

# Improving the Optical Burst Switching Networks Quality of Service by Ensuring the Fairness among the Network Traffic Types

Mohammed Al-Shargabi<sup>a\*</sup>, Faisal Saeed<sup>b,c</sup>, Zaid Shamsan<sup>d</sup>, Abdul Samad Ismail<sup>b</sup>, Sevia M Idrus<sup>e</sup>

<sup>a</sup>College of Computer Science and Information Systems, Najran University, Kingdom of Saudi Arabia

<sup>b</sup>Faculty of Computing, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

<sup>c</sup>Information Technology Department, Sanhan Community College, Sanaa, Yemen

<sup>d</sup>Al-Imam Muhammad ibn Saud Islamic University, Kingdom of Saudi Arabia

<sup>e</sup>Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

\*Corresponding author: mashargabi@nu.edu.sa

## Article history

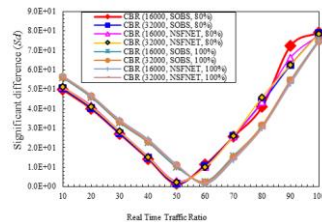
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## Graphical abstract



## Abstract

The Optical burst switching (OBS) networks have been attracting much consideration as a promising approach to build the next generation optical Internet. Aggregating the burst in the OBS networks from the high priority traffic will increase the average of the loss of its packets. However, the ratio of the high priority traffic (e.g. real-time traffic) in the burst is a very important factor for reducing the data loss, and ensuring the fairness between network traffic types. This paper introduces a statistical study based on the significant difference between the traffics to find the fairness ratio for the high priority traffic packets against the low priority traffic packets inside the data burst with various network traffic loads. The results show an improvement in the OBS quality of service (QoS) performance and the high priority traffic packets fairness ratio inside the data burst is 50 to 60%, 30 to 40%, and 10 to 20% for high, normal, and low traffic loads, respectively.

**Keywords:** OBS; real time traffic; burst assembly schemes; fairness

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## 1.0 INTRODUCTION

Optical Burst Switching (OBS) [1, 2] network seems to be the next generation of the optical Internet backbone infrastructure due to its attractive characteristics. There are different studies on routing strategies and burst scheduling algorithms [3, 4] in order to improve the performance of OBS. For instance, the end-to-end delay of constant-bit-rate traffic in optical-burst-switching networks was improved through enhancing burst-assembly and offset-time scheme [5]. Zhang [6] developed a framework for fiber delay-line buffers in packet-based asynchronous multifiber optical networks, and Gjessing [7] improved the performance of burst deflection in OBS networks using multi-topology routing. In addition, several burst assembly algorithms were developed to improve the performance of OBS [8, 9, 10, 11].

Moreover, the optical burst switching networks quality of service (QoS) was improved by prioritized contention resolution [12, 13, 14], which is effective contention resolution schemes in which the edge node combines packets of different traffic priorities into the same burst, whereas lower priority traffic packets aggregate the tail of the burst, or the head of the burst. Accordingly, a complete isolation of the highest priority traffic can be achieved, which will provide better quality of service (QoS) than the single traffic burst. However, the existing schemes

have not considered the fairness factor among the traffic types. Moreover, the best ratio of the high priority traffic in the burst has not been mentioned, although this ratio is significant for providing the QoS for this type of traffics. For example, if the edge node aggregates 10% of the burst as a high priority traffic and 90% as a low priority traffic, this ratio could reduce the loss of the high priority traffic; conversely, it will increase the overall loss in the core node and then affect the performance of the network; this loss is due to the large number of burst that will be aggregated in the edge node which will increase the overall loss at the core node. Additionally, if the edge node aggregates 90% of the burst as high priority traffic and 10% as low priority traffic, this ratio can reduce the loss in the core node due to the small number of burst that will be aggregated but will also increase the loss of the high priority traffic. Thus, the ratio of the real time traffic inside the burst is essential to reduce the real time traffic packets loss rate. In this paper, a statistical study based on the significant difference between the traffics to find the fairness ratio for the high priority traffic packets against the low priority traffic packets inside the data burst with various network traffic loads is introduced.

## 2.0 METHODS

This statistical study is carried out to find the best ratio (fairness ratio) for the real time traffic packets against the non real time traffic packets in various network traffic loads. The statistical study is based on the Significant difference ( $Sd$ ) factors between the network's Over all loss ( $O_{loss}$ ) and the Real time traffic loss ( $R_{loss}$ ). The  $Sd$  factor indicates the fairness among the traffics, where the high value of  $Sd$  means means that no fairness is provided due to the high difference of the data loss among the traffics. In the opposite, the  $Sd$  low value means that there is a fairness in this ratio due to the low difference among the data loss of both traffics (real time and non-real time). The significant difference factors are found by using a simulation model which deals with two types of real time traffic variable bit rate (VBR) and constant bit-rate (VBR), two values of burst size (16000 Kbytes and 32000 Kbytes [15]), two different topologies (four nodes SOBS topology and National Science Foundation Network (NSFNET) topology [16]), incremental load traffic rate, and ten ratio values for real time traffic (10 to 100 %). As a result, ten  $Sd$  values are produced for each case in the study as follows:

$$\begin{aligned} & \text{for } x = 10, 20, 30, \dots, 100 \\ & sd(x) = \|O(x)_{drop} - R(x)_{drop}\| \quad (1) \end{aligned}$$

where  $x$  determines the real time traffic ratio in the data burst. In Equation (1), the value of  $x$  will be replaced, ten times, with the real time ratios in the data burst and stored in the  $Sd$  group. Consequently, based on these results, other mathematical equations are used to find the range of the best ratio for real time traffic in the burst that can guarantee the fairness between real time traffic and non real time traffic. These mathematical equations aim to find the lowest two minimum ratios in  $Sd$ ; the Lowest ratio ( $Low_{ratio}$ ) and Second Lowest ratio ( $SLOW_{ratio}$ ). The  $Low_{ratio}$  can be derived by using the minimum  $Sd$  value,  $Low_{value}$  which is given by

$$Low_{value} = \min \{Sd\} \quad (2)$$

Subsequently, Equation (2) aims to find out the ratio of the value of  $Low_{ratio}$  by searching in the entire  $Sd$  group ratio as follows:

$$\begin{aligned} & \text{for } i = 10, 20, 30, \dots, 100 \\ & Low_{ratio} = i, \text{ if } Low_{value} = Sd(i). \quad (3) \end{aligned}$$

The second minimum  $Sd$  ( $SLOW_{ratio}$ ) can be found by using a temporary group of elements  $Sd_{temp}$  that contains all  $Sd$  except  $Low_{ratio}$ :

$$\{Sd_{temp}\} = \{Sd\} / Low_{ratio}. \quad (4)$$

Therefore,  $SLOW_{value}$  will be the minimum value of the new temporary group  $Sd_{temp}$ :

$$SLOW_{value} = \min\{Sd_{temp}\} \quad (5)$$

Subsequently, this value of  $SLOW_{value}$  can be used to find  $SLOW_{ratio}$  by searching in the entire  $Sd_{temp}$  group ratio

$$\begin{aligned} & \text{for } i = 10, 20, 30, \dots, 100 \\ & SLOW_{ratio} = \{i, \text{ if } SLOW_{value} = Sd_{temp}(i)\} \quad (6) \end{aligned}$$

Thus, after getting the values of  $Low_{ratio}$  and  $SLOW_{ratio}$ , the average ratio of the real time traffic in the burst ( $Avg_{ratio}$ ) will be in the range between  $Low_{ratio}$  and  $SLOW_{ratio}$  based on the network traffic load according to Equation (7):

$$Avg_{ratio} \in Low_{ratio} \wedge SLOW_{ratio} \quad (7)$$

This equation will identify the range of the best ratios of real time traffic inside the data burst, which will reduce the real time traffic packets loss, at the same time guarantee the fairness for non real time traffic packets.

Generally, the objective of this method is to demonstrate the best ratio that can reduce both the real time traffic loss and to ensure fairness for the non real time traffic loss requirements. Moreover, this study aims to make sure that the accuracy of fairness ratio is capable to work under various conditions such as different types of real time traffic, various values of burst size, or various designs of the topology.

## 3.0 EXPERIMENTAL DESIGN

Depending on the aforementioned equations in the previous section, the simulation model is build using NCTUns simulator [15] to obtain the fairness ratio. The configuration of the simulation models is divided into two parts: the OBS network configuration and the real time traffic configuration. In the real time traffic configuration, CBR traffic and VBR traffic trace files are created with incremental load.

## 4.0 RESULTS AND DISCUSSION

The results show that the aggregation process can be categorized based on the traffic load into three categories, which are the low, normal, and high loads. In the high load, the results show that the best ratio for real time traffic in the burst that can guarantee the fairness between real time traffic and non real time traffic is between 50 % and 60 %.

Figures 1 and 2 show the  $Sd$  factor in the high traffic load for CBR and VBR traffic. The  $Sd$  has been studied, as shown in these figures, with several factors that are the traffic type (CBR, and VBR), burst size (16000 Kbyte, 32000 Kbyte [14]), network topology layout (four nodes OBS (SOBS), NSFNET [15]), and traffic load (80%, 100%). The results show that the best ratio (which ranging from 50 % to 60 %) is based on the network traffic load value. It is noted that the value of  $Sd$  gradually decreases when the ratio of real time traffic in the burst decreased from the ratio of 10% to 50%. This is because of the numerous numbers of data burst that are created and sent to the core network due to the small ratio of real time traffic in each burst. This leads to an increase in the number of data burst needed to send all the real time traffic available in a certain period, and this in turn increases the rate of burst loss in the core node which creates a discrepancy between the value of the network overall loss and the real time traffic packets loss. Thus, it can be noted that the  $Sd$  value goes high in the case of ratio of 10% and reduces with the increase of the ratio of real time traffic in the burst which reduces the rate of burst loss until it reaches to the ratio 50%.

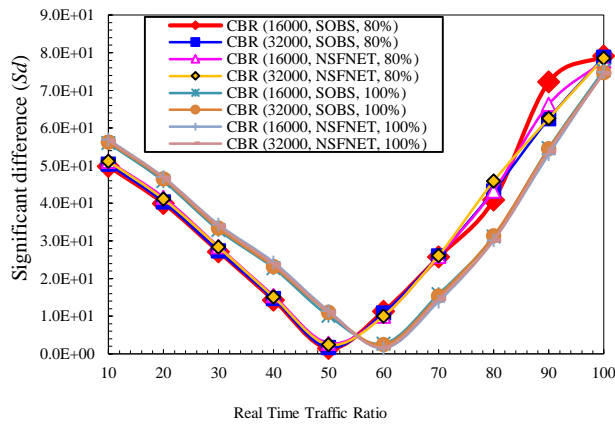


Figure 1 The significant difference (*Sd*) factor values in the high traffic load for CBR traffic

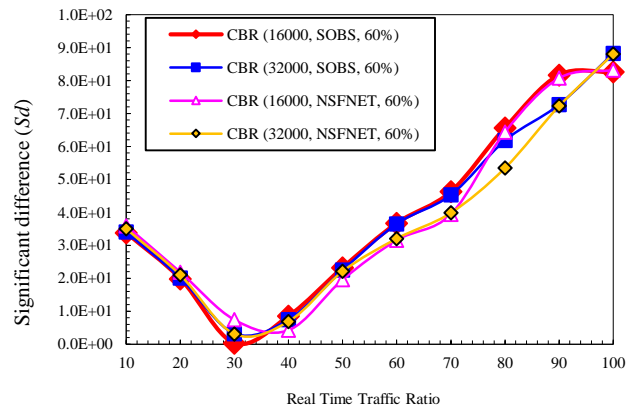


Figure 3 The significant difference (*Sd*) factor values in the normal traffic load for CBR traffic

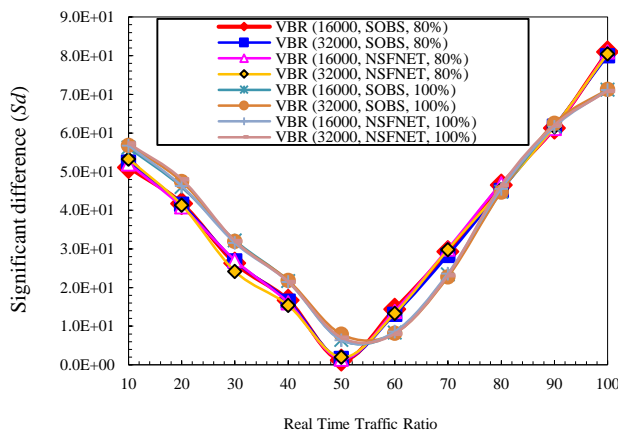


Figure 2 The significant difference (*Sd*) factor values in the high traffic load for VBR traffic

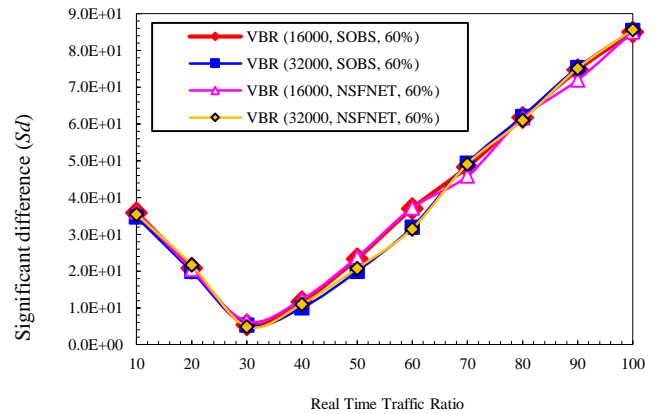


Figure 4 The significant difference (*Sd*) factor values in the normal traffic load for VBR traffic

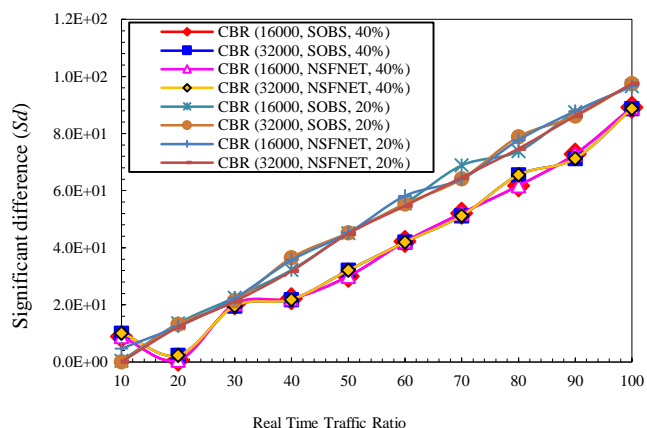
In contrast, it can be noted from Figures 1 and 2 that the value of *Sd* gradually increases when the ratio of real time traffic in the burst, from 60% up to 100%, due to the rise of the rate of real time traffic packets loss caused by its high ratio in the burst and the low rate of overall loss which is created by the low number of bursts. Thus, it can be noted that the *Sd* value is high at those ratios and getting a raise with the increase of the ratio of real time traffic in the burst, which causes an increasing of the rate of real time traffic packets loss until it reaches to the ratio 100%.

In the normal load case, the results in Figures 3 and 4 show that the best ratio for real time traffic in the burst that can guarantee the fairness between real time traffic and non real time traffic. This ratio is between 30% and 40%.

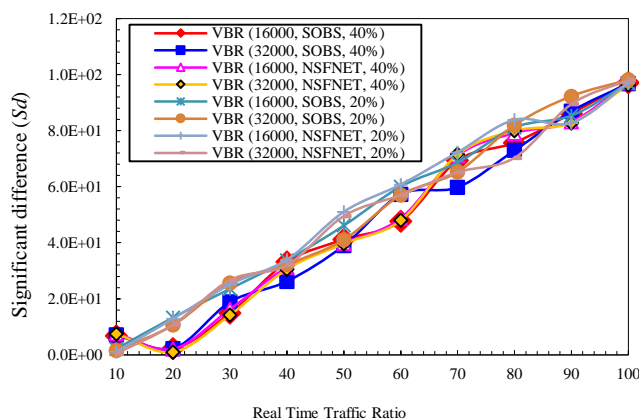
The *Sd* is also studied using the same factors that used in the high traffic load mentioned above. It can be noted in the normal load case that the value of *Sd* is low for the low ratios (10 to 50%) and high for the higher ratios compared with the high load traffic case.

This variation is due to the traffic load which increases the traffic load rate in the high load case; while the rate of real time traffic packets loss is similar in both cases which make the *Sd* value goes high in the high traffic load case. In contrast, for the high ratios from 50% up to 100%, it is noted that the value of *Sd* is higher than that of the low ratios due to the decrease of overall rate loss in this case; while the rate of real time traffic packets loss is similar in both normal and high traffic load cases, which makes the *Sd* value higher in the normal traffic load case.

In the low traffic load, the findings show that the best ratio for real time traffic in the burst that can guarantee the fairness between real time and non real time traffic ranges between 10 and 20%. Figures 5 and 6 show the significant difference factor in the low traffic load for CBR and VBR traffic. Similarly, same factors are used for the cases mentioned above.



**Figure 5** The significant difference ( $S_d$ ) factor values in the low traffic load for CBR traffic



**Figure 6** The significant difference ( $S_d$ ) factor values in the low traffic load for VBR traffic

In addition, it can be observed that the lowest  $S_d$  values are within the ratios 10% and 20%, which make them the best ratios for the real time traffic in the burst to guarantee the fairness concept. This finding is a result of the low traffic load which decreases the loss rate of overall traffic loads in this case; similarly the rate of real time traffic packets loss is approximately same in all cases which make the  $S_d$  value low in the low traffic load case.

Generally, it can be noted that there are some differences between the results of VBR traffic and CBR traffic, these differences are dating back to the nature of VBR traffic which comes with different size and bursty load traffic that leads to increase VBR traffic packets loss probability.

## 5.0 CONCLUSION

In this paper, a statistical study based on the significance difference between the traffics has been carried out to obtain the best ratio (fairness ratio) for the real time traffic packets against the non real time traffic packets under various network traffic

loads. It has been found that the real time traffic packets fairness ratio inside the data burst is ranging from 50 to 60%, 30 to 40%, and 10 to 20% for high, normal, and low traffic loads, respectively. The results show that OBS data burst using these ratios provides a better performance, reduces the high priority packet loss probability and ensure the fairness for other traffic types.

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