

Optical Parameters and Link Delay Dependent Routing Metric for OBS Networks

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Abstract—New routing metric is proposed for Optical burst switching (OBS) networks taking into account some optical parameters as number of channels, load and link bandwidth. Also path delay is taken into account for best serving real time dependant applications. The results show better routing decisions than link bandwidth dependent routing metrics leading to lower BLR by more than 22% in some topologies. Also controllable BLR and path delay combination for OBS networks can be achieved.

Index Terms—Optical burst switching, Routing metric, optical routing, traffic load, channel bandwidth, number of channels, delay, real time applications

I. INTRODUCTION

At the beginning of the new millennium, several trends can be observed in the field of communications. First, convergence as a dream starts to be a fact with bandwidth requirement growth without limit for accessing unlimited resources. Internet protocol (IP) based data networks and mainly the internet plays a central role in network convergence. This is not only due to the fact that data traffic has surpassed voice traffic but even more as both of them plus many other services like video will rely on this IP cloud. Second, any increase in the network access bandwidth leads to exponential bandwidth increase needed in the core of the network to deliver this traffic from source to destination. Third, optical technology continues to provide a huge bandwidth at the physical layer which is not utilized due to problems in switching and routing layers.

In this paper, we elaborate on these trends and show how they motivate OBS as a new switching paradigm for future transport networks [1]. Then, we discuss briefly routing protocol concepts and routing metrics. After that, a detailed simulation analysis for various optical parameters that affect BLR in OBS networks is described. A new routing metric based on optical parameters dependent metric and path delay will be shown. The remaining sections focus on some examples showing the benefits of the new routing technique.

A. Photonic Network Evolution

In the late 70s of the 20th century, the first fiber based optical transmission systems were installed. Today, most wide area traffic in communication networks is carried via fibers. Until a few years ago, most systems used a single high speed optical channel and multiplexing was done in the electrical domain.

In 1995, a new technology entered the market in the USA: wavelength division multiplexing (WDM). This optical multiplexing technique allows a better exploration of fiber capacity by simultaneously transmitting multiple high-speed channels on different wavelengths [2]. WDM spans from today's point-to-point transport links over add/drop multiplexers (ADM) for ring and mesh networks to networks with higher reconfiguration speeds.

Due to low utilization factor for circuit switching, optical packet switching (OPS) seems to be a promising technology. But, due to its complexity it is expected to remain a research topic for some more years. Recently, OBS is proposed as a new switching paradigm for optical networks requiring less complex technology than OPS while conserving better utilization than circuit switching networks.

B. IP Network Evolution

The Internet is a packet-oriented network based on IP, a connectionless networking protocol. Recent years have seen an increasing demand for bandwidth mainly due to new applications, communication convergence, increasing number of users, traffic volume and growing commercial interest in network services. The Internet traffic is bursty in nature making it a typical case for applying OBS.

C. OBS Definition and Motivation

OBS is, in some way, a combination of OPS and circuit switching (CS). One can describe its main characteristics as:

1. OBS granularity is between CS and OPS.
2. There is a separation between control information (header) or setup message and data. Header and data are usually carried on different channels with a separation in time as illustrated in Fig. 1.
3. Resources are allocated without explicit two-way end to-end signaling, instead so-called one-pass reservation is applied.
4. Bursts may have variable lengths.
5. Burst switching doesn't require buffering.

OBS keeps data in the optical domain and avoids optoelectronic conversion while processing data in electronic domain. On the other hand, all-OPS is still too complex to perform all processing in the optical domain. Therefore, a hybrid approach like burst switching seems very promising. It keeps data in the optical domain but separates control information which allows sophisticated electronic processing

of this control data. Figure 1 shows some of the main characteristics of an OBS network.

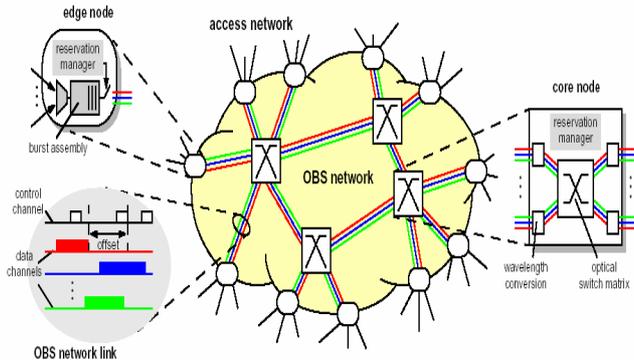


Fig.1. OBS network.

There are two types of nodes. In edge nodes, traffic is collected from access networks and assembled into larger data units, so-called bursts. Core nodes serve as transit nodes in the core network. Their main task is switching bursts without extensive processing. To achieve this, some control information containing reservation requests is necessary ahead of every burst's transmission time [3].

These reservation concepts are based on a separation of control information and data. A reservation request is sent in a separate control packet on a different channel while the actual transmission of the data burst is delayed by a certain basic offset. This basic offset enables the intermediate nodes to process control information and set up the switching matrix, thus having a complete established path from source edge node to destination edge node all in optical domain without buffering the data burst in each core node along the path [1]. There are several possibilities to perform reservation of data channel bandwidth. A reservation request is sent in a separate control packet on a different channel while the actual transmission of the data burst is delayed by a certain basic offset, as shown in Fig. 1. This basic offset enables the intermediate nodes to process control information and set up the switching matrix. In contrast to systems with immediate transmission, which send control information together with the burst, the network can do without buffering the data burst in each node along the path.

II. ROUTING

A. Routing in Optical Networks

Data routing is the process of selecting the best path for traffic between a source and destination networks based on a specific metric [4]. It is one of the most important parameters in network efficiency. Routing techniques used in optical networks such as wavelength routing is not efficient in

network utilization; as it is sort of circuit switching; [5]. Header processing in optical domain still needs more time to mature to deliver the long waiting optical packet switching.

The most used routing technique in today's networks is header processing in electronic domain. But, this downgrades the link speed to the electronic processing speed. OBS solves this problem as stated before.

The motivation, in this paper, is to select more than one routing path; if exists; and load balance the traffic between these paths based on each path BLR which leads to best utilization and minimum BLR through the whole network.

B. Routing Protocol

A routing protocol is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select routes between any source and destination on a network cloud. The choice of the route is done by using routing algorithms. Each router has knowledge only of networks attached to it directly. A routing protocol shares this information among neighbors, and then throughout the network. In this way, routers gain knowledge of the topology of the network [4].

C. Routing Metric

Routing protocols depend on a metric technique to determine the best route path. Some routing protocols depend on link bandwidth as the only parameter in calculating its metric such as open shortest path first (OSPF) while others depend on hop count such as routing information protocol (RIP) [4]. So, selecting the best path depends on the metric used such as link bandwidth or number of hops. But, optical networks are special networks having some special parameters such as number of channels. These have a great effect on utilization and BLR. Therefore, a new optical parameters dependent metric based on BLR is introduced to calculate the optimum routing path. In modern networks real time application such as voice over ip (VOIP) and video conferencing are a very important traffic loads that need some extra care. These applications are delay sensitive applications. In this paper we will aim to add delay to our routing metric, thus making our routing technique delay dependant, this will be discussed in the next sections. In the rest of this paper, we will refer to best route as the route with lowest BLR.

D. Optical Parameters Used in Routing Metric

Our mission is to get a new routing metric for OBS networks. This metric takes into account the optical parameters and delay. A detailed simulation that studied the effect of some parameters is shown including:

1. Traffic load.
2. Link bandwidth.
3. Number of channels.

At the end, we will try to get an optimized metric that depend on the BLR, taking into account the effect of these parameters on our routing decision and then adding the new delay factor. It will be seen later that this will lead to better routing, thus better utilization and minimum BLR.

III. SIMULATION

A. Simulation Software

Network simulator 2 (NS-2) is used as a simulation software in this parametric study. It is one of the best tools in the network simulation market. NS-2 is an open source code with many references and documentation [5-7]. OBS version 0.9 which is an OBS module under the NS-2 is used. Many papers have used these network simulation tools. These papers are published in the most respected magazines and conferences [7-9]. Also, all results were validated with the OBS module and also with some published paper working on the same module [10].

B. Simulation Topology

Our new routing metric requires only the link BLR at different traffic load, number of channels and link bandwidth. Figure 2 shows a simple topology used only to gather the data needed and used by our routing metric. This leads us to study different load generation on single segment with variable number of channels and link bandwidth. Our simulation topology is composed of two core nodes (C0 and C1) and one segment in between. In this topology input traffic is generated towards C0 and output traffic comes out of C1.

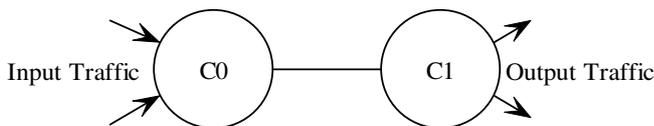


Fig. 2. OBS one segment simulated network topology.

Traffic distribution follows Poisson distribution [11] with burst size equals to 120,000 byte. Traffic flows are launched between the source and destination across studied segment. No fiber delay line (FDL) is used. By using this topology we can simulate contention over a single core link between two core nodes.

IV. SIMULATION GATHERED DATA

In this simulation we study a set of traffic load values from 10 Gbps to 100 Gbps with different link bandwidth from

10 Gbps to 100 Gbps at different number of channels (1, 5 and 10).

These result data are gathered and can be stored on a router chip with larger ranges of load, link bandwidth and number of channels (n). These selected ranges are just for demonstrating the idea. The simulation gathered data are shown in Figs. 3, 4 and 5 each for different number of channels.

These figures only show the effect of the selected parameters on BLR for a single link. But any network topology is composed of many links. That's why these data will be used as an input for our equations to calculate the total path BLR that will be used in our routing metric for any topology.

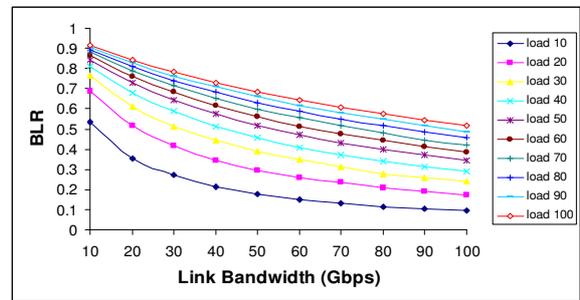


Fig. 3. Relation between link bandwidth and BLR at different loads and n=1.

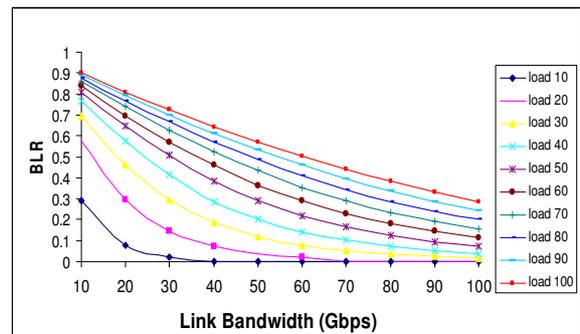


Fig. 4. Relation between link bandwidth and BLR at different loads and n=5.

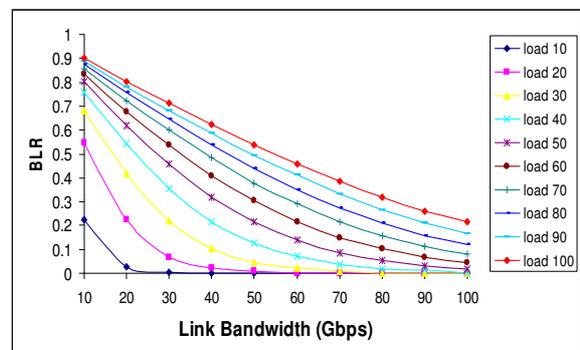


Fig. 5. Relation between link bandwidth and BLR at different loads and n=10.

V. DELAY PARAMETER

As stated before, delay is a very important factor in modern networks. The main major delay is propagation delay which is calculated in milliseconds, other processing, queuing and serialization delays are neglected as they are in microseconds. Our problem in adding delay to our introduced routing metric is that delay has no relation to BLR. But our new metric is BLR dependant. Also delay may have a different effect on different networks based on the importance and amount of real time traffic passing across these networks. Thus, a work around is introduced in this paper. A linear relation is proposed between BLR and delay. The constant factor in this relation will be the variable parameter set by the network administrator giving the importance of delay for this network.

$$BLR_L = BLR_O + BLR_D \quad (1)$$

where BLR_L is the burst loss ratio across any link, BLR_O is the burst loss ratio due to different parameters as link bandwidth, number of channels and traffic load (this can be extracted from previous figures) and BLR_D is the burst loss ratio compensating link delay.

$$BLR_D = K \times DLY \quad (2)$$

where K is the linear relation constant set by the network administrator presenting the importance of delay in this OBS network and DLY is link propagation delay in milliseconds.

The K constant ranges from zero, then delay will have no effect on BLR, and as we increase it link delay will have a great effect on BLR_L .

Figure 6 illustrates the proposed relation between BLR_D and link delay. It can be seen that the OBS network admin can set the constant K according to the OBS network needs. In this example K can be set to 0.001 making 100 ms link delay adds 0.1 to the BLR_D , also if K equals 0.002 only 50 ms link delay adds the same BLR_D as before.

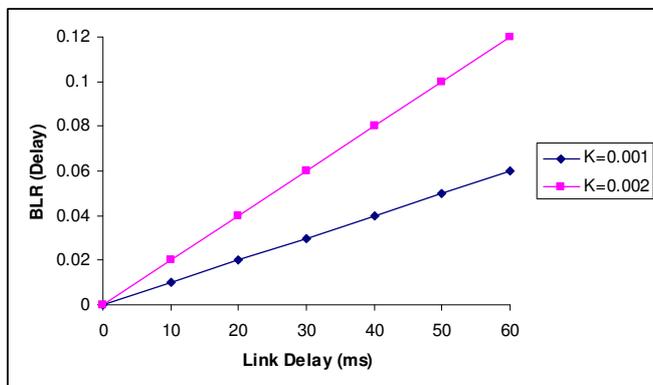


Fig. 6. Proposed relation between BLR_D and link delay.

VI. ROUTING TOPOLOGIES

This section demonstrates the benefit of the new routing metric; some topologies will be shown as an example.

A comparison is shown between a link bandwidth only dependent metric such as open shortest path first (OSPF) and the proposed metric with and without link delay effect on these topologies and the increase in performance will be calculated.

Topology 1 can be shown in Fig. 7 showing two routers, router A and router B having three links in between. These links forms three paths x, y and z. The parameters of these links are as follows.

Link X: Bandwidth=20 Gbps, n=10, Delay=10 ms

Link Y: Bandwidth=40 Gbps, n=5, Delay=100 ms

Link Z: Bandwidth=60 Gbps, n=1, Delay=50 ms

These parameters are random and just for demonstration

We will assume a load of 20 Gbps going from node A to node B.

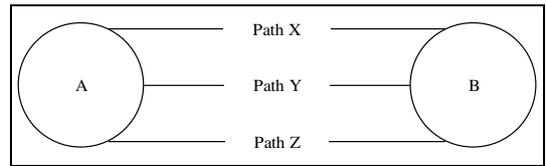


Fig. 7 two core nodes topology.

A. OSPF Calculation

$$\text{Cost} = \sum_{s=1}^M \frac{C1}{BW_s} \quad (3)$$

where BW is link bandwidth for i segment, and M are the number of link segments in the path, $C1$ is our scaling factor and it has no effect on selecting the best path. We will assume it 10^{15} in this paper

B. OSPF calculation for Selecting Best Path for Topology 1

For path X the cost (x) = $C1/(20 \cdot 10^9) = 50000$

For path Y the cost (y) = $C1/(40 \cdot 10^9) = 25000$

For path Z the cost (z) = $C1/(60 \cdot 10^9) = 12500$

OSPF always select the best path with the lowest metric (bigger link bandwidth) and insert it in its forwarding table (routing table). In this example the best path will be through z, also if z is down then through y and then x.

C. Proposed Metric Calculation for Selecting Best Path with No Delay Effect, $K=0$.

In our metric calculation, we will depend on the BLR as our routing path selecting factor. To deduce a relation for the drop rate, one can assume that the transmission probability $(1-(BLR)_l)$ for each link is independent from other links. Also, the traffic will go across all the links of the path. Thus, it can be seen that an independent probability relation exist. Then the transmission rate $T(\text{path})$ can be calculated according to

$$T(\text{path}) = L(\text{path}) \times \prod_{l=1}^n (1 - (BLR)_l) \quad (4)$$

The drop rate can be calculated as

$$D(\text{path}) = L(\text{path}) - T(\text{path}) \quad (5)$$

Substituting Eq. 4 in Eq. 5, drop rate is

$$D(\text{path}) = L(\text{path}) \times (1 - \prod_{l=1}^n (1 - (BLR)_l)) \quad (6)$$

where $D(\text{path})$ is the burst drop rate per path, $L(\text{path})$ is the traffic load carried on this path and $T(\text{path})$ is the transmission rate across the path.

$BLR(\text{path})$ can be derived by dividing Eq. 6 by $L(\text{path})$

$$BLR(\text{path}) = 1 - \prod_{l=1}^n (1 - (BLR)_l) \quad (7)$$

Equation 7 shows that, $BLR(\text{Path})$ depends only on BLR_L . From Eq. 2, $BLR_L = BLR_O$ as $BLR_D = 0$; $K=0$; no delay effect is studied in this section.

BLR_O Values can be extracted from Figs. 3, 4 and 5 based on link parameters and traffic load used on the links. In practical implementation these values will be stored in a chip on the router.

Using previous figures and link parameters one can extract the BLR values for links x , y and z .

$$BLR(x) = 0.22258, BLR(y) = 0.07231, BLR(z) = 0.25639$$

The best path will be through y , also if y is down then through x and then z . One can see that this is totally different than before.

In this example, it can be seen that by using the new metric the BLR is decreased by 18% (BLR is 25% through path z and 7% through path y) but path Y is the longer in delay (100 ms).

D. Proposed Metric Calculation for Selecting Best Path with Delay Effect, $K>0$.

We will assume $K=0.002$, in this case BLR_D will be added to the previous $BLR(\text{path})$ leading to,

$$BLR(x) = 0.24258, BLR(y) = 0.27231, BLR(z) = 0.35639$$

This result shows that path x is chosen then path y and then path z . BLR through path x is decreased by 3.4% than path z which is chosen by OSPF. But we lost around 15% of our burst than path y while gaining 90 ms of path delay. So, it is a trade off between burst loss and path delay. This compromise is controlled through the relation constant K .

Another example is shown in Fig. 8. Topology 2 is composed of four routers connected with four segments. The parameters of these link segments are as follows:

- Link S1: Bandwidth=60 Gbps, $n=1$, Delay=10 ms
- Link S2: Bandwidth=90 Gbps, $n=5$, Delay=20 ms
- Link S3: Bandwidth=40 Gbps, $n=10$, Delay=80 ms
- Link S4: Bandwidth=50 Gbps, $n=10$, Delay=70 ms

These parameters are random and just for demonstration

We will assume a load of 30 Gbps going from node A to node D.

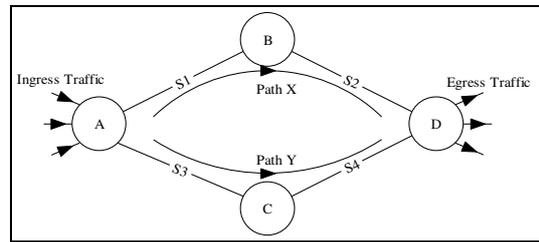


Fig.8 Four core nodes topology.

A. OSPF Calculation for Selecting Best Path for Topology 2

By using equation 1 one can calculate the total cost as follows.

$$\text{Total Cost (path x)} = \text{cost (s1)} + \text{cost (s2)}$$

$$\text{Cost (s1)} = C1/(60 \cdot 10^9) = 12500$$

$$\text{Cost (s2)} = C1/(90 \cdot 10^9) = 11111$$

$$\text{Total cost (path x)} = 23611$$

By the same method, we can calculate total cost for path y

$$\text{Total Cost (path y)} = \text{cost (s3)} + \text{cost (s4)}$$

$$\text{Total cost (path y)} = 25000 + 20000 = 45000$$

In this example, the best path will be through x, also if x is down then through y.

B. Proposed Metric Calculation for Selecting Best Path with no Delay Effect, K=0

Based on equation 2 $BLR_L = BLR_O$ as $BLR_D = 0$; $K=0$; no delay effect is studied in this section. BLR_O can be extracted from Figs. 3, 4 and 5 as shown below:

$BLR (s1) = 0.34920$, $BLR (s2) = 0.02454$
 $BLR (s3) = 0.10467$, $BLR (s4) = 0.04507$

One can calculate the BLR (path) using Eq. 5

$BLR (x) = 0.36517$, $BLR (y) = 0.145$

It can be seen that path y is preferred when using the new proposed routing metric. It is shown that a gain of around 22% decrease in the BLR is achieved in this topology when we used the new metric instead of OSPF metric.

Figure 9 shows the relation between traffic load and BLR for topology 2. It can be seen that the number of channels has the upper hand effect on BLR for low and medium traffic load. When traffic load is high, link bandwidth is the dominant factor on BLR. It can be shown that path y is the better path (lower BLR) for traffic load less than 60 Gbps. For higher traffic load path, x is the preferred path because of its lower BLR.

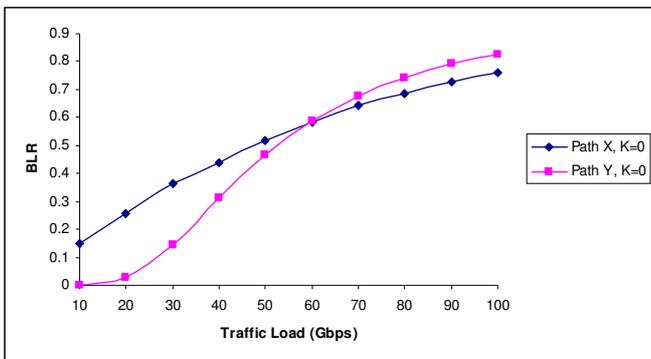


Fig. 9. Relation between traffic load and BLR for topology 2 with K=0.

D. Proposed Metric Calculation for Selecting Best Path with Delay Effect, K>0.

We will assume $K=0.002$, in this case BLR_D will be added to the previous BLR (path) leading to,

$BLR (x) = 0.42517$, $BLR (y) = 0.445$

Thus path x will be the best path.

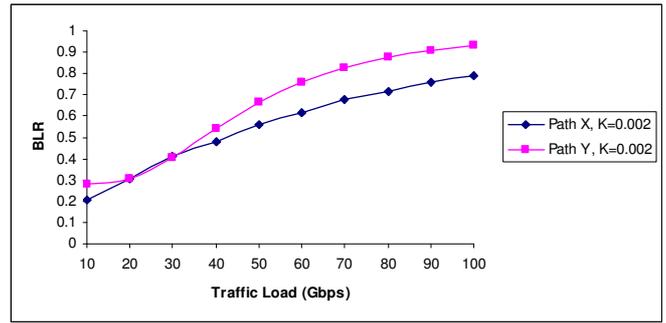


Fig. 10. Relation between traffic load and BLR for topology 2 with K=0.002.

The delay effect added to the BLR can be illustrated in Fig.10. It shows the relation between traffic load and BLR for topology 2 with K value of 0.002. It can be seen that routing decision will be totally different than Fig.9. Path x is nearly the preferred path for all traffic loads because of its lower BLR. It can be seen that, this path has a much lower delay which is 30 ms instead of 150 ms through pass y. Even that path x has a higher real BLR than path y as shown in Fig.9. The network admin has the upper hand to make delay the dominant parameter in the network.

VII. CONCLUSION

New routing metric based on BLR is introduced in this paper. It calculates better routing paths than link bandwidth dependant routing metric. Some topologies show that by using the new metric the BLR is decreased by 22%. The new metric takes into account the effect of number of channels, load and link bandwidth on BLR and thus on the new routing decision. Also path delay is taken into account for best serving real time dependant applications. This gives the flexibility to network administrators to compromise between BLR and path delay based on the network needs. Results show better routing decisions lead to controllable path delay and better BLR and path delay combination for OBS networks.

REFERENCES

- [1] C. Qiao and M. Yoo, "Optical burst switching (obs) - a new paradigm for an optical internet," J. High Speed Networks, vol. 8, pp. 69-84, 1999.
- [2] Ant'nio Jaime Ramos, "Optical network architectures: routing and protection," Proc. OADM Workshop, Netherlands, April 1998.
- [3] J.Y. Wei and R.I. McFarland, "Just-in-time signaling for wdm optical burst switching networks," J. Lightwave Technol., vol.18, no. 12, pp. 2019-2037, 2000.
- [4] Cisco Systems Inc. (2007), "cisco press - 1587200546 cnp practical studies: routing", Cisco Press. URL: <http://safari.ciscopress.com/1587200546/ch02>, last access in 30 December 2007.

- [5] Kevin Fall and Kannan Varadhan (Editors), The ns Manual (formerly ns Notes and Documentation), The VINT Project, A Collaboration between researchers at UC Berkeley, LBL, USC/ISI, and Xerox PARC, Nov. 2, 2003.
- [6] Ramakrishna Shenai, Sunil Gowda, Krishna M. Sivalingam, Candan Cankaya, Optical Burst-Switched Wavelength Division Multiplexed Network Simulator (OBS-ns): Design, Implementation, and User Manual, Washington State University/School of EECS, Report on Alcatel Sponsored Research, (available with OBS-ns version 0.6 distribution), Nov. 2001.
- [7] Ye, Q. MacGregor, M.H., "Combining petri nets and ns-2: a hybrid method for analysis and simulation," Communication Networks and Services Research Conference, CNSR 2006. Proceedings of the 4th Annual Publication, May 24-25, 2006.
- [8] Pablo Molinero-Fernández and Nick McKeown, "Performance of circuit switching in the internet," Journal of Optical Networking, vol. 2, Issue 4, pp. 83-96, 2003.
- [9] Callegati, Franco, Cerroni Walter and Raffaelli Carla, "Impact of optical packet loss and reordering on TCP performance," Global Telecommunications Conference, GLOBECOM, pp. 1-5, Nov. 2006.
- [10] Wael Hosny Fouad Aly, Mohamed Faten Zhani, Halima Elbiaze, "Using closed loop feedback control theoretic techniques to improve obs networks performance," IEEE Workshop on Optical Burst Switching (WOBS 2007), 10 pages, Raleigh, NC, USA, Sep. 2007.
- [11] Tai-Won Urn et al. "Soft-state bandwidth reservation mechanism for slotted optical burst switching networks," ETRI Journal, vol. 30, no. 2, April 2008.