Analysis of Some Wavelength Assignment Techniques in WDM Optical Networks

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Abstract – **Dynamic traffic demands in all optical networks employing wavelength division multiplexing (WDM) require carefully designed network in terms of efficient usage of existing network resources. This is primarily related to routing and wavelength assignment (RWA) in order to minimize the blocking probability. In this paper two wavelength assignment techniques, first-fit and most-used, in case of fixed routing are tested and compared according to the blocking probability performance.**

Keywords – **optical network, fixed routing, wavelength assignment, blocking probability, first-fit, most-used**

I. INTRODUCTION

Having in mind that next generation networks dictate large demands in terms of capacity and quality, all optical networks (AON) employing wavelength division multiplexing are certainly one of the solutions for such demands. Networks where no electro-optic conversion is required and the routing is done in the optical domain are called wavelength routed optical networks (WRON). Systems employing WDM allow efficient utilization of a fiber bandwidth by dividing the bandwidth into smaller and manageable channels, each operating at an electronic speed and modulated at different wavelengths [1]. The WDM network nodes are called optical cross-connects (OXC) capable of routing optical signal at a given wavelength between nodes, making it possible to establish end-to-end lightpaths. A lightpath is an optical connection between two end nodes which is assigned the same wavelength throughout the route along which the signal is transmitted. Optical links where WDM systems are installed can be extremely large, in order of Tbit/s, since nowadays one wavelength is capable of carrying 40 Gbit/s while one optical fiber can realize up to around 100 different wavelengths. The end-to-end lightpath establishment process for a given set of connection requests is known as routing and wavelength assignment (RWA) problem [2]. It means that, it is necessary first to determine the route over which the lightpath would be established and then assign a wavelength along the route respecting the wavelength continuity constraint if the nodes are without wavelength conversion. If no wavelength is available for this lightpath on the selected route, then the connection request is blocked.

Connection requests may be of static and dynamic type. In the static traffic case the set of connections is known in advance so it is necessary to establish lightpaths for these connections while minimizing network resources such as the number of wavelengths or the number of fibers [3]. This is known as static lightpath establishment (SLE) problem. For the dynamic traffic case, the lightpath is established for each connection as it arrives in time and then released after the connection is finished. This is known as dynamic lightpath establishment (DLE) problem. Because WDM networks are circuit-switched loss networks blocking may occur because of lack of resources. Also, in circuit switched networks many paths use the same links. So the blocking probability is referred to the probability that a lightpath cannot be set up in the network. Dynamic RWA, which is considered in this paper, tries to solve the connection blocking because very high data rates are carried on a wavelength channel.

The remainder of this work is organized as follows. Section II describes the problem where we talk about fixed routing and wavelength assignment techniques. First-fit and most-used wavelength assignment techniques are emphasized here. Simulation results related to the connection blocking probability for the mentioned techniques are given in section III while section IV concludes the paper.

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II. PROBLEM STATEMENT

In this paper, we consider a wavelength routed optical network without the wavelength conversion operating in circuit-switched mode under dynamic traffic demands what means that resources must be assigned dynamically to the connection requests, having in mind that no two lightpaths share the same wavelength on a given fiber link (in networks with one optical fiber per link). There exists a lot of papers describing RWA algorithms solving this problem [2-5].

The first part of the dynamic RWA problem is to choose the route between the source and destination node. Three routing methods are used for this purpose and referred to as: fixed routing, fixed-alternate routing and exhaust routing. Details on each of these algorithms can be found in [3], [6]. In this paper, for an optical network example a fixed routing method is considered so we will describe it in more detail.

A. Fixed routing

The term ”fixed” indicates that something is not changing here and it is known in advance. This is the simplest routing method because only one pre-calculated route is available between each node pair (source-destination node pair) and less computation time is needed for lightpath establishment. Although there is a change of traffic demands in time, this route is not changed and it is usually the shortest path between node pair. When a connection request arrives, for a given node pair, the algorithm calculates if there is a free wavelength along this route (this is referred to all of the links on the route). If there is no free resources (wavelengths) along the route it leads to the lightpath blocking.

In order to reduce the blocking probability it is necessary to apply an efficient wavelength assignment technique for a given path between node pair. This is the second part of the RWA problem.

B. Wavelength assignment techniques

Wavelength-division multiplexing is a method of combining multiple signals on laser beams at various wavelengths for transmission along fiber optic media. Wavelengths must be assigned to each lightpath such that any two lightpaths that are sharing the same physical link are assigned different wavelengths. Depending on the method in which the free wavelength is searched for connection establishment (the wavelength list is ordered), there exists various wavelength assignment techniques, such as:

- Random-Fit (RF)
- First-Fit (FF)
- Least-Used (LU)
- Most-Used (MU)
- Min-Product (MP)
- Least-Loaded (LL)
- Relative Capacity Loss (RCL).

The three last listed techniques are used in multi-fiber networks. Since our network for which the simulation is done is a single fiber, which means that each physical link has only one optical fiber for each direction, we could consider between the first four listed wavelength assignment techniques. Details on each of these techniques can be found in [3], [7]. These papers analyze the performance of the wavelength assignment strategies to reduce the network block rate of the request considerably. Using FF and MU techniques, similar results are obtained according to the minimum blocking probability. In order to get the best results in terms of efficient allocation of resources (wavelengths) it is necessary to apply one of these wavelength assignment techniques, so we will show which one is better – FF or MU, or both of them are applicable. The routing and wavelength assignment algorithm generally can be presented as given by Fig. 1. The other steps of our Matlab code for the used techniques are described as follows.

In the first-fit scheme all the wavelengths are numbered. When searching for available wavelengths (by determined fixed order) a lower numbered wavelength is considered before a higher numbered wavelength [3]. The first available wavelength for lightpath establishment is then selected. First-fit does not require global knowledge about the network. No storage is needed to keep the network states and no communication overhead is needed [8]. The computational overhead is small and the complexity is low. When the request is finished, the wavelength is added back to the free wavelength set.

In the most-used scheme, the set of wavelengths is searched in descending order with respect to the number of links on which each of them is used. The wavelength that has been used the most in the network (that is used on the greatest number of fibers in the network) is selected for a lightpath. Except the number of links, usage also can be defined as the number of active connections using a wavelengths. If several

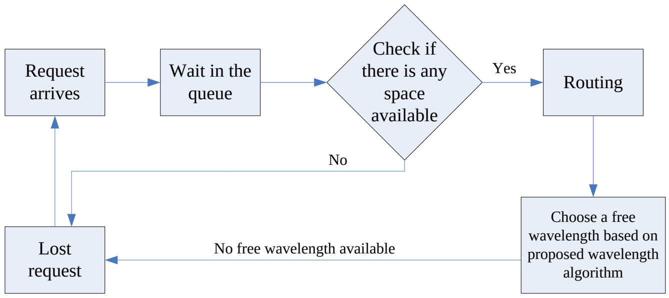

Fig. 1. Routing and wavelength assignment algorithm [7]

available wavelengths share the same maximum usage, the wavelength with a specific index is chosen.

III. Simulation Results Analysis

Fixed routing and two wavelength assignment techniques, first-fit and most-used are applied here to the 7 node optical WDM network topology, shown at Fig. 2. As mentioned before, a single fiber network is assumed.

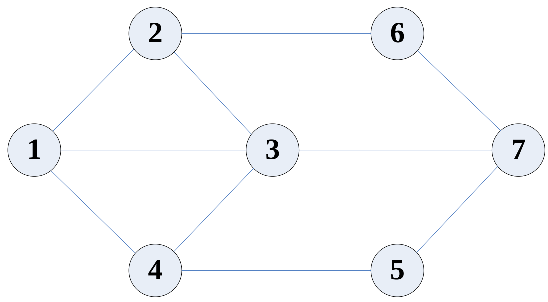

Fig. 2. Optical WDM network topology

The arrived lightpaths with a random holding time need to be established dynamically by choosing a route connecting the source and destination node and assigning a free wavelength along the route. It is considered that only one lightpath can use a specific wavelength in a fiber for a certain period of time. Dynamic traffic demands arrive according to the Poisson distribution with mean arrival rate of λ requests per time. Network load can be written as $\rho=\lambda/\mu$ and is measured in Erlangs. The mean connection holding time is one time unit and we only changed the arrival rate λ as the number of requests per time unit. Dynamic traffic scenario with 5000 generated requests is simulated where the number of requests per time unit is varied in the range of 60 to 100. Matlab R2013a (8.1.0.604) is used for simulation.

First, we analyze the blocking probability for first-fit and most-used wavelength assignment techniques as a function of wavelength number (W). We assumed that network load is the same (first for ρ= 60 Erl, then for ρ= 100 Erl) and varied W as 4, 8, 12, 16. Fig. 3. shows these blocking probabilities per 5000 requests. One may see that for small number of wavelengths (W= 4, 8) the compared wavelength assignment techniques give almost the same results. This means that the lack of resources essentially determines the connection blocking. If we increase the number of wavelengths (W= 12, 16) the blocking probability decrease and it could be seen that most-used wavelength assignment technique is a slightly better than the first-fit technique (the number of blocked

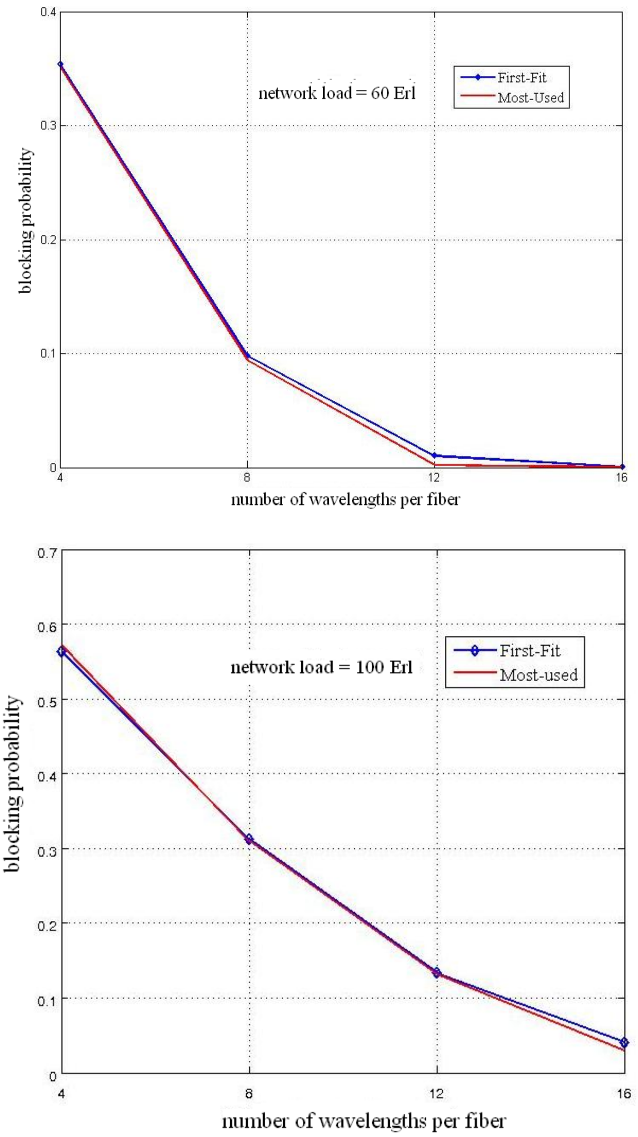

Fig. 3. The blocking probability for different number of wavelengths per fiber link

requests in case of MU is smaller for 5-10 requests).

Then, we analyze the simulation results when observing the call blocking probability as a function of network load. For a given optical network example we varied the traffic load from minimum 60 to maximum 100 Erl per time unit. Fig. 4. presents the simulation results in case of 4, 8, 16 wavelengths per fiber link. It is obviously that traffic load increasement cause the blocking probability increasement too.

Note that for very small and small number of wavelengths (W = 4, 8), when increasing the network load, first-fit technique gives insignificiantly better results so both wavelength assignment techniques could be used here.

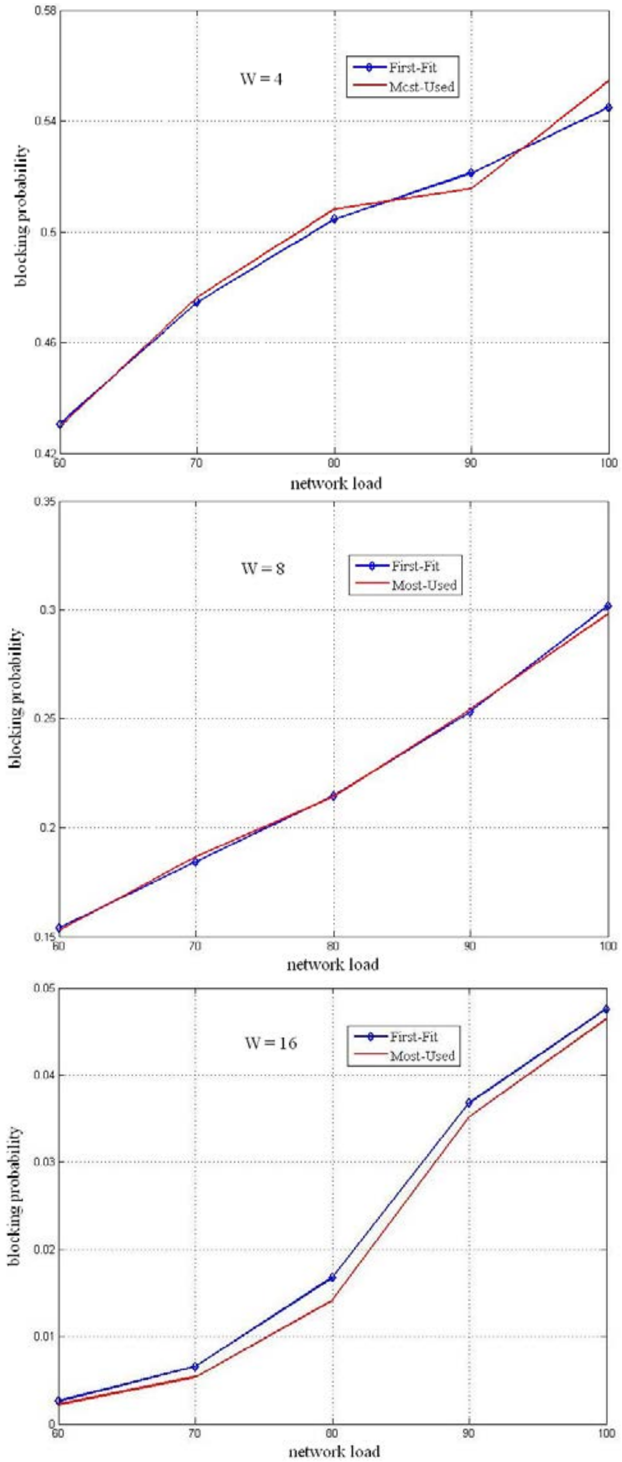

Fig. 4. The blocking probability for different values of network load

As we increased the number of wavelengths (Fig. 4.) over 8 up to 16, the number of blocking requests was significantly smaller and so the blocking probability. Now (for W= 16) , it is more clearly that most-used wavelength assignment technique gives better results than first-fit scheme when increased the network load.

IV. Conclusion

Using different wavelength assignment techniques as part of RWA problem results in more or less connection blocking probability. Based on Matlab program code we simulated two of them to test which one is better and under what conditions.

The obtained results show that fixed routing results in high number of blocked lightpaths (and so the blocking probability) in case of small number of wavelengths per fiber link. In order to reduce it, first-fit wavelength assignment scheme, generally should be used for small number of wavelengths ($W< 16$) if the network load is increased while most-used technique is better for larger number of wavelengths ($W\geq 16$) and higher values of traffic load.

Except of using different wavelength assignment techniques, the number of blocked request can be reduced applying some other types of routing as fixed-alternate routing what would be the subject of our further research.

Acknowledgement

This paper is partially supported by the Serbian Ministry of Education, Science and Technological Development (research project: TR-32025).

References

[1] K. Iyad and D Medhi, "Adaptive Alternate Routing in WDM Networks and its Performance Tradeoffs in the Presence of Wavelength Converters", Optical Switching and Networking, vol. 6, no. 3, pp. 181-193, 2009.

[2] V. S. Shekhawat, A. K. Saini and V. K. Chaubey, "Efficient Heuristic Algorithms for Routing and Wavelength Assignment in Optical WDM Networks", The IUP Journal of Telecommunications, vol. 4, no. 3, pp. 31-42, 2012.

[3] H. Zang, J. P. Jue and B. Mukherjee, "A Review of Routing and Wavelength Assignment Approaches for Wavelength- Routed Optical WDM Networks", Optical Networks Magazine, vol. 1, no. 1, pp. 47-60, 2000.

[4] K. Christodoulopoulos, K. Manousakis and E. Varvarigos, "Comparison of Routing and Wavelength Assignment Algorithms in WDM Networks", Global Telecommunications Conference, IEEE GLOBECOM, pp. 1-6, New Orleans, LO, 2008.

[5] G. Markovic and V. Acimovic-Raspopovic, "The Comparison of Some RWA Algorithms in Case of Dynamic Traffic", TELFOR 2008, Conference Proceedings, pp. 472-475, Belgrade, Serbia, 2008.

[6] J. P. Jue, "Lightpath Establishment in Wavelength-Routed WDM Optical Networks", Optical Networks, pp. 92-122, Norwell, MA, USA, 2001.

[7] M. Arunachalam, S. Nandhini and P. Pavithra, "Experimental Analysis of Wavelength Assignment Strategies in Optical Networks", International Journal of Emerging Technology and Advanced Engineering, vol. 2, no. 8, pp. 292-295, 2012.

[8] X. Sun, Y. Li, I. Lambadaris and Y. Q. Zhao, "Performance Analysis of First-Fit Wavelength Assignment Algorithm in Optical Networks", Telecommunications, ConTEL 2003, Conference Proceedings, vol. 2, pp. 403-409, 2.