A Study of the Number of Wavelengths Impact in the Optical Burst Switching Core Node

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***Abstract* — In Wavelength Division Multiplexing (WDM), several wavelengths run on an optical fiber link that connects two optical switches. The multiple wavelengths are exploited that minimized the contention problem in the Optical Burst Switching (OBS) core node. Mathematical model is used in order to investigate the impact of the wavelengths numbers OBS core node. Two performance metrics are proposed such as the steady-state throughput and the probability of burst loss using steady-state occupancy probabilities and Poisson traffic model arrivals. Numerical results show that at different values of network traffic and some design parameters such as wavelength conversion capability and the mean arrival rate could reveal the OBS performance.**

Keywords— Wavelength Division Multiplexing (WDM), Optical Burst Switching (OBS), wavelength converter, burst loss probability.

I. INTRODUCTION

The optical fiber has to provide huge of bandwidth for internet services broadband needed. By the amount of huge bandwidth, the optical fiber could provide multimedia services development. The services of bandwidth providing for internet services only if provided in optical fiber links. The performance of bandwidth is implemented by wavelength division multiplexing (WDM) networks [1-3]. On the optical networks, a several wavelength channels are traveled over an optical fiber link and multiplexing by WDM. Therefore, a huge bandwidth is provided in the optical networks which are exploited the WDM transmission technology [4-7].

The bandwidth requirements for internet traffic is fulfilled by optical circuits networks (OCS), in another hand, optical burst switching networks are designed to achieve a balance between optical circuit switching networks (OCS) and optical packet switching networks (OPS) [8, 9]. In static OCS networks, the adjustment and adaptable to rapidly dynamically varying traffic are not easy. To addressing this limitation, optical burst switching (OBS) is deployed in the networks. The higher bandwidth utilization efficiency is one of the advantages OBS compared to OCS in supporting IP traffic [10]. Moreover, in order to avoid complexity in optical processing at the core nodes that are mandatory in OPS networks, OBS is used at which the bandwidth and other resources are reserved for the data burst transmission using out-of-band signaling in the networks, [11].

By assigning different wavelengths independently, the data is transmitted by OBS through the optical fiber in different channels. The OBS has comprises of control burst (CB) and data burst (DB), which CB is transmitted ahead of the DB by an offset time to setup the data burst's route in the switching [12, 13]. Otherwise, the assigned resources may comprise two or more data bursts in the core node leads to the burst contention or data loss that degrading the switch performance [14].

To increase the network performance and treat with the data loss, the contention resolution strategies are an important issue in the OBS networks [15]. These strategies such as the wavelength conversion [16], fiber delay line [17], burst segmentation [18], and deflection routing [19] are suggested. The most effectively contention resolution technique is the wavelength conversion in the OBS networks. Wavelength conversion devices may be supported Full Wavelength Conversions (FWC) capability, in which optical bursts are switching from any input wavelength to any output wavelength using Tunable Wavelengths Converters (TWC). The deployment of FWC could reduce the probability of bursts loss significantly compared to the No Wavelength Conversion (NWC). However, a complexity development and cost expenditure of the optical wavelength conversion devices are still undergoing research and development [20]. Therefore to address this limitation, Partial Wavelengths Converters (PWC) is used. In PWC, there is a limited number of TWCs, which works partially when all converters are busy and some burst is blocked.

In this paper, we study the effect of increasing the number of switch wavelengths in the performance of the OBS intermediate node at different traffic values and taking into account the impact of the wavelength conversion capability as a contention resolution mechanism. The remainder of this paper is organized as follows; in section 2, a basic description of the model including the assumptions and mathematical equations are introduced. Section 3 is devoted to numerical results and performance analysis. Finally, in Section 4 the conclusion is

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presented.

II. SYSTEM MODEL

In order to evaluate the OBS core node switch performance at the impact of the number of wavelengths, we have used the analytical model of an OBS core node with and without wavelength conversion introduced by M.H.Morsy *et al.* [21], whenever used to evaluates the OBS node performance while contention among the bursts occurs. The aim's to estimated steady-state system throughput β and investigated the probability of burst loss P_B in the OBS networks.

The system model assumes that:

1. There are ω wavelengths on each optical fiber link, represented by a set $\Lambda = \{\lambda_1, \lambda_2, \ldots, \lambda_\omega\}$
2. The burst length is exponentially distributed with mean L = 1/μ and it's constant in the analysis and equal to 50 per burst time;
3. The burst arrival at a given output port of an OBS node is a Poisson process with a mean rate *A* (bursts/burst time).
4. The equivalent offered load is a = A/μ.
5. The node has *c* wavelength converters where $c \in \{0,1,2,\ldots,\omega\}$. The node conversion capability is $0 \le \gamma \le 1$.
6. If γ=0, there is no wavelength conversion capability. At γ=1, this implies that the node has full wavelength conversion capability. If 0<γ<1, the node has partial wavelength conversion capability.

The steady-state probability at state k; (k=1,2,..,ω) π_k which is the steady-state probability that the Markov chain corresponding to the Output Fiber (OF) at γ=0 is obtained as follows:

$$\pi_k = \begin{cases} \dfrac{a}{1 + a + \sum_{j=2}^{\omega} (a)^j \dfrac{1}{j!} \cdot \prod_{i=1}^{j-1} \left(\dfrac{\omega - i}{\omega} \right)} & , k = 1 \\ \dfrac{(a)^k \dfrac{1}{k!} \cdot \prod_{i=1}^{k-1} \left(\dfrac{\omega - i}{\omega} \right)}{1 + a + \sum_{j=2}^{\omega} (a)^j \dfrac{1}{j!} \cdot \prod_{i=1}^{j-1} \left(\dfrac{\omega - i}{\omega} \right)} & , k \ge 2 \end{cases} \tag{1}$$

The steady-state throughput β is the averaged number of successfully served burst arrivals by a node within a time interval equal to the burst duration; and calculated as:

$$\beta = \sum_{k=0}^{\omega} k\pi_k \tag{2}$$

While, the average burst loss probability P_B, which is the probability that a data burst DB arrival is being blocked on the average; and defined as:

$P_B = P_r$ {*incoming DB finds i free wavelengths in system*} × Pr {*incoming DB rides on busy wavelength*}

$$P_B = \sum_{i=1}^{\omega} \pi_i \cdot \frac{i}{\omega} \tag{3}$$

The steady-state probability π_k at $0<\gamma\le 1$ is obtained as follows:

$$\pi_k = \begin{cases} \dfrac{a}{1 + a + \sum_{j=2}^{\omega} (a)^j \dfrac{1}{j!} \cdot \prod_{i=1}^{j-1} \left(\dfrac{\omega - i}{\omega} + \dfrac{i\gamma}{\omega} \right)} & , k = 1 \\ \dfrac{(a)^k \dfrac{1}{k!} \cdot \prod_{i=1}^{k-1} \left(\dfrac{\omega - i}{\omega} + \dfrac{i\gamma}{\omega} \right)}{1 + a + \sum_{j=2}^{\omega} (a)^j \dfrac{1}{j!} \cdot \prod_{i=1}^{j-1} \left(\dfrac{\omega - i}{\omega} + \dfrac{i\gamma}{\omega} \right)} & , k \ge 2 \end{cases} \tag{4}$$

In the case of availability of wavelength conversion, the steady-state throughput β is the same as when γ=0, while the averaged burst loss probability P_B with wavelength conversion capability determined as follows:

$P_B = P_r$ {*incoming DB finds all ω wavelengths channels occupied*

$+ \sum_{i=1}^{\omega-1}$ Pr {*incoming DB finds i free wavelengths in system*} ×

Pr{*incoming DB rides on busy wavelength*} × Pr{*its wavelength is nonconvertible*}

$$P_B = \pi_\omega + \sum_{i=1}^{\omega-1} \pi_i \cdot \frac{i}{\omega} \cdot (1 - \gamma) \tag{5}$$

III. NUMERICAL RESULTS

In this section, the performance analysis results of the effect of the number of wavelengths in the OBS core node is presented. Both of the steady-state system throughput β and the probability of burst loss P_B are investigated by representing the different network parameters. Figure 1 shows the steady-state throughput β versus the number of wavelengths ω of the average traffic arrivals A=2, 1, 0.7, 0.4, and with no wavelength conversion capability γ=0. The results show that the steady-state throughput increases as the number of wavelengths increases. Moreover, higher wavelength number is a good solution for higher network traffic.

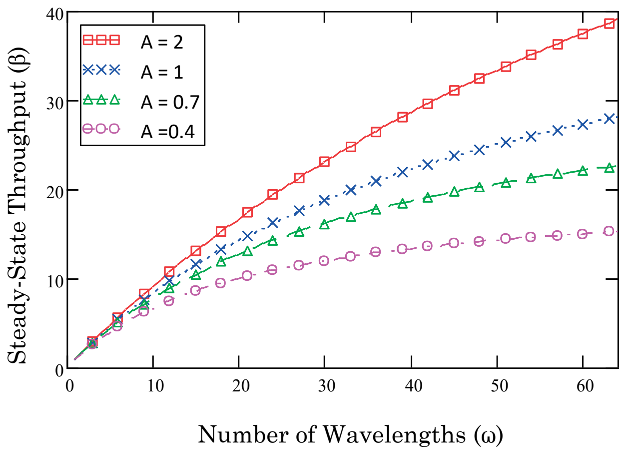

Figure 1. The Steady-State Throughput β vs. the number of wavelengths ω at different values of the arrivals A and γ=0.

In Figure 2, the probability of burst loss P_B is plotted versus the average arrivals rate A, with the availability of the wavelength numbers ω=5, 16, 32, 64 and with γ=0. When the traffic load is increased, the loss probability increases significantly at a lower number of wavelengths, while increases slowly at a large number of wavelength.

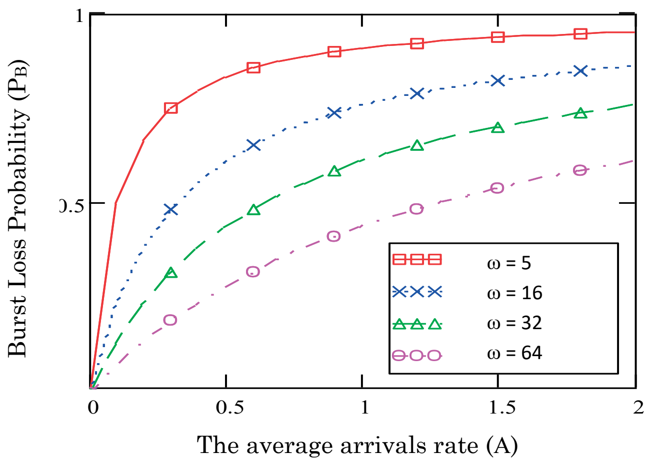

Figure 2. The Burst Loss Probability P_B vs. the arrivals A at different values of available wavelength numbers ω and γ=0.

It's clearly shown in figure 1 and Figure 2, which there is no wavelength conversion capability (γ=0), it is better to use more wavelengths in order to address contention problem, especially at higher traffic loads.

Figure 3 shows the probability of burst loss P_B versus the average arrivals rate A, with the availability of wavelength numbers ω=5, 16, 32, 64, but here at full wavelength conversion γ=1.

The observetion of adding a wavelength converter effect is indicated that at a high number of wavelengths is more useful, especially at lower traffic loads. Otherwise, adding wavelength converters at a low number of wavelengths does not have a significant impact.

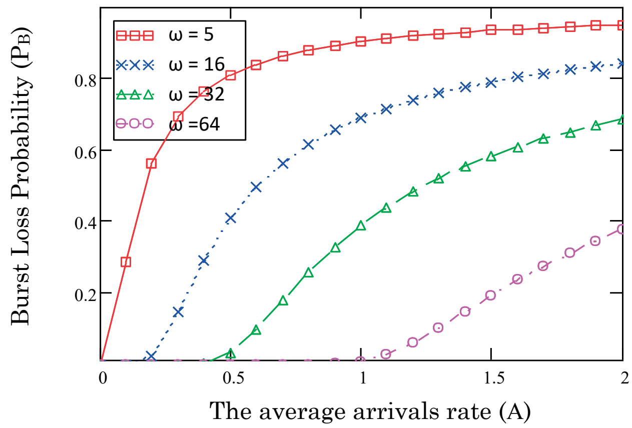

Figure 3. The Burst Loss Probability P_B vs. the arrivals A at different values of available wavelength numbers ω and γ=1.

Figure 4 shows the steady-state throughput β versus the number of wavelengths ω at A=1, and 0.4 and with γ=0, and 1. It is clear that increasing the number of wavelengths is notable at high traffic than lower traffic. Moreover, adding wavelength converters are recommended at a high number of wavelengths.

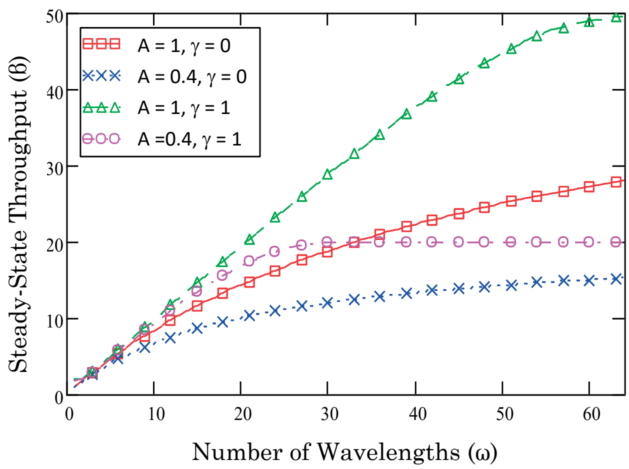

Figure 4. The Steady-State Throughput β vs. the number of wavelengths ω at the arrivals A=0.4, 1, and γ=0, and 1.

Finally, in figure 5, the loss of probability P_B versus conversion capability γ at ω=16, 32, 64 and with A=1, 0.4 is plotted. Here, the probability blocking is increased at a low number of wavelengths and higher traffic. Adding wavelength converters to the node is required for any large number of wavelengths and impacted if the load is lower.

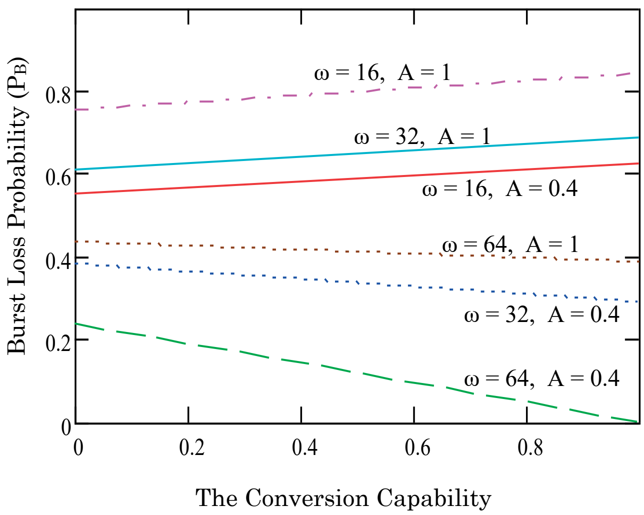

Figure 5. The Burst Loss Probability P_B vs. the conversion capability γ at different values of the number of wavelengths ω and the arrivals A =1, 0.4.

IV. Conclusion

A study on the effect of the number of wavelengths in the OBS core node in the mathematically model is evaluated. Two performance metrics of the steady-state throughput and the probability of burst loss are investigated. Performance analysis results are presented at different values of network average burst arrival rates with and without wavelength conversion capability. At a low number of wavelength channel and under heavy loads, the blocking is occurred due to the lack of a sufficient number of wavelengths. Moreover, the presence of converters does not have as much effect as at higher loads. When the number of wavelengths is larger, adding more wavelengths is preferred for higher burst traffic arrivals. In this case, the blocking occurs due to the inability of the network that uses resources efficiently in the absence of conversions. Thus converters are more useful when the number of wavelengths is larger, and it may reduce blocking systems probabilities by several orders of magnitude, which compared to with no wavelength conversion capability. Furthermore, the adequacy of the number of wavelengths channels with wavelength conversion capabilities in higher arrival traffics of the OBS core node performance could be improved.

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