Asian Journal of Information Technology 15 (13): 2123-2132, 2016
ISSN: 1682-3915

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

[1]Bharathi Lakshmanan, [2]Sasikala Ramasamy and [3]Srinivasan Alavandar
[1]Department of Electronics and Communication Engineering, Excel College of Technology,
637303 Komarapalayam, Tamil Nadu, India
[2]Department of School of Computing Science and Engineering, VIT University,
632014 Vellore, Tamil Nadu, India
[3]Department 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.

Corresponding Author: Bharathi Lakshmanan, Department of Electronics and Communication Engineering, Excel College of Technology, 637303 Komarapalayam, Tamil Nadu, India

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 aburst 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 unavailable of 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 Hyrbid 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 assumesshortest 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 nth 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

$$y_z(j) = y_Z(j-1)+ae_Z(j-1)Z(j-1)$$

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 nth burst is estimated using the following Eq. 2:

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

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

$$y_Q(j) = y_Q(j-1)+ae_Q(j-1)Q(j-1)$$

Where:

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

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

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

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

$$y_X(j)= y_X(j-1)+ae_X(j-1)X(j-1)$$

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 traffis 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.

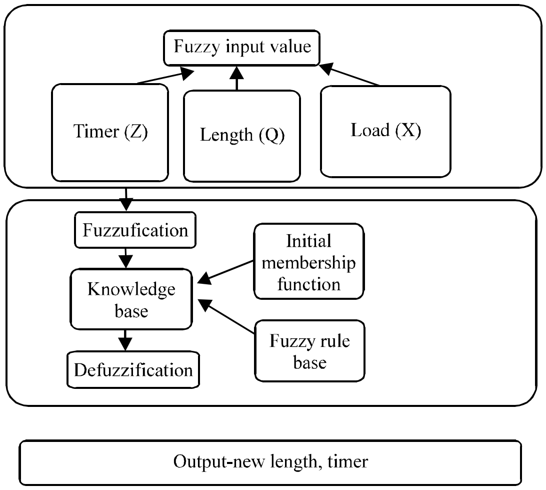

Fig. 1: Fuzzy inference system

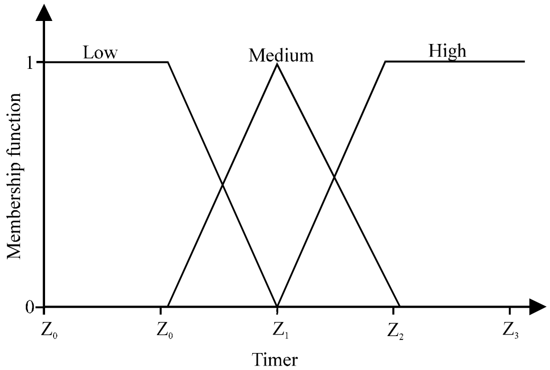

Fig. 2: Membership function of timer

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

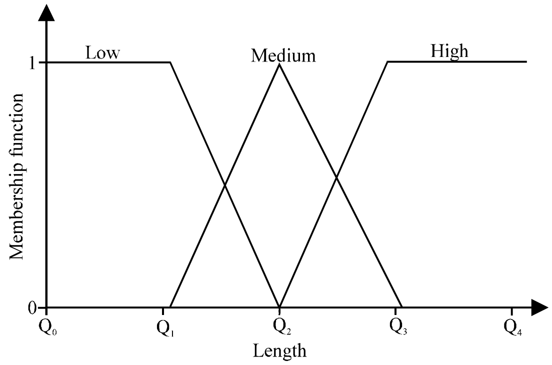

Fig. 3: Membership function of length

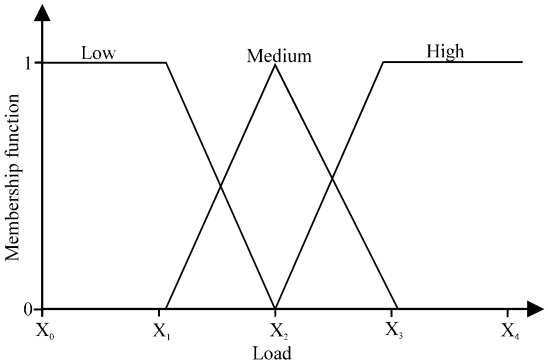

Fig. 4: Membership function of load

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

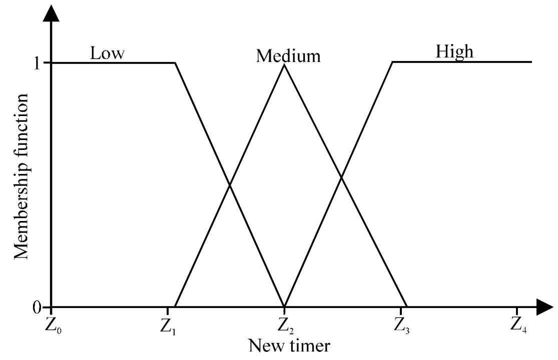

Fig. 5: Membership function of new timer

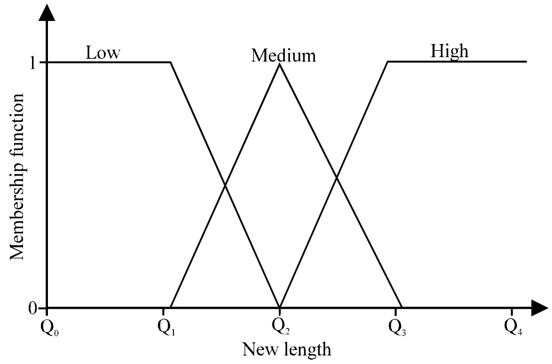

Fig. 6: Membership function of new length

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

```
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:

$$\text{Fuzzy\_cost} = \frac{\left[\sum_{\text{allrules}} f_i \times \psi(f_i)\right]}{\left[\sum_{\text{allrules}} \psi(f_i)\right]} \tag{4}$$

Where:

Fuzzy_cost = It is used to specify the degree of decision making

f_i = The fuzzy all rules and variable

ψ(fi) = 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:

$$C\left({}_{Ni,\,Ni+1}\right) = \pi_{i-1}^{R}\left[(\omega_{N_i,\,N_{i+1}}) + (\gamma_{N_i,\,N_{i+1}})\right] \tag{5}$$

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

$$T_o = T_{ct} + H_i + T_p \tag{6}$$

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)

```
If $C_d$ ($_{Ni, Ni+1}$) < threshold
Then
NACK is sent to S
The burst packet is re-transmitted
End if
```

Threshold = W1*+W2*γ* W3* delay

where, $W_{1\text{-}3}$ 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:

$$CV\left(NH,D\right)=1\text{-}Z\pi_{i\text{-}1}^{R}\left[C\left(_{Ni+1}\right),D\right]$$

Where:

NH = Next Hop

$C\left(_{Ni+1}\right)$, 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

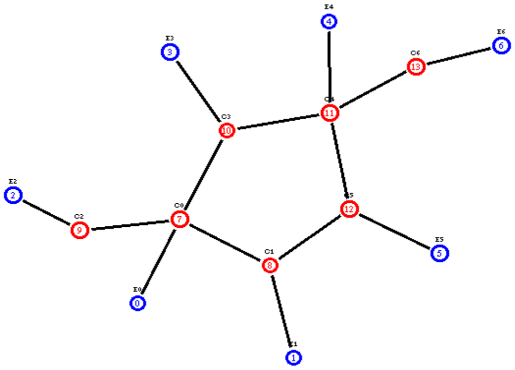

Fig. 7: Simulation topology

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.

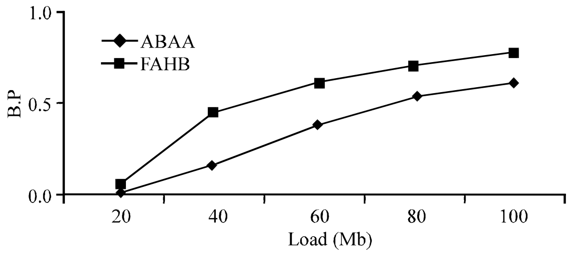

Fig. 8: Load vs blocking probability

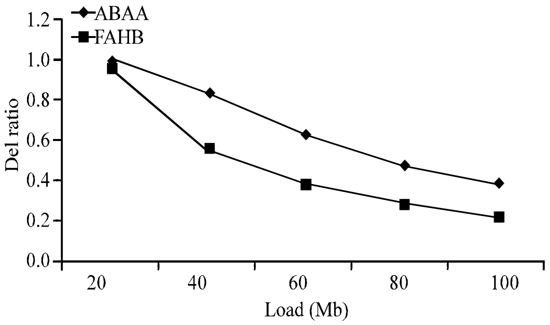

Fig. 9: Load vs delviery ratio

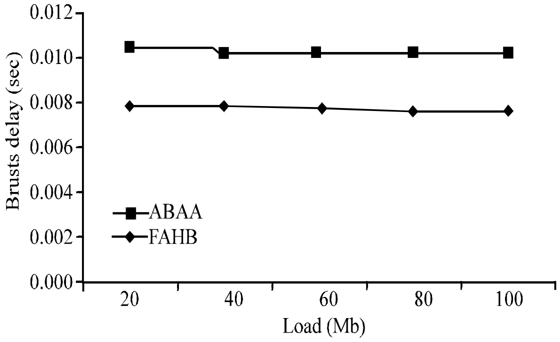

Fig. 10: Load vs burst delay

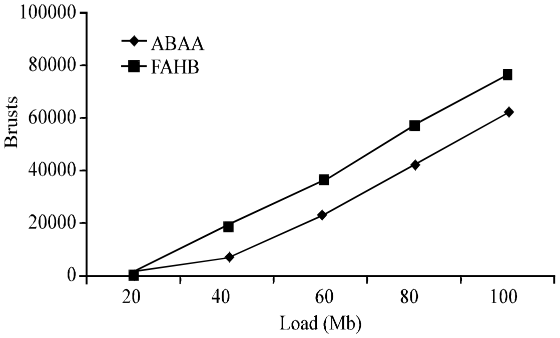

Fig. 11: Load vs burst drop

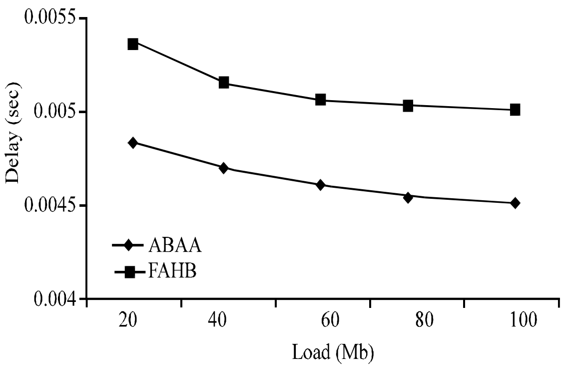

Fig. 12: Load vs SSIM delay

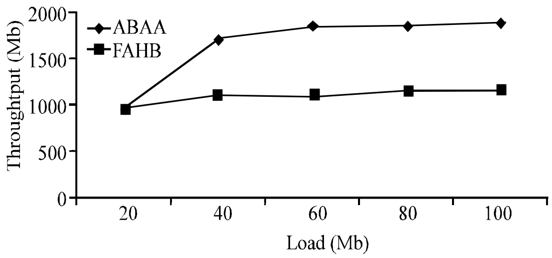

Fig. 13: Load vs SSIM throughput

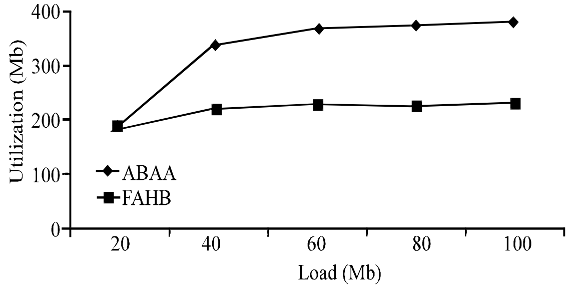

Fig. 14: Load Vs bandwidth utilization

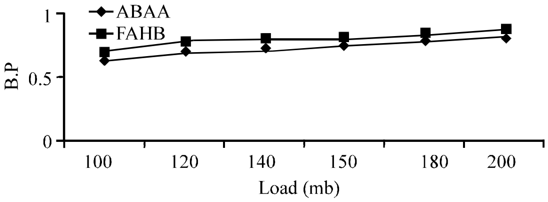

Fig. 15: Load vs blocking probability

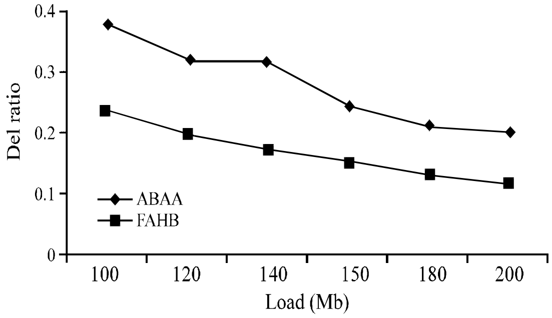

Fig. 16: Load Vs delviery ratio

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

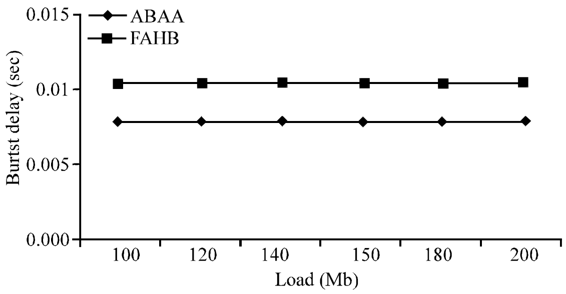

Fig. 17: Load Vs burst delay

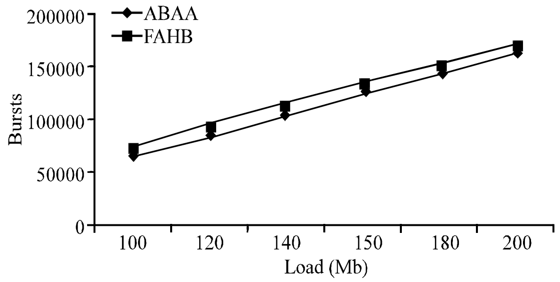

Fig. 18: Load Vs burst drop

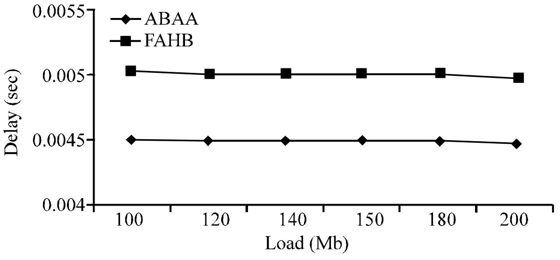

Fig. 19: Load vs SSIM delay

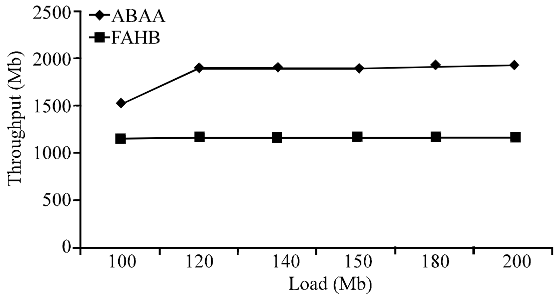

Fig. 20: High load vs throughput

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.

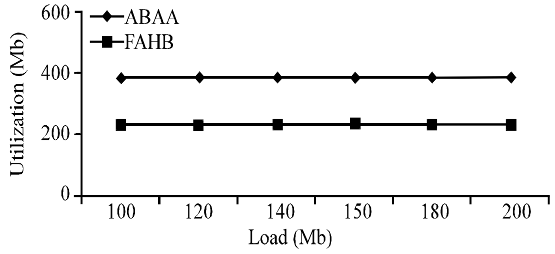

Fig. 21: Load vs bandwidth utilization

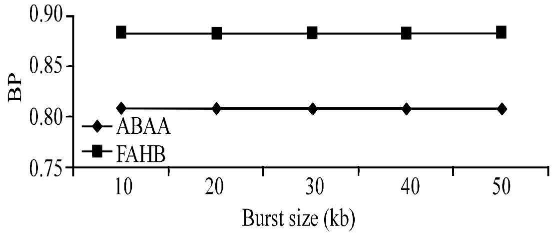

Fig. 22: Burst size vs blocking probability

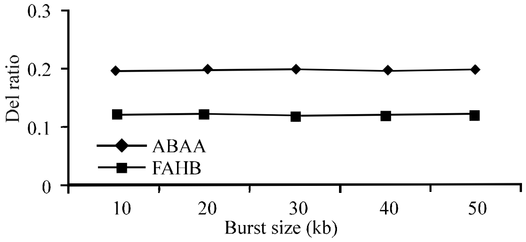

Fig. 23: Burst size vs delviery ratio

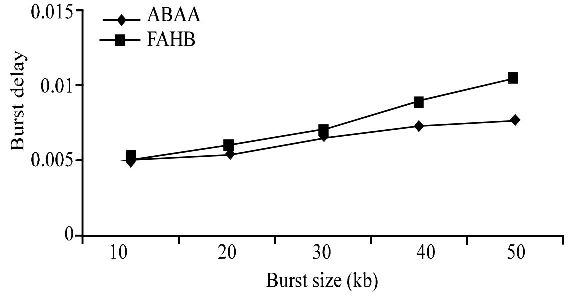

Fig. 24: Bust size vs burst delay

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

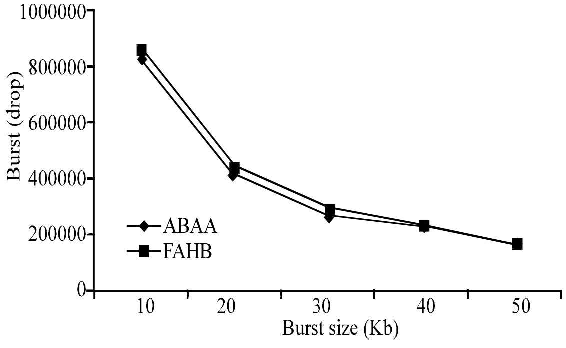

Fig. 25: Burst size vs burst drop

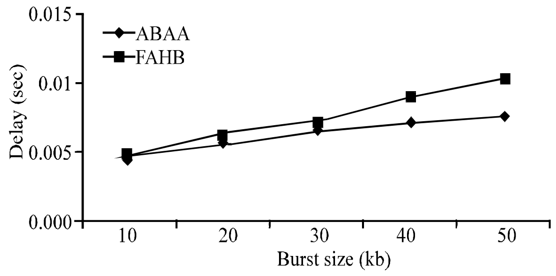

Fig. 26: Burst size vs delay

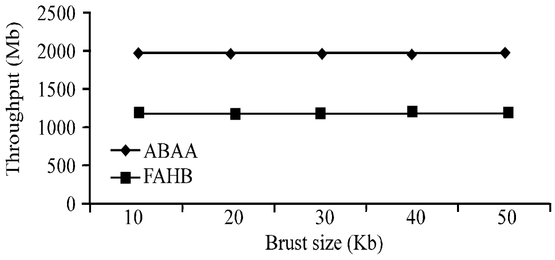

Fig. 27: Burst size vs bandwidth throughput

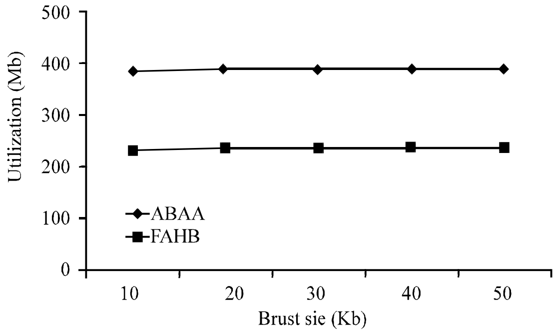

Fig. 28: Burst size vs bandwidth utilization

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.

REFERENCES

Aly, W.H.F. and E.H. Biaze, 2011. Dynamic contention resolution protocol for OBS networks. Int. J. Sci. Eng. Res., 2: 1-8.

Bikram, R.R., N. Charbonneau and V.M. Vokkarane, 2011. Multi-layer loss recovery in TCP over Optical Burst-Switched (OBS) networks. Springerlink Photonic Network Commun., 21: 158-169.

Boobalan, P., B.M. Krishnachandran, K. Vignesh and K.P. Nizhalan, 2011. Controlling burst loss ratio in obs using feedback control and dynamic techniques. Int. J. Comput. Sci. Eng. IJCSE., 3: 291-298.

Coulibaly, Y., M.A. Latiff, A.B. Mohammad and A.M. Umaru, 2011. Priority-based time slot assignment algorithm for hierarchical time sliced optical burst switched networks. Proceedings of the ICSNC 2011 the Sixth International Conference on Systems and Networks Communications, June 10, 2015, Universiti Teknologi Malaysia, Johor Bahru, Malaysia, pp: 199-205.

Garg, A.K., 2013. Traffic prediction based burst assembly mechanism for OBS. Optik Int. J. Light Electr. Opt., 124: 2017-2019.

Odeh, M.H., M. Mahmoud and M.H. Aly, 2013. Enhancing optical burst switching networks throughput at low and high traffic loads. Proceedings of the Conference on ICCTA, October 29-31, 2013, Alexandria, Egypt, pp: 159-165.

Patil, P.H. and N.P. Dafedar, 2014. Optical burst switching (OBS): A new area in optical networking. IEEE. Network, 18: 16-23.

Ramalakshmi, K. and K. Thanushkodi, 2014. Traffic based random deployment of relay nodes in wireless sensor networks. J. Theor. Appl. Inf. Technol., 63: 408-419.

Seklou, K., A. Sideri, P. Kokkinos and E. Varvarigos, 2013. New assembly techniques and fast reservation protocols for optical burst switched networks based on traffic prediction. Optical Switch. Network., 10: 132-148.

Um, T.W., J.K. Choi, S.G. Choi and W. Ryu, 2006. Performance of a partial burst retransmission mechanism in OBS networks. Proceedings of the International conference on Networking and Services (ICNS'06), July 16-18, 2006, IEEE, Slicon Valley, California, ISBN: 0-7695-2622-5, pp: 108-108.

Umaru, M.A., A.M.S. Latiff and Y. Coulibaly, 2014. Fuzzy-based adaptive hybrid burst assembly technique for optical burst switched networks. J. Comput. Networks Commun., Vol. 2014,

Vokkarane, V.M. and Q. Zhang, 2006. Forward redundancy: A loss recovery mechanism for optical burst-switched networks. Proceedings of the 2006. IFIP International Conference on Wireless and Optical Communications Networks, July 21-23, 2006, IEEE, Bengaluru, India, ISBN: 1-4244-0340-5, pp: 5-5.

Vu, L.H., A. Zalesky, M. Zukerman, Z. Rosberg and J. Guo et al., 2005. Delay analysis of optical burst switching networks. Proceedings of the IEEE International Conference on Communications ICC, May 16-20, 2005, IEEE, Melbourne, Victoria, Australia, ISBN: 0-7803-8938-7, pp: 1656-1662.

Xiong, Y., M. Vandenhoute and H. Cankaya, 2000. Control architecture in optical burst-switched WDM networks. IEEE J. Selected Areas Commun., 18: 1838-1851.

Yayah, A.A., Y. Coulibaly, A.S. Ismail and G. Rouskas, 2016. Hybrid offset-time and burst assembly algorithm (H-OTBA) for delay sensitive applications over optical burst switching networks. Int. J. Commun. Syst., 29: 251-261.