QoS provisioning in optical burst switching with variable offset time and active drop policy

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In optical burst switching (OBS) networks, one way reservation is usually used for transmitting data burst. The chance of bursts to collide with each other increase leading to degrade the performance of the optical network. In this paper, a new scheme is reported in order to improve the performance of the OBS networks. This is performed by enhancing the techniques used to improve quality of service (QoS) in these networks. A combination of variable offset time scheme in edge router and active drop policy in core router is used to decrease the contention of bursts. Simulation is carried out using several parameters. The obtained results assure that bursts of high priority traffic has a significantly lower loss (drop) compared to that of bursts of low priority traffic. Also, as compared with a standard contention resolution scheme like fiber delay line (FDL), it gives a better loss rate that is enhanced by ~ 30%.

(Received January 23, 2019; accepted April 9, 2020)

Keywords: Optical burst switching, Contention resolution, Quality-of-Service, Variable offset time, Active drop policy, Burst loss rate

1. Introduction

Optical burst switching (OBS) is a new switching techniques that takes the advantages of both optical circuit switch (OCS) and optical packet switch (OPS). In OBS, a new technique is used that separates the optical transmission layer into two plans; control plan and data plan [1]. The OCS needs to set up the connection by reserving the whole path before transmitting the data. So, it does not use a permanent path. It can reserve any path available to originate the connection leading for some times for a delay and latency. While for OPS, a scheme called store and forward in is used, at which each node can use buffers for querying data. Packets can be stored inside these buffers so that they could be processed by each node in the optical plan. Packets transverse to the next hop node repeating the same steps of buffering and processing till reaching their destination. This technique requires a large number of optical buffers which are hard to implement beside the complexity in processing each packet separately. Therefore, the OBS technique has been used so that the control header packet which is processed electrically and contains all the information about the data burst from its source to destination is used to reserve the path. Then, it aggregates many number of packets to contain a major packet of data called burst that transverses from one node to another which is treated optically [1].

The OBS network has two types of routers; edge router and core router. Aggregation of packets takes place at the edge node where different incoming data of access nodes are assembled either according to their destination or to their Quality of Service (QoS). Therefore, based on assembly and disassembly process, packets are assembled into a burst using either time based or threshold based [1].

Most of OBS networks use one way reservation scheme in which bursts are launched into core node reaching their destination without receiving acknowledge at the source node [1]. This will give a probability of dropping packets in intermediate node due to contention of bursts with each other. Contention occurs when more than a burst reach next node trying to reserve the output port at the same time. Also, contention occurs when two different wavelengths try to reserve the same output wavelength at the same time. In OPS, the problem of contention can be solved by using the optical buffers that store the contending packets [2,3].

Wavelength division multiplexing (WDM) is a method of transmitting data from different sources over the same fiber optic link at the same time. Each data channel is carried on its own unique wavelength. The result is a link with an aggregate bandwidth that increases with the number of wavelengths employed [2]. We adopt the contention solution for networks including WDM. The OBS schedules the packets based on wavelength channels of the links.

Several OBS schemes were reported to resolve the contention resolution of dropping bursts with different trade off. They are FDL, offset time, wavelength converter and active drop policy [4-5]. Active drop policy was reported [6] so that bursts are divided into segments in which packets have been classified into different priorities with different size depending on the position of the burst. This is done either by putting the high priority burst in the head of the burst using explicit staged reservation scheme or by putting the high priority burst in the middle of the burst surrounding by the lower priorities burst using implicit staged reservation. Other researchers have worked on the same technique by modifying tail dropping policy in which the part of dropping burst can be determined according to a drop algorithm reported [7]. It determines which part of burst will be dropped beside that a hybrid method for burst assembly is modified by making experimental to determine the optimum threshold used for the number of burst to get the minimum burst drop. Another scheme has been reported by B. Shivae et al. [8] such that the assembly of burst is modified for the classification of the incoming packets in optical ring network by using three reported scheduling algorithms of different query. Also, by using a common control packet containing a flag for reservation algorithm. This totally eliminates the contention as only one node will transmit burst for a certain time. Also, by continuous working in burst assembly, a new burst scheduling algorithm for variable size burst was reported for burst control to avoid burst overlapping in the egress router of OBS network according to channel capacity by using FDL [9]. Another method was reported by M. Dawood et al. [10], where Adaptive Burst Assembly with a new and simple algorithm was used. It depends on changing some features of data burst in queuing model by taking into consideration the presence of QoS for multiple data priorities. Others have reported a combination scheme by combining burst aggregation, extra offset time and FDL in an algorithm called (TCCR) traffic control based on contention resolution process [11] to offer absolute service differentiation QoS for multi priority bursts. Burst retransmission was reported to enhance the performance by increasing the throughput of the receiving bursts either by using time based or by using retransmission count of dropping burst [12, 13]. Finally, a combination of variable FDL is used between edge and core routers and wavelength preemption which is used in the core part to reduce the probability of dropping burst [14].

In this paper, we work on the last reported technique that is based on FDL and wavelength preemption. We introduce a new combining scheme by eliminating the FDL in edge part and enhance the scheme of the offset time. This is performed instead of using offset time scheme for the priorities classification such that the higher priority traffic takes a higher time. Extra offset time in this assumed will be given to every edge router as a variable delay instead of using a variable FDL to achieve this delay. In the core part, we will use the same technique of active drop policy [7] to avoid complexity in the optical core devices.

This enhancement will lead to remove the extra hardware component of the FDL in the optical network. It also allows the variety to select extra delay time required based on the buffers used in each edge router that are able to store the querying burst without the restriction of the bulky model of FDL [15]. Finally, this new combining scheme will minimize the blocking probability in the edge part leading to less collision than before in the core part. Although, it is impossible to ignore the contention in the practical case, the delay lines will be unnecessary and could be removed from our design if there is no contention. Through this paper, we call this approach as OFFSET_DPA mechanism which stands to variable offset time and drop policy algorithm.

The remainder of the paper is organized as follows. Section 2 introduces the reported QoS enhancement in OBS networks. Performance metrics are explained in Sec. 3, followed by the simulation setup and simulation parameters in Sec. 4. The obtained results are displayed and discussed in Sec. 5. Section 6 is devoted for the main conclusions.

2. Reported QoS enhancement in OBS network

2.1. Offset time scheme in edge part

In edge part, or the part between edge router and core router, the general use of offset time scheme is that we give an extra time for high priority burst. This grantees the path reservation in comparison of lower offset time that is given to the low priority burst. In our approach, every edge router will take a different varying offset time based on the processing time of each hop count in optical network. By taking this variable delay, bursts will lunch out through the output port of each edge routers in a different time leading that they will not reach the common core router at the same time. In this study, the processing time (T) for each optical node is set to 10 μs.

Fig. 1 shows that the use of the variable offset time scheme which contains a number of edge routers that are connected to a common core router.

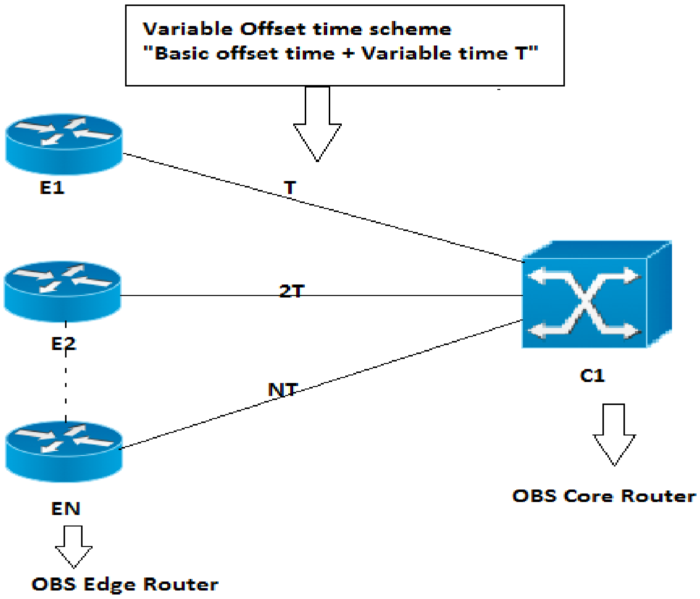

Fig. 1. Reported variable offset time scheme

Data burst in the first edge router will lunch out after a time equal to the basic offset time plus extra variable time which is equal to time T. Then, the next edge router will launch its burst after the basic offset time gone out plus a time equal to 2T and so on. This approach which is called variable offset-time can be used to increase the delay time by increasing the offset-time without using many FDLs.

2.2. Drop policy in core part

In core part, due the complexity in operation for data burst, data is treated optically and there is no optical to electrical conversion. Active Segment Drop Policy will be used for two priority segments [6]. High priority segments will be placed at the head of burst and low priority segments will be behind the higher one. In this case, tail drop policy is used in order to avoid undelivered packet sequence. Also, by using the algorithm modified by V. Vokkarane et al. [7], we take into consideration all the possible collisions that can occur either between different priority bursts, or between two similar priorities, at which the action drop policy will be based on the length of burst.

First bursts in the edge part are divided into two priorities; high priority burst which is called critical traffic and low priority burst which is called non-critical traffic. In core part; core routers will take the drop action when these bursts are assembled and transverse from the edge part to the core router. After that, collision will occur between cores router. Core routers will use the service differentiation algorithm based on tail drop policy such that segments placed at the tail of the burst will be dropped which will be the low priority burst in case of multi priority burst collision. But, if the two bursts are on the same priority, core router will take the action according to the length of the burst. The dropping algorithm is divided into three techniques; the first one which is called Drop Policy [DP] is used to drop the whole contenting burst. The second algorithm which is Segment Drop Policy [SDP] is used to drop the tail of the original burst if the tail length of its burst is longer compared to that of the length of the contenting burst. The last one which is Drop tail Policy [DTP] is always used to drop the tail of the original burst regardless the relative lengths which is used in multi-priorities burst as shown in Fig. 2.

Referring to the drop algorithm reported by V. Vokkarane et al. [7], Table 1 represents the comparison of these algorithms in case of burst collision of same priority while Table 2 represents burst collision in case of different priorities.

Table 1. Contention conditions without burst priorities [7].

Condition	Longer Burst	Drop Policy Algorithm
1	Original	DP
2	Contenting	SDP
3	Equal	DP

Table 2. Contention condition with burst priorities [7].

Condition	Original burst priority	Contenting burst priority	Algorithm Drop Policy
1	High	High	SDP
2	High	Low	DP
3	Low	High	DTP
4	Low	Low	SDP

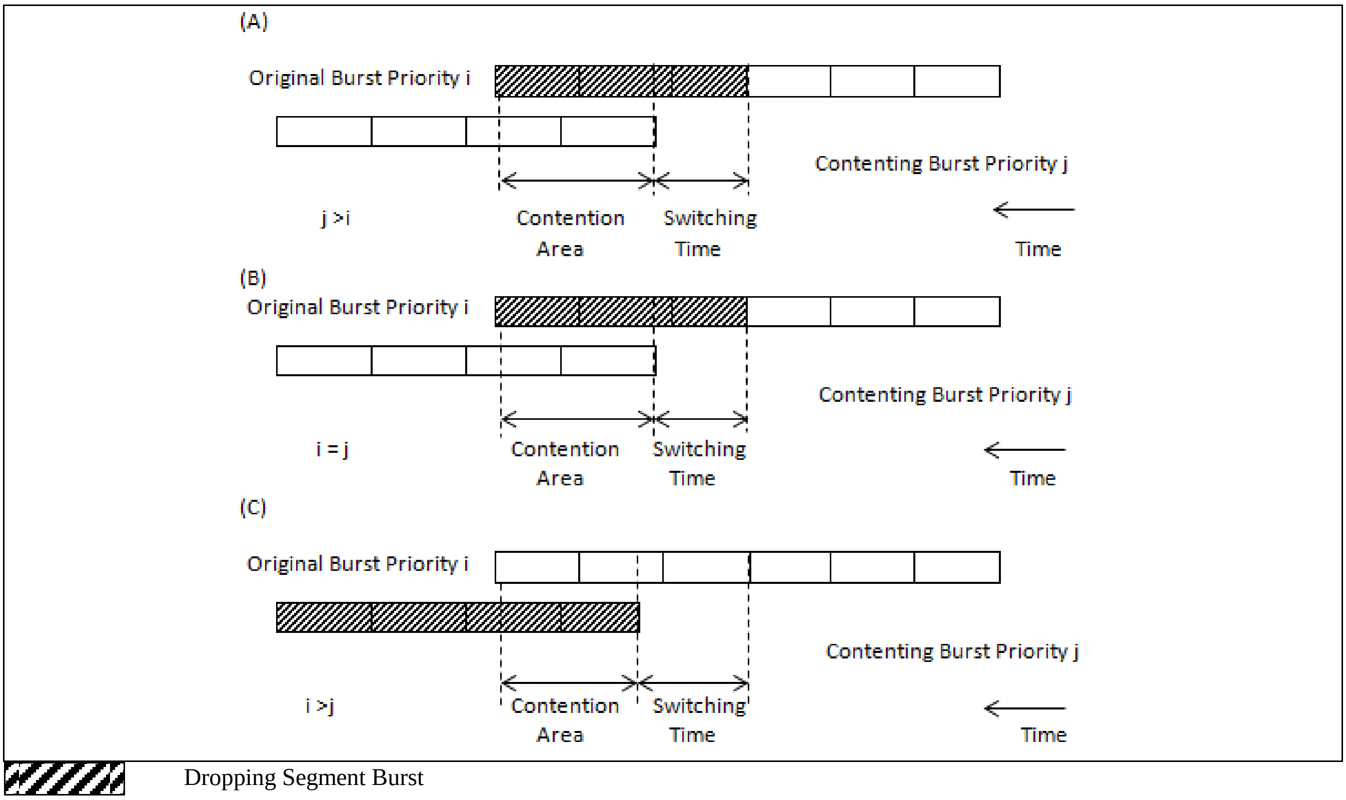

Fig. 2. Reported drop policy in core node (A) Contention of low-priority burst with high-priority burst. (B) Contention of equal priority bursts. (C) Contention of high-priority burst with low-priority burst [7]

3. Performance metrics

Burst Loss Rate, BLR, is one of the main parameters used to measure the performance of the QoS in OBS networks. Using the M/M/1/K queue with K buffer [16], the loss rate is given by

$$\text{BLR} = \frac{\rho^K}{\sum_{i=0}^{K} \rho^i} \tag{1}$$

where $\rho = \lambda/\mu$, λ is the connection arrival rate and μ is the service rate, k is an integer with value between 0 and ρ. Therefore, the way to calculate the loss rate from the simulation result is to divide the total number of losses by the total number of arrivals.

Another parameter can be used to measure the performance of network which is Normalized Throughput or Burst Delivery Factor which is inversely proportional to BLR [8,17] and is given by

$$\text{Throughput} = \frac{Total\ number\ of\ bursts\ received}{Total\ number\ of\ bursts\ sent} \tag{2}$$

The average end to end delay parameter [8] can also be obtained by calculating first the total delay of transverse burst which is represented by

$$\text{End-to-End Delay} = Dproc + Dtrans + Dprop + Dqueue + Doffset + Dbat + Dbdat \tag{3}$$

where D*proc* is the processing delay, D*trans* is the transmission delay, D*prop* is the propagation Delay, D*queue* is the queueing delay, D*offset* is the offset time and extra delay caused by the variable offset time scheme, D*bat*is the burst assembling time delay, and D*bdat*is the burst de-assembling time.

Therefore, the average delay is represented by dividing the total end to end delay by the total number of packets, i.e. [18]

$$Average\ delay = \frac{\sum_{i=1}^{n} \mathrm{D_i}}{n} \tag{4}$$

where D_i is the delay of the i^{th} packet and n is the total number of packets received.

4. Simulation setup and parameters

By moving to the practical part, service differentiation model is used in the OBS network shown in Fig. 3. In this network model, two types of traffic are being served. The first is for the high priority burst and is used for critical traffic that does not allow time delay like real time application. So, it is simulated as a real-time (CBR) constant bit rate as a traffic simulator. While the other one is for the low priority burst and is used for non-critical traffic that has a tolerance of time delay and is simulated as non-real time (VBR) variable bit rate as a traffic simulator. Therefore, the critical traffic is mapped with a uniform traffic pattern and on the other hand the non-critical traffic is mapped with Pareto traffic pattern [20].

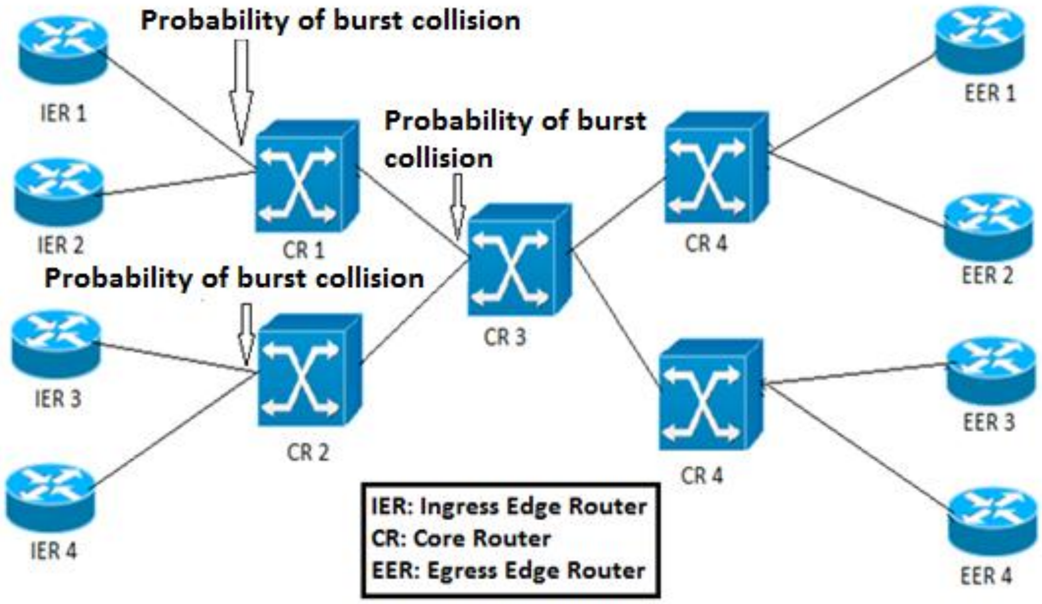

Fig. 3. Architecture of reported OBS network

Starting with burst assembly, bursts have being classified as discussed into two priorities one for high critical traffic and other for low critical traffic. We choose the segments with high priority to be placed at the head of the data burst with a small size compared to that of low priorities burst. We have to keep on the reliability of the traffic besides decreasing delay for the assembly of critical traffic. Also, during the collision, if those bursts are need to be dropped, we will not face a large number of bursts lost. Timer based assembly is being used where bursts are created and sent into the optical network at a periodic time. So, the length of the burst varies as the load changes. This fixed timer is set to a ratio of 30% for critical traffic as a threshold. This lower assembly timer threshold leads to a lower burst segment size against 70% for non-critical traffic in case of multiple priorities traffic that is injected in our study. Therefore, in this approach, the size of the critical traffic is equal to 256 bytes which is suitable for voice while for non-critical traffic size, we set its size to 1000 bytes which is suitable for all classes [14]. In our topology, we have used a link of maximum 1000 Mbps so that the collision can be observed in the core part. In real environment size, it can be increased to the maximum transmitting unit which is 1500 bytes in which the rate of the link between the sources to the ingress node is set to 100 Mbps which represents LAN network while the link between the cores are set to high rate at 10 Gbps which has the enough capacity to carry all traffic with minimum congestion [14].

One way reservation which is Just Enough Time, JET, is used where the optical burst is transmitted from the source node just after a control packet lunched out to the OBS network. The offset time in JET is equal to the sum of processing and switching delays of the burst header at the intermediate and destination nodes.

Table 3 represents the parameters used for each traffic in simulation.

Table 3. Traffic parameters [14].

Parameters	value
Threshold time burst	7 ms
BCP processing time	10 µs
High priority simulator	CBR
High priority packet rate	284 kbps
High priority packet size	256 bytes
Low priority simulator	Pareto
Low priority packet rate	384 kbps
Low priority packet size	1000 bytes
Reservation protocol	JET

5. Results and discussion

In this study, the network simulator NS-2, ver. 2.1 [20] is used to perform simulation. The system performance could evaluated through its BLR, delay and throughput. We first concentrate on the BLR because the main purpose of the contention resolution is to minimize the burst drop. We have first carry out the simulation with an equal traffic rate for the high priority traffic (CBR) and the low priority traffic (Pareto) which are graduated from small to higher load as in Fig. 4.

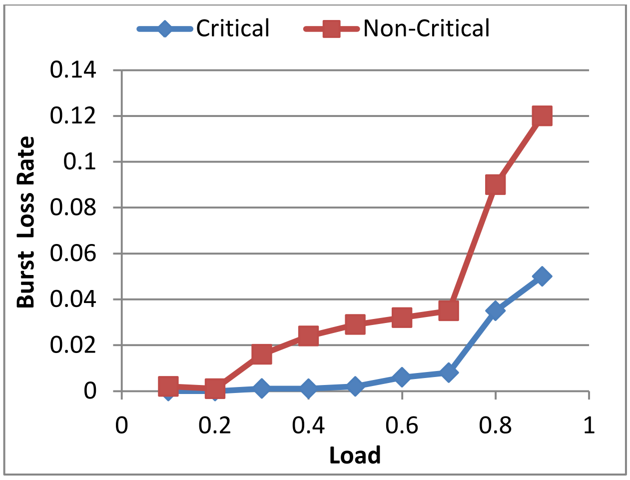

Fig. 4. BLR for both critical and non-critical traffic at equalload (color online)

After that, we have fixed the traffic rate at 0.2 for the non-critical traffic and varied the load of the critical traffic from 0.1 to 0.9 as in Fig. 5. Repeating the same step by reversing the load for both traffic as in Fig. 6.

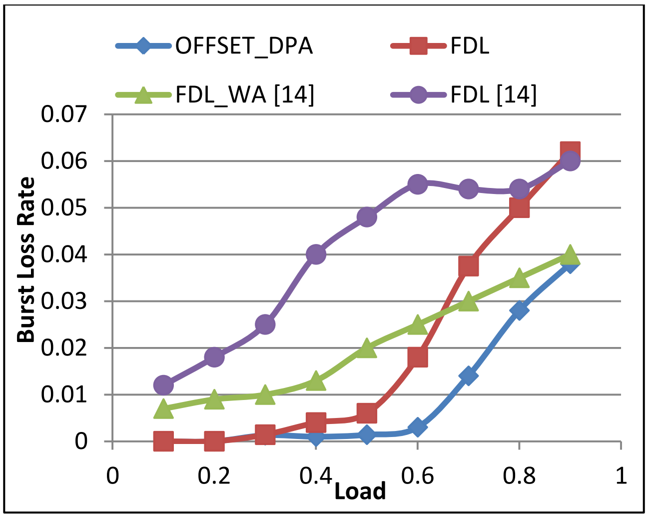

Fig. 5. BLR for critical traffic at load of 0.2 for non-critical traffic. The red and blue symbols are obtained by our design and the violet and green symbols are obtained by Ref. [14] (color online)

From Fig. 4, it is observed that the loss rate (burst dropping) increases by varying the offer load from smaller to higher values. Also, the traffic of high priority bursts has less drop compared to the bursts with low priority. This is in a fair agreement with results obtained in Refs. [14,19]. The small loss rate value for both of high and low traffic at the beginning of offered load are for two reasons. The first one is because during the low load traffic, the bandwidth of the link is not saturated so that bursts cannot fulfil the shared output capacity assigned for their service classes. The second reason is that a small burst collision in the edge part compared to that in core part when varying the delay. Continuing after half of the offered load, the reason of the low drop rate for the critical traffic is that collision occurs on the core part pre-empting the low priority segment burst of non-critical traffic. So, we have kept bursts of high priority traffic and at the same time the size of the bursts of the critical traffic is small leading to a better result for loss rate for both high and low priority traffics.

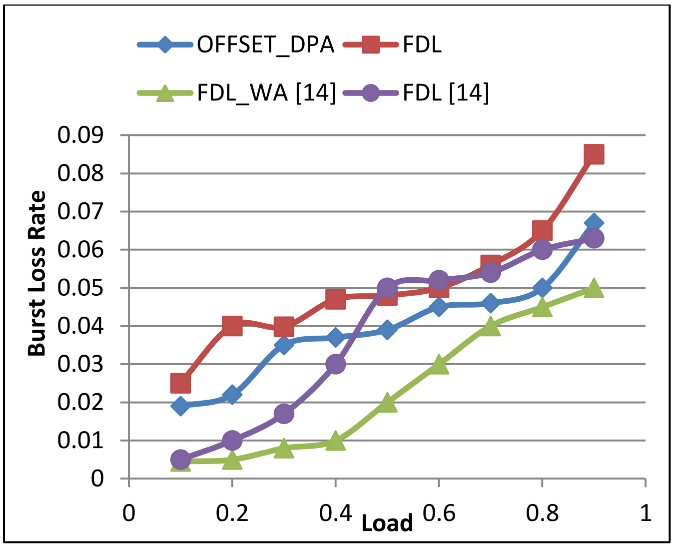

Fig. 6. BLR for non-critical traffic at load of 0.2 for critical traffic. The red and blue symbols are obtained by our design and the violet and green symbols are obtained by Ref. [14] (color online)

From both Figs. 5 and 6, it is clear that traffic of high priority has a better result in less loss rate compared to that of low priority traffic. Also, the reported algorithm achieves a better result ~ 30% for the high priority traffic ~ 20% for the low priority traffic compared to the contention resolution by using FDL. As in Fig. 5, the low drop rate occurs for the same reason, where during the low load traffic, transmitted bursts cannot fulfil the shared output capacity assigned for their service classes. Also, by comparing our results with the work of Suriani, et al, which was worked by using a variable FDL and wavelength assignment (FDL_WA) [14], both Fig. 5 and Fig. 6 show an acceptable result in the BLR. In our study, we are using different contention resolution technique which is OFFSET_DPA with 2 types of priorities, unlike the previous work of Suriani, which used 3 types of traffic priorities. Hence, in this study it will be observed that the loss rate is higher than that in the previous work. This is due to the loss burst divided by the total number of burst, which is in our case two types not three.

The other evaluating parameter is the average delay, which is calculated the difference between receiving time and sending time divided by total number of bursts. First, we have been applied equal offered load for both high priority and low priority traffic leading to the results displayed in Fig. 7. Then, load is set at 0.2 for the non-critical traffic and the load for the critical traffic is varied, where the obtained delay is shown in Fig. 8. After that, we have reversed the step so that the offered load of 0.2 is set to the critical traffic and load for the non-critical traffic is varied, leading to the delay plotted in Fig. 9.

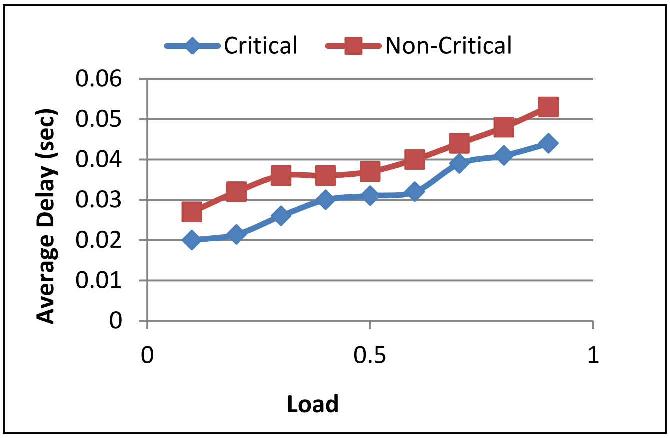

Fig. 7. End to end delay for both critical and non-critical traffic (color online)

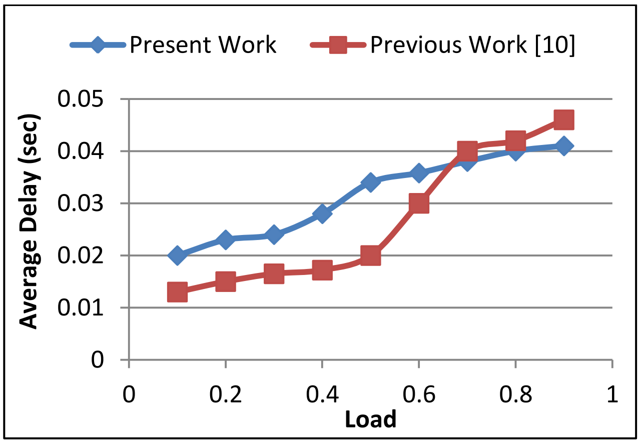

Fig. 8. End to end delay for critical traffic at load of 0.2 non-critical traffic (color online)

Figs. 7-9 show that the average end to end delay increases by increasing in the offered load. Also, the burst with high priority traffic has lower delay compared to that of low priority traffic which agrees with previous work in Refs. [10,20,18] and shown a better result. The obtained results can be explained as follows. The position of those packets which are placed at the head of burst and the size of the segment burst of the high priority traffic is small. So, it is assembled and received quickly rather than that of low priority traffic as clearly observed in Figs. 8 and 9. Also, after half of the offered load, a contention is observed leading to more delay for the non-critical traffic compared to that of critical traffic due to pre-empting of high priority traffic against the low priority traffic.

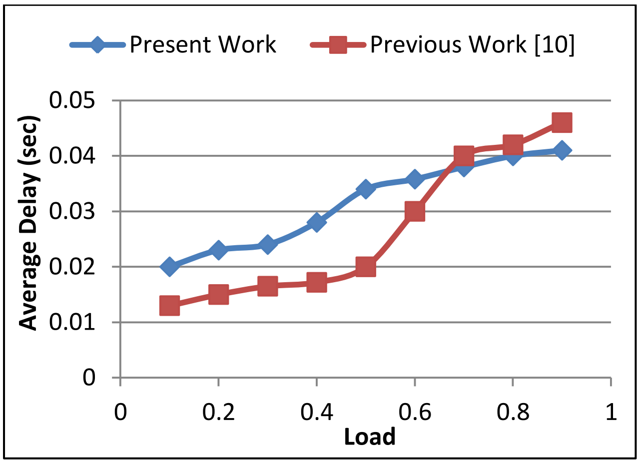

Fig. 9. End to end delay for non-critical traffic at load of 0.2 critical traffic (color online)

Another time variable is now introduced with a load which is the assembly time or the time that allows the burst to be assembled during its period. This study is on time in the range 4-9 ms with full load for both high priority and low priority traffics as shown in Fig. 10 and half load for both priority traffics as shown in Fig. 11.

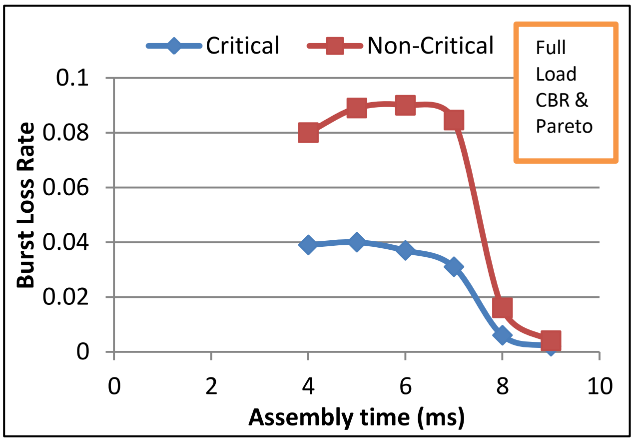

Fig. 10. BLR for both critical and non-critical traffics at full load (color online)

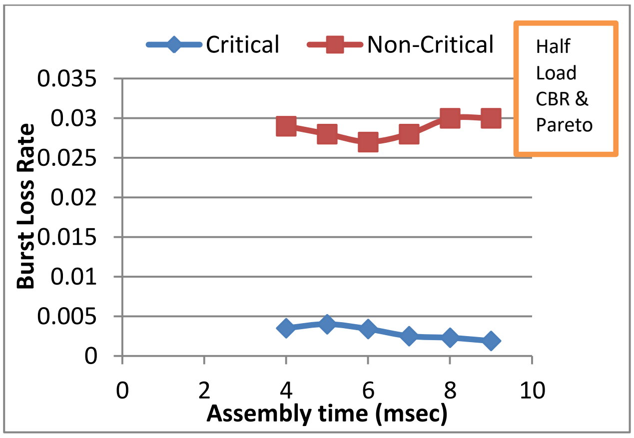

Fig. 11. BLR for both critical and non-critical traffics at half load (color online)

From Figs. 10 and 11, when the assembly time is small, it gives a small uniform gap between each burst leading to more chance for burst to collide. On the other hand, using a higher assembly time gives a wider uniform gap between each successive burst and so, the load affects the length of the burst. For an assembly time in higher offer load, we will have a longer burst length which leads to a higher drop rate unlike a small load that gives a smaller length leading to a small burst loss. Therefore, this can be taken as a solution for enhancing the QoS in addition to the standard resolution schemes that show a better result compared to FDL shown in Figs. 5-6. The delay of the burst has to be put into consideration. Using assemble timer of either 6 ms or 7 ms gives an acceptable delay with a better loss rate.

6. Conclusion

In this work, a combining technique is reported for the resolution of the burst contention by combining offset time scheme with the active drop policy in a technique called OFFSET_DPA. This technique provides an extra time offset delay for lunching the burst without using any extra hardware. So, it has the ability to change the variable delay time depending on buffers used in the edge router without the restriction of FDL according to the demand traffic network besides using active drop policy of several algorithms by dividing the burst into two segments with high and low priority traffic. This technique keeps bursts of high priority traffic to have a significantly lower burst loss compared to that of bursts of low priority traffic. Several parameters are provided for to evaluate the performance of the network such as BLR and average end to end delay that improve the enhancement of QoS in OBS network. The OFFSET_DPA scheme enhances the performance of the network by 20% to 30% compared to standard resolution scheme as FDL. Timer assemble is one of the main parameters that has been considered affecting the average delay of the bursts. The obtained results reveal that, using assemble timer of either 6 ms or 7 ms gives an acceptable delay with a better loss rate.

References

[1] W.-S. Park, M. Shin, H.-W. Lee, S. Chong, Journal of Lightwave Technology **27**, 3820 (2009).
[2] T. Zhang, K. Lu, J.P. Jue, IEEE J. on Selected Area in Commun. **24**, 118 (2006).
[3] W. A. Vanderbauwhede, H. Novella, Photonics Technology Letters **17**, 1749 (2005).
[4] Y. Wang, T. Chen, N. Zhou, International Conference on Communication Software and Networks (ICCSN), 12-15 June 2019, Chongqing, China.
[5] M. Gitmez, M. Karabatak, A. Varol, International Informatics and Software Engineering Conference (UBMYK), 6-7 November 2019, Ankara, Turkey.
[6] A. Abdelouahab, B. Gattoufi, A. H. Al-Badi, Proceeding of the IEEE 2011 International Conference on Information Technology and Multimedia, ICIM, pp. 1-4, Kuala Lumpur, Malaysia, 2011.
[7] V. Vokkarane, K. Haridoss, J. P. Jue, SPIE OptiComm. **4874**, 125 (2002).
[8] B. Shivae, K. A. Meerja, S. Song, A. Shami, Proceedings of the IEEE 2013 Tenth International Conference on Wireless and Optical Communications Networks,WOCN, TIT College, Bhapal, Madhya Pradesh, India 1-6 (2013).
[9] M. H. Odeh, M. Mahmoud, M. H. Aly, Proceeding of the 2013 23rd International Conference on Computer: Theory & Applications, ICCTA, 159 (2013).
[10] M. A. Dawood, M. Mahmoud, M. H. Aly, Optoelectron. Adv. Mat. **12**(7-8), 447 (2018).
[11] E. Dhavarudha, C. Charoenlarpnopparut, S. Runggeratigul, International Journal of Computers Communications & Control **10**(1), 49 (2014).
[12] L. Kim, S. Lee, J. Song, Photonic Network Communications **12**(1), 29 (2006).
[13] R. Hou, J. Lei, T. Mao, T. He, IEEJ Transactions on Electrical and Electronic Engineering **10**(2), 209 (2015).
[14] S. M. Sam, H. Sayuti, N. Fisal, N. Mohamed, International Journal of Future Computer and Communication **4**(1), 18 (2015).
[15] I. Ashry, H. Shalaby, 12^{th} IEEE International Conference on Transparent Optical Networks, 2010.
[16] E. Altman, T. Jimenez, Synthesis Lectures on Communication Networks **5**(1), 1 (2012).
[17] M. Imran, K. Aziz, Proceeding of the 2015 26th IEEE International Conference on Signals and Systems Conference, ISSC, Institute of Technology Carlow, Ireland, pp. 1-6, (2015).
[18] S. M. Sam, S. M. Daud, K. Kamardin, N. Maarop, Indian Journal of Science and Technology **9**(48), (2016).
[19] A. Belbekkouche, J. Rezgui, A. Hafid, Computer Networks **55**(1), 159 (2011).
[20] G. Gurel, O. Alparslan, E. Karasan, Annals of Telecommunications **62**(5), 618 (2007).

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