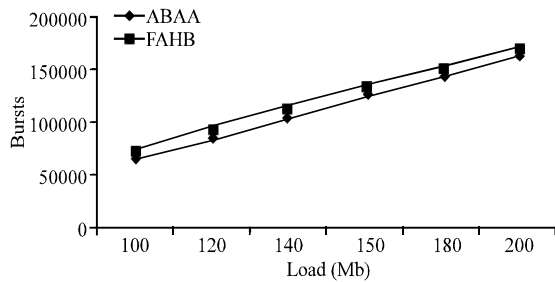


Fig. 18: Load Vs burst drop

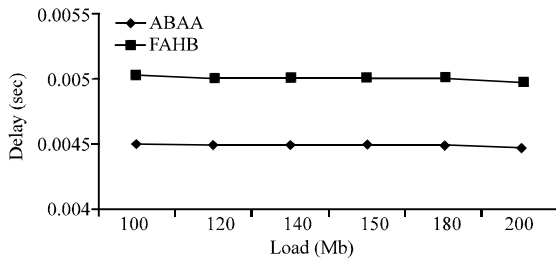


Fig. 19: Load vs SSIM delay

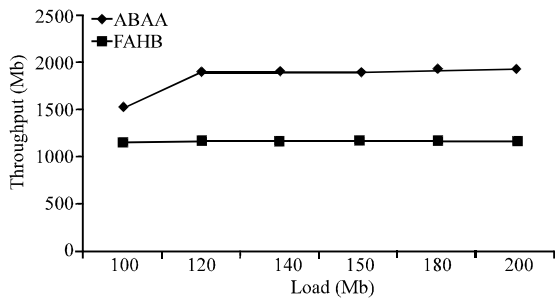


Fig. 20: High load vs throughput

FAHBA protocols. When comparing the performance of the two protocols, we infer that ABAA outperforms FAHBA by 12% in terms of blocking probability, 41% in terms of delivery ratio, 26% in terms of burst delay, 13% in terms of burst drop, 25% in terms of delay, 40% in terms of throughput and 39% in terms of bandwidth utilization.

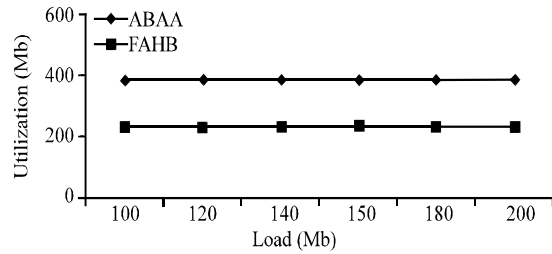


Fig. 21: Load vs bandwidth utilization

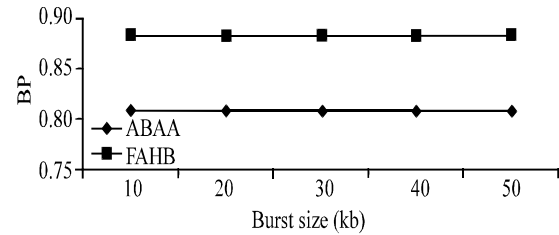


Fig. 22: Burst size vs blocking probability

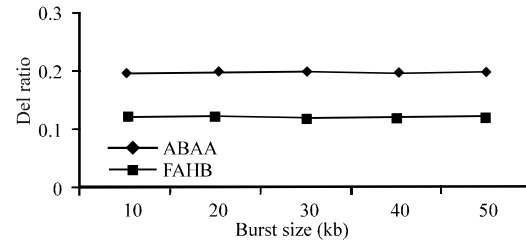


Fig. 23: Burst size vs delivery ratio

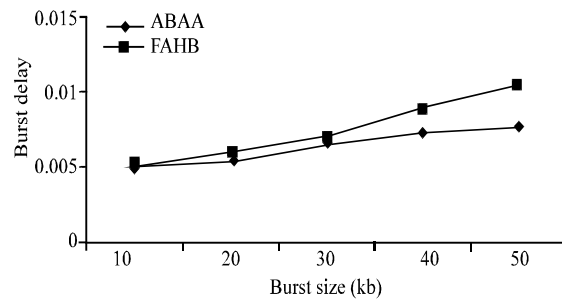


Fig. 24: Burst size vs burst delay

Based on burst size: In our third experiment we vary the burst size as 10, 20, 30, 40 and 50 Kb.

Figures 22-28 show the results of blocking probability, delivery ratio, burst delay, burst drop, delay, throughput and bandwidth utilization by varying the burst size from 10kb-50kb in self-similar traffic for ABAA and FAHBA protocols. When comparing the performance of the two protocols, we infer that ABAA outperforms FAHBA by 9% in terms of blocking probability, 9% in

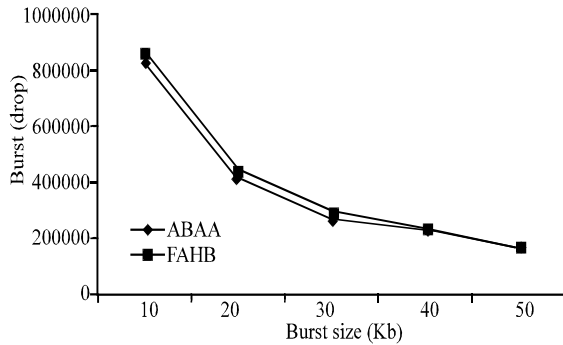


Fig. 25: Burst size vs burst drop

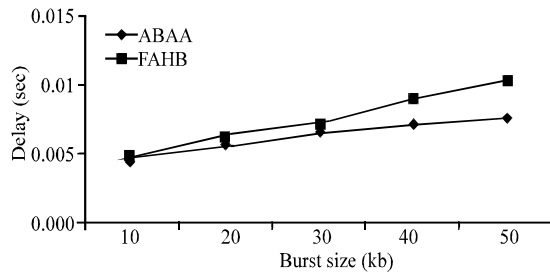


Fig. 26: Burst size vs delay

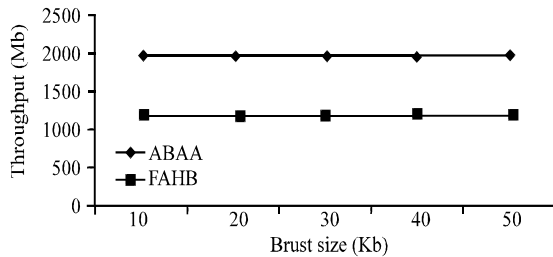


Fig. 27: Burst size vs bandwidth throughput

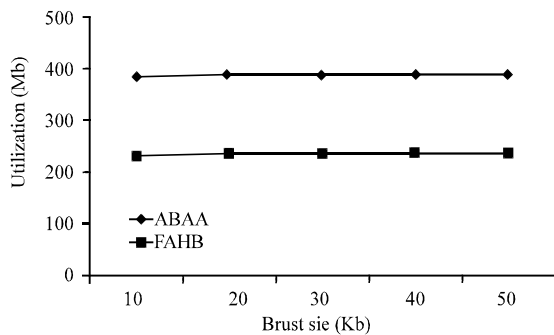


Fig. 28: Burst size vs bandwidth utilization

terms of delivery ratio, 19% in terms of burst delay, 9% in terms of burst drop, 19% in terms of delay, 39% in terms of throughput and 39% in terms of bandwidth utilization.

CONCLUSION

In this study, we have proposed to design an Adaptive Burst Assembly Algorithm for Reducing Burst Loss and Delay in OBS networks. In this technique, the traffic for next interval is predicted using linear prediction filters. This predicted traffic along with the timer and burst length is then considered as input for fuzzy logic and the new burst length and output values are generated as output. At core routers, the contention is measured based on the BLR and link utilization and then sent as a feedback to the ingress. Based on the measured contention, the new offset time, burst length and timer are determined and used for the next frame. By simulation results, we have shown that the proposed approach resolves the contention and reduces the burst delay.

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