A Novel Scheme for OBS Network Resources Dimensioning

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Abstract— **Optical burst switching (OBS) technology is a promising solution for the next generation Internet backbone. The deployment of the OBS technology needs to address dimensioning and resource optimization issues that constitute an essential task in the development of OBS services. In this paper, we develop a QoS-oriented method to address these issues during the design of an OBS network. An analytic model is developed for formulating the network resource dimensioning and optimization problem. Simulation experiments are performed to validate the proposed schemes and show the determination of the optimal network configuration.**

I. INTRODUCTION

The explosive growth of Internet traffic is driving the demand for high-speed transmission technologies. Wavelength Division Multiplexing (WDM) technology [1], which can support a number of wavelength channels within a single optical fiber, has the capacity to transmit data at speeds up to a Terabit/s. Thus, an all-optical switching technology, that is able to match WDM transmission capabilities, is required to efficiently use this huge transmission capacity. Optical burst switching (OBS) [2, 3] is a promising technology for an efficient utilization of the huge bandwidth provided by the WDM optical networks.

The deployment of WDM networks introduces an acute need to consider the dimensioning and optimization aspects [4]. Different schemes have been proposed for WDM optical networks optimization. The majority of these schemes consider the routing optimization problem in wavelength routed (WR) optical networks [4-5]. A few works have addressed the optimization aspects in optical burst switched networks (e.g., [6]). However, several issues have not been considered in these works. Particularly, the use of wavelength conversion, burst segmentation, QoS management, and transmission capacity optimization were little addressed.

The aim of this paper is to study the dimensioning and resource optimization problems in the design and planning of OBS networks. We mainly address the development of an optimization work for a novel OBS network architecture suitable for contention resolution and QoS provisioning. The presented work is mainly based on the development of an analytic model for network resources dimensioning and optimization problem formulation and a simulation model to determine an optimal network configuration. We mainly consider the optimization of the buffering and transmission units, which constitute the key components of the considered OBS network architecture.

The work presented in this paper uses and extends an OBS node architecture that has been introduced in [7]. In this architecture the authors have considered the provision of differentiated services to IP packets over an OBS network as well as a QoS-oriented contention resolution scheme. The architecture is based on the re-design of optical nodes architecture to include optical delays lines and adapting the signaling protocol. Several issues, models, and experiments have been needed to validate the architecture and study its features [7-8]. Our contribution is 3-fold. First, it gives a mathematical formulation of the dimensioning problem for a large set of OBS networks. Second, our model considers an advanced QoS model that allows users to define the QoS requirements. Third, our approach is made general in the sense that it can integrate more QoS parameters and be refine to achieve deeper granularity.

The remaining part of this paper is organized as follows. Section 2 discusses the basic aspects of the considered OBS network architecture. Section 3 presents an analytic model developed for network and traffic specification. Section 4 discusses the mathematical setup of the network optimization problems. Section 5 presents a simulation model developed for an experimental resolution of the considered network resources dimensioning and optimization problems. Section 6 concludes the paper.

II. OBS NETWORK ARCHITECTURE

The reader can find in [7] a complete description of the considered OBS network architecture. In the following subsections, we recall the most important features that can be involved in node dimensioning, communication signaling, and contention resolution.

A. OBS Node Architecture

The considered OBS node architecture is composed of N input/output ports. Each port is assumed to handle multiple wavelengths. The OBS node is mainly composed of: a switching unit (SU), a waiting unit (WU), a switching control unit, an input processing unit, and an output processing unit:

- The *Switching Unit* is responsible of the transfer of input traffic units to the intended output channels, or to the waiting unit in the case of output port contention.
- The *Waiting Unit* is composed of a set of shared multi-wavelengths fiber delay line (FDL) buffers, used for output ports contention resolution. A Feed-backward FDL buffering mechanism [9] is used to allow a delayed traffic unit emerging from an FDL buffer to be re-buffered, in case of contention persistence.

- The *Switch Control Unit* supervises the SU activity and makes reservation of the needed resources. It is responsible for signaling, and contention resolution.
- An *Input Processing Unit* is associated with each input channel. It is mainly used for the reception and the Optical/Electrical (OE) conversion of burst header packets.
- An *Output Processing Unit* is associated with each output channel. It is mainly responsible for wavelength conversion in the case of output port contention.

B. *Signaling Protocols*

The JET-like signaling protocol proposed in [10] is extended to the context of the considered OBS network architecture. A burst is a pure payload composed of a set of fixed-length segments of the same traffic type. A segment is composed of a fixed number of packets of the same traffic type. A traffic type is characterized by a set of QoS constraints. The following control information are considered for a burst specification:

- *Offset time*: the period of time separating the control packet and the associated burst transmission start.
- *Burst-Length*: Number of segments in the burst.
- *Routing information*: Burst destination edge node. It is used to establish a lightpath for burst transmission.
- *Delay constraint*: Burst requirements in term of network-wide transfer delay. It allows a network node to estimate the maximum authorized blocking delay for each segment in the burst.
- *Loss constraint*: Burst sensibility level of the to the traffic loss. It is used during contention resolution as a decision criterion when the contending segments have the same delay constraints.

Optical bursts are assumed to be segmented. The burst segmentation implementation had considered several issues and challenges, including the following factors:

- *False decision alleviation:* When a segment inside a burst is dropped or delayed, a control message is sent to downstream nodes to correct segment related control information; thus, alleviate possible false decisions.
- *Segment boundary detection:* In order to facilitate segments boundary detection, we have considered that bursts are segmented using fixed-size segments.

C. *Contention Resolution Scheme*

The design of the considered OBS network architecture has required the development of a new contention resolution for a better QoS provision, and optimized resource utilization. Based on dynamic parameters of the observed traffic, the adopted scheme works as follow: For every data segment Si, we mainly consider two parameters:

- S_i_MBD: maximum network-wide blocking delay.
- Si_BD: measured online network-wide blocking delay.

In case of an output channel contention between two segments Si, and Sj, the SCU compares the differences (Si_MBD-Si_BD), and (Sj_MBD-Sj_BD). Segment, which has the lower difference between the maximum and the online blocking delay, is privileged. In case of equality, the segment of the least tolerant traffic type in term of traffic loss is privileged. In case of contention, the privileged segment is switched to the appropriate output channel, while the other is routed to another available wavelength. If no wavelength is available, a FDL buffer is used. If no FDL buffer is available, it is then dropped. Due to end-to-end transfer delay constraints, a data segment is dropped when the estimated online blocking delay exceeds the maximum authorized blocking delay.

III. OBS NETWORK MODELLING

In this section, we present the analytic model developed for the setup of the optimization formulas of the OBS network architecture. First, we consider the modeling of an OBS node, and then we try to generalize the developed model at a network level.

A. *OBS Node Modeling*

1) *Notations and Assumptions*

We consider a network system with N traffic types labeled 0,1,…, N-1. Type 0 is assumed to be the most constraining one. The arrival of segments of type i that are addressed to a specific output port of an OBS node is assumed to be Poissonian with rate λ_i. As it is mentioned above, a threshold corresponding to a maximum network-wide blocking delay is imposed for each data segment. Let m_i, $0 \le i \le N-1$, denotes the maximum WU-visits number for type i data segments. Let $ST_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$, represents the traffic sub-type consisting of segments of type i which have been delayed j times. Let $\lambda_{i,j}/\gamma_{i,j}$ denotes the arrival/departure rate of $ST_{i,j}$ data segments. Let k be the number of wavelengths available at each output port, and d the buffering capacity of the waiting unit. Let $B_{i,j}$, and $F_{i,j}$ denote the blocking probability of a $ST_{i,j}$ data segment, respectively due to the lack of wavelengths, and the unavailability of the buffering unit.

2) *Analytic Model*

Considering the presented assumptions, it becomes easy to model an output port of the considered OBS node architecture. The model, which is depicted by Figure 1, is an open queuing network system composed of two stations. Station 1, which represents the output port transmission unit has a M/D/k/k preemptive priority type. Station 2, which represents the waiting unit, has a M/D/d/d type. The whole system is assumed to handle different customers classes. Each customers class correspond to one of the considered traffic sub-types $ST_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$.

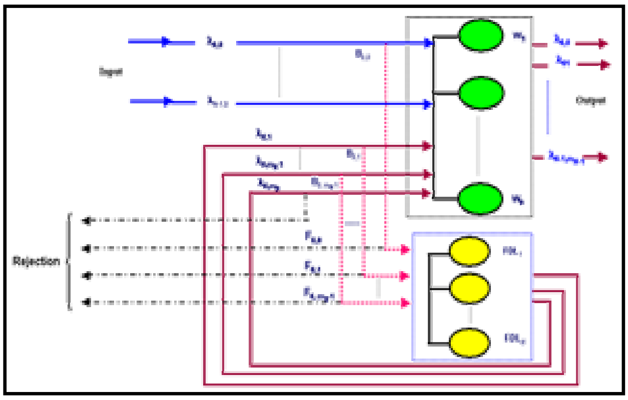

Figure 1: *OBS node modeling*

Let us consider the path followed by a customer through the proposed queuing network model. Let suppose that the arriving customer is a segment of type i, i.e., a customer of class $ST_{i,0}$. This customer can be serviced immediately or be blocked. In the first case, the customer leaves the system after being serviced during a fixed duration *Segtt* (sgment transmission time). In the second case, it is sent to station 2, where it can be serviced immediately or be dropped. In the first case, a FDL buffer is allocated to this customer during a service time *Segtt*. Then, the customer moves to station 1as a customer of class $ST_{i,1}$. Each time the customer returns to station 1, its class is updated according to the previous definition $ST_{i,1}$ $ST_{i,2}$,…$ST_{i,mi}$. A customer of the class $ST_{i,mi}$, $0 \le i \le N-1$, which cannot seize one transmission server at station 1 will be dropped.

B. *Model Generalization: Path and Network Modeling*

1) *Path Modeling*

We consider a path of length L from an ingress OBS node N_1 to an egress OBS node N_L: (N_1, N_2,…, N_L). Arriving segments of type i at the input of the considered path is assumed to be Poissonian with rate λ_i. Let m_i, $0 \le i \le N-1$, denotes the total WU-visits number threshold for a type i data segment. $ST_{i,j}$, $0 \le j \le m_i$, represents segments of class i which have been delayed j times through the considered path. Let $\lambda_{i,j}^{\ n}$, and $\gamma_{i,j}^{\ n}$, $0 \le j \le m_i$, $1 \le n \le L$, denote the arrival and the departure rate of $ST_{i,j}$ data segments at node n. Let $B_{i,j}^{\ n}$, and $F_{i,j}^{\ n}$ denote the blocking probability of a $ST_{i,j}$ data segment, at node n, due to the lack of wavelengths, and the unavailability of the waiting unit.

Once the above assumptions are made, it becomes easy to model a network path by cascading the queueing network systems associated to the different path nodes.

Received at a node n, $1 \le n \le L$, a customer of class $ST_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$, can be:

- Directly transmitted to the next node as a customer of the same class,
- Transmitted to the next node as a customer of a class $ST_{i,k}$, $j<k \le m_i$, after being delyed (k-j) times at node n,
- Dropped when the total WU-visits number threshold is exceeded, or when it is swhitched to the waiting station, and all ODLs are busy.

2) *Network Modeling*

As it is shown in figure 2(a), the queuing network system developed in the previous sub-section considers only the traffic generated at the input of the considered path. Thus, the input traffic at a given node n corresponds exactly to the output traffic of its predecessor node in the considered path, which constitutes a too particular case for a network modeling. To generalize the proposed model at a network level, a general case where a network node considers traffics received on different paths, is discussed. Figure 2(b) shows an exemple of a general case where a node n receives traffics on different paths. In the considered example, $\alpha_{i,j}$, and $\beta_{i,j}$ denote the arriving rate of $ST_{i,j}$ segments to node n, on two different paths. $\alpha_{i,j}$, and $\beta_{i,j}$ can be estimated based on the analysis of the associated paths models. Once $\alpha_{i,j}$, and $\beta_{i,j}$ are analyzed, we can estimate $\lambda_{i,j}$, the total arrival rate of STi,j data segments at the input of node n; $\lambda_{i,j}$ is eaqual to the sum ($\alpha_{i,j}+\beta_{i,j}$). Based on this example, we can say that, using the above presented models, an analytic model can be easily developed for the analysis of the considered OBS network architecture.

C. *Model Analysis*

1) *Node Performances Analysis*

Let TLP_i and ABD_i denote the traffic loss probability and the average blocking mean delay for traffic-type i, $0 \le i \le N-1$. Based on the proposed node model, we could establish the following expressions for evaluating the considered performance metrics.

$$TLP_i = B_{i,0}.F_{i,0} + \sum_{t=1}^{m_i-1} \Big(\prod_{j=0}^{t} B_{i,j}\Big).\Big(\prod_{j=0}^{t-1} (1-F_{i,j})\Big).F_{i,t} + \Big(\prod_{j=0}^{m_i} B_{i,j}\Big).\Big(\prod_{j=0}^{m_i-1} (1-F_{i,j})\Big) \qquad (1)$$

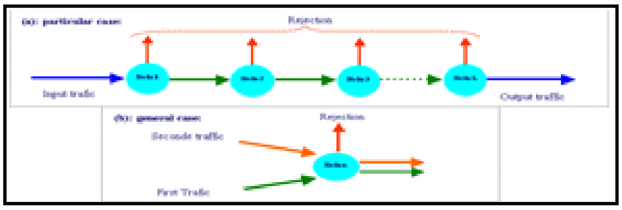

Figure 2: Analytic model generalization

$$ABD_i = \sum_{j=1}^{m_i} j.segtt.(1-B_{i,j}).\prod_{t=0}^{j-1} ((1-F_{i,t}).B_{i,t}) \qquad (2)$$

As it is shown in the above established expressions, the evaluation of cosnidered metrics require the analysis of the blocking probabilities: $B_{i,j}$, and $F_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$ of the different considered traffic sub-types.

Considereing the modeling assumptions, and the adopted contention resolution scheme, data segments are serviced (transmitted, buffered) according to a premptive priority based scheme, considerng the following order of priorities:

$$ST_{0,m_0}, ST_{1,m_1}, \ldots, ST_{(N-1),m_{(N-1)}},\ ST_{0,(m_0-1)}, ST_{1,(m_1-1)} \ldots, ST_{(N-1),m_{(N-1)}},$$
$$\ldots\ldots\ldots\ldots\ldots\ldots, ST_{0,1}, ST_{1,1}, \ldots, ST_{(N-1),1}, ST_{0,0}, ST_{1,0} \ldots, ST_{(N-1),0}$$

Let $\lambda_{i,j}$ and $\rho_{i,j}$ denote the arrival rate and the traffic intensity of the traffic sub-types $ST_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$. $\lambda_{i,j}$ and $\rho_{i,j}$ are given by the following expressions:

$$\begin{cases} \lambda_{i,0} = \lambda_i \\ \lambda_{i,j} = \lambda_{i,0} \prod_{t=0}^{j-1} B_{i,t}(1-F_{i,t}),\ 1 \le j \le m_i \end{cases}$$
$$\rho_{i,j} = Segtt\ .\lambda_{i,j},\ 0 \le j \le m_i \qquad (3)$$

Let $\beta_{i,j}$, and $\varphi_{i,j}$ denote the arrival rate and the traffic intensity of the traffic sub-type $ST_{i,j}$, $0 \le i \le N-1$, $0 \le j \le m_i$ estimated for the WU queuing station. $\beta_{i,j}$, and $\varphi_{i,j}$ are given by the following expressions:

$$\beta_{i,j} = (1-B_{i,j}).\lambda_{i,j},\quad \varphi_{i,j} = (1-B_{i,j}).\rho_{i,j} \qquad (4)$$

$ST_{0,m0}$, is supposed to be the highest priority traffic sub-type, then the corresponding blocking probabilities can be easily established using the Erlang-B formula as follow:

$$B_{0,m_0} = \frac{\ell_{0,m_0}^{k}/k!}{\sum_{i=0}^{i=k} \ell_{0,m_0}^{i}/i!}\ ;\quad F_{0,m_0} = \frac{\varphi_{0,m_0}^{d}/d!}{\sum_{i=0}^{i=d} \varphi_{0,m_0}^{i}/i!} \qquad (5)$$

The blocking probabilities of the other traffic sub-types can be easily analyzed based on of the new conservation law [11], as it is shown in [8].

2) Path Performances Analysis

Considering the above assumptions, we could establish the following expressions for the analysis of a network path of length L; (N_1, N_2, …, N_L):

$$TLP_i = (1 - \frac{\sum_{j=0}^{m_i} \gamma_{i,j}^{L}}{\lambda_i}); \quad ABD_i = \frac{\sum_{j=1}^{m_i} j.segtt.\ \gamma_{i,j}^{L}}{\sum_{j=0}^{m_i} \gamma_{i,j}^{L}} \tag{6}$$

Based on the developed model, we could establish the following expressions for the analysis the departure rate of the considered traffic sub-types:

$$\begin{cases} \gamma_{i,0}^{1} = \lambda_i.(1 - B_{i,0}^{1}) \\ \gamma_{i,j}^{1} = (1 - B_{i,j}^{1}).\lambda_i.\prod_{t=0}^{j-1} B_{i,t}^{1}.(1 - F_{i,t}^{1}),\ 1 \le j \le m_i \end{cases} \tag{7}$$

$$\text{For} \quad 2 \le n \le L, \text{ we have} \quad : \\ \begin{cases} \gamma_{i,0}^{n} = \gamma_{i,0}^{n-1}.\ (1 - B_{i,0}^{n}) \quad 0 \le i \le N-1 \\ \gamma_{i,j}^{n} = (1 - B_{i,j}^{n}).\ \left(\gamma_{i,j}^{n-1} + \sum_{k=0}^{j-1} \gamma_{i,k}^{n-1}.\prod_{t=k}^{j-1} B_{i,t}^{n}.(1 - F_{i,t}^{n})\right), \quad 1 \le j \le m_i \end{cases} \tag{8}$$

As it is shown in expressions 7-8, the analysis of the departure rates of the considered traffic sub-types requires the analysis of the blocking probabilities of the different traffic sub-types at every node of the considered path: ($B_{i,j}^{n}$, $F_{i,j}^{n}$), $0 \le i \le N-1$, $0 \le j \le m_i$, $1 \le n \le L$. These probabilities can be analyzed using the new conservation law, as it mentioned in the previous section.

3) Network Performances Analysis

Let remember that, based on the queueing network systems developped for node and path modeling, an analytic model can be easily developped for an OBS network. Thus, the above estalished analytic expressions can be simply extended for the analysis of the performances of the considered OBS network architecture.

IV. NETWORK DIMENSIONING AND OPTIMIZATION

The analyze of the above-presented analytic expressions shows that the considered performance metrics can be xpressed based on the following system input parameters: λ_i, m_i, Segtt, k, and d. Thus, one can consider, for all traffic types, two functions f, and g as:

$$TLP_i = f(\lambda_i, Segtt, m_i, k, d); \quad ABD_i = g(\lambda_i, Segtt, m_i, k, d) \tag{10}$$

Let MBD_i and $MTLP_i$, $0 \le i \le N-1$, denote respectively, the maximum blocking delay, and the maximum traffic loss probability for traffic type i. Based on these notations, the considered network resources dimensioning and optimization problems can be formulated as follow:

- *Buffering capacity optimization problem:*

  Minimize (d)
  Subject to:
  - *TLPi= f(d) < MTLPi, for all i*
  - *ABDi= g(d) < MBDi , for all i*
  - *Transmission capacity: k wavelengths/link.*

- *Transmission capacity optimization problem:*

  Minimize (k)
  Subject to:
  - *TLPi= f(d) < MTLPi, for all i*
  - *ABDi= g(d) < MBDi , for all i*
  - *Buffering capacity: d segments.*

V. SIMULATION AND NUMERICAL RESULTS

In this section, we present the simulation model developed for an experimental resolution of the considered network dimensioning and optimization problems.

A. ***Simulation Model***

- *OBS network configuration:* Figure 3 shows the topology of the OBS network on which simulation is conducted. The network is composed of N core nodes (C_1, ..., C_N) and a set of edge nodes (E_1, ..., E_8). Each core node is composed of two input/output ports. Each port is assumed to handle k wavelengths. A core node is also equipped of a WU with a buffering capacity limited to d segments. Simulation experiments consider that, an input traffic is generated at each input port of core nodes C_1 and C_2. The traffic received at an input port of a network node is supposed to be uniformly distributed between its two output ports. Moreover, all data segments must cross the same network nodes number before reaching destination (E_5, E_6, E_7, E_8).

- *Traffic model:* An input traffic is composed of bursts of different traffic types. A burst is composed of a set of fixed-length segments of the same traffic type. The inter arrival time between two successive bursts is assumed to be exponentially distributed with a mean value called MTSSB (mean time separating two successive bursts).

- *Traffic types:* Three traffic types, (type 0, type 1, and type 2) have been considered. Type 0 is the most coercive traffic type. We assumed that the input traffic ratios for traffic types 0, 1, and 2 are fixed to 40%, 20%, and 40%, respectively.

- *Input/Output parameters*: Two output parameters have been considered by the developed simulation model: The average network-wide burst transfer delay and the traffic loss mean rate. The following input parameters have been considered: the network nodes number (N), the mean time separating two successive bursts (MTSSB), a packet length (T), a segment length (Segl), and burst length (burst).

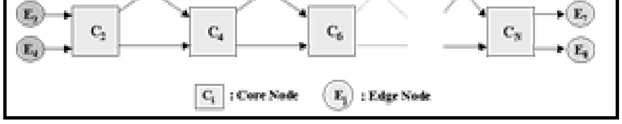

Figure 3: Evaluated OBS network configuration

B. ***Simulations Results***

Simulation experiments have been conducted for an experimental resolution for our approach to the buffering and transmission capacities optimization problem. For all simulation experiments, we have considered the following configuration: N=4 nodes, T=1µs, Segl=5 packets, Burstl=20 segments, MTSSB=2.5 µs, and the maximum network-wide blocking delays for traffic types 0, 1, and 2 (MBD_T_0, MBD_T_1, MBD_T_2) are fixed to (15µs, 30µs, and 50µs).

1) Buffering capacity dimensioning

Figures 4-5 present the impact of the buffering capacity variation respectively on the traffic loss mean rate and the average burst transfer delay when, the number of wavelengths per link (k) is fixed to 2 wavelengths. We observe that, for all traffic types, the traffic loss mean rate decreases with the increase of the buffering capacity. This corresponds to the decrease the loss probability due to the lack of buffering units; and thus the decrease of the loss probability. Figure 5 shows that, for all traffic types, the average transfer delay increases with the increase of the buffering capacity. This is because the increase of the buffering capacity decreases the blocking probability at the input of the waiting unit, and so increases the network-wide blocking delay of an accepted data segments.

Figures 4 and 5 constitute an experimental resolution of the buffering capacity (d) dimensioning and optimization problem. In fact, it allows picking up the optimal buffering capacity, to support the QoS constraints of the considered traffic types. Based on these simulation results, we can say that, a buffering capacity d=80 is needed to support the considered traffic types with the following QoS constraints: ($TLP_0 \leq 0.05$, $ABD_0 \leq 107\mu s$), ($TLP_1 \leq 0.15$, $ABD_1 \leq 115\mu s$), and ($TLP_2 \leq 0.2$, $ABD2 \leq 120\mu s$).

2) Transmission capacity dimensioning

Figures 6 and 7 show, for the three considered traffic types, the impact of the wavelengths number variation respectively on the traffic loss mean rate, and the average burst transfer delay when a node buffering capacity (d) is equal to 50 segments. We observe that, for all traffic types, performances are improved with the increase of the transmission capacity. This corresponds to the decrease of the traffic load on each output port; and thus, the decrease of contention and blocking probabilities.

Figures 6 and 7 present an experimental resolution of the above presented transmission capacity dimensioning and optimization problem. In fact, it allows picking up the optimal transmission capacity, i.e., the required wavelength number per link, to support the different QoS constraints of the considered traffic types. Based on these simulation results, one can say that, a minimum of two wavelengths per link is required to support the considered traffic types with the following QoS constraints: ($TLP_0 \leq 0.1, ABD_0 \leq 110\mu s$), ($TLP_1 \leq 0.2$, $ABD_1 \leq 115\mu s$), and ($TLP_2 \leq 0.25$, $ABD_2 \leq 120\mu s$).

3) Network resources dimensioning

S notice that the above presented simulation experiments are limited to the provision of a relative dimensioning of the network buffering and transmission capacities. In fact, the minimum number of ODLs (d_{min}) obtained through simulation results presented in figures 5 and 6 is relative to the considered network transmission capacity; k=2 wavelengths. Also, the minimum number of wavelengths (k_{min}) required to support a given traffic type, that can be determine based on figures 7-8, is relative to a node buffering capacity equal to 50 segments.

The resolution of a global network dimensioning problem, trying to optimize at the same time the network buffering and transmission capacities (k_{min}, d_{min}), can be achieved as follow: We start by determining k_{min} , for a given buffering capacity d using the above presented approach. Then, we repeat the same simulation experiment with lower values of d until we obtain d_{min}; thus, we obtain the optimum values, (k_{min}, d_{min}), of the considered parameters.

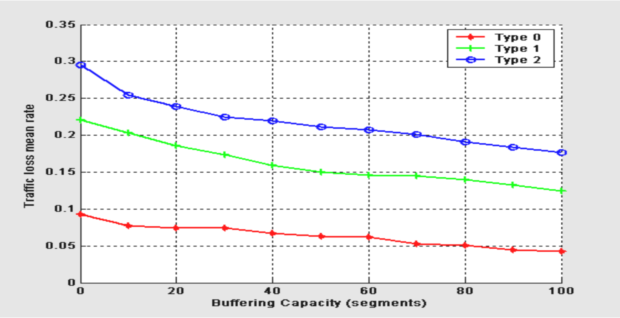

Figure 4: Buffering capacity vs. Traffic loss mean rate

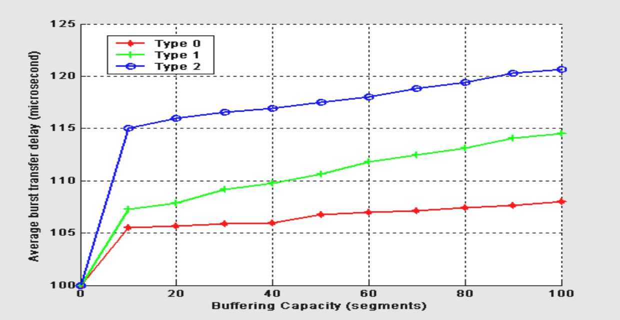

Figure 5: Buffering capacity vs. Average burst transfer delay

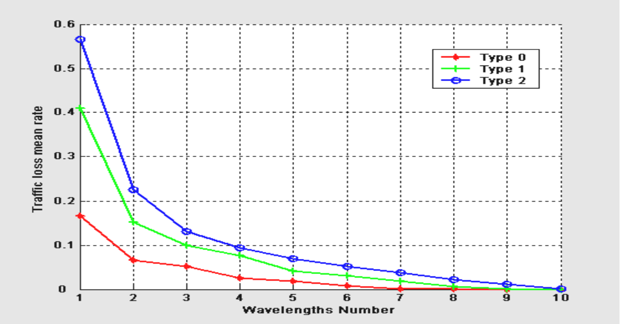

Figure 6: Wavelength number vs. Traffic loss mean rate

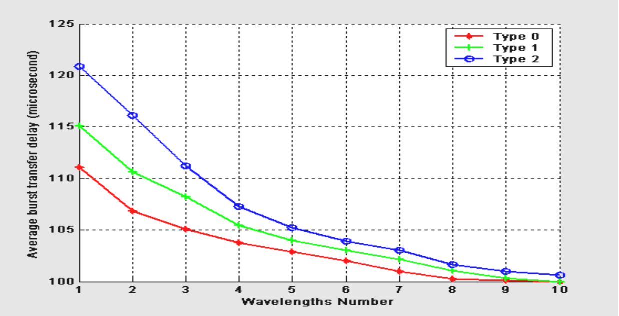

Figure 7: Wavelengths number vs. Average burst transfer delay

VI. CONCLUSION

In this paper, we have addressed a dimensioning and optimization study for an OBS network architecture suitable for contention resolution and QoS provisioning. An analytic model has been developed for formulating the network resource dimensioning and optimization problems. The formulation has been based on a conservation law. Simulations experiments have been conducted to pick up the optimal network configuration. In the presented study, we have mainly considered the optimization of the network buffering and transmission capacities. Future work will consider others network parameters such as bandwidth, jitter, and node number.

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