Minimum Blocking Probability in OBS Networks Optimized for an Initial Static Load

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Abstract. *Dynamic traffic demands are becoming important in optical networks design. In the transition towards full dynamic traffic, optical networks optimized for a specific set of static connections will most likely also be used to support on-demand traffic. We consider a loose topology, in which static and dynamic traffic demands share the physical resources of the network. For this purpose, we consider one different static VTD/RWA heuristic, the AMLDA (Adaptative Minimum-Delay Logical Design Algorithm), to accomplish the static demand. We also consider an optical burst switching strategy to solve the dynamic RWA problem. Our objective is to evaluate the impact, in terms of blocking probability, of different static VTD/RWA heuristics over the burst requests from the dynamic traffic.*

Resumo. *A demanda por tráfego dinâmico é cada vez mais importante no planejamento de redes ópticas. Nesta fase de transição do tráfego estático para dinâmico, a otimização de um conjunto das requisições estáticas deve ser realizada para dar suporte ao futuro tráfego dinâmico. Neste artigo, nós consideramos uma topologia "frouxa" em que demandas estáticas e dinâmicas compartilham os recursos físicos da rede. Para isto, nós consideramos uma nova heurística para o tradicional problema VTD/RWA, a AMLDA (Adaptative Minimum-Delay Logical Design Algorithm), que acomoda demandas estáticas, baseada num método iterativo. Nós também consideramos uma estratégia de comutação por rajadas para solucionar o dinâmico RWA. Nosso objetivo é analisar o impacto, em termos de probabilidade de bloqueio, de diferentes heurísticas VTD/RWA estáticas na requisição de rajadas do tráfego dinâmico.*

1. Introduction

Planning real world telecommunications is a task of growing complex. The complexity results not only from the fact that the networks are large and functionally complex, subject to continuous technological evolution and growth, but also that network planning is a multidimensional techno-economic optimization problem [Mukherjee et. Al., 1996; Chlamtac et. al.,1993].

Optical Networks planning draws an increasing amount of attention nowadays. An all-optical network with wavelength division multiplexing (WDM) can use the large bandwidth available in optical fiber to realize many channels, each at a different optical wavelength, and each of these channels can be operated at specific data rates (up to 40Gbps) [Ramaswami, 1998]. In such networks, a significant gap exists between the huge transmission capacity of WDM fibers and the electronic switching capacity, generating an electronic switching bottleneck [Ramaswami, 1998].

Several different switching strategies have been developed for the transfer of data over WDM networks bypassing the electronic switching bottleneck. An optical signal can bypass though intermediate nodes without undergoing conversion to electronics, thereby reducing the cost associated with providing high-capacity electronic switching at each node.

Optical burst switching (OBS) is a technology positioned between wavelength routing (i.e., circuit switching) and optical packet switching [Qiao et. al., 1999]. All-optical circuit networks tend to be inefficient for dynamic traffic that has not been groomed or statistically multiplexed, and optical packet switching requires practical, cost-effective, and scalable implementations of optical buffering and optical header processing. OBS is a technical compromise that does not require optical buffering or packet-level parsing, and it is more efficient than circuit switching when the sustained traffic volume does not consume a full wavelength.

In this paper we propose a loose topology [Assis and Waldman 2004; Assis et. al. 2005; Maranhão et. al., 2006] i.e., we decided to focus on the combination of static and dynamic traffic. So we decided to start with a somewhat arbitrary approach for the dimensioning of the resources allocated to the static demand, assigning a fixed number of ports per node for this purpose. In this scheme, static and dynamic demands use different ports, but share the wavelengths. However, the static path configuration does not follow any classic method for static virtual topology design and Routing and Wavelength Assignment (RWA) problem, but is rather done through the proposed Adaptative Minimum Logical Delay Algorithm AMLDA, which is oriented the minimization of blocking probability of future unknown demands OBS. In other words, we have used a (modified) classical MLDA algorithm [Ramaswami and Sirvajan, 1996] to configure the static path topology.

2. Statement Problem and Previous Work

In general, the network design problem can be formulated as an optimization problem aimed at maximizing network throughput or other performance measures of interest. Typically, the exact solution can be shown to be NP-hard, and heuristic approaches are needed to find realistic good solutions [Murthy and Gurusamy, 2002].

In optical networks, Chlamtac, Ganz and Karmi [Chlamtac et. al.,1992; Chlamtac et. al., 1993] introduced the concept of lightpath as an optical communication path (data channel) established between two nodes in the network, created by the allocation of the same wavelength throughout the path. Transmissions between lightpath endpoints does not require processing or buffering at the intermediate nodes, and as such, lightpath communication alleviates the bottleneck created at intermediate nodes. Ramaswami and Sivarajan [Ramaswami et. al., 1995] showed the RWA as an NP-hard problem and formulated it as an integer linear program(ILP). Datta, Mitra, Ghose and Sengupta [Datta et. al., 2004] proposed a polynomial time optimal RWA algorithm, which optimizes the assignment of a wavelength in terms of maximizing one-hop traffic in a tree topology.

The virtual topology is the network topology in which a link represents a lightpath that has been established between two physical nodes. The virtual topology is also sometimes called the optical connection graph or the logical topology. We will use the terms interchangeably. The virtual topologies can fall into two categories: Static, which is formed with the help of static lightpath establishment and Reconfigurable, which is formed with the help of dynamic lightpath establishment. In dynamic lightpath establishment, the lightpaths are set up according to some connection requests at regular intervals and torn down after it's holding time elapses [Mokhtar et al., 1998].

To design a lightpath topology for a given physical topology, we need to determine the edges (lightpaths) in the virtual topology, choose a route for each of the lightpaths, choose a wavelength for each of the lightpaths. Lightpath topology problem can therefore be decomposed in subproblems. Although this result in a suboptimal solution, it is well acceptable for complexity reasons.

Currently, we are witnessing a new evolution of WDM networks today, as a consequence of a big change in the application scenario. Data traffic is going to overcome traditional telephone traffic in volume: statical modeling of network load has to be modified to describe a new reality with less regular flows, more and more independent from geographical distances. The change is also reflected be evolution of WDM protocol standardization. The simple static Optical Transport Network (OTN) is already well-defined by the main standard bodies, while the new model known as Automatic Switched Optical Network (ASON) is currently under development [ITU-T, 1990], [ITU-T, 2001]. Its main feature is the ability to accommodate on-line connections request issued to the network operating system, which is responsible of the activation of new lightpaths in real time. The ASON architecture also supports creating dynamic server layer connectivity in response to a demand for new topology from a client layer.

In the ASON model, the new technology OBS is designed to achieve a balance between optical circuit switching and optical packet switching. In an optical burst-switched network, a data burst consisting of multiple IP packets is switched through the network all-optically. A control packet is transmitted ahead of the burst in order to configure the switches along the burst's route. An offset time allows for the control packet to be processed and the switch to be set up before the burst arrives at the intermediate node; thus, no electronic or optical buffering is necessary at the intermediate nodes while the control packet is being processed. The control packet may also specify the duration of the burst in order to let the node know when it may reconfigure its switch for the next arriving burst.

Our focus here will be on topology routing strategy to accomplish the static and dynamic traffic. We use the OBS strategy to solve the dynamic traffic. Our objective is to evaluate the impact, in terms of blocking probability, of each static VTD/RWA heuristic on the burst requests from the dynamic future traffic.

3. Heuristics for the Virtual Topology Design

3.1 Classical Heuristics

In this paper we assume that the physical topology is already given and that a static traffic matrix representing long-term average flows between end nodes is also given. We decided to start with a somewhat arbitrary approach for the dimensioning of the resources allocated to the static demand, assigning a fixed number of ports per node for this purpose. The number of ports indicates the maximum number of lightpaths originating or terminating in a node. In this scheme, static and dynamic demands use different ports, but share the wavelengths. Three different algorithms were used to solve the static VTD/RWA problem [Ramaswami and Sirvajan, 1996]:

1) HLDA: The Heuristic Topology Design Algorithm idea is that routing most of the traffic in one hop may lower the congestion. For this purpose, this heuristic tries to place logical links between nodes in order of descending traffic. The HLDA does not take delay constraints into account when designing the logical topology.

2) MLDA: We next consider another heuristic, which we call MLDA (for minimum-delay logical design algorithm) which is only defined if the number of transmitters/receivers is larger than the degree the physical topology. If this case, the MLDA creates a pair of directed logical edges for each physical edge and the remaining edges are added according to the HLDA. Thus the logical topologies created by the MLDA are capable of routing all flows on the shortest physical path between every pair of nodes and therefore, capable of satisfying the tightest delay constraints that are physically realizable; hence the term “minimum-delay”.

3) RLDA: The Random Logical Design Algorithm places logical edges randomly but respecting the limited number of ports per node restriction. The algorithm is utilized for a comparison purpose.

3.2 The proposed AMLDA algorithm

Step 0: Analyze the network under dynamic traffic load (in terms of burst blocking probability) and compute the maximum wavelength usage in each physical link. If there are remaining wavelengths in link, therefore there is also remaining capacity.

The Adaptative Minimum-Delay Logical Design Algorithm (AMLDA):

Step 1: With the static matrix traffic: Creates a pair of directed logical edges for each physical edge. The number of transmitters/receivers needs to be larger than the nodal degree of the physical topology.

Step 2: To make a list of all pairs source-destination of initial static demand in increasing routes (excluding the ones that had been established in the first step).

Step 3: Exam the list of step 2 and to try the allocation of the source-destination pairs of the list in the remaining capacity of the Step 0.

Step 4: Add remaining logical edges according to the HLDA. Thus the logical topologies created by the AMLDA are capable of routing all flows on the shortest physical path between every pair of node.

4. Dynamic RWA for the loose topology

Over the last years, several switching techniques have been proposed in literature for supporting dynamic traffic over WDM-based optical network. Recently, a substantial amount of research addressing the logical topology design problem in wavelength-routed networks was considered [Data et. al., 2004; Ghose et al. 2005]. Although, the same problem has received little attention in the context of optical burst switching. The wavelength-routed network does not use statistical sharing of resources and therefore provide low bandwidth utilization if the dynamic traffic to be supported is bursty.

Although all the complexity of the virtual topology design, it only serves to get the best static solution. For the case of dynamic traffic is need set up for each connection request as it arrives, and the lightpath is released after some finite amount of time. It is need in function of the intermittent nature of the proper traffic self-similar generated for the Internet. This new context generates complex models still more, generally boarded through heuristics algorithms. In this paper, we attempted to fill this gap by presenting a logical topology design problem in the context of optical burst switching.

The loose virtual topology considered in this paper is constructed using the static VTD/RWA heuristic with all available wavelengths. Wavelengths not assigned during the heuristic are adaptively used for conveying burst requests from dynamic traffic demands.

The network load corresponding to the dynamic traffic demand is given by λ / μ Erlang. The burst requests arrive to the network following a Poisson process with rate λ. The burst length is exponentially distributed with an average $1 / \mu$.

In our studies, we consider an optical network topology with, at least, capacity to accommodate all the static traffic demand. Remaining capacity will be utilized to attempt accommodate the dynamic traffic.

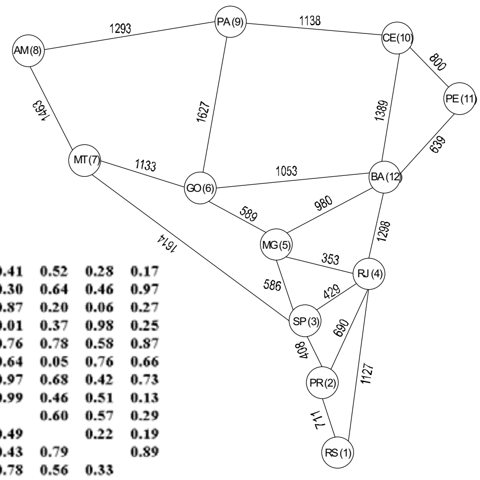
5. Network Setup and Simulation Model

A 12-node Brazilian hypothetical network of Fig. 1b was considered. Each node corresponds to one of 12 States in Brazil, chosen for their economic regional importance [www.ibge.gov.br; 2006]. A plausive mesh was assumed for the physical links. All links are bi-directional and each has *W* wavelengths in both directions. The distances among nodes were based on the geographical positions of the State capitals. A traffic matrix, corresponding to the static traffic demands, is generated with values uniformly distributed in the range [0,1], fig. 1a.

Each topology node is an OBS switch which employs JIT reservation scheme [Wei, J.Y and McFarland, R.I, 2000]. The propagation delay on the fiber is 5µs/Km. Setup message processing delay was fixed to 50µs, and the switching time was fixed to 10ms. These parameters are essential to configure the OBS network [Teng, J. and Rouskas,G., 2005]. The offered load to the network is fixed in 10 Erlangs, with $\lambda = 200$ and $1 / \mu = 0.05$.

	0.92	0.13	0.84	0.30	0.32	0.49	0.83	0.41	0.52	0.28	0.17
0.23		0.20	0.52	0.29	0.96	0.89	0.56	0.30	0.64	0.46	0.97
0.60	0.17		0.20	0.19	0.72	0.82	0.37	0.87	0.20	0.06	0.27
0.48	0.40	0.60		0.68	0.41	0.64	0.70	0.01	0.37	0.98	0.25
0.89	0.93	0.27	0.83		0.74	0.81	0.54	0.76	0.78	0.58	0.87
0.79	0.01	0.41	0.42	0.59		0.30	0.88	0.64	0.05	0.76	0.66
0.76	0.91	0.19	0.01	0.57	0.26		0.44	0.97	0.68	0.42	0.73
0.45	0.41	0.01	0.68	0.15	0.43	0.34		0.99	0.46	0.51	0.13
0.61	0.81	0.46	0.70	0.85	0.83	0.72	0.52		0.60	0.57	0.29
0.44	0.35	0.93	0.50	0.86	0.21	0.53	0.95	0.49		0.22	0.19
0.82	0.05	0.44	0.83	0.37	0.68	0.34	0.79	0.43	0.79		0.89
0.01	0.89	0.74	0.37	0.69	0.93	0.28	0.62	0.78	0.56	0.33	

(a)



(b)

Figure. 1. a) Matrix traffic for Brazilian Network. b) Hypotetical Brazilian network.

We use the random wavelength assignment algorithm to select a free wavelength for nodes transmit their bursts. The route for each node pair is defined by a shortest path algorithm.

Simulations for the Brazilian hypothetical topology were carried out with *W* increasing from 16 to 64 wavelengths. For each simulation, 10 replications with different seeds of random variable were made, and for each replication, 200,000 burst requests were generated. All results also show the confidence intervals calculated with 95% confidence level. Simulations were carried out using OB2S – Optical Burst Switching Simulator, a simulation tool developed for this work.

6. Numerical Results

In this section we compare the impact of HLDA, MLDA, RLDA and AMLDA schemes on the dynamic traffic in terms of burst blocking probability. In addition, we use different numbers of available wavelengths and available ports per node for the static VTD/RWA heuristics. The idea is to evaluate the impact of these two parameters on the loose topology performance. Figures 3 and 4 plots the burst blocking probability of the network using HLDA, RLDA MLDA and AMLDA static VTD/RWA heuristic. The measurement is done just over the dynamic traffic, otherwise the resources to accommodate the static traffic is previously allocated. The number *W* of wavelengths varies from 16 to 64, for the two scenarios, and we consider total wavelength conversion.

The number of available ports per node for the static traffic is 5 and 7. Therefore, all static VTD/RWA heuristics will work with a maximum of 5 or 7 lightpaths originating or terminating in a node, respectively for each scenario. The remaining capacity of the network is utilized for the dynamic traffic. Note, that for the MLDA e AMLDA heuristics are needs 5 or more ports, because the number of ports needs to be larger than the nodal degree of the physical topology (degree 5 for nodes 4 and 12).

The lower bound is the simulation only with dynamic traffic, because this is the optimal value for resources utilization of dynamic demand. Therefore, no resource would be used by the static demand.

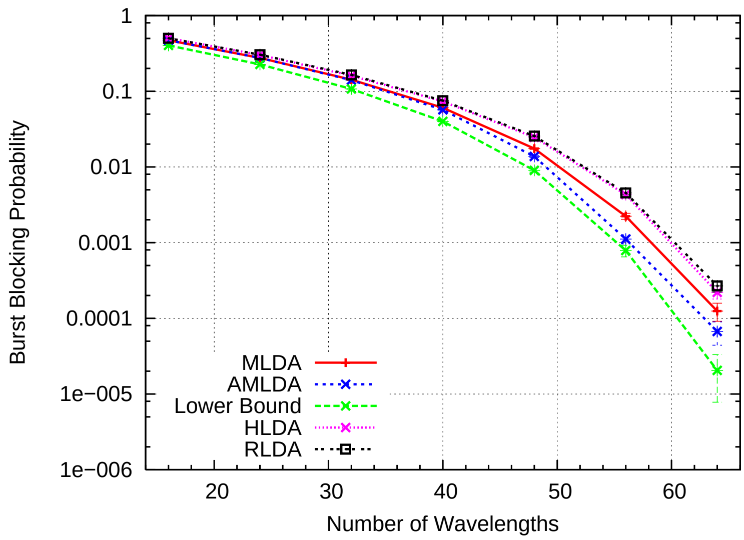


Figure. 2. Network performance with 5 ports available per node.

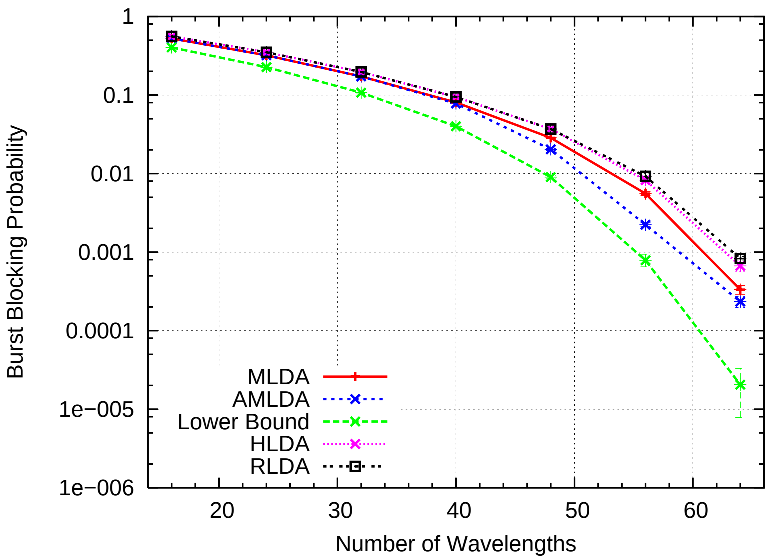


Figure. 3. Network performance with 7 ports available per node.

In all results we observe a better network performance when the AMLDA heuristic is used to support the static traffic. Results of HLDA, MLDA and RLDA were very similar for 16 available wavelengths in the network. However, if we increase the number of available wavelengths in the network, MLDA heuristic achieves a better performance than HLDA and RLDA. AMLDA provides a reasonable compromise between using short hop paths as well as placing direct logical edge for those source destination pairs with a lot of traffic between them. Thus, with AMLDA is possible to accomplish the static demand allocating fewer resources than MLDA, HLDA and RLDA. The higher available resources provided by AMLDA allow a higher dynamic traffic to be established. However, the key point to AMLDA get better resulted is the accomplishment of the previous study (step 0).

7. Conclusions

We presented one new algorithm with previous study for designing virtual topology in optical networks. Traditional approaches to the assignment of network resources to static traffic demands tend to maximize the use of the available resources in order to optimize some objective function. However, for a loose topology with static and dynamic traffic demands sharing the same physical resources, the static VTD/RWA heuristic must economize the use of available resources and, at the same time, guarantee that the objective functions will be accomplished.

Amongst the alternatives studied in this paper, AMLDA proved to be more appropriated to compose a loose topology for OBS networks.

Results suggest that it is feasible to approach the static VTD/RWA problem to preserve enough available resource to avoid blocking of future requests.

Perhaps using some heuristic routing algorithm resembling the ideas behind the proposed previous study will result in more good solution with a manageable computational effort. This is a subject for further study.

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References

Assis, K. D. R. and Waldman, H. [2004] *Approaches to maximize the Open Capacity of Optical Networks*, ONDM, vol. 1, pp. 599-618, February, 2004.

Assis, K.D.R; Savasini, M. and Waldman, H. [2005], IVTD: *Iterative Virtual Topology Design for Maximize the Traffic Scaling in WDM Networks* Simpósio Brasileiro de Redes de Computadores-SBRC, Fortaleza-CE. SBRC05, v. 2. p. 843-854.

Chlamtac, I., Ganz, A., and Karmi, G. [1992] *Lightpath communication: a novel approach to high bandwidth optical WAN's*, IEEE Transactions on Communications, 40(7), pp. 1171–1182.

Chlamtac, I., Ganz, A., and Karmi, G. [1993], *Lightnets: Topologies for high speed optical networks*, IEEE/OSA Journal of Lightwave Technology, 11(5/6), pp. 951–961.

Datta, R., Mitra, B., Ghose, S. and Sengupta, I. [2004] *An algorithm for optimal assignment of a wavelength in a tree topology and its application in WDM networks*, IEEE Journal on Selected Areas in Communications, 22(9), pp. 1589–1600.

Ghose, S., Kumar. R., Banerjee, n. and Datta, R. [2005] *Multihop virtual topology design in WDM optical networks for self-similar traffic*, Photonic Network Communications, 10(2), pp. 199–214.

http:// www.ibge.gov.br [2006]

ITU-T Intern. Telecom. Union. Standart. Sector. [1990] Architechture of Optical Transport Networks, Number G.872.1990.

ITU-T Intern. Telecom. Union. Standart. Sector. [2001] Network Node Interface for The Optical Transport Network (OTN), Number G.709.2001.

Maranhão, J. ;Ferreira, A; Assis, K.D.R, Waldman, H; Giozza, W.F. [2006] *Loose Topology Design for OBS Networks*, III Workshop TIDIA (Projeto Kyatera).

Mokhtar, A. and Azizoglu, M. [1998] *Adaptive wavelength routing in all-optical networks* IEEE/ACM Transactions on Networking, 6(2), April 1998, pp. 197–206.

Mukherjee, B., Banerjee, D., Ramamurthy, S. and Mukherjee, A. [1996] *Some principles for designing a wide-areaWDM optical network* IEEE/ACM Transactions on Networking, 4(5), pp. 684–695.

Murthy, C.S and Gurusamy, M. [2002] *WDM Optical Networks – Concepts, Design and Algorithms*, Prentece Hall PTR.

Qiao, C. and Yoo, M. [1999] *Optical Burst Switching (OBS) – A New Paradigm for an Optical Internet,* Journal of High Speed Networks, vol. 8, pp. 69-84.

Ramaswami, R. and Sivarajan, K. N. [1995] "Routing and wavelength assignment in all-optical networks", IEEE/ACM Transactions on networking, 3(5), pp. 489–500.

Ramaswami R. and Sivarajan, K. N. [1996] *Design of logical topologies for wavelength-routed optical networks*, IEEE Journal on Selected Areas in Communications, 14(5), , pp. 840–851.

Ramaswami R. and Sivarajan, K. N. [1998], *Optical Networks: A practical perspective*, Morgan Kaufmann Publishers.

Teng, J. and Rouskas, G. [2005] *A Detailed Analysis and Performance Comparison of Wavelength Reservation Schemes for Optical Burst Switched Networks*, In Proceedings of Photonic Network Communications, vol. 9, n. 3, pp. 311-335.

Wei, J. Y. and McFarland, R.I.[2000] *Just-In-Time Signaling for WDM Optical Burst Switching Networks*, Journal of Lightwave Technology, vol. 18, n. 12, pp. 2019-2037.