Quality of Service for Slotted Optical Burst Switched Network

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***Abstract* — This paper presents a quality of service based on three parameters, number of wavelengths, wavelength conversion capability, and number of slots per burst. An analytical model for calculating Burst Loss Rate (BLR) is presented for each parameter. We also show the influence of the three parameters on the BLR.**

***Index Terms* — Quality of Service (QoS), Optical Burst Switching (OBS), Burst Loss Rate (BLR), Wavelength conversion capability.**

I. INTRODUCTION

OPTICAL networks are a logical choice to meet future communication demands, with optical fiber links offering huge bandwidths on the order of 25 THz. Optical wavelength-division multiplexing (WDM) communication systems have been deployed in many telecommunications backbone networks, in order to meet these growing needs. In WDM networks, channels are created by dividing the bandwidth into a number of wavelength or frequency bands, each of which can be accessed by the end-user at peak electronic rates. In order to efficiently utilize this bandwidth, one needs to design efficient transport architectures and protocols based on state-of-the-art optical device technology. The first generation optical network architectures consist of point-to-point WDM links. Such networks are comprised of several point-to-point links, at which all traffic coming into each node from an input fiber is dropped and converted from optics to electronics. All outgoing traffic has to be converted back from electronics to optics before being sent on the outgoing fiber. This dropping and adding of the entire traffic at every node in the network incurs a significant overhead in terms of switch complexity and data transmission cost, particularly if the majority of the traffic in the network happens to be a bypass traffic. In order to minimize the network cost, all-optical add-drop devices can be used.

Second-generation optical network architectures are based on wavelength add-drop multiplexers (WADM) [1], where traffic can be added and dropped at the WADMs location. WADMs can terminate only selected channels from the fiber and let other wavelengths pass through untouched. In general, the amount of bypass traffic in the network is significantly higher than the amount of traffic that needs to be dropped at a specific node. Hence, by using WADM, one can reduce the overall cost by dropping only the wavelengths whose final destination is same as the current node, and allowing all other wavelengths to bypass the node. WADMs can serve as a basis for switching, wherein the WADMs is remotely configured to drop any wavelength to any port without manual intervention we can perform circuit, or point-to-point, switching in the optical domain with a WADM. The WADMs are mainly used to build optical WDM ring networks which are expected to be deployed mainly in the metropolitan area market. In order to build a mesh network consisting of multi-wavelength fiber links, one needs appropriate fiber interconnection devices [2]. Third generation optical network architectures are based on all-optical interconnection devices. A passive router can separately route each of several wavelengths incident on an input fiber to the same wavelength on separate output fibers. The active switch also allows wavelength reuse and can support simultaneous connections through itself.

A. Paper Organization

The main objective of this paper is to present an analytical model that captures the essential features of Just-In-Time (JIT) based OBS (OBS-JIT) networks, and show different parameters for Quality of Service (QoS). It also gives stronger insight into factors that affect the burst loss rate (BLR). We start by briefly describing the background of OBS in Section 2. In Section 3, we briefly described previous models for calculating the burst blocking probability in [3]. The effect of Quality of Service is described in Section 4. Finally, we gave our conclusion in Section 5.

II. OPTICAL BURST SWITCHING

An optical burst consists of two parts, a header and a data burst. The header is called the control burst (C) and is transmitted separately from the data, which is called the data burst (B). The (C) is transmitted first on a separate signaling channel to reserve the bandwidth along the path for the corresponding (B). Figure 1.a. shows the transmission of an optical burst, after a given delay. The control burst is followed by the data burst, which travels over the same path reserved by the control burst. The delay between sending the (C) and the (B) is called the burst offset time. The value of the offset time is chosen to be greater than or equal to the total processing delay encountered by the (C). As shown in Fig. 1.a, consequently, no buffering is needed for the (B) at intermediate nodes. Several signaling protocols have been proposed for OBS [3].

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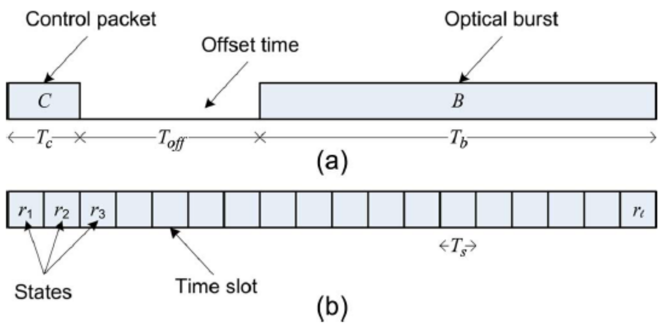

Fig.1. (a) Transmission of an optical burst (b) slotted timing diagram.

The nodes of the core network, through which the aggregated data is transmitted, are referred to as core nodes. This process of aggregating several packets into a burst is called burst assembly. During burst assembly, data is buffered at the edge node where electronic RAM is easily available. Before each data burst is transmitted, a control burst is transmitted over a separate control channel. The control burst contains an information about the sender, receiver and transmission wavelength of the corresponding burst. This control burst, which is sent ahead of the data burst, undergoes Optical/Electronic/Optical (O/E/O) conversion and is processed electronically at each intermediate node, to configure the switch for the data burst that is to arrive later. This process is called a burst reservation. Hence, no optical RAM or buffers are needed at any intermediate node. An intermediate node gets many control bursts and needs to configure the switches for all the corresponding data bursts and decide channels (wavelengths) on which to schedule each data burst. This process is called as burst scheduling.

A. Burst Aggregation

An important design aspect of OBS network is the burst aggregation process performed at the edge nodes. This process concentrates upper layer packets which are then transmitted optically over the OBS network. In view of this, the burst aggregation strategy defines the burst arrival process to the OBS network. The burst arrival process depends on the parameters of the burst aggregation process. So far, it has not been adequately studied. In the majority of OBS related studies, it is assumed that burst arrivals are similar to a packet arrival. The Poisson assumption has been used extensively to represent the burst arrival process [4].

B. Signaling Protocols

A number of signaling protocols for OBS networks have been proposed. The signaling schemes found in the literature can be categorized into two main classes: two-way and one-way protocol, such as Just-Enough-Time (JET), Just-In-Time (JIT) and Tell-And-Go (TAG), in which a data burst follows a corresponding control packet without waiting for an acknowledgement. Among these, two protocols are widely studied in the literature: JIT and JET protocol [5, 6]. Other protocols can be considered a variation of one of these two. In this section, we briefly describe the operation of the JIT and JET protocols [7].

The JIT protocol works as follows. Upon the arrival of a (C) to a core OBS node, a wavelength channel is immediately reserved if available. If no wavelength is available the request is blocked and the corresponding (B) is dropped. When the wavelength is successfully reserved, it remains reserved until the data burst transmission has finished. The only information that needs to be kept in the network nodes is whether the wavelength is currently reserved or not.

The control packet is not aware of the burst length and reserves the relevant link bandwidth (if available) for the entire burst as soon as it arrives at the switch. The JET protocol, on the other hand, is reserve-a-fixed duration scheme that reserves resources exactly for the transmission time of the data burst. In JET, when a (C) arrives at a core node, a wavelength channel scheduling algorithm is invoked to find a suitable wavelength channel on the outgoing link for the corresponding (B). The wavelength channel is reserved for duration equal to the burst length starting from the arrival time of the (B). The information required by the scheduler such as the data burst arrival time and its duration are obtained from the control burst.

III. Evaluation of Burst Loss Rate (BLR)

The total time T spent from the transmission of the control packet until the end of the optical burst is $T = T_c + T_{off} + T_b$ where T_{off} is the offset time, T_c and T_b are the control packet and optical burst time durations, respectively. Due to the one-way reservation scheme, burst loss may occur in an OBS network because the control packets may not succeed in reserving resources at some of the intermediate OBS core nodes. In addition, burst loss is possible if the control channel itself suffers from congestion or other failure. Because of these reasons, the burst loss probability is an important performance measure of OBS architecture. In this paper, we consider JIT based OBS protocol but a little modification of the slotted OBS timing model in [3] is presented. Here, we only need to reserve the wavelength for time duration $T_{off} + T_b$. This paper addresses how BLR differentiation can be provided in slotted buffer less OBS. In our analysis, slotted timing model (Fig. 1.b.) is used in which we divide the time $T_{off} + T_b$ of a burst into small time slots, each of duration

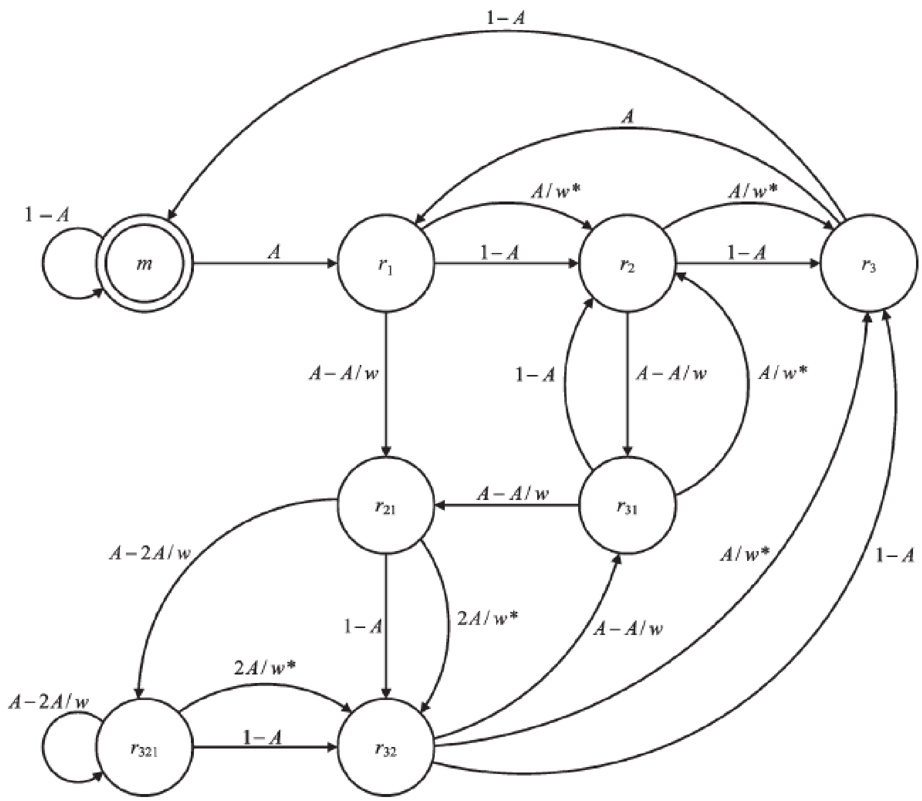

Fig.2. State diagram for an OBS network with ℓ = 3 and $w \geq \ell$ the stars denote blocking probabilities.

T_s called slot time. The total number of slots ℓ is calculated as $\ell = (T_{off} + T_b)/T_s$, where ℓ is an integer. It should be emphasized that during a time slot T_s, a node would get enough information about the selected wavelength.

From the state-diagram in [3], we assume that initially, an OBS node is in initial state m, Fig. 2. If there is an arrival with probability A, the OBS node will enter the following state r_1 and starts processing the control burst. On the other hand, if there is no arrival with probability $(1-A)$, the OBS node will remain as is.

Let $r_1, r_2, \ldots, r_\ell$ are the *(1- λ)* states, Fig. 2. If an OBS node is in state m and there is an arrival, it will reserve one of the available wavelengths and enter state r_1. The node in r_1 state is serving slot *1* of the first burst. If it is in state r_1 and there are no arrivals after T_s, it enters state r_2. The node in r_2 state is serving slot *2* of the first burst. On the other hand, if it is in state r_1 and there is an arrival that needs to use the same wavelength, the burst will be blocked with probability (A/w) and the node will again enter state r_2. However, if the node is in state r_1 and there is an arrival that needs to use another wavelength (an event that occurs with probability. $A(w-1)/w$, the node will serve both bursts and enters state r_{21}. The node in r_{21} state is serving slot *2* of the first burst and slot *1* of the second burst [7].

Let us consider an OBS network with w number of wavelengths and the network is equipped with u number of wavelength converters. Only u number of wavelengths among w wavelengths can be converted but the remaining ($w-u$) wavelengths cannot be converted. So, can define the wavelength conversion capability (ρ) by the following equation:

$$\rho = \frac{u}{w}, \qquad 0 \leq \rho \leq 1 \tag{1}$$

Assume that $w < \ell$, and consider an *n -λ* state $r_{i_n i_{n-1} i_{n-2},\ldots,i_1,i_2}$ where $n \in \{1,2,3,\ldots\ldots \ell \wedge w\}$ and $i_1, i_2, \ldots, i_n \in \{1,2,3,\ldots,\ell\}$ with $i_n > i_{n-1} > i_{n-2}, \ldots, i_1$, *here* $\ell \wedge w = \min(\ell, w)$.

The node in this state is serving slot i_n of the first burst, slot i_{n-1} of the second burst and so on. After $T_s s$, if there is an arrival that needs to be served let us consider $r_{i_n i_{n-1} i_{n-2},\ldots,i_1,i_2} = e_n$

Using expression for e_n is available in [3], one gets for any $k \in \{1,2,3,\ldots,\ell \wedge w\}$

$$e_k = \frac{\prod_{i=0}^{k-1} \frac{w - i(1-\rho)}{w\frac{1-A}{A} + i(1-\rho)}}{1 + \sum_{n=1}^{\ell \wedge w} \binom{\ell}{n} \prod_{i=0}^{n-1} \frac{w - i(1-\rho)}{w\frac{1-A}{A} + i(1-\rho)}} \quad (2)$$

Thus, if $n \neq w$, the blocking probability [3] for this node is given by

$$P_b(n) = \frac{A(\ell-1)}{w\ell}(1-\rho)n\binom{\ell}{n}e_n \quad (3)$$

If $n = w$, however, blocking probability is given by

$$P_b(w) = \frac{A(\ell-1)}{w\ell}(1-\rho)w\binom{\ell}{w}e_w + A\rho\binom{\ell-1}{w}e_w \quad (4)$$

We denote the burst arrival probability on an input wavelength in a given time slot as $A\ (0 < A < 1)$ and assume that A is independent on burst arrivals in other wavelengths and burst arrivals in previous time slots [8].

Let $A_k\ (0 < A_k < 1)$ be the probability for $k\ (0 < k < w)$ arrivals to the output fiber on a given time slot. A_k is then distributed according to a Binomial process $P_A(k/w)$.

$$A_k = P_A(k/w) = \binom{w}{k}(A)^k(1-A)^{w-k} \quad (5)$$

The average number of burst arrivals in a time slot is $E[A_k] = Aw$. If two control bursts are to reserve the same wavelength at a given core node for two different bursts, then only one burst will be offered to this wavelength. The other will be blocked and lost unless there is an available wavelength converter. So, we obtain the average burst loss rate as 6 [8].

$$BLR = \frac{1}{Aw}\sum_{k=1}^{\ell \wedge w} A_k.k.P_b(k) \quad (6)$$

VI. Proposed Parameters for QoS in OBS Network

In this paper, there are three different parameters to control the QoS for OBS network. These parameters are:

A. Number of wavelengths (w).

B. Wavelength conversion capability (ρ).

C. Number of slots per burst (ℓ).

In each parameter, there are three classes representing high priority traffic (H), medium priority traffic (M), and low priority traffic (L).

At BLR=10^{-3}, we will assume a system with a number of wavelengths equal to 16, wavelength conversion capability ranges from 0 to 1, and number of slots per burst ranges from 20 to 100.

A. QoS Using Number of Wavelengths (W).

At BLR=10^{-3}, we assume that the minimum wavelength reservation for high priority class (H) is 5 wavelengths, for medium priority class (M) is 2 wavelengths, and for low priority class (L) is 0 wavelengths. So, the maximum reservation for each priority class is 14, 11, and 9, respectively.

By using Eq. 6, the BLR and burst arrival probability is plotted with the number of wavelength parameter as shown in Figs. 3 and 4.

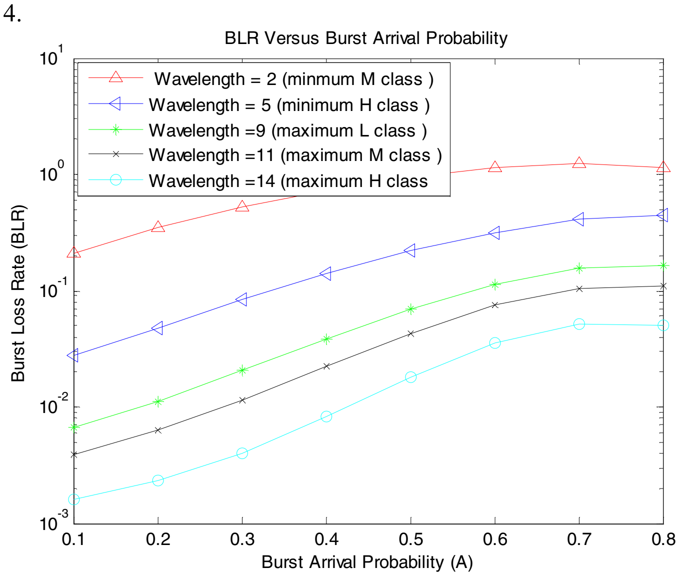

Fig.3. Burst arrival probability (A) versus BLR of three classes with ρ =0, ℓ =100 and $w < \ell$

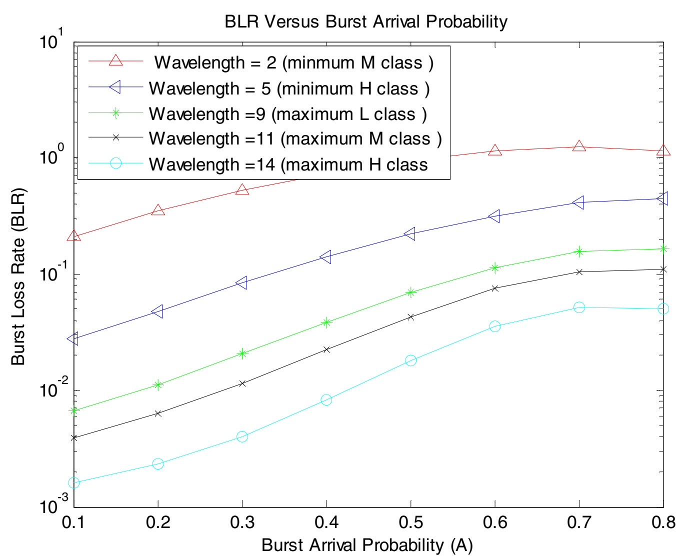

Fig.4. Burst arrival probability (A) versus BLR of three classes with ρ =1, ℓ =100 and $w < \ell$

Figures 3 and 4 show that when burst arrival probability (A) increasing, BLR increases and at constant burst arrival probability, BLR decreasing as the number of channel wavelength increases. When at ρ=1, BLR in H, M, and L classes is less than at ρ=0.

It can be noted that the number of wavelength has a huge impact on BLR and therefore we used it in QoS for classes and the different between low priority traffic (L) and maximum priority traffic (H) is 30%.

The relation between BLR and wavelength conversion capability with number of channel wavelength parameter are illustrated in Figs. 5 and 6.

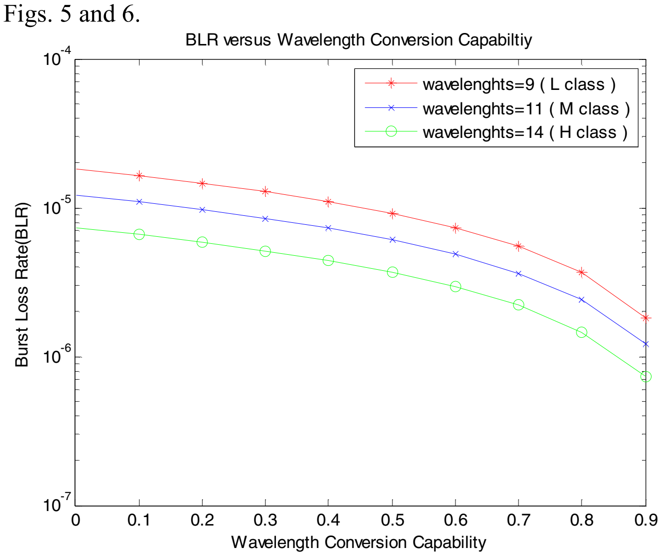

Fig.5. BLR versus wavelength conversion capability of three classes with ℓ=20, A=0.01 and $w < \ell$

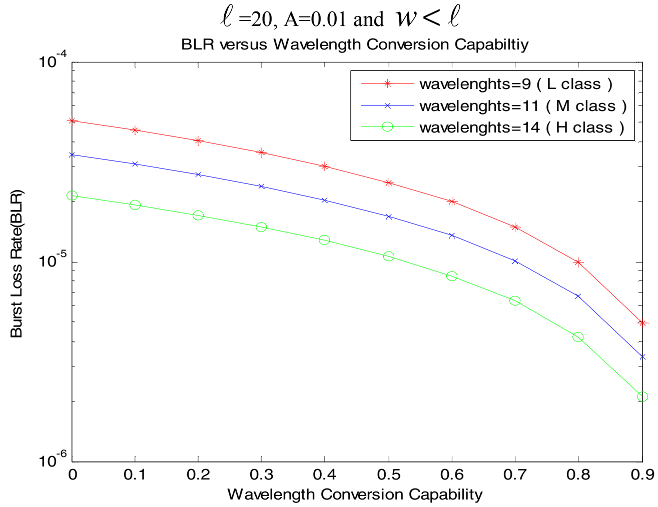

Fig.6. BLR versus wavelength conversion capability of three classes with ℓ=100, A=0.01 and $w < \ell$

Figures 5 and 6 show that when wavelength conversion capability increase, BLR decreases, and at constant wavelength conversion capability, BLR decreases as the number of channel wavelength increases. Also, at ℓ=20, the BLR in H, M, and L classes is less than when ℓ=100, as shown in Figs. 5 and 6.

The effect of BLR and number of slots per burst with number of channel wavelength are described in Figs. 7 and 8.

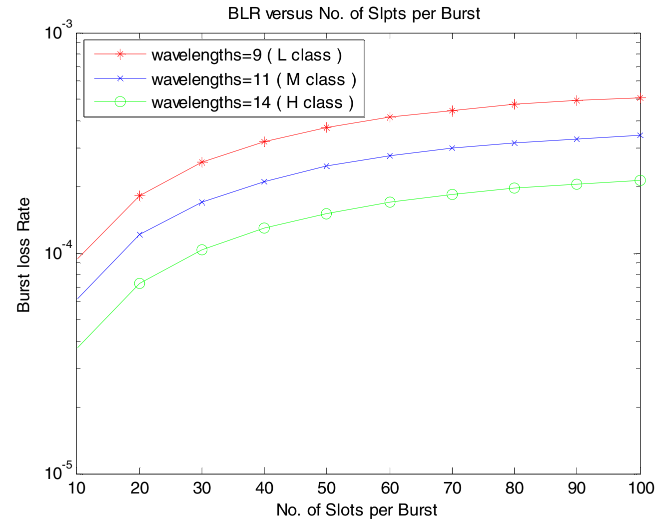

Fig.7. BLR versus number of slots per burst of three classes with ρ=0, A=0.01 and $w < \ell$

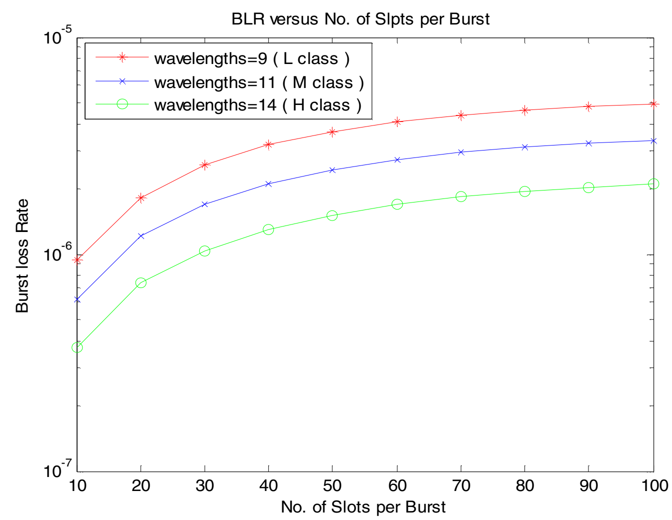

Fig.8. BLR versus number of slots per burst of three classes with ρ=1, A=0.01 and $w < \ell$

Figures 7 and 8 describe that BLR decreases with increasing of number of channel wavelength. At w=14, BLR is less than when w=9.

To get good QoS as possible, this is need huge number of channel wavelength.

B. QoS Using Wavelength Conversion Capability (ρ).

We assume there is three different values of wavelength conversion capability $(0, 0.5, 1)$ for low priority traffic (L), medium priority traffic (M), and high priority traffic (H) respectively that affecting the QoS in OBS. By using Eq. 6, the BLR and number of slots per burst is plotted with the wavelength conversion capability parameter as shown in Figs. 9 and 10.

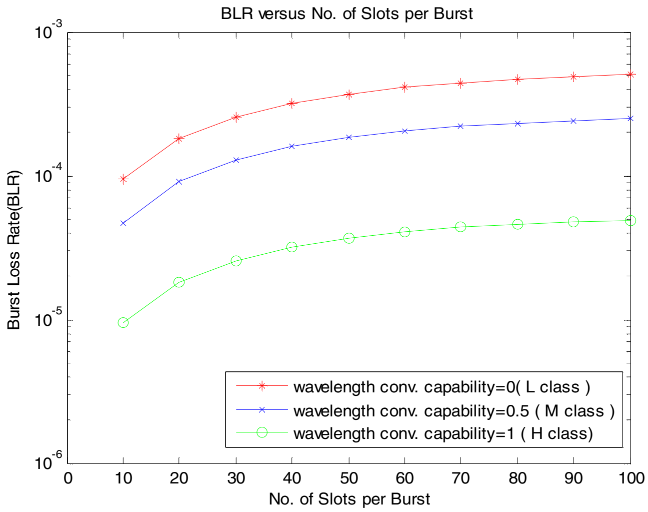

Fig.9. BLR versus number of slots per burst of three classes with w=9, A=0.01 and $w < \ell$

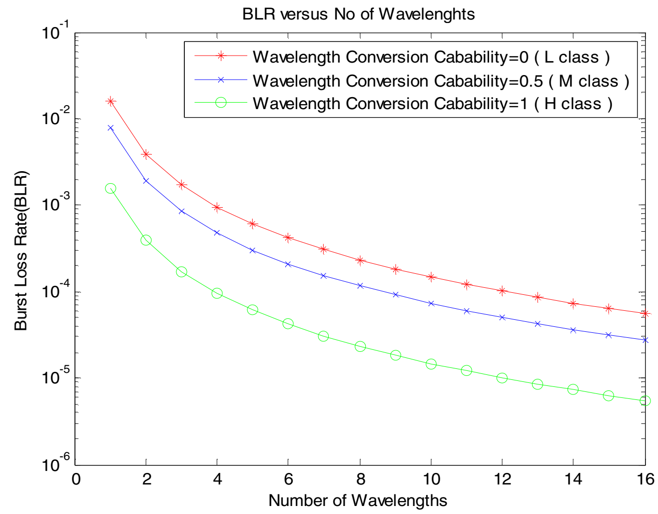

Fig.11. BLR versus number of channel wavelength for three classes with ℓ =20, A=0.01 and $w < \ell$.

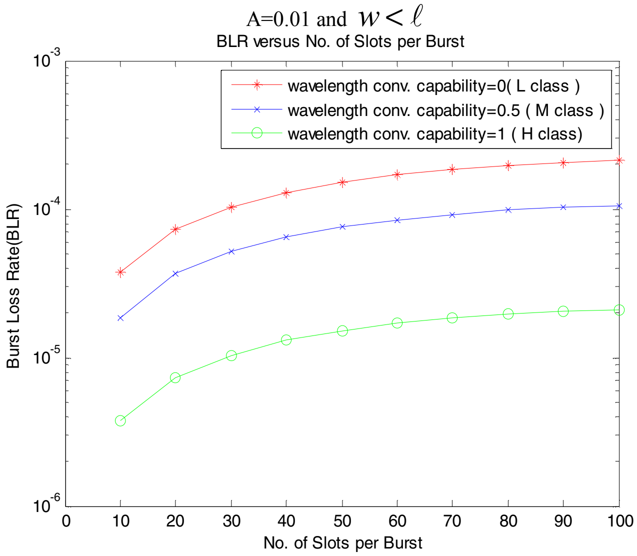

Fig.10. BLR versus number of slots per burst of three classes with w=14, A=0.01 and $w < \ell$

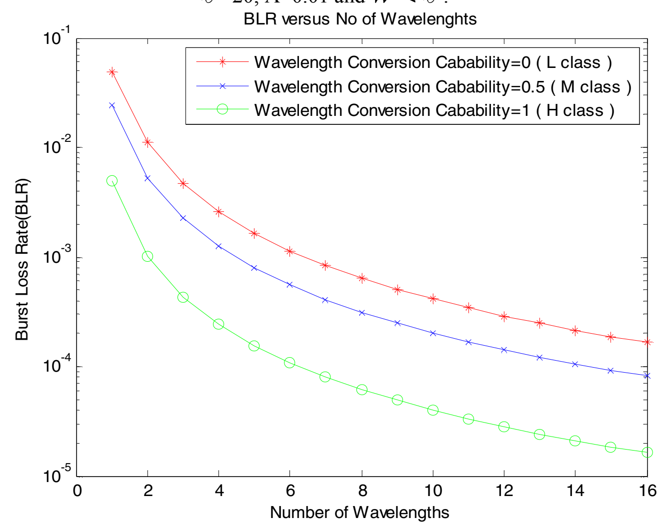

Fig.12. BLR versus number of channel wavelength for three classes with ℓ =100, A=0.01 and $w < \ell$.

Figures 9 and 10 describes that when number of channel wavelength equal 9, the BLR is greater than when it's equal 14, which means at w=14 it gives good QOS in H class.

It can be illustrate the value of wavelength conversion capability has a good impact on BLR and therefore we used it in QoS and the different between Low priority traffic (L) and Maximum priority traffic (H) is 25%.

The relation between BLR and number of channel wavelength with wavelength conversion capability and different values of number of slots per burst is shown in Figs. 11 and 12.

Figures 11 and 12 show that two different value of number of slots per burst $(\ell = 20{,}100)$ affecting on BLR, where at ℓ =20 (H class) is good BLR and this is means best QoS.

C. QoS Using Number of Slots per Burst (ℓ).

As in the second parameter, three values of number of slots per burst are assumed for this parameter with different classes represent high priority traffic (H), medium priority traffic (M), and low priority traffic (L) and $\ell = (20{,}50{,}100)$ for each class respectively.

By using Eq. 6, the relation of BLR and wavelength conversion capability with number of slots per burst parameter is plotted Figs. 13 and 14.

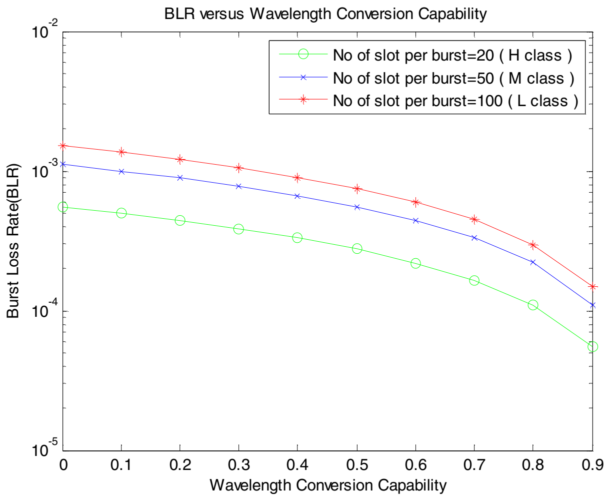

Fig.13. BLR versus wavelength conversion capability for three classes with w=9 and A=0.01

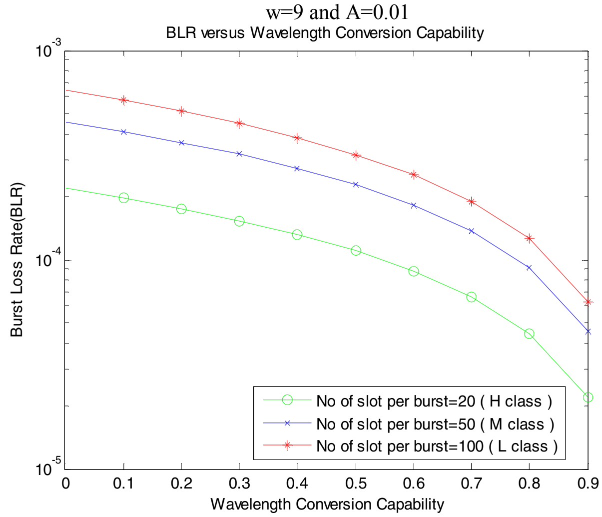

Fig.14. BLR versus wavelength conversion capability for three classes with w=14 and A=0.01

Figures 13 and 14 show at constant wavelength conversion capability, BLR decreasing as the number of slots per burst decreasing and the value of BLR when number of channel wavelength=14 is better than when it's equal 9.

It can be shown the number of slots per burst has a lowest impact on BLR and therefore it is used in QoS and the different between low priority traffic (L) and maximum priority traffic (H) is 20%.

The effect of changing number of channel wavelength on BLR is described in Figs. 15 and 16.

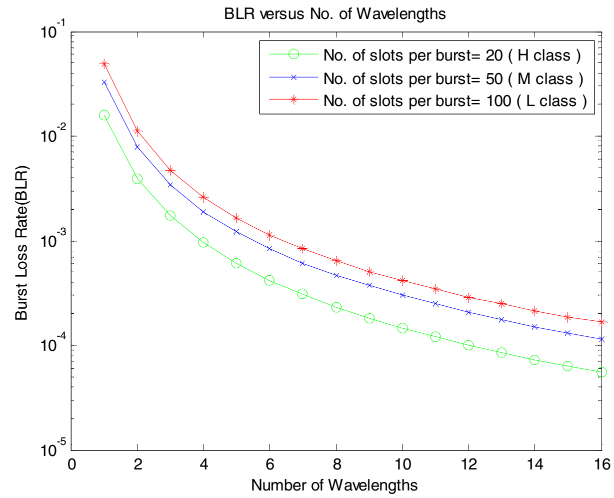

Fig.15. BLR versus number of channel wavelengths for three classes with ρ =0 and A=0.01

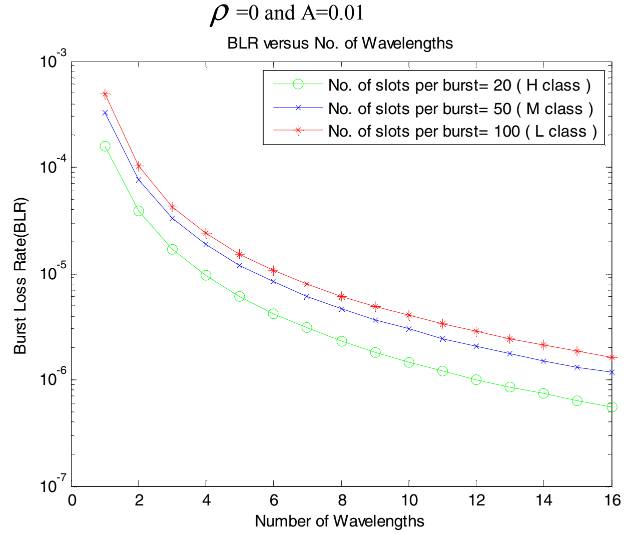

Fig.16. BLR versus number of channel wavelengths for three classes with ρ =1 and A=0.01

Figures 15 and 16 show the relation between BLR and number of channel wavelength with the number of slots per burst parameter, as when number of channel wavelength is increasing, the BLR decreasing.

At constant number of channel wavelength, BLR increasing as the number of slots per burst increasing. Also at ρ =1(full wavelength conversion) the BLR is better than at ρ =0(no wavelength conversion.

V. Conclusion

This paper shows the effect of QoS by using three parameters on BLR, number of wavelengths, wavelength conversion capability, and number of slots per burst. These parameters are used to apply QoS to traffic as high, medium, and low priority traffic based on the effect of these parameters on the BLR. It is found that, the number of wavelength has the largest effect than the wavelength conversion capability, while the number of slots per burst has the smallest effect on BLR.

So, the use of number of wavelength to apply QoS for OBS network is recommended.

For future work, in the following, we suggest some research points (on the same scope of paper) that are recommended to be further investigated:

1- Reconsidering Just-In-Time No Wavelength Conversion (JIT-NWC) without assuming that channels are evolving independently from each other.
2- Studying the case of JET with wavelength conversion or Fiber Delay lines.
3- Studying JET assuming Poisson arrivals.

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