OBS networks enhanced performance: A smart adaptive technique

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In this study, a simple, smart and adaptive algorithm is proposed for data burst creation. It depends on modifying some characteristics in data burst assembly algorithms in Optical Burst Switching (OBS) networks by taking into consideration the Quality of Service (QoS) for multiple data priorities. Simulating the OBS network using the proposed algorithm shows that it deals with the burst assembly mechanism with a smart technique as it adaptively modifies the data burst size according to the offered load. It reduces the maximum end to end delay and the burst drop rate for high priority packets. It also provides high data burst utilization.

(Received November 1, 2017; accepted August 9, 2018)

Keywords: Smart, Optical Burst Switching, Burst Assembly, Contention, Burst Drop Rate

1. Introduction

The upsurge growth of the Internet is resulting in an increased instance for higher transmission rate and faster switching technologies. Switching in core optical telecommunications networks is implemented using high speed electronic or all-optical switches. Switching with high speed electronics demands optical-to-electronic (O/E) and electronic to optical (E/O) conversions of the data stream. The transmitting node converts electrical data into optical signal (E/O) conversion and sends it on the optical fiber link. Then, the receiving node converts the optical signal back into electrical domain (O/E) conversion for electronic processing [1, 2]. This makes the switch a probable bottleneck of the network.

On the other hand, the all-optical switching is divided into three schemes which are Optical Circuit Switching (OCS), Optical Packet Switching (OPS) and Optical Burst Switching (OBS). The OCS depends on the presence of line of sight light path between the transmitter and the receiver. So, it is not able to keep up with the bursty nature of internet traffic in a functional manner [3]. In OPS, the packets are switched and routed through the network in the optical domain without conversion back to electronics at each node. But, since network resources are not reserved in advance in OPS, packets may experience contention in the network [4].

The third scheme is the OBS which is a revolution in optical networks. In OBS, a control packet is sent first to configure a connection by reserving an appropriate amount of bandwidth and configuring the switches along a route. Then, a burst of data is transmitted without waiting for an acknowledgement for the connection establishment. To reduce the burst contention, one has to choose a suitable offset time between control packet and data burst transmission and a suitable data burst size [5].

There are three types of assembly algorithms: timer-based, burst-length-based, and mixed timer-burst-length. In the timer based algorithm, the timer starts at a new assembly period after a fixed time, T. Packets arriving at the egress node are aggregated into a burst. The timeout is set with care as long timeout will result in high packet delay and short T will produce many small bursts which lead to overhead in network [6]. For a burst-length-base scheme, the bursts are formed when burst length reaches the threshold set by the ingress node. The control packets are sent at non-periodic intervals and the bursts from an ingress node are of fixed length. In this strategy, there is not prediction for assembly delay time [7]. The third algorithm mixes between time based and burst-length based algorithm by choosing proper length and time to reduce the delay and overhead on network [8].

In this paper, a simple and smart algorithm is proposed to overcome the disadvantages of the ordinary bursting algorithms. When the ordinary algorithms yield small bursts, this causes high overhead network processing, and when yield large bursts, this increases the network contention. On the other hand, the proposed algorithm works with a smart technique which makes the data burst size adaptive to the offered load in the presence of minimum and maximum size thresholds. The proposed algorithm is also characterized by taking into consideration the presence of Quality of Service (QoS) for multiple data priorities. So, in case of high offered load, this algorithm will reduce the end-to-end delay and increase the data burst utilization for high priority packets. This algorithm is different from that discussed in Ref. [9] which did not take QoS into consideration by simulating the algorithm to only one priority traffic. But, in our proposed algorithm the QoS is performed to the smart data burst assembly algorithm by generating two types of traffic which are low and high priority traffics.

2. Concept of adaptive burst assembly

The three mentioned algorithms of data burst assembly have a common disadvantage because they depend on fixed time or fixed burst length without taking the offered load and various priority classes into consideration. This leads to high contention and low burst utilization [10].

In our proposed algorithm, the smart burst assembly puts a minimum (BS_{min}) and maximum (BS_{max}) length for data burst as the minimum length does not lead to many small bursts and the maximum length does not lead to high delay. We apply this algorithm to enhance the transmission of high priority packets in the presence of low priority packets in the same fiber link. So, in the edge node, two queues are created: one for the high priority packets (Class 1) and the other is for low priority packets (Class 0). For low priority queue, a mixed-timer-length based assembly algorithm is applied while the smart burst assembly algorithm is applied on the high priority packets in case of high offered load.

Two transitions are created: Q_{low} which is the lowest number of packets in queue to create a burst and Q_{high} the most number of packets in queue which can be increased in case of high offered load. The cross-over count number is the common factor between the burst size and the queue size [9]. If the packets in queue reach Q_{high}, the cross-over count number is raised by one step as shown in Fig. 1, where n is an initial value of cross-over count number.

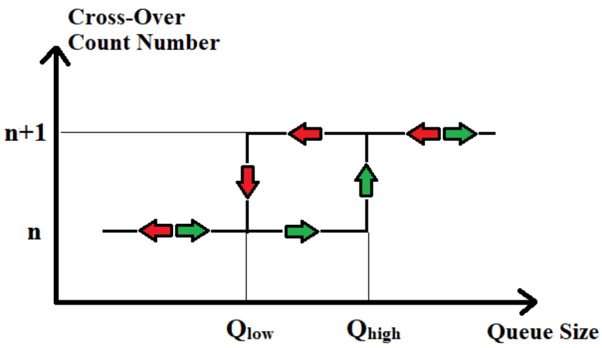

Fig. 1. Behavior of cross-over count number transitions

To monitor the input traffic arrival, the data burst-size should be modified. The burst size is decided either discretely or continuously. Because the function of the control is sensitive in optical burst switching, we adopt a discrete type burst-size technique that uses a simple transition method to enhance the data burst size adaptation process. Fig. 2 shows that, when the cross-over count number reaches its maximum limit, the size of burst is exceeded by one step [9, 11].

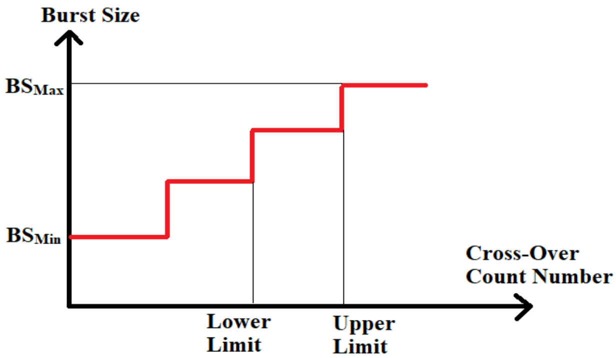

Fig. 2. Discrete type burst size decision technique

The overall flow diagram for the smart data burst assembly algorithm is illustrated in Fig. 3.

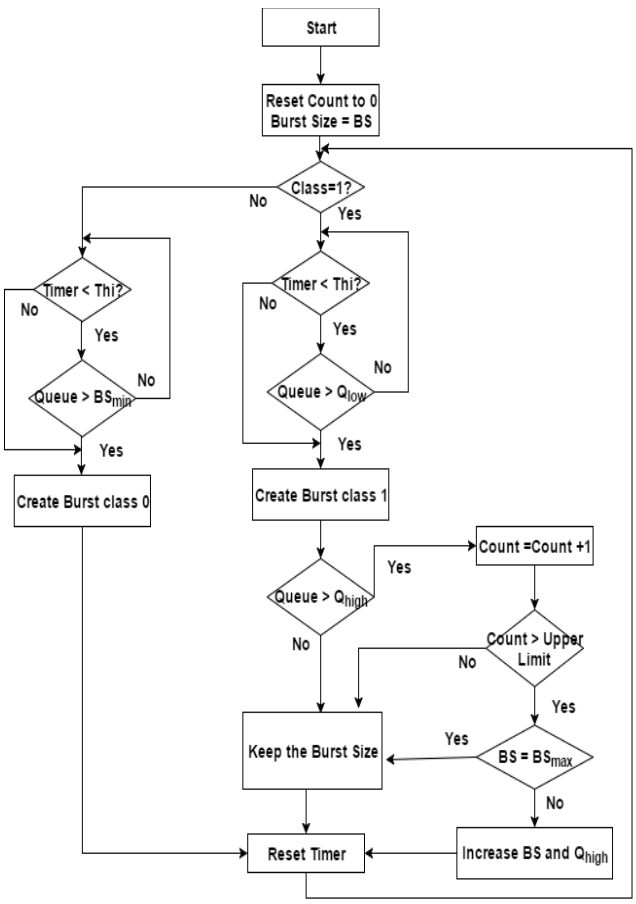

Fig. 3. Flow diagram for smart burst assembly

The procedure can be explained as follows, showing how the burst size is adaptively changed.

- A timer starts when the first packet reaches the queue. Then, it starts to classify the priority of the incoming packet.
- If the packet's priority is low (Class 0) and if the timer arrives to the threshold value, Thi, or if the timer value is less than Thi and the queue size is greater than the minimum burst size, a new burst including Class 0 packets is created.
- If the packet's priority is high (Class 1) and if the timer arrives at the threshold value, Thi, or if the timer value is less than Thi and the queue size is more than Q_{low}, a new burst including Class 1 packets is created.
- For the high priority packets queue, if the queue size is greater than Q_{high}, the counter number is raised by one step.
- The cross-over count number is compared with the maximum limit. If it exceeded the maximum limit, the burst size is raised by one step, otherwise, it is not changed.
- Reset the timer to 0 and go back to step 1.

By this way, the burst size is adaptively changed according to the input traffic to enhance the data burst utilization.

3. Simulation results and discussion

3.1. Simulation parameters

To evaluate the effect of the proposed smart burst assembly algorithm, it was simulated using NS2 software. We generate Transmission Control Protocol traffic from two different sources. The first one generates high priority packets and the second one generates low priority packets with an average value of 800 Byte packet lengths. In the ingress node, we set the default values for BS_{min} and BS_{max} to 50 KB and 800 KB respectively for high priority packets (Class 1). Qlow is set to be the lowest data burst length and the initial value for Qhigh is 200 KB. After that, it will be variable according to the offered traffic. We set a value for lowest data burst size for low priority traffic to 50 KB and we assumed that the threshold time is 50 ms for both priority classes as in case of low traffic load. This time will be the maximum time for data burst creation.

Simulation is carried out with three different cases:

- Traffic includes 80% high priority and 20% low priority.
- Traffic includes 50% high priority and 50% low priority.
- Traffic includes 20% high priority and 80% low priority.

Several throughputs: 20%, 50% and 80% of the fiber link are investigated to test the proposed algorithm at different traffic loads and with three different step sizes (low, medium and high) for data burst adaptation:

- Step size is equal to 20% of data burst minimum size.
- Step size is equal to 50% of data burst minimum size.
- Step size is equal to 80% of data burst minimum size.

Two different values are assumed for the threshold time: 20 ms and 50 ms for both priority classes. As for high and low traffic loads, this time will be the maximum time for data burst creation.

Fig. 4 shows the network topology that consists of two transmitter electronic nodes (S1, S2), two optical nodes (R1, R2) connected with a fiber link and two receiver electronic nodes (S3, S4).

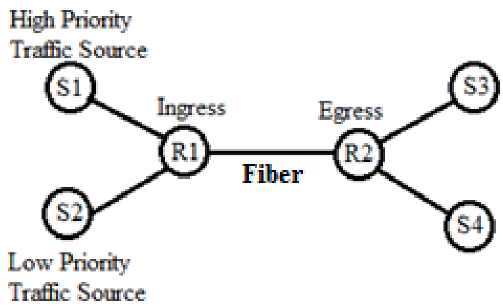

Fig. 4. Optical network topology

3.2. Simulation results

In this section, the burst drop rate, average packets number per burst and end-to-end delay will be discussed and compared for high and low priority traffics at different cases. The performance is compared in high and low priority traffics to test the effectiveness of the smart data burst assembly algorithm which has been applied on the high priority traffic.

The comparison of burst drop rate between the high (H) and low (L) priority traffics is shown in Figs. 5 and 6 using only two adaptation step sizes 20% and 50% of the minimum burst size. Two threshold times are assumed 20 ms and 50 ms in Figs. 5 and 6, respectively.

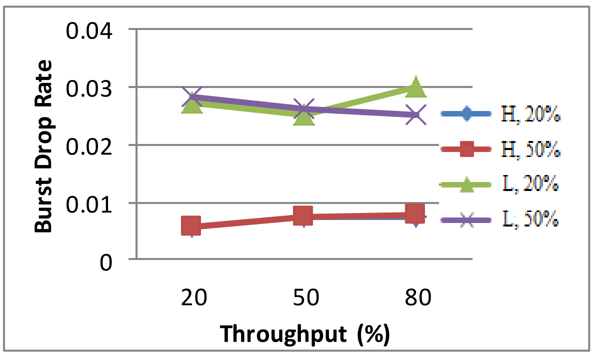

Fig. 5. Burst drop rate for high (H) and low (L) priority traffics at 20 ms threshold time

It is clear, from Fig. 5, that the low priority traffic suffers from high burst drop rate more than the high priority traffic. For high priority traffic, it is noted that the adaptation step sizes 20% and 50% of the minimum burst size do not affect the burst drop rate in the low and medium throughputs. But, the 20% step size introduces a slight decrease in the burst drop rate than the 50% step size in the high throughput due to the increase of the burst size when the throughput increases in the case of 50% adaptation step size.

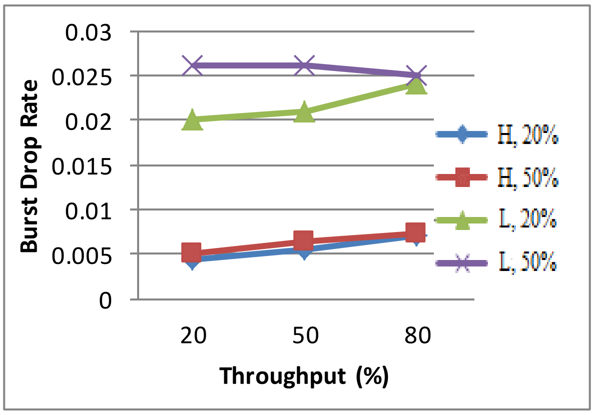

Fig. 6. Burst drop rate for high (H) and low (L) priority traffics at 50 ms threshold

From Fig. 6, like the case of 20 ms threshold time in Fig. 5, it is clear that the low priority traffic suffers from high burst drop rate in both adaptation step sizes. For high priority traffic, the burst drop rate of the 50% step size is slightly more than the burst drop rate of the 20% step size. This is expected because the burst size increases with the increase in step size, which makes the number of dropped packets high in case of contention for this burst [12].

The burst drop rate is displayed against throughput in Figs. 7-9, for the high priority traffic at different adaptation step sizes. These figures compare the effect of the two threshold times (20 and 50 ms) of creating the burst for the high priority bursts.

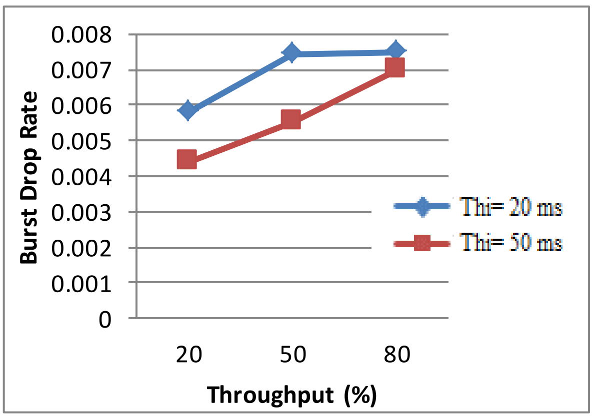

Fig. 7. Burst drop rate for high priority traffic with 20% adaptation step size

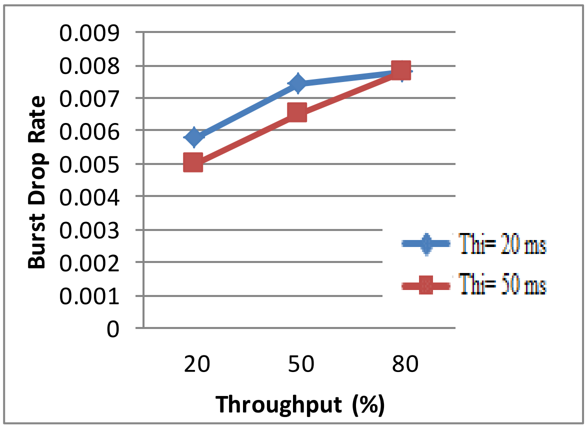

Fig. 8. Burst drop rate for high priority traffic with 50% adaptation step size

From Figs. 7 and 8, one can see that the 50 ms threshold time introduces lower burst drop rate than the 20 ms for low and medium throughputs. But, for high throughputs, the two threshold times introduce the same burst drop rate as the threshold time 50 ms produces bursts with suitable size to avoid contention. But, the 20 ms threshold generates small burst which increases the contention and the overhead on switching nodes that lead to high drop rate with the two adaptation step sizes 20% and 50% from the minimum burst size.

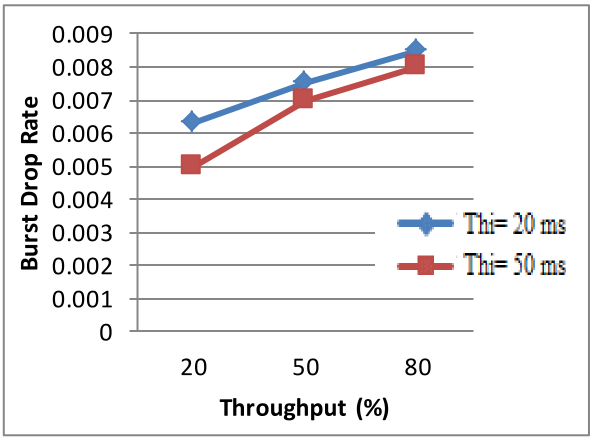

Fig. 9. Burst drop rate for high priority traffic with 80% adaptation step size

It is obvious, from Fig. 9, that for low and medium throughputs, the 50 ms threshold produces lower burst drop rate than the 20 ms. But, for high throughput, the two thresholds produce a very close burst drop rate. This is because when the throughput and adaptation step size increases, the size of burst also increases which raises the number of dropped packets in case of contention and leads to high drop rate.

For a wider view of system performance, simulation was carried out for another two cases:

- The traffic includes 80% high priority (H 80) and 20% low priority (L 20).
- The traffic includes 20% high priority (H 20) and 80% low priority (L 80).

The obtained results, for both cases, are summarized in Tables 1 and 2.

Table 1. Burst drop rate for 20 ms threshold time

		Step= 20%		Step= 50%		Step= 80%	
Stat-us	**Thro-ug-hput**	**Drop Rate (H)**	**Drop Rate (L)**	**Drop Rate (H)**	**Drop Rate (L)**	**Drop Rate (H)**	**Drop Rate (L)**
H 80 L 20	**20%**	**0.0048**	0.032	0.006	0.032	0.008	**0.035**
H 20 L 80	**20%**	0.0065	0.02	0.0067	0.016	0.007	0.018
H 80 L 20	**50%**	0.0069	0.034	0.007	0.03	0.0073	0.03
H 20 L 80	**50%**	0.0052	0.028	00065	0.025	0.0069	0.02
H 80 L 20	**80%**	0.0067	0.032	0.0069	0.028	0.0076	0.03
H 20 L 80	**80%**	0.0055	0.033	0.008	0.022	**0.0082**	0.02

Table 2. Burst drop rate for 50 ms threshold time

		Step= 20%		Step= 50%		Step= 80%	
Stat-us	**Thro-ug-hput**	**Drop Rate (H)**	**Drop Rate (L)**	**Drop Rate (H)**	**Drop Rate (L)**	**Drop Rate (H)**	**Drop Rate (L)**
H 80 L 20	**20%**	0.0043	0.027	0.0046	0.03	0.0053	0.023
H 20 L 80	**20%**	0.0055	0.012	0.0058	0.012	0.0063	0.018
H 80 L 20	**50%**	0.0052	**0.032**	0.0055	0.027	0.006	0.02
H 20 L 80	**50%**	0.0044	0.025	00045	0.024	0.0048	0.02
H 80 L 20	**80%**	0.0063	0.03	0.0067	0.023	0.0071	0.028
H 20 L 80	**80%**	**0.0042**	0.028	0.007	0.02	**0.0075**	0.02

Given the amount of high priority traffic according to the whole traffic, and using the obtained results, one can manage the suitable parameters for the used application to enhance the performance of the high priority traffic.

The average number of packets per burst plays a great role in the adaptive burst assembly algorithm because it changes the size of burst. The average number of packets per burst against throughput is shown in Figs. 10 and 11 at 20 ms and 50 ms threshold times, respectively, for high priority traffic with three adaptation step sizes 20%, 50% and 80%

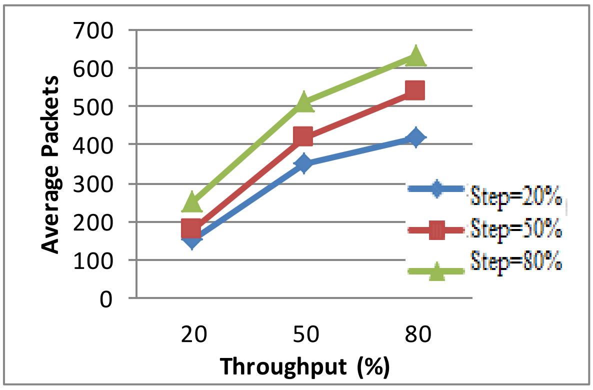

Fig. 10. Average number of packets per burst for high priority traffic at 20 ms threshold

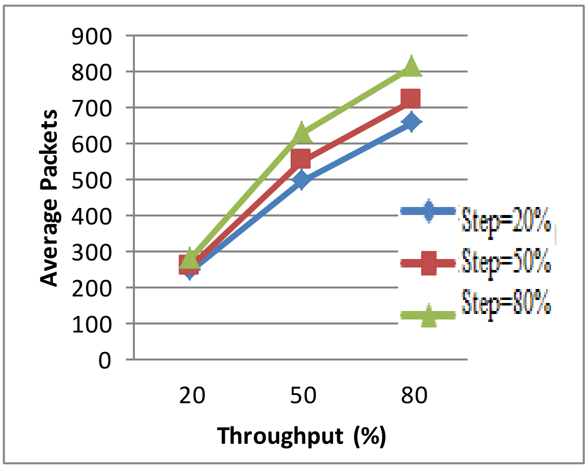

Fig. 11. Average number of packets per burst for high priority traffic at with 50 ms threshold

It is obvious that, the average number of packets per burst increases with the adaptation step size. The packets number per burst for the 80% adaptation step size is higher than that produced by the two other step sizes for the two threshold times. Also, the differences between the average numbers of packets per burst produced by several adaptation step sizes is very small for low throughput and it increases with the throughput. This is expected because when the traffic load increases, the adaptation occurs by our proposed algorithm and increases the size of burst. So, the 80% step size will expand the burst size more than the two adaptation step sizes which leads to high average number of packets per burst for this step size.

A comparison of end-to-end delay between the high and low priority traffics is shown in Figs. 12 and 13 at 20 and 50 ms threshold times, respectively, using only two adaptation step sizes (20% and 50%) of the minimum burst size. These sizes are the practical sizes that generate suitable size for packet. Though, the 80% one generates long bursts as if the burst size is doubled.

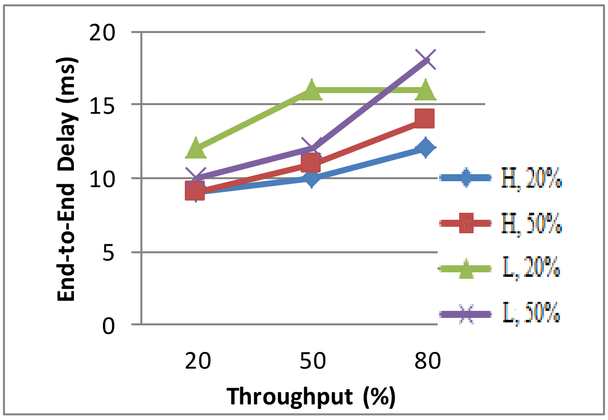

Fig. 12. Delay for high (H) and low (L) priority traffics with 20 ms threshold

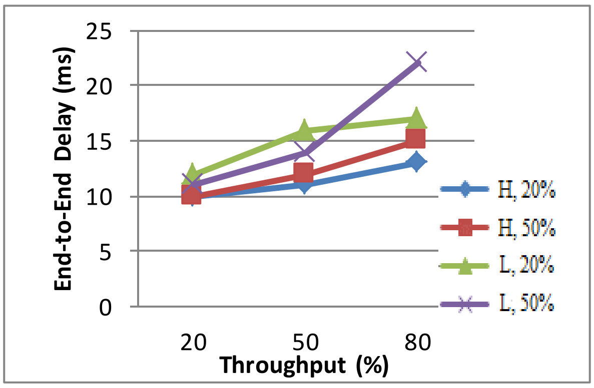

Fig. 13. Delay for high (H) and low (L) priority traffics with 50 ms threshold

It is clear that the low priority traffic suffers from high end-to-end delay more than the high priority traffic. The 20% step size offers low delay for high throughput traffic. This is because, in cases of low and medium throughputs, the 20% step size generates small high priority bursts that leads to high delay for high and low priority traffics due to the high overhead processing.

For high priority traffic, one can see that, the adaptation step sizes 20% and 50% do not make any difference in the end-to-end delay in the throughput. The 20% step size introduces a decrease in delay more than that produced by the 50% step size in the medium and high throughputs. This is due to the increase of the burst size when the throughput increases in the case of 50% adaptation step size which leads to an increase in the burst size. So, the packet is forced to wait more until the burst creation that leads to a greater delay.

The end-to-end delay for the high priority traffic is displayed in Figs. 14-16, which compare the effect of the two threshold times (20 and 50 ms). As shown, the proposed algorithm reduces the burst end-to-end delay for high priority traffic. This is because this algorithm not only depends on the threshold time and burst length threshold but depends also on the offered load. Therefore, the high priority packets do not consume a lot of time waiting burst creation.

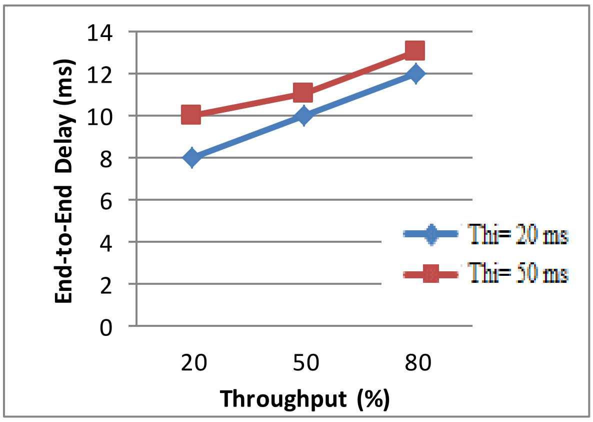

Fig. 14. Delay for high priority traffic with 20% adaptation step size

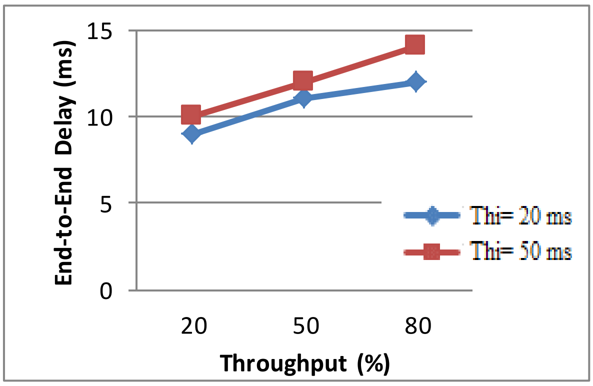

Fig. 15 . Delay for high priority traffic with 50% adaptation step size

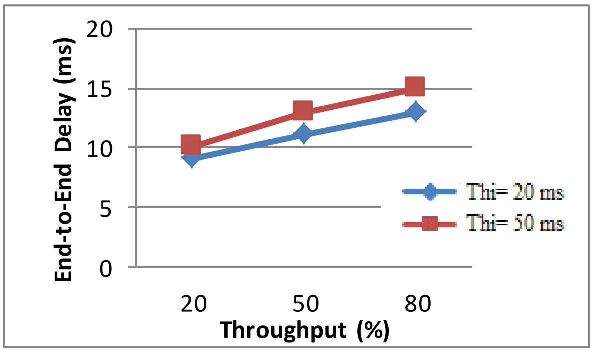

Fig. 16. Delay for high priority traffic with 80% adaptation step size

It is clear that, the 20 ms threshold time offers a lower end-to-end delay than the 50 ms for the three adaptation step sizes. This is because when using the 50 ms threshold time, the packet has to wait until this threshold time or until the burst reaches its maximum size. Hence, focusing on the threshold time, it is realized that in the 50 ms the packet waits more time until burst creation which leads to greater end-to-end delay than the 20 ms.

Tables 3 and 4 illustrate the simulation results carried at different step sizes out for the two following cases:

- The traffic includes 80% high priority (H 80) and 20% low priority (L 20).
- The traffic includes 20% high priority (H 20) and 80% low priority (L 80).

Table 3. End-to-end delay (in ms) for 20 ms threshold time

		Step= 20%		Step= 50%		Step= 80%	
Stat-us	Thro-ug-hput	Dela y (H)	Delay (L)	Dela y (H)	Delay (L)	Delay (H)	Delay (L)
H 80 L 20	20%	8	11	9	10	10	12
H 20 L 80	20%	10	10	10	11	9	11
H 80 L 20	50%	9	14	10	13	10	15
H 20 L 80	50%	10	19	9	16	11	18
H 80 L 20	80%	11	16	12	14	12	15
H 20 L 80	80%	10	20	9	19	11	19

Table 4. End-to-end delay (in ms) for 50 ms threshold time

		Step= 20%		Step= 50%		Step= 80%	
Stat-us	Thro-ug-hput	Delay (H)	Delay (L)	Delay (H)	Delay (L)	Delay (H)	Delay (L)
H 80 L 20	20%	10	13	9	12	11	12
H 20 L 80	20%	11	12	10	12	11	13
H 80 L 20	50%	12	15	11	13	11	16
H 20 L 80	50%	10	21	11	19	12	18
H 80 L 20	80%	12	18	14	17	14	19
H 20 L 80	80%	11	21	10	27	12	24

Using this data, if the percentage of high priority traffic according to the whole traffic is known, one can manage the suitable parameters for the used application to enhance the system performance.

From the obtained results, one can recommend the optimum values to be used according to the required application as shown in Table 5.

Table 5. Optimum values according to applications

	Threshold Time	Adaptation Step Size
Low Delay Applications	20 ms	20%
Low Drop Rate Applications	50 ms	20%
General Applications	20 ms	50%

When the lower threshold time, 20 ms, is combined with the lower adaptation step size, 20%, a minimum end-to-end delay of 8 ms is introduced, which is suitable in applications that require low delay time; like VoIP. When the 50 ms threshold time is combined with the 20% adaptation step size, this offers the minimum burst drop rate to be used for applications like streaming media and online games. But, for general applications, one can use the 20 ms threshold time with 50 adaptation step size. Although they do not offer the best results but, they offer the advantages of low delay resulting from 20 ms time threshold with acceptable burst drop rate as shown in Fig. 8.

4. Conclusion

In this paper, we discussed the core concept of OBS and presented the tasks of ingress, edge and egress nodes. An adaptive data burst assembly algorithm is proposed that depends on data burst size adaptation according to the offered load by taking into consideration the QoS for multiple priority classes. This algorithm is simulated at different throughputs and priority classes with different step adaptation sizes. According to the obtained results, this algorithm leads to:

- Increasing data burst utilization by changing the burst size adaptively for the offered load in a smooth way by adjusting the minimum and maximum burst sizes.
- Reducing the burst contention leading to a decrease in the burst drop rate for high priority traffic using a suitable burst length.
- Reducing the end-to-end delay for bursts as the high priority traffic suffers from 14 ms maximum delay while the low priority traffic suffers from 27 ms maximum delay.

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