Performance Evaluation of Algorithms for Wavelength Assignment in Optical WDM Networks

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Summary
This paper evaluates the performance of three algorithms for allocating wavelength optical networks WDM (Wavelength Division Multiplexing) and they are: first-fit, least-used e most-used. The objective of the experiment was to simulate the performance of allocation algorithms on relevant aspects: throughput and blocking probability. To this end, a series of measurements were performed using a simulation tool for networks WDM called OWNS (Optical WDM Network Simulator) to perform an analysis of the problem RWA (Routing and Wavelenght Assignment) based on the algorithms studied in this article. The results of the experiments back in a different analysis where the allocation of wavelengths where overlaps in importance to routing

Key words:
Wavelength Division Multiplexing, Routing and Wavelenght Assignment, Optical Network.

1. Introduction

The services offered and made available in telecommunications networks can already be considered as one of the pillars of the modern world for the development of a society. At the beginning, telecommunications network offered voice traffic as the main service, but today, the data traffic significantly influences the way networks are designed [1]. With the new demand for data services including multimedia, in addition to free competition in the telecommunications market, companies in this industry such as mobile telephony are putting an infrastructure able to extend its communication services to all cities across the country. The physical infrastructure of cable, extended along the beds of roads or transmission lines and distribution of electricity, has typically a few tens of optical fibers, capable of conducting light signals for hundreds or even thousands of miles in ideal conditions [1]. With new services every day available in telecommunications networks and the development of new applications, the demand for higher bandwidth is continuous. This has driven the development of optical networks, of high capacity. In particular, the WDM technology (Wavelength Division Multiplexing), showed promising to meet high demands on bandwidth [2], yet it is necessary to resolve some issues related to the design of the topology virtual (logical) process beyond the RWA (Wavelenght Assignment Routing) [3]. The design of virtual topology is similar to the problems of data networks, where connectivity between different nodes is resolved by providing various parameters such as arrays of traffic demand of the User, resource nodes etc. In WDM optical networks, switching of wavelengths is performed in the optical domain eliminating OEO converters (Opto-Electro-Opto) and its limitations. Information of users of the optical network are routed from source to destination based on the wavelengths associated with optical channels. Therefore this type of optical network is also known as WDM optical network routed by wavelength. To carry information between clients of an optical network, a connection must be established in the optical layer. The optical connection between a source node it and a destination node d is called the optical path (lightpath). To establish an optical path is necessary to allocate and route a wavelength for each of the route set. This problem is known as the problem of routing and assigning wavelength (RWA). After establishing the connection, the wavelengths allocated to the selected route are reserved exclusively to the optical path until the completion of the connection. In order to better utilize the resources of an optical network under dynamic traffic, the RWA strategies aim to meet the requests of optical paths in the network (d) minimizing the blocking probability of future connections [3]. Under dynamic traffic optical connections are established and terminated dynamically, according to the customer's requirements of optical network. This means that the demand for optical connections can be much higher than the capacity of optical network in terms of optical links (fiber and wavelength). In the RWA under dynamic traffic, the algorithms should have low computational complexity, since the choices of routes and the wavelengths are made at run time [3]. This paper dealt with the RWA problem with static and dynamic routing, which has been widely studied by different authors to verify the blocking probability [4,5] and for a differentiated analysis of the RWA problem in this experiment was working on the

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performance of allocation algorithms and wavelength routing for both static and dynamic routing, where is was verified not only the possibility of blockage but also of network throughput. In this introductory section, the article is composed of five sections. In section 2, it describes the technique of restriction and conversion and wavelength. In Section 3, we describe the routing algorithms used. In section 4, we describe the algorithms for allocating a wavelength to be analyzed. Then, in section 5, we present the case study where simulations were performed to verify the performance of each allocation algorithm considering the criteria and throughput and blocking probability. Finally, section 6 presents the considerations and suggestions for future work.

2. Conversion Wavelength

In network routing entirely optical Fig.1 containing wavelengths and two switches OXCs (Optical Cross Connects) labeled Optical Switch (SO1) and Optical Switch (SO2) and five access stations (1, 2, 3, 4 and 5). To establish a path of light end-to-end, it is necessary that the same wavelength be allocated on all links forming the route. This requirement is known as restriction of continuity of the wavelength [6].

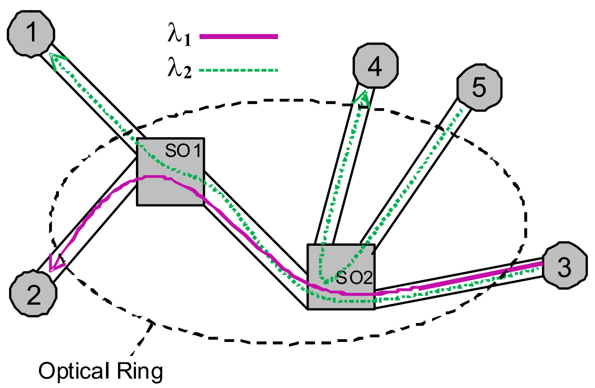

Fig. 1 Network routing entirely optical.

A situation quite different from the previous one is illustrated in Fig. 2, where two light paths were established on the network: (i) between node A and node B at the wavelength λ_1, and (ii) between the node B and node C in the wavelength λ_2. To be sure, now, the need for setting a light path between nodes A and C. Establishing such a path is impossible even if there is a wavelength available on each of the links between nodes A and C. This is because the wavelengths available on each link are different.

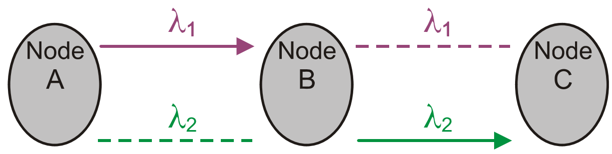

Fig. 2 Restriction of continuity (without converter).

Given the possibility to convert the incoming data by one wavelength to another in an intermediate node, the constraint of continuity would be eliminated. This technique is currently feasible and is called conversion wavelength [6]. In Fig. 3, a converter wavelength is used in node B to convert the data λ_2 to λ_1. Thus, the new path of light between nodes A and C can now be established. For this we use the wavelength λ_2 of the link between nodes A and B, is λ_1 then used to arrive at the node C.

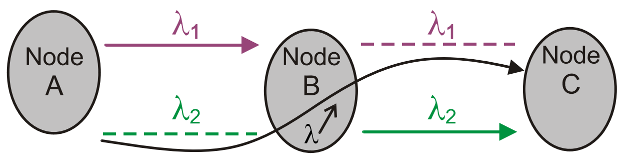

Fig. 3 Restriction of continuity (with converter).

In networks with this type of converter, a single light path employs different wavelengths along the links of the route. Thus, the conversion of wavelengths can increase network efficiency by eliminating conflicts.

3. Routing Algorithm

To establish an optical path, it is necessary to determine the route by which the call will traffic on and which is the wavelength that will be used on all links along the route. For the specific problem of routing, several solutions have been proposed in the literature, which can be divided into two distinct groups: the static and dynamic routing. For networks with few resources (wavelength available) and because of the routes between nodes are static, this type of routing takes a huge disadvantage compared to dynamic routing when comparing the blocking probability in the network. This paper used two routing algorithms which are described briefly below: Dijkstra [7] and WLCR [8].

3.1 Dijkstra (Dij)

Static routing is an example of the shortest path routing, where the criterion used to choose the route is the number of hops between (d). Assuming that the cost associated with each of the links of a telecommunication network is fixed, the Dijkstra algorithm [7] can then be described as follows. First are all the shortest paths from a given source node to all other nodes in the network. This is done through the development of routes that increase the path length available in the links. Since each node n is added to a set T, then the path from the source node is automatically calculated by Eq.(1) provides the upgrade paths for lower costs.

$$L(\mathrm{x}) = \min\left[L(\mathrm{n}), L(\mathrm{x}) + w(\mathrm{x}, \mathrm{n})\right]. \quad (1)$$

L(n)= Cost path.

$\mathrm{w}(i, j) =$ link cost from node i to node j;

$\mathrm{w}(i, j) = \infty$, if two nodes are not directly connected;

$\mathrm{w}(i, j) \geq 0$, if two nodes are directly connected;

$\mathrm{L(n)} = \mathrm{w}(i, j)$, to n ≠ s, that is, the costs of the initial path to the neighboring nodes are simply the costs of the links.

$\mathrm{L}(x) = \min\limits_{j \notin \mathrm{T}} [\mathrm{L}(j)]$: Add x a T; Add a T edge that is incident on x that contributes to lower component cost L(x).

3.2 WLCR

In dynamic routing the routes are determined in accordance with the current state of the network, which basically depends on the active connections. The algorithm Weighted Least-Congestion Routing [8] performs routing function better than the static algorithm, due to work with the conversion in the network. The function is based on distribution of wavelengths λ in the segments that have lengths free. The logic is based on the calculation for each route where the parameter is to assign weight to the lengths free. The calculation of the weight is determined by the following Eq.(2):

$$\mathrm{W(R)} = \frac{\mathrm{F(R)}}{\sqrt{\mathrm{h(R)}}}. \quad (2)$$

where:
F(R): Lengths available in a given route R.
h(R): Path of a route R.

4. Allocation Algorithm

The optical networks, like the electrical system, require that a route is established between a pair of nodes (origin-destination) when establishing a connection. However, as to the power grids the issue of routing ends to establish the route, the optical network begins a second action that is essential to the functioning of the system, allocating a wavelength to the route established. These two steps, the route selection and allocation of wavelengths can be made jointly, but it is common to be done in separate steps. At a closer look at the RWA problem, we see that the action of assigning wavelengths overlap in importance to the action of routing in optical networks. This perception occurs when analyzing the problem RWA from the traditional criterion used to establish a route: the choice of the shortest path between origin and destination. Despite the identification of a shortest path, this does not guarantee, in optical networks, that it will be used, as is needed for that path, an appropriate wavelength. The suitability of a wavelength for a route may depends on several factors, according to the restrictions imposed by the network studied. In a simple network (without any wavelength, for example) would be the appropriate length that is present in all the links that form the route. Thus, one can see that ultimately which dictates the route to be used is the availability of wavelength, which comes in different routes identified as the shortest path. It is important to emphasize that the allocation of wavelengths should be done in such a way that does not allow the use of the same wavelength on the same fiber [9].

A goal of routing and allocation of wavelength is to minimize the number of wavelengths λ needed to establish a set of paths for a given physical topology. With the growth of networks, we need to have algorithms that offer a way to provide an answer as quickly as possible, so that there is no delay in the network.

The choice λ is related especially to the way the list of wavelengths is sorted and accessed. For a given optical channel candidate, the wavelengths are evaluated in the order they appear in the list to find a free wavelength in order to meet the connection request. In general, as mentioned before, lies with those who are present on all links that make up the route, because it may even be no need for conversion, and especially the possibility of blocking [9].

This paper analyzes three of the main algorithms allocation length that will be briefly described as follows: first-fit, least-used and most-used.

4.1 First-Fit (FF)

This algorithm first-fit [3] numbers all wavelengths, so that when demand for wavelengths available, those of a smaller number are considered first that the highest number, that is, he labels the lengths of available wave 1 to w where w is the total number of wavelengths in the link. The first available wavelength is then selected. This algorithm does not require global information system, and thus its computational cost is lower because it is not necessary to search wavelengths available in the entire space of wavelengths on each route. It works well in terms of blocking probability and fairness of allocation and in practice is preferred for its small overhead and low computational complexity [3].

4.2 Least-Used (LU)

This algorithm least-used [3] selects the wavelength that was used at the network in order to try to balance the load among all the wavelengths. Thus, it facilitates the breaking of very long optical paths. Its performance falls by introducing an additional communication overhead, since it requires global information network to determine which was the last wavelength used. It also presents a need for additional storage and a higher computational cost. It is preferred in practice [3].

4.2 Most-Used/Pack (MU)

Opposite the LU algorithm, the most-used algorithm [3] selects the wavelength most often used in the network. Outperforms the LU algorithm and the algorithm FF, as it seeks to establish connections with few wavelengths while maintaining idle capacity of wavelengths less used. Displays communication overhead, storage requirements and computational cost similar to the LU algorithm [3].

5. The Case Study

It is observed that in the preceding paragraphs performance differences have already been established to solve the RWA problem based on the algorithms studied in this article, according to some aspects such as: need to use the global information network, the need for storage, communication overhead and computational cost. It is important to note that the points highlighted are restricted to the performance of allocation algorithms in length and not on issues of interest to the system as a whole, ie, the performance of the network that also involves the routing algorithms. Because of this, this article addresses the problem RWA using as a parameter a hypothetical scenario and the allocation algorithms described above. In another study on allocation and wavelength WDM optical networks [5] the authors perform experiments in their analysis of the blocking probability only for the first-fit algorithm.

4.1 Methodology

The aim of the experiment was to simulate the performance of allocation algorithms on issues relevant to WDM networks: throughput and blocking probability. To this end, a series of measurements were performed using a simulation tool for WDM networks called OWNS (Optical WDM Network Simulator) [10] which is an extension of the NS-2 Network Simulator [11]. In its context the simplest OWNS [12] is a set of classes properly constructed language OTcl-TCL and C + + [13], which provides the researcher with all the tools needed to make a simulation of optical networks.

4.2 Scenario

The scenario presented in Fig. 4, was chosen after several measurements grains by the simulator from the archives (creator topology, traffic and creator scritp owns) that based on a hypothetical network with 10 nodes, 14 links and 4 lambda.

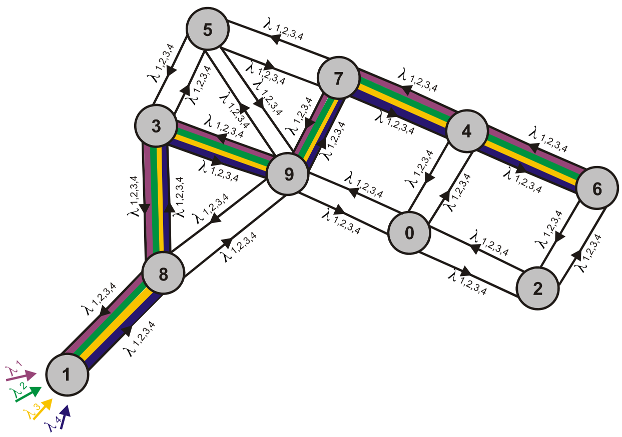

Fig. 4 Hypothetical network used in the simulation.

In order to analyze the performance of algorithms allocation of wavelengths, the routing algorithm, which is the action that initiates the process RWA, is represented in the simulator either by the classical Dijkstra [7] or by the Weighted Least-Congestion Routing-WLCR [8].
Traffics on all links were generated, considering parameters with fixed values in the scenario. The parameters and their fixed values and variables are shown in Table 1 and 2 respectively.

Table 1: Fixed Parameters of Simulation (OWNS)

Parameters	*Values Fixed*
traf_num	10 sessions
traf_max_req	20 sessions
traf_start_time	0 Seg.
traf_stop_time	0 Seg.
traf_exp_idle_time	0,1 Seg
exp_burst_time	0,7 Seg
util_sample_interval	0,5 Seg.
link_delay	0,020 Seg.
wvlen_conv_time	0,024 Seg.
traf_pkt_size	500 bytes
traf_pkt_rate	2 Mbps
traf_type	Exponential

Table 2: Variables Parameters of Simulation (OWNS)

Parameters	*Values Variables*
node_num	10
link_wvlen_num	4
wvlen_conv_factor	1
wvlen_alloc_path2	1
traf_holding_time	2,2 Seg
traf_arrival_rate	0,5 Mbps
wvlen_assign	First-Fit (FF) Least-Used (LU) Most-Used (MU)
wvlen_routing	WDMSession (Dijkstra and WLCR)

Despite being generated traffic on all links, the analysis was performed in a pre-determined route. Communication evaluated was established between nodes 1 and 6 and the route composed by nodes 1, 8, 3, 9, 7, 4 and 6.

4.3 Results

The following are the results of simulations comparing the algorithms for allocating wavelength. The algorithms for allocating wavelength underwent two scenarios with different routing algorithms: static and dynamic with their Dijkstra [7] and WLCR [8]. The performance of algorithms for allocating wavelength through completion of the simulations to verify the blocking probability as a function of load is also known as the utilization factor or intensity of traffic, measured in Erlangs (E), and throughput network measured in mega bits per second (Mbps). Fig. 5 illustrates the probability curve for the blocking of all allocation algorithms mentioned above according to the network load (in Erlangs) for the hypothetical network used in the simulation with a single fiber and 4 wavelengths and static routing. It is observed that among the algorithms allocation FF, MU and LU all showed high rates of blocks and the algorithm FF is the least affected mainly busiest.

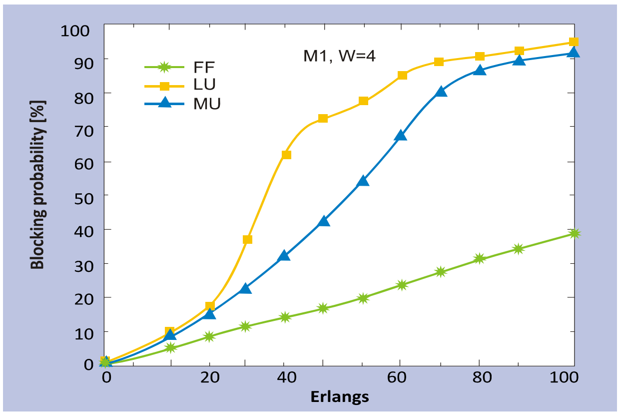

Fig. 5 Blocking probability of the network with static routing.

The graph in Fig. 6, shows the throughput of the network measured by the allocation algorithms FF, MU and LU with fiber and single 4 wavelengths and static routing. In general, it is observed in Fig. 6 that among the algorithms FF, MU and LU all have a clear downward trend in performance and the algorithm FF has the best throughput rate as the number of nodes in the network traffic increases exponentially.

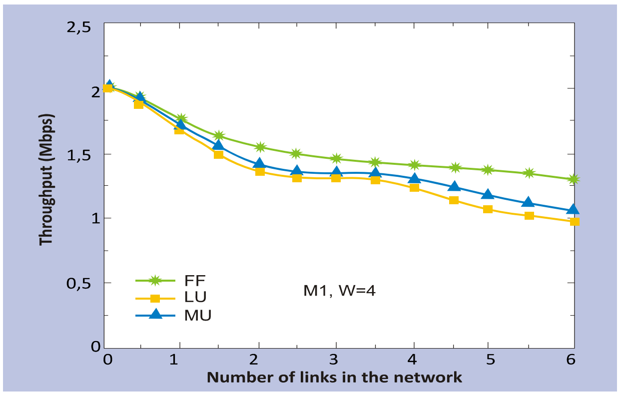

Fig. 6 Throughput network with static routing.

Fig. 7 illustrates the probability curve for the blocking of all allocation algorithms mentioned above according to the network load (in Erlangs) for the hypothetical network used in the simulation with a single fiber and 4 wavelengths and dynamic routing. It is observed that among the algorithms FF, MU and LU all have had high rates of blocking probability and the algorithm LU which does load balancing, is the most affected.

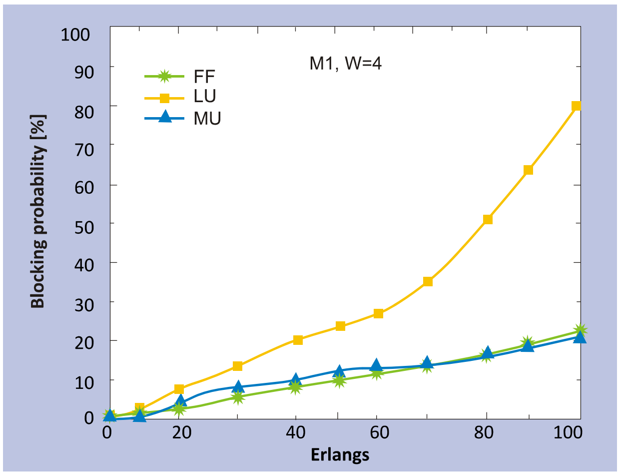

Fig. 7 Blocking probability of the network with dynamic routing.

The graph in Fig. 8, shows the throughput of the network measured by the allocation algorithms FF, MU and LU with fiber and single 4 wavelengths and dynamic routing.
In general, there is an improvement in the performance of algorithms FF and MU. The MU algorithm has the best performance with dynamic routing and traffic on exponentially.

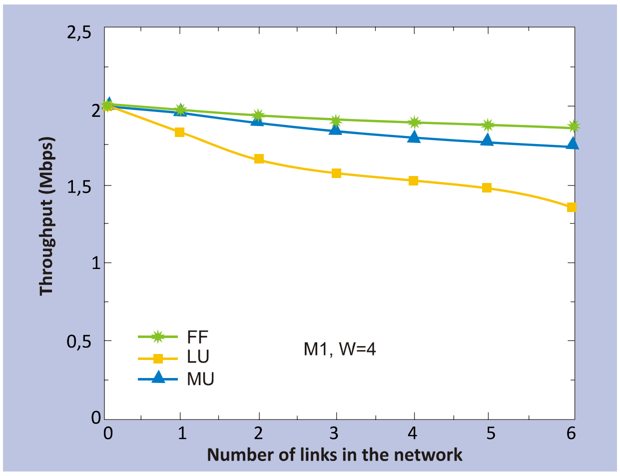

Fig. 8 Throughput network with dynamic routing.

6. Conclusion

The emergence of optical networks is of fundamental importance for the future of infrastructure transport of backbones providers of telecommunications services with the main feature of wavelengths multiplexed in the WDM optical fibers. The allocation algorithms studied here, gives us an insight into the performance of available resources in WDM networks as the technology of converting the wavelength is not yet mature and competitive. The RWA problem has been extensively studied in recent years. Several routing strategies have been proposed to improve the performance of optical networks primarily in terms of blocking probability [4, 14, 15, 16]. Was recently proposed in [17] algorithm Restricted Routing Technique (RRT) for fixed routing in transparent optical networks.
This paper can be analyzed through a hypothetical scenario of results measured by simulation which examines the implementation of some algorithms in the literature such as first-fit (FF), least-used (LU) and most-used (MU), and the first-fit (FF) and most-used (MU) more competitive in terms of cost-performance. You can also identify that the downgrading of information on the resources (wavelength) of the network directly affects the performance of allocation algorithms studied.
The least-used algorithm (LU) that operates with global information network, making load balancing, was the most affected in both scenarios with static and dynamic routing.
For future work, we intend to introduce the FOG (Generic Objective Function) [18] in simulator OWNS [8], to perform a comparative analysis of performance between the algorithms of allocation of wavelengths simulated in this article, (FOG) and the one that is RWA Problem, integrating routing and allocation of wavelengths, without the establishment of restrictions.

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