Performance Analysis of a Core Node Equipped with Wavelength Converter Pool in an Optical Burst Switched Network

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Abstract— **A performance analysis of a core node in an OBS network having wavelength converters in the node resources is presented. The analysis assumes that the wavelength converters are deployed at the input ports of the node such that the node may have variable wavelength conversion capability. This means that the node may have no, partial or full conversion capability. The no and partial wavelength conversion is imitated by modeling each output port in the node as an M/M/*w*/*w* queue with limited server accessibility. Two performance measures are derived from the model; namely, the steady state throughput and the average burst loss probability assuming Poisson traffic arrivals. In addition, a simulation work is performed in order to validate the results of our proposed model. After taking into consideration the cost of the wavelength converters, optimum values for the wavelength conversion capability in the node, which lead to minimum burst loss probability, are reached for different traffic conditions.**

Keywords-component; Optical Burst Switching (OBS); Optical Circuit Switching (OCS); Optical Packet Switching (OPS); Just-In-Time (JIT); Just-Enough-Time (JET); Equilibrium Point Analysis (EPA) .

I. INTRODUCTION

Optical Burst Switching (OBS) is a new switching paradigm that can support bursty traffic introduced by upper layer protocols or high end user applications. OBS can be considered as the gate through which the envisaged realm of all-optical internet will be realized by implementing IP software directly over WDM optical layer (IP/WDM). The idea of burst switching, first proposed by researchers in [1] and [2], emerges to combine the best of both OCS and OPS. The burst is the basic switching unit in OBS networks. The variability in the burst length from being as short as a packet to being as long as a session puts OBS as an intermediate solution between OCS and OPS.

The OBS network architecture; as fully illustrated in [4], simply comprises of three parts; the ingress nodes, the core network and the egress nodes. The ingress node is the node at which the aggregation process of packets takes place to form a burst, which is considered the basic switching unit in the OBS network. The core network is the part that contains the intermediate nodes (core nodes) that have the function of forwarding the burst along a certain route until reaching its destination egress node. At the egress node, the burst is disassembled back into packets each of them to go to its own destination. It should be noted that the ingress and egress nodes in this connection can perform as core nodes in another connection setup, i.e. the functions are assigned logically.

Generally, the main idea beyond all OBS protocols is the separation between the data and control planes. Thus, the control packet (header) will be on a separate channel, called the control channel, while the data burst (payload) is sent on one of the data channels. The key concept in OBS is that each control packet is sent by the ingress node prior to its corresponding data burst by an offset time sufficient enough to eliminate the need of optical buffers in the subsequent core nodes.

Considering the reservation protocols proposed for OBS networks in previous literature, the two most common are Just-In-Time reservation protocol (JIT) [5], [6] and Just-Enough-Time reservation protocol (JET) [1], [2]. Both are one-way reservation protocols where the control packet carries information about the upcoming burst. Briefly, the control packet is sent prior to the data burst by some offset time to reserve appropriate resources, if available, after the processing of the control packet at the core node and configure the switching fabric to route the upcoming data burst to the destined output port.

The two main differences between JET and JIT are the time of reservation and the release mechanism of the resources. In JIT, the reservation of the core node resources is done immediately after the processing of the control packet, while the release of the core node resources is performed explicitly using a release packet sent on the control channel. On the other hand, the control packet in JET contains information about the time of arrival of the data burst to the node, so the resource reservation can be made immediately prior to the burst arrival, i.e. delayed reservation. The control packet also contains information about the burst length, so the release is performed implicitly when the burst departs the node. To make the proposed model valid to be used for both JIT and JET protocols, it is obligatory to compensate for the difference between the two reservation schemes applied in both protocols. This difference can be modeled as an artificial increase in the burst length in the case of the JIT protocol whereas no increase is introduced to the actual burst length in the case of JET protocol.

The major problem in such networks is the unacceptable burst dropping probability due to contention between two control packets which may occur while reserving resources for their ensuing data bursts. Various techniques were proposed in previous work for contention resolution to reduce the burst dropping probability; one of which is the availability of wavelength converters in the resources of the core node. Availability of wavelength conversion in the core node resources may take either two forms; one is the Full Wavelength Conversion (FWC); while the other is the Partial Wavelength Conversion (PWC). In FWC, a burst arriving at a certain wavelength channel can be switched onto any other idle wavelength channel towards its destination. FWC reduces burst dropping probabilities significantly compared with the case of No Wavelength Conversion (NWC); however, implementing all-optical FWC is very costly. Thus, PWC is proposed as a cost-conscious alternative to FWC. In PWC, there is a limited number of Tunable Wavelength Converters (TWCs), and consequently some bursts cannot be switched towards their destination, i.e., dropped, when all converters are busy despite the availability of free wavelength channels on the output fiber.

In PWC, TWCs may be configured as a single converter pool for converter sharing across all fiber lines, which is referred to as the Share-Per-Node (SPN) architecture [11]. An alternative architecture allows separate TWC banks per output fiber and the corresponding solution is called the Share-Per-Line (SPL) architecture [12]. Although the SPN architecture leads to a better performance, the complexity of the switching matrix is lower in the SPL architecture [11].

Another issue regarding wavelength conversion is whether there is a specified range of wavelengths that a given wavelength can be converted to. Such a TWC is said to be *limited-range*. If there is no tuning range limit then the converter is called *full-range*. The focus of the current paper is on studying the performance of an OBS core node employing PWC with full-range TWCs. The core node architecture adopted is illustrated in Fig. 1. The node is equipped with an internally non-blocking switching matrix and has M input and output fiber lines, w wavelength channels per fiber, and u TWCs implemented at each one of the input fiber lines, where $u \leq w$. It should be noted that each TWC in the adopted architecture is dedicated to a certain wavelength channel from the w available wavelength channels on each input fiber line. This is going to be called Dedicated-Per-Input-Line (DPIL) architecture. In such architecture, only u wavelengths from a total of w wavelengths can be converted to any other free wavelength, while the remaining w-u wavelengths are non-convertible ones.

Several papers appeared in the literature studying the performance of OBS networks. In [7], Yoo *et al.* model the performance of an OBS core node as an M/M/w/w queue. The drawback of that model is that it assumes that the node always has full wavelength conversion capability. In [3], Shalaby proposed a more realistic model based on EPA analysis to study the performance of an OBS core node having either no, partial or full wavelength conversion capability. In his model, he assumes Bernoulli distribution as an approximation for the Poisson arrivals per time slot. Our previous work in [9] outperforms the Shalaby's model in terms of the range of consistency by deploying a better approximation than the Bernoulli distribution for the Poisson arrivals, whereas our model suffers from a drawback that it only considers the case of absence of wavelength conversion capability in the node.

The aim of this paper is to present a new mathematical model that precludes the drawbacks of all previously presented models while being very simple in terms of the complexity of its equations. The newly proposed model studies the performance of a core node in an OBS network while presuming that the node has either no, partial or full wavelength conversion capability. Also, the model does not make any approximations for the distribution of the traffic arrivals, yet it adopts the Continuous-Time Markov Chain (CTMC) approach while assuming Poisson traffic arrivals which turns the model to be consistent for any traffic scenario. Via the model, two performance measures are obtained; namely, the steady state throughput and the average burst loss probability. Furthermore, from the results reached for the burst loss probability, we get the optimum values for the number of wavelength converters that should be implemented in each node for different traffic scenarios in order to give the best possible performance in terms of minimum burst dropping probability. Finally, we compare the results of our model which adopts a DPIL architecture for implementing PWC with the previous model in [12] that assumes an SPL architecture for implementing PWC inside the OBS core node.

The remainder of this paper is organized as follows. In Section II, we present a detailed description for our proposed model. Section III is devoted for the numerical results of the derived performance measures from both the proposed mathematical model and simulation. Finally, we give our conclusion in Section IV.

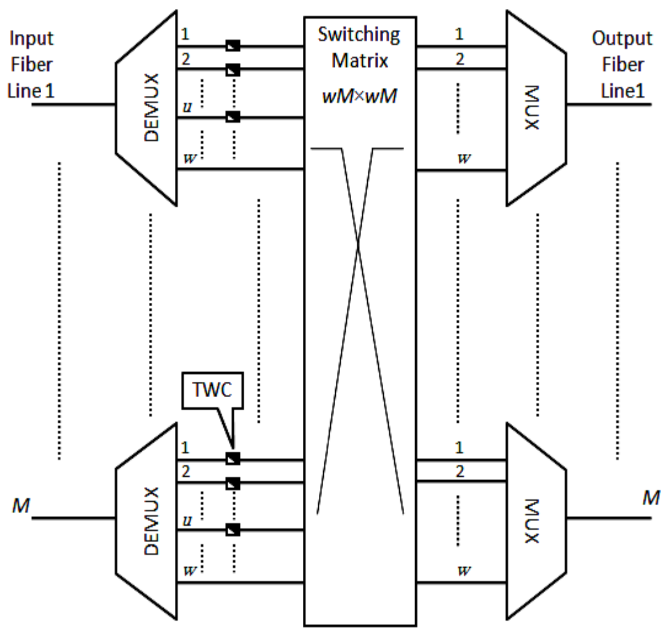

Fig.1. OBS core node architecture.

II. Model Description

This section is divided into three parts. First, we present the assumptions made on which our model is based. Second, a detailed state diagram aided with a clear explanation for its parameters is introduced. Finally, a steady-state analysis is carried out to derive the model equations.

A. Model assumptions

We formulate a Markovian model to characterize the performance of an OBS core node. This model is built under the following assumptions:

- We assume that the destination output port for an incoming burst to the OBS core node is uniformly distributed among all available output ports. Thus, it is sufficient to model the behavior of a single output port instead of considering all output ports of the node.
- Each OBS core node considered in our model is assumed to have the following resources:
  - A number of *w* wavelengths available to serve the incoming burst arrivals.
  - No fiber delay lines, i.e. there are no buffering capabilities for contention resolution in the OBS nodes.
  - A number of wavelength converters, each of them can convert the wavelength of the incoming burst to any other free wavelength from the set of the available wavelengths *w* whenever a contention is encountered by the arriving burst. Typically, the set of available wavelengths is denoted by $\Lambda \stackrel{\text{def}}{=} \{\lambda_1, \lambda_2, \dots, \lambda_w\}$ while the node has *u* wavelength converters where $u \in \{0,1,2,\dots,w\}$. This means that only *u* wavelengths of Λ can be converted to any other wavelength in the set, while the remaining *w-u* wavelengths are nonconvertible ones. We define the node conversion capability as $\gamma \stackrel{\text{def}}{=} \frac{u}{w}$. If $\gamma = 0$, this means that the node has no wavelength conversion capability, whereas if $\gamma = 1$, this implies that it has full conversion capability. If $0 < \gamma < 1$, the node has partial wavelength conversion capability.
- Incoming bursts are assumed to arrive at the node according to a Poisson process with a mean arrival rate λ bursts/ burst time. The service time of an incoming burst is assumed to have an exponential distribution with a mean $1/\mu$ time unit which is equal to the average duration of the data burst.

Upon the aforementioned assumptions, we are going to evaluate the performance of the OBS node by modeling one of its output ports as an M/M/*w*/*w* queue with limited server accessibility. For that queue, there are *w* servers in the system simulating the available *w* wavelengths in the node.

The key idea is that the *w* servers are not fully accessible unless the node has full wavelength conversion capability $(\gamma = 1)$, otherwise, for the no and partial conversion capabilities ($\gamma = 0$ & $0 < \gamma < 1$), the free servers are not allowed to be reserved by every incoming burst, i.e., the server accessibility is restricted somehow. For instance, if the node does not have any wavelength conversion capability, then each incoming burst is destined for a specific server that represents the wavelength on which it arrives and it will be blocked if this specific server is busy at the time of arrival of the data burst, i.e. the contention cannot be resolved. Moreover, if the node has partial wavelength conversion capability, then an incoming burst will be blocked if its own wavelength (server) is busy and its wavelength is nonconvertible which implies that the free servers (if any) in this case are not accessible by this burst.

The M/M/*w*/*w* queue is also characterized by a maximum number of users in the system equal to *w* which can be justified by the fact that there is no buffering capability in the node which is modeled by a queue length equal to zero.

The idea of how to imitate the limited server accessibility in the M/M/*w*/*w* queue is quoted from an analogous idea to model the customer impatience in queueing theory [10]. In such queues, where the customers tend to join the queue only if the waiting time is short enough, the birth rate is state-dependent, i.e. it is contingent on the number of customers in the system. Likewise, in the following section, we are going to model the limited server accessibility in the M/M/*w*/*w* queue by making the birth rate reliant on both the number of customers in the system and the wavelength conversion capability *γ*.

B. State Diagram

In this part, we present the state diagram representing our OBS network model. We study the OBS network in two different cases depending on the availability of wavelength conversion capability in the node. The first case is when the node has no wavelength conversion ($\gamma = 0$), while the other describes the network whose nodes are equipped with wavelength converters ($0 < \gamma \leq 1$).

- **Case (1):**

Fig.2a presents the state diagram of the OBS network in case of absence of wavelength conversion capability ($\gamma = 0$). The notation used to label each state is based on the following criterion; a state *k*, where $k \in \{0,1,2,\cdots,w\}$), represents the node when it is currently serving exactly *k* bursts. It can be easily noted that this state diagram represents a birth-death process of the Markovian model of an M/M/*w*/*w* queue with adjusted birth rate. The limited server accessibility is imitated by adjusting the birth rate to be dependent on the number of customers currently served by the node, i.e. the birth rate from state *k* to state *k*+1 is set to $\lambda.\frac{w-k}{w}$. This is shown as follows:

Birth rate = arrival rate× probability that an arrival requests a free wavelength

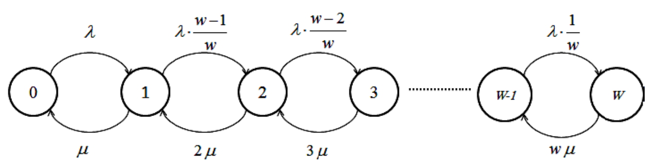

Fig.2a state diagram for an OBS core node in case of absence of node conversion capability (γ = 0)

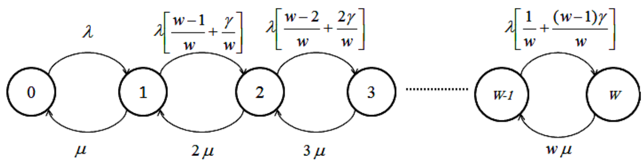

Fig.2b state diagram for an OBS core node with node conversion capability ($0 < \gamma \leq 1$)

In addition, the death rate from state k to state k-1 is set to $k.\mu$ because the rate of finishing the service of a burst that is currently served by the node has to be directly proportional to the number of busy wavelengths in this state k.

- **Case (2):**

Fig.2b presents the state diagram of the OBS network in case of presence of wavelength conversion capability ($0 < \gamma \leq 1$). The state diagram in this case is similar to the previous one except for the birth rate which will be dependent on both the number of customers currently served by the node and the network conversion capability γ, i.e., the birth rate from state k to state k+1 is set to $\lambda[\frac{w-k}{w} + k\frac{\gamma}{w}]$. This can be justified as follows:

Birth rate = arrival rate

$$\times\begin{pmatrix} \mathit{probability\ that\ an\ arrival\ requests\ a\ free\ wavelength} + \\ \mathit{probability\ that\ an\ arrival\ requests\ a\ busy\ wavelength} \times \\ \mathit{probability\ that\ the\ requested\ wavelength\ is\ convertible} \end{pmatrix}$$

In addition, the death rate from state k to state k-1 is also set to $k.\mu$.

C. Model Equations

In this part, mathematical analysis is carried out in order to evaluate two performance measures from our model; namely, the steady-state system throughput β and the average burst loss probability P_B. We perform this analysis for both previously presented cases; the case of absence of wavelength conversion ($\gamma = 0$) in addition to the case of presence of wavelength conversion ($0 < \gamma \leq 1$). Finally, we check the backward compatibility of the model equations with the conventional Erlang-B formula.

- **Case (1):**

First, we are going to derive the steady-state probabilities for the state diagram presented in Fig.2a.

By writing the cut equations for the state diagram in Fig.2a, an expression for the steady-state probability π_k in terms of π_0 is obtained as follows:

$$\pi_k = \begin{cases} \frac{\lambda}{\mu}\cdot\pi_0 & ,k = 1 \\ \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}\prod_{i=1}^{k-1}\left(\frac{w-i}{w}\right)\pi_0 & ,k \geq 2 \end{cases} \tag{1}$$

Imposing the condition that the sum of all state probabilities equals one, we can easily obtain the value of π_0. Then, substituting by π_0 into (1), one can easily evaluate the steady-state probability π_k as follows:

$$\pi_k = \begin{cases} \dfrac{\frac{\lambda}{\mu}}{1+\frac{\lambda}{\mu}+\sum_{j=2}^{w}\left(\frac{\lambda}{\mu}\right)^j\frac{1}{j!}\prod_{i=1}^{j-1}\left(\frac{w-i}{w}\right)} & ,k = 1 \\ \dfrac{\left(\frac{\lambda}{\mu}\right)^k\frac{1}{k!}\prod_{i=1}^{k-1}\left(\frac{w-i}{w}\right)}{1+\frac{\lambda}{\mu}+\sum_{j=2}^{w}\left(\frac{\lambda}{\mu}\right)^j\frac{1}{j!}\prod_{i=1}^{j-1}\left(\frac{w-i}{w}\right)} & ,k \geq 2 \end{cases} \tag{2}$$

After evaluating the steady-state probability π_k, we can find the two performance measures of our model. First, the steady-state system throughput β, which is defined as the average number of successfully served burst arrivals by the node within a time interval equal to the burst duration; is calculated as:

$$\beta = \sum_{k=0}^{w} k\pi_k \tag{3}$$

Next, the average burst loss probability P_B, which is defined as the probability that a burst arrival is being blocked or dropped on the average; can be derived also as follows:

$$\begin{aligned} P_B &= \pi_1\cdot\frac{1}{w} + \pi_2\cdot\frac{2}{w} + \cdots + \pi_{w-1}\cdot\frac{w-1}{w} + \pi_w \\ &= \sum_{i=1}^{w}\pi_i\cdot\frac{i}{w} \end{aligned} \tag{4}$$

- **Case (2):**

In this case, the node is assumed to have wavelength conversion capability ($0<\gamma\leq1$), and we can similarly derive the steady-state probability π_k from Fig.2b.

$$\pi_k = \begin{cases} \dfrac{\frac{\lambda}{\mu}}{1+\frac{\lambda}{\mu}+\sum_{j=2}^{w}\left(\frac{\lambda}{\mu}\right)^j\frac{1}{j!}\prod_{i=1}^{j-1}\left(\frac{w-i}{w}+\frac{i\gamma}{w}\right)} & ,k = 1 \\ \dfrac{\left(\frac{\lambda}{\mu}\right)^k\frac{1}{k!}\prod_{i=1}^{k-1}\left(\frac{w-i}{w}+\frac{i\gamma}{w}\right)}{1+\frac{\lambda}{\mu}+\sum_{j=2}^{w}\left(\frac{\lambda}{\mu}\right)^j\frac{1}{j!}\prod_{i=1}^{j-1}\left(\frac{w-i}{w}+\frac{i\gamma}{w}\right)} & ,k \geq 2 \end{cases} \tag{5}$$

In the case of availability of wavelength conversion, the steady-state throughput β can be derived also according to equation (3) while substituting for the steady-state probability π_k from equation (5). However, the burst loss probability P_B is calculated from the state diagram in Fig.2b in conjunction with the definition of π_k in (5) as follows:

$$\begin{aligned} P_B &= \pi_1\cdot\frac{1}{w}\cdot(1-\gamma) + \pi_2\cdot\frac{2}{w}\cdot(1-\gamma) + \cdots \\ &\quad + \pi_{w-1}\cdot\frac{w-1}{w}\cdot(1-\gamma) + \pi_w \\ &= \pi_w + \sum_{i=1}^{w-1}\pi_i\cdot\frac{i}{w}\cdot(1-\gamma) \end{aligned} \tag{6}$$

Turning our focus to validating *the backward compatibility* of the model, we compare the burst loss probability P_B

calculated from the proposed model with that obtained using the Erlang-B formula in (7) for the conventional M/M/*c*/*c* loss system.

$$P_B = \frac{\left(\frac{\lambda}{\mu}\right)^c / c!}{\sum_{i=0}^{c} \left(\frac{\lambda}{\mu}\right)^i / i!} \tag{7}$$

The Erlang-B formula cannot be used to find the loss probability for the partial wavelength conversion case because it always assumes that all the *c* servers in the M/M/*c*/*c* model are fully accessible by any incoming customer arrival. However, we can employ the Erlang-B formula to derive the loss probability in two cases; the full and no wavelength conversion. First, in case of availability of full wavelength conversion (γ=1), one can calculate the loss probability from the Erlang-B formula by simply putting the number of servers *c* equal to the number of wavelengths *w*. Second, in case of absence of wavelength conversion, one can also use the Erlang-B formula to obtain the loss probability by putting the number of servers *c* equal to one while replacing the original arrival rate λ by $\lambda/_{w}$. This is justified by the fact that each one of the *w* servers available is accessible only by bursts incoming on its specific wavelength which arrive by a rate $\lambda/_{w}$, i.e. the M/M/*w*/*w* queue in case of no wavelength conversion can be replaced by *w* similar M/M/1/1 queues one for every wavelength.

Comparing the loss probability results reached via the Erlang-B formula in case of full and no wavelength conversion (γ=1 & γ=0) with that obtained from equations (6) and (4), one can easily corroborate that our proposed model is *backward compatible* with the Erlang-B formula in case of no and full wavelength conversion.

III. SIMULATION AND RESULTS

A simulation work is performed assuming Poisson traffic arrivals to the node in order to validate our proposed model results. In this work, the throughput is measured by counting the number of burst arrivals that are successfully served by the node. Figure 3 shows the steady-state throughput β versus the average traffic arrivals λ at different values of node conversion capability γ presenting both the results of our proposed model and that of simulation assuming a fixed burst length of 50 time unit and the availability of 16 wavelengths. Fixing the burst length may be at the first glance not convenient with the OBS network, but actually it is compelling when we fix the burst length at the mean of its Gaussian distribution [8]. This figure reveals the consistency of our proposed model results with that of the simulation for a very wide range of traffic arrivals, unlike the previous model proposed by Shalaby [3] that is consistent up to an average traffic arrival rate of 0.1 burst / burst time as represented by the lower curve in Fig. 3. Moreover, our proposed model takes into consideration the degree of availability of wavelength conversion capability, unlike previous models [7] that adopt M/M/w/w model assuming full wavelength conversion capability.

There are two methods to solve the contention problem that can be discussed using our proposed model; one of which is to increase the number of available wavelengths, while the other is to increase the conversion capability in the node. In order to make the comparison between both techniques somewhat fair, Shalaby [3] has adopted a certain criterion that is based on the following equation:

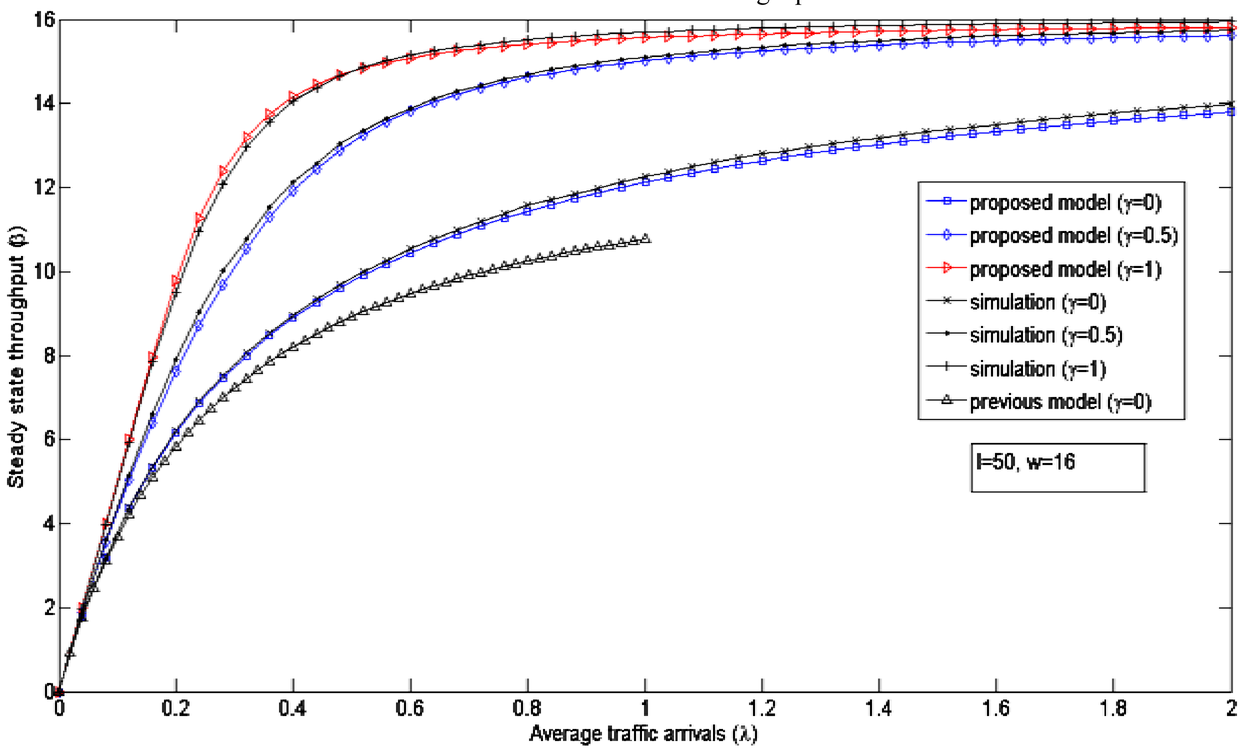

Fig. 3. Steady-state throughput versus average traffic arrival rate for both proposed model and simulation at different values for node conversion capability.

$$w = \frac{2w_o}{1+\gamma} \qquad (8)$$

where w_o is the initial number of available wavelengths and w is the number of wavelengths used at this value of γ. That is, if we increase the node conversion capability, this should be compensated by decreasing the available number of wavelengths and vice versa.

In Fig. 4, we plot the steady-state throughput β versus the average traffic arrivals λ, taking into account the condition in (8), to illustrate the tradeoff between increasing the number of wavelengths and the degree of node conversion capability.

Comparing the two techniques, it is clear that the effectiveness of increasing the conversion capability is higher at low traffic arrivals, while at high traffic arrivals the increase in the number of wavelengths is more effective in resolving the contention problem. That is, there is somehow an optimum value of node conversion capability γ_{opt} corresponding to each value of average traffic arrival rate λ.

In Fig. 5, the burst loss probability P_B is plotted versus the node conversion capability γ at different values of average traffic arrival rate λ. It is obvious that for each value of λ, there is an optimum value of γ that provides a minimum value of burst loss probability at the node. In addition, optimum values of node conversion capability decrease with the increase of the traffic, which stands with the results obtained from Fig. 4.

Intuitively, we now target the optimum values of node conversion capability γ_{opt} for each value of average traffic arrival rate λ. This relation is illustrated in Fig. 6; from which we can conclude that when the traffic arrivals goes higher, the need for wavelength converters diminishes, while adding more wavelength converters is a more convenient contention resolution technique at low values of average traffic arrival rate λ.

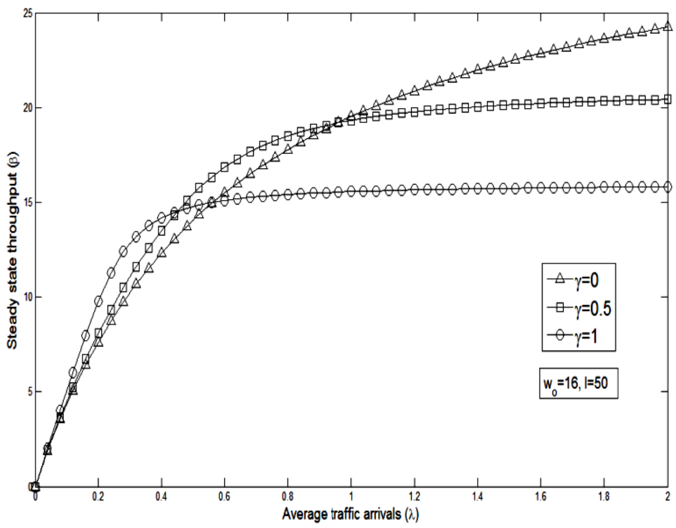

Fig. 4. Steady-state throughput versus average traffic arrival rate for different values of node conversion capability and a constraint on the number of available wavelengths and wavelength converters.

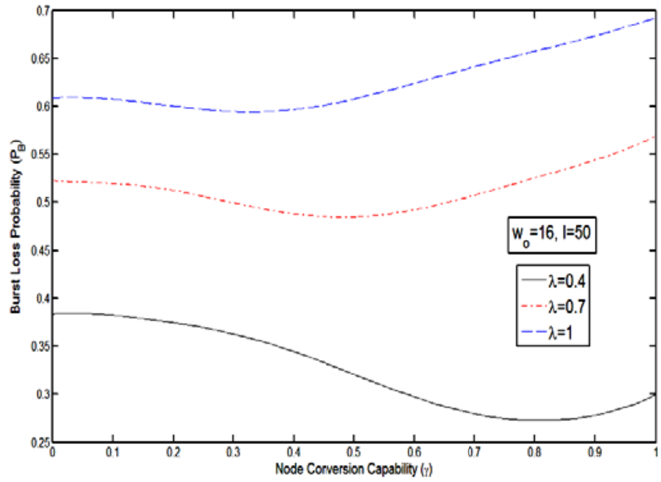

Fig. 5. Burst loss probability versus node conversion capability at different values of traffic arrival rate and a constraint on both the number of available wavelengths and wavelength converters.

Finally, in Fig. 7, we compare the burst loss probability P_B calculated from our proposed model equations for the DPIL architecture previously shown in Fig. 1 with those calculated in [12] by Akar *et. al.* for the SPL architecture. The comparison between the two models is held at different values of the offered load per wavelength ρ, where $\rho \stackrel{\text{def}}{=} \lambda / w\mu$. It is clear from the figure that SPL architecture outperforms DPIL architecture for light traffic scenarios; whereas DPIL architecture is better than SPL architecture for heavier traffic loads. This can be justified by the fact that SPL architecture is advantageous over DPIL architecture for light traffic scenarios where there is a larger number of free TWCs at each output port ready to be used by any incoming burst suffering from contention on any wavelength channel; while in DPIL architecture, there is a certain number of TWCs dedicated for specific number of incoming wavelength channels.

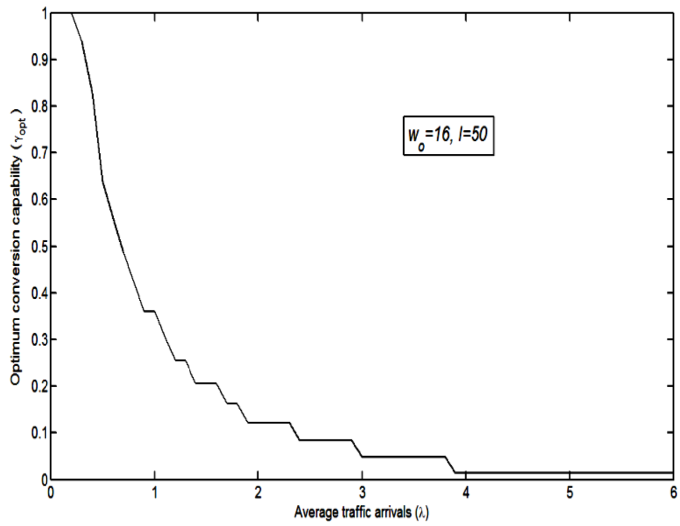

Fig. 6. Optimum values of node conversion capability versus average traffic arrival rate preserving a constraint on both the number of available wavelengths and wavelength converters.

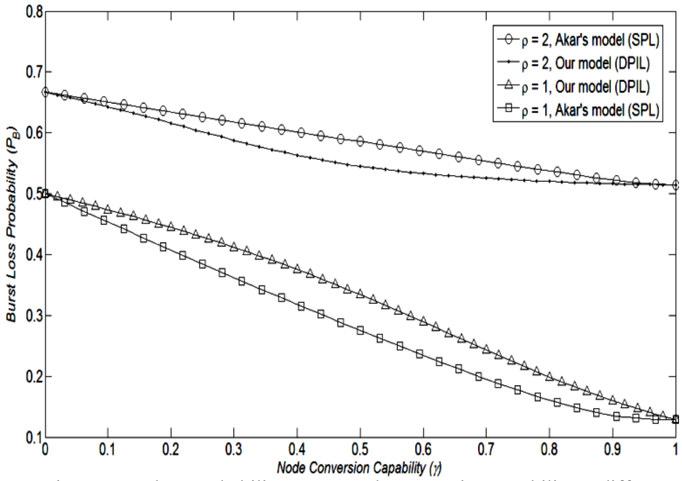

Fig. 7. Burst loss probability versus node conversion capability at different values of the offered load per wavelength for both DPIL and SPL architectures.

IV. Conclusion

A new simple mathematical model has been proposed to study the performance of intermediate node of optical burst switching networks. Our proposed model evaluates two performance measures of OBS core nodes; namely, the steady-state throughput and the burst loss probability. Numerical results are presented at different values of network traffic and various network parameters. Based on the presented results, one can come up with the following conclusions:

- In spite of the simplicity of the proposed model, it provides accurate results when compared to the simulation in addition to strong consistency for a very wide range of traffic arrival rates, which meets the nowadays high traffic demands.
- Our proposed model simulates the real case where full wavelength conversion capability is not applicable due to its unaffordable cost.
- Results of our model reveal that adding wavelength converters is effective in case of low traffic introduced to the node, while adding more wavelengths to node resources is the better choice for resolving the contention problem in case of high traffic arrivals.

Optimum values for node conversion capability obtained in the results provide suitable designing points for different values of traffic arrivals leading to minimum burst loss probability.

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