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# Performance Analysis of Asynchronous Optical Burst Switching Networks

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*Abstract*— **The ever increasing demand for higher bandwidth due to the growth of bandwidth intensive applications such as video-on-demand, video conferencing, on-line banking, on-line auction and other multimedia applications motivated the search for alternatives to traditional electronic networks. Optical Burst Switching (OBS) is one such paradigm developed to handle the future bandwidth demands for next-generation optical Internet. Quality-of-service (QoS) provisioning is an essential feature in next-generation networks. This paper aims at providing loss-free transmission inside the OBS network for guaranteed bursts and also to utilize wavelength efficiently. This QoS approach called Link Based QoS Provisioning (LQP) is accomplished by efficient Routing and Wavelength Assignment Scheme. It is discussed for Asynchronous and Synchronous case depending on number of paths and number of available wavelengths. In Asynchronous LQP, each path is assigned with one or more wavelength in order to establish non-overlapping paths between each pair of edge node. On the other hand, in case of Synchronous LQP only limited number of wavelengths is available, hence often paths overlap. The best routing path is selected and wavelength is assigned to the pertaining path, to provide loss-free transmission inside the OBS network. This is carried out for efficient utilization of wavelength.**

*Keywords*— **Integer linear programming, Optical burst switching (OBS), Quality-of-service (QoS) provisioning, routing, wavelength assignment.**

## I. INTRODUCTION

There is a massive bandwidth requirement for the next-generation Internet backbone networks. Wavelength Division Multiplexing (WDM) has emerged as a core transmission technology for such networks. WDM network include optical circuit switching (OCS), optical packet switching (OPS), and optical burst switching (OBS). One of the primary issues with OCS is that the link bandwidth is not utilized efficiently in the presence of bursty traffic. On the other hand, many technological limitations have to be overcome for OPS to be commercially viable. OBS networks overcome the technological constraints imposed by OPS and the bandwidth inefficiency of OCS networks. In OBS the user data is transmitted all-optically as bursts with the help of an electronic control plane. OBS is a good switching technology that benefits from the potential bandwidth that exists in optical fibers. For instance, for metrocore networks OBS networks can be, perhaps a better choice than OCS networks and they may play the role of edge optical networks to reduce the electronic-grooming requirements at the edge-core interface. Hence, this OBS paradigm is a candidate that could play an important role in next-generation networks framework for which QoS provisioning is an essential feature.

In OBS networks, data packets with the same destination are aggregated into bursts of variable lengths at the ingress node. This procedure is called Burst Assembly. After the burst assembly is created, a Control Packet (also referred to as Burst Header Packet) is first sent, using a dedicated control wavelength, from source to destination so as to reserve the required resources along the lightpath. This control packet receives an appropriate processing by undergoing Optical/Electronic/Optical (O/E/O) transformations at each core node (OBS switch). The corresponding data burst is eventually sent, on one of the data wavelengths, through the same lightpath (all-optically) without any buffering requirement inside the OBS network. This process is carried out after a delay, called Offset Time (OT).

In case of electronic networks, QoS mechanisms are based on the *store-and-forward* concept. Due to the lack of efficient optical buffering, QoS provisioning mechanisms for OBS networks less straightforward compared to the case of electronic networks. The superior buffering capabilities of electronic networks (e.g., IP networks) allow QoS provisioning using per-class queuing, buffer management, and advanced scheduling policies, which are not possible to implement at the core of the OBS network because of the lack of efficient buffers. Another issue with the QoS provisioning mechanism for OBS networks is to determine how to tackle the wavelength contentions (i.e., when two or more bursts intend to take the same output fiber, on the same wavelength, at the same time) for each class of traffic. In fact, the level of wavelength contentions in the network is reduced by reducing loss probability for the OBS network. Moreover, in the context of multiclass traffic, reduction in the loss probability of a given class of traffic can be performed by prioritizing this class when contentions occur.

In this paper, the ability of OBS networks to provide absolute QoS provisioning in terms of loss probability at end-to-end path level [(i.e., Link-based QoS provisioning (LQP)] is investigated. To be more specific, we investigate the ability of OBS networks to provide loss-free transmission inside the OBS networks for guaranteed traffic. The number of wavelengths required to establish non-overlapping paths between each pair of OBS edge nodes is much smaller than $O(N^2)$, where $N$ is the number of edge nodes; since it is less likely that all of the paths in the OBS network will be in conflict with each other. Moreover, if the issue of assigning wavelengths to links is modeled as a vertex coloring problem (VCP), the number of required colors (wavelengths) is the chromatic number of the conflict graph of the OBS network. For a given routing paths configuration, each vertex in the conflict graph represents a path and an edge exists between two vertices if the corresponding paths overlap. The number of wavelengths required can be reduced by finding a routing paths configuration, which pertains to the conflict graph with the minimum chromatic number. This reduces the number of required wavelengths to color the conflict graph, and hence, this approach makes LQP a viable solution for most OBS networks topologies.

The contribution in this paper is as follows:

A novel approach is proposed for routing and wavelength assignment problem which includes an efficient integer linear programming (ILP) formulation for the routing paths and a wavelength assignment problem for non-overlapping paths.

Here the wavelength converters and FDLs are not taken into account for the OBS network. This assumption is relevant since currently, wavelength conversion devices are complex, expensive, and not technologically mature and FDLs suffer from the lack of flexibility. Thus, the network under study can be implemented simply and cost-effectively using the existing optical networks technology. Furthermore, these assumptions allow measuring the performance improvement brought exclusively by this proposed approach. For resource reservation, Just Enough Time (JET) protocol is adopted. The remainder of this paper is as follows. Section II presents related work on QoS provisioning. Section III presents the proposed Link based QoS provisioning approach (LQP) Section IV introduces the proposed routing and wavelength assignment approach (OBS-RWA). Section V presents the results and Section VI concludes the paper.

## II. RELATED WORK

There are two kinds of QoS differentiation schemes for OBS networks: relative QoS differentiation [2], [3] and absolute QoS differentiation [4]–[8]. The difference between absolute and relative scheme is that absolute QoS guarantees, quantitatively, hard QoS requirements for high-priority bursts, whereas relative QoS importance to high-priority bursts compared to low-priority bursts. Therefore in relative scheme high priority bursts is served with higher quality (e.g., smaller loss probability). The main QoS parameter inside the OBS network is loss probability, when FDLs are not used; data bursts are switched in the optical domain at each OBS switch without any queuing delay. In [4]–[8], different absolute QoS differentiation schemes are discussed. Those schemes are based on dynamic wavelength provisioning which are applied to different classes of traffic [4], early dropping and wavelength grouping [5], Adaptive pre-emptive drop policy scheme records traffic statistics for each class of traffic and it uses pre-emption scheme to guarantee a maximum loss probability threshold for guaranteed bursts [6] and to improve the bandwidth provisioning of best effort traffic distance-to-threshold metric is used [7], [8]. All of these schemes provide a maximum loss probability threshold for high-priority traffic, and hence, allow high-priority bursts losses inside the OBS network. In this work, a new QoS scheme is introduced which provides loss-free transmission inside the OBS network for high-priority traffic. In [9], a wavelength partitioning approach is discussed. This scheme allocates one or more wavelengths to each OBS edge node in order to send its guaranteed traffic with loss-free transmission guarantee inside the OBS network; the assumption is that fiber links are operated with dense wavelength-division-multiplexing (DWDM) technology, and the number of wavelengths is bigger than the number of nodes in the network. This paper discusses about the ability of the OBS network to provide loss-free transmission inside the OBS network at path level without any limitations/assumptions on the number of wavelengths in each fiber link and the topology of the OBS network.

## III. LINK BASED QOS PROVISIONING

In this section, the approach of LQP is dealt with. First, we present LQP for two different scenarios: 1) the number of available wavelengths, the number of paths, and the routing paths configuration allow to establish non-overlapping paths between each pair of edge nodes; this scenario is called *asynchronous LQP*; and 2) the limited number of wavelengths makes that some paths overlap (i.e., use the same wavelength on at least one link); this scenario is named as *synchronous LQP*. In this section, how the LQP provides QoS provisioning in each case is discussed.

### *A. Overview*

The LQP aims at providing absolute QoS provisioning to high priority traffic classes. Without loss of generality, we consider two classes of traffic: 1) loss sensitive (LS) traffic (e.g., mission critical applications traffic); and 2) best effort (BE) traffic. For simplicity, a burst belonging to LS traffic is called LS burst and a burst belonging to BE traffic is called BE burst. LS bursts have higher priority compared to BE bursts. Based on the number of available wavelengths in each fiber link, the number of paths in the OBS network and the routing paths configuration, we distinguish *asynchronous LQP* and *synchronous LQP*.

### *B. Asynchronous LQP*

In this case, each of the two overlapping paths in the routing configuration is assigned different wavelengths. Hence, each path can be assigned a number of wavelengths (one or more wavelengths) to send its loss-free transmission guaranteed LS bursts inside the OBS network. The LS bursts can use only the wavelength(s) assigned to the particular path, whereas BE bursts are allowed to use any wavelength available at their OBS source node. The mode of sending BE traffic preserves statistical multiplexing and high resource utilization, which represent the strengths of OBS networks. The method of sending LS traffic allows loss-free transmission inside the OBS network to this class of traffic.

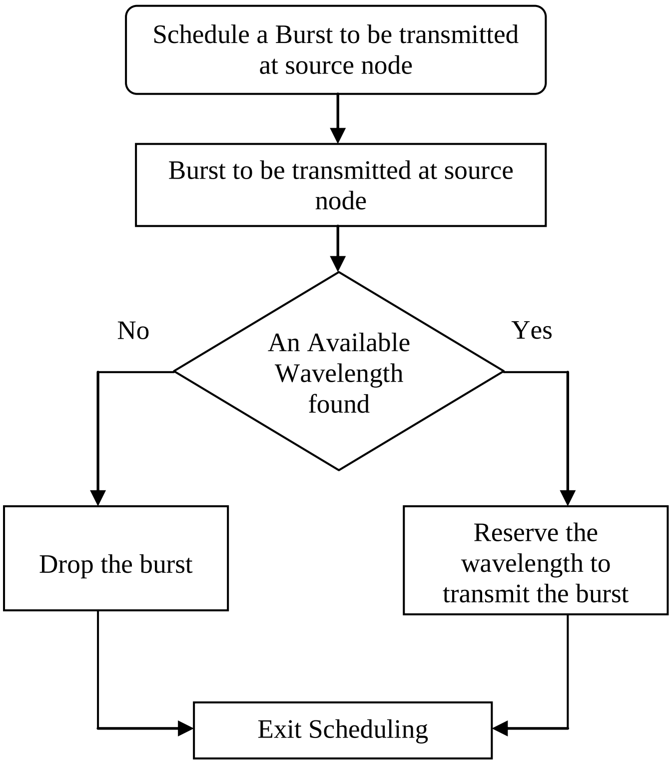

Fig. 1. Operation of asynchronous LQP

In case a LS burst contends with a BE burst, the LS burst is prioritized and it can preempt the BE burst if necessary. Fig. 1 shows the operation of asynchronous LQP.

### *C. Synchronous LQP*

In this case, few overlapping paths in the routing configuration (i.e., sharing at least one link) are assigned the same wavelength. Hence, in order to avail absolute QoS provisioning for loss-free transmission guaranteed LS bursts inside the OBS network, a subwavelength utilization scheme is required. Thus, a limited range synchronization scheme is used to provide absolute QoS provisioning to LS traffic. Once synchronization of the overlapping paths is completed, each path carries LS traffic during a period of time called time slot. More specifically, each path can only transmit a LS burst during its guaranteed time slot. If the amount of arriving LS traffic is larger than the capacity of a path to carry (or to buffer) LS traffic, the exceeding LS traffic is dropped due to buffer overflow.

## IV. ROUTING AND WAVELENGTH ASSIGNMENT APPROACH

In this section, we present the routing paths optimization part of OBS-RWA by presenting an exact and efficient formulation of the problem as an ILP model.

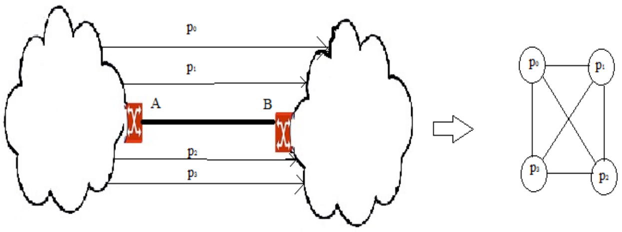

Fig. 2. Example of four paths sharing the link (A,B)

### *A. Overview*

The objective of routing paths optimization is to determine the optimal routing paths configuration which would reduce the number of required wavelengths to establish the completely non-overlapping paths, or at least, minimizes the cases of overlaps of paths. This is equivalent to finding a routing paths configuration for which the chromatic number the minimum number of colors required to color a graph properly of the conflict graph is minimum.

For example, let us consider the case, as shown in Fig. 2. In this example, the fiber link from node A to node B is shared among four paths ($p_0$-$p_3$); these paths form a complete subgraph in the conflict graph of this routing paths configuration, since they all are overlapping one another. Hence, the number of wavelengths required to alleviate path overlapping in this case is the number of paths itself (i.e., four wavelengths). The size of the maximum complete subgraph in the conflict graph (i.e., a complete subgraph of maximum size) is a lower bound on the chromatic number of the conflict graph. However, finding the maximum complete subgraph size is a NP-hard problem. In the following, instead of trying to find a routing paths configuration that minimizes the size of the maximum complete subgraph in the conflict graph, a simpler quantity to handle, such as, the largest flow (number of paths) traversing any link (i.e., a lower bound on maximum clique size and the number of wavelengths needed for contention-free routing) is optimized.

### *B. Exact Formulation*

We formulate the problem of finding routing paths between the edge nodes of the OBS network as an ILP model. We model the OBS network as a graph G (N,M), where N is the number of nodes , M is the number of fiber links and $W_m$ is the number of wavelengths in fiber link ‘m’, $D_{in}^{n}$ is the number of O/E receivers (in-degree) in node ‘n’ and $D_{out}^{n}$ is the number of E/O receivers (out-degree) in node ‘n’.

**ILP model**

**Decision variables:**

$$\mathrm{p}_{\mathrm{i,j,w}}^{\mathrm{m}} = \begin{cases} 1\text{: if a lp from node i to node j} & \mathrm{i,j} = 1, \dots \mathrm{N} \\ \text{uses wavelength w in link m,} & \mathrm{m} = 1, \dots \mathrm{M} \\ 0\text{: otherwise} & \mathrm{w} = 1, \dots \dots \mathrm{Wm} \end{cases}$$

**Objective:**

$$\text{Minimize}[\text{Maximize} \textstyle\sum_{m,w} p_{i,j,w}^{m}] \tag{1}$$

**Constrained equations:**

$$\sum_{\substack{m=m_{in}(n)\\ w=\{1,\ldots W_m\}}} p_{i,j,w}^{m} - \sum_{\substack{m=m_{out}(n)\\ w=\{1,\ldots W_m\}}} p_{i,j,w}^{m} \; i = \begin{Bmatrix} \geq 0 & \text{if} \quad n=j \\ \leq 0 & \text{if} \quad n=i \\ 0 & \text{otherwise} \end{Bmatrix} \; \forall (i,j), n \tag{2}$$

$$\sum_{i,w=\{1\ldots W_m\}, m=m_{in}(j)} p_{i,j,w}^{m} \leq D_{in}^{j} \quad \forall j \tag{3}$$

$$\sum_{j,w=\{1\ldots W_m\}, m=m_{out}(i)} p_{i,j,w}^{m} \leq D_{out}^{i} \quad \forall i \tag{4}$$

$$\sum_{i,j} p_{i,j,w}^{m} \leq 1 \quad \forall m, w \tag{5}$$

The main objective of formulation of ILP model is to maximize the number of routing paths and minimize the number of wavelengths required to color the graph to establish the completely non overlapping paths. Equation (2) is classical flow conservation constraints. Equations (3) & (4) limit the maximum length of routing paths in terms of the number of hops; both the parameters $D_{in}$ and $D_{out}$ in these constraints are specific to each network topology and they can be determined based on the diameter of the OBS network. Equation (5) guarantees that the obtained routing paths are loop less, i.e., each node in the network is visited only once by a routing path.

## V. RESULTS

In this section, we present simulation results that show the performance analysis of asynchronous LQP. We use ns-2 simulator [12] and modules that implement OBS in ns-2 [13]. We use NSFNET topology with 14 nodes (see Fig. 3).

We assume that each single fiber link is bidirectional, and all links have the same number of wavelengths each one operating at 1 Gb/s. Since the number of required wavelengths to establish completely non-overlapping paths in NSFNET topology with OBS-RWA solution is 13, we use 10 wavelengths for asynchronous LQP (i.e., the case of sufficient number of wavelengths to establish completely non-overlapping paths). Each node in the network can generate, route, and receive traffic (i.e., each node in the network is an edge and core node at the same time), however, any two nodes in the network are taken randomly as the sources and destinations of traffic connections, i.e., the traffic is dynamic and uniformly distributed over source nodes. The traffic load is expressed in terms of the normalized traffic load per link, i.e., traffic load =(mean amount of traffic carried by a link per second)/(mean link capacity per second) where the link capacity is the sum of the capacities of all the wavelengths in this link. The capacity of a link is the sum of the capacities of all the wavelengths in the link. We use exponential ON/OFF traffic. We consider loss probability, which is the main performance metric in buffer-less OBS networks. We call guaranteed traffic *loss sensitive (LS) traffic* and nonguaranteed traffic *best effort (BE) traffic*.

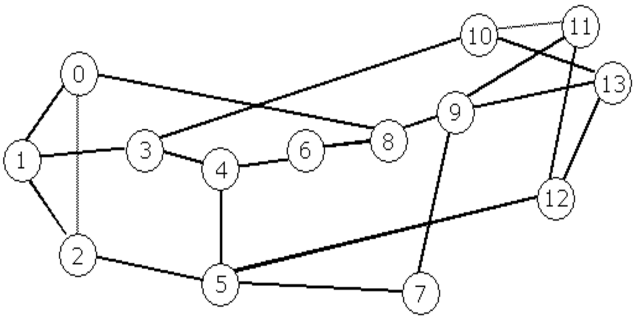

Fig. 3. NSFNET topology

The traffic arrival is Poisson process with exponentially distributed burst arrival rate and burst length (holding time) [10]. This system can be modeled as an M/M/*w*/*w* queuing system, where *w* is the wavelengths in the fiber link. The blocking probability in this system can be determined using Erlang-B formula as follows:

$$P_b = B(\alpha, n) = \frac{\frac{\alpha^n}{n!}}{\sum_{i=0}^{n} \frac{\alpha^n}{n!}} \tag{6}$$

Where α is the total amount of offered traffic in erlangs and n is the number of wavelengths.

Here we compare the performance of asynchronous LQP for two different traffic patterns. The first one being the loss sensitive traffic, which is an example for real time traffic pattern and the other is the fixed traffic where the burst is transferred between two nodes which have been defined earlier. The performance curve is better when the blocking probability decreases. From the Fig. 4 it is shown that for the same load, blocking probability decreases for LS traffic compared to fixed traffic. It is concluded that with minimum wavelengths, asynchronous LQP is able to accommodate more LS traffic inside the OBS network with loss-free transmission guaranteed and utilizes the resources efficiently compared to fixed traffic.

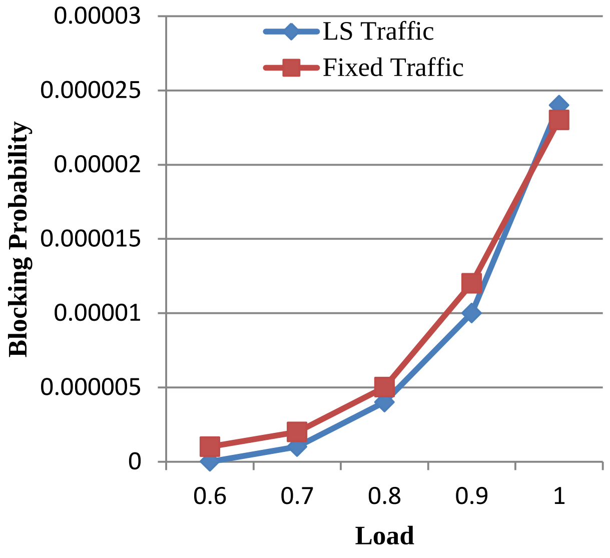

Fig. 4. Blocking probability of asynchronous LQP

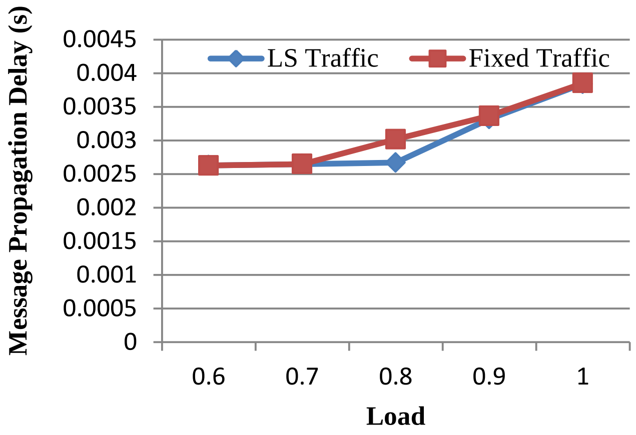

Fig. 5. Message Propagation Delay of asynchronous LQP

Fig. 5 shows the impact of Message Propagation delay or mean waiting delay for asynchronous LQP for two different traffic patterns. The mean waiting delay for real time traffic pattern i.e., loss sensitive traffic patterns like multimedia and mission critical application is considered. For this the delay decreases compared to fixed traffic. We conclude that for the maximum load, the minimum delay incurred by asynchronous LQP is 4ms. Thus with minimum delay, bursts are transferred with minimum blocking probability.

## VI. CONCLUSIONS

We proposed a novel QoS provisioning approach (LQP), which offers loss-free transmission inside the OBS network.LQP is based on a routing and wavelength assignment approach (OBS-RWA) that reduces the number of required wavelengths in order to assign a different wavelength to each path in a set of overlapping paths (asynchronous LQP). Simulation results using ns-2 simulator did show that asynchronous LQP provides loss free transmission in terms of the number of required wavelengths with minimum blocking probability and with minimum propagation delay to guarantee loss-free transmission inside the OBS network. This work can be extended to synchronous LQP which is based on limited range synchronization scheme to synchronize the transmissions of overlapping paths.

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## REFERENCES

[1] C. Qiao and M.Yoo, “Optical burst switching (OBS)—A newparadigm for an optical internet,” *J. High Speed Netw.*, vol. 8, no. 1, pp. 69–84, 1999.

[2] M. Yoo, C. Qiao, and S. Dixit, “QoS performance of optical burst switching in IP-over-WDM networks,” *IEEE J. Sel. Areas Commun.*, vol. 10, no. 10, pp. 2062–2071, Oct. 2000.

[3] Y. Chen, M. Hamdi, and D. H. K. Tsang, “Proportional QoS over OBS networks,” in *Proc. IEEE GLOBECOM*, 2001, pp. 1510–1514.

[4] S. Kim, J. S. Choi, and M. Kang, “Providing absolute differentiated services for optical burst switching networks: Loss differentiation,” in *IEE Proc.-Commun.*, 2005, vol. 152, no. 4, pp. 439–446.

[5] Q. Zhang, V. M. Vokkarane, J. P. Jue, and B. Chen, “Absolute QoS differentiation in optical burst-switched networks,” *IEEE J. Sel. Areas Commun.*, vol. 22, no. 9, pp. 1781–1795, Nov. 2004.

[6] J. Phuritatkul, Y. Ji, and S. Yamada, “Proactive wavelength pre-emption for supporting absolute QoS in optical-burst-switched networks,” *IEEE/OSA J. Lightw. Technol.*, vol. 25, no. 5, pp. 1130–1137, May 2007.

[7] L. Hongbo and H. T. Mouftah, “A new absolute QoS differentiation scheme supporting best-effort class in OBS networks,” in *Proc. ICTON*, 2007, pp. 201–204.

[8] L. Hongbo and H. T. Mouftah, “Absolute QoS differentiation with besteffort class support in optical burst switching networks,” in *Proc. IEEE ISCC*, 2007, pp. 127–131.

[9] A. Belbekkouche, A. Hafid, M. Tagmouti, and M. Gendreau,“Topology-aware wavelength partitioning for DWDM OBS networks: A novel approach for absolute QoS provisioning,” *Elsevier Comput. Netw.*, vol. 54, no. 18, pp. 3264–3279, 2010.

[10] A. Belbekkouche, A. Hafid, M. Tagmouti, and M. Gendreau,”Path-based QoS provisioning for Optical Burst Switching Networks”,*IEEElight wave tech.*,vol 29, no. 13, pp. 2048 – 2063, July 2011.

[11] M. Garey and D. Johnson, *Computers and Intractability: A Guide to the Theory of NP-Completeness.* San Francisco, CA: Freeman, 1979.

[12] NS-Simulator [Online]. Available: www.isi.edu/nsnam/ns/

[13] S. Gowda, R. K. Shenai, K. M. Sivalingam, and H. C. Cankaya, “Performance evaluation of TCP over optical burst-switched (OBS) WDM networks,” in *Proc. IEEE ICC 2003*, pp. 1433–1437.