Wavelength Assignment Problem in Optical WDM Networks

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Summary
This paper proposes analyses of the wavelength assignment problem. The first-fit wavelength assignment algorithm is compared with the random wavelength assignment algorithm. These algorithms are compared on the basis of blocking probability; number of channels and number of links are kept constant whereas the response of the algorithms is calculated by varying the load per link (in Erlangs). The blocking probability is also calculated for the network with wavelength conversion and without wavelength conversion

Key words
Wavelength division multiplexing (WDM), blocking probability, performance analyses, routing and wavelength assignment (RWA)

1. Introduction

One of the basic properties of the optical fiber is its enormous low-loss bandwidth of several tens of terahertz. Due to dispersive effects and limitations in optical device technology single channel transmission is limited to only small fraction of fiber capacity. To take the full advantage of potential of fiber, the use of Wavelength Division Multiplexing (WDM) technology has become the option of choice. With WDM, a number of distinct wavelengths are used to implement separate channels [1]. WDM technology [2] is proposed as an alternative method for carrying the data. With WDM, one strand of fiber can accommodate about 128 channels nowadays and more in the future. WDM systems are also transparent for data format and data rates, therefore they can promise to integrate data and voice into one telecommunication system. Sitting in the heart of WDM is the Routing and Wavelength Assignment (RWA) problem [3]. RWA is the unique feature of WDM networks in which lightpath is implemented by selecting the path of a physical link between the source and destination edge nodes, and reserving a particular wavelength on each of these links for the lightpath. Thus for establishment of an optical connection, one must deal with both the selection of the path (Routing) and allocating the available wavelengths for the connections (Wavelength Assignment). This resulting problem is known as *routing and wavelength assignment* problem. The two constraints must be taken into consideration while assigning the wavelengths and these are *Wavelength continuity constraint* and *Distinct Channel constraint.*

In literature there are two methods to tackle the RWA problem. One of them is taking routing and wavelength assignment problem as a single problem and the other method is taking routing and wavelength assignment as two separate problems. In this paper the routing and wavelength assignment problem is considered as two separate problems, *Routing problem* and *Wavelength Assignment* problem. Several routing algorithms are proposed in the literature of which some are represented as below:

- *Fixed routing* [4]: The path for the source-destination pair is calculated off-line using algorithms, say, Dijkstra algorithm
- *Fixed alternate routing* [4-5]: Instead of calculating one path for each pair, several alternate paths are calculated off-line in fixed alternate routing.
- *Adaptive routing* [6]: the paths are calculated on-line, depending on the networks state which reflects the resource usage.

There are many wavelength assignment algorithms some of them are mentioned as:

- *Random wavelength assignment* [7]: A wavelength is selected randomly from the available wavelengths.
- *First-fit assignment* [8, 6]: All the wavelengths are numbered. The wavelength with the lowest number is selected from the available wavelengths.

The performance of the above wavelength assignment algorithms is calculated in terms of blocking probability and fairness and the performance of the first-fit wavelength assignment method is found better than the random algorithm. Erlang-B formula is used to compute the Blocking probability.

This paper is organized as follows. Section 2 describes the framework of the random and first-fit wavelength assignment problem. Simulation part is covered in the section 3. The conclusion of the paper is given in section 4.

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2. Analytical Models

In this section the framework of the random and first-fit wavelength assignment algorithms will be covered. We developed approximate analytical models for the clear channel blocking probability of the network with arbitrary topology, both with or without wavelength translations. The goal of our analyses is to calculate the blocking probability. In order to do the analyses following assumptions are made:

- The network is connected in an arbitrary topology. Each link has a fixed number of wavelengths.
- Each station has array of transmitters and receivers, where W is the wavelengths carried by the fiber.
- Point to point traffic.
- There is no Queuing of connection request. The connection blocked will suddenly be discarded.
- Link loads are mutually independent.
- Static Routing is assumed.

2.1 Analyses of wavelength assignment algorithms

We have considered the blocking probability in the case where no wavelength translation is taking place. The two constraints which are followed for the wavelength assignment and are:

1. Wavelength continuity constraint: a lightpath must use the same wavelength on all the links along the path from source to destination edge nodes.
2. Distinct wavelength constraint: all lightpaths using the same link must be allocated the distinct wavelengths.

If there is no free wavelength available on any link the call will be blocked.
In simple terms the blocking probability can be calculated as:

$$P_{Bavg} = \frac{\text{Total number of calls blocked}}{\text{Total number of calls generated}}$$

Also the blocking probability on the link can be calculated be the famous Erlang-B formula:

$$P_{b(L,W)} = \frac{\frac{L^W}{W!}}{\sum_{i=0}^{W} \frac{L^i}{i!}} \quad (1)$$

Where $P_{b(L,W)}$ is the Blocking Probability for L load and W wavelengths.

The algorithms which are used for the simulation are first-fit algorithm and random algorithm. These algorithms can be illustrated as below:

1. *First-fit algorithm*: In this algorithm, first the wavelengths of the traffic matrix are sorted in the non-decreasing order. Then the algorithm steps through this sorted list for selecting candidate chains joined. Let u_{ij} be the next highest wavelength element in the sorted list. Then, if both the nodes *i* and *j* are the end nodes of the two chains, the largest chain is formed by joining the two ends, otherwise the next highest element is considered. This process is carried on until all the chains are considered to form a single chain representing the linear topology.
2. *Random algorithm*: In this algorithm the wavelength is selected randomly from the available wavelengths. In this algorithm a number is generated randomly and wavelength is assigned to this random generated number.

The algorithm for the random wavelength assignment is very simple and is limited to the generation on a random number but the algorithm for first-fit is a bit complex. The algorithm for the first-fit wavelength assignment can be illustrated by the given algorithm in fig 1.

Algorithm First-fit
begin
sort elements of U in non-decreasing order;
While (two or more chain exist) **do**
begin
let u_{ij} be the next highest element in U;
if (*i* and *j* are the end nodes of the two chains '*ij*' and '*jl*') **then**
connect *i* and *j* to get the chain '*kl*';
discard u_{ij} ;
end;

Fig. 1 Algorithm First-fit

3. Simulation Results

In this section we will present the simulation results for random and First-fit wavelength Assignment algorithms

In all the simulations the blocking probability of the network is compared depending upon the number of channels, Loads and the number of links. The number of wavelengths on all the links is kept constant.

The simulation is carried out on MATLAB 7.2 of Mathworks. In the first case we have fixed the values of the number of channels C=11, number of links= 10 and load (in Erlangs) is varied. The results are shown in fig 2-11.

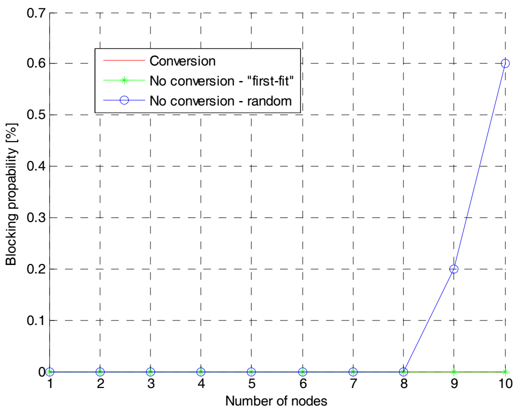

Fig. 2 Blocking Probability of 10 nodes for load 1 Erlang per link

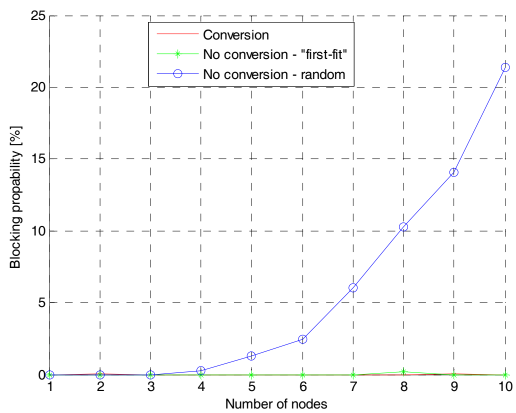

Fig. 3 Blocking Probability of 10 nodes for load 2 Erlangs per link

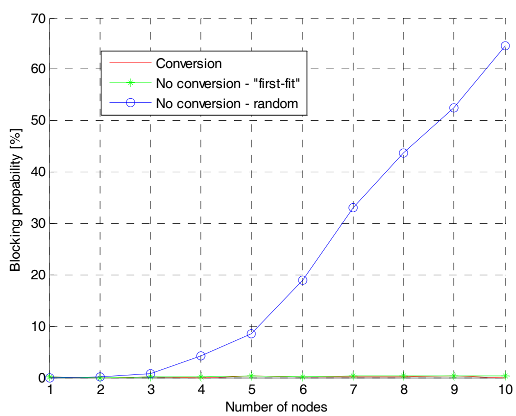

Fig. 4 Blocking Probability of 10 nodes for load 3 Erlangs per link

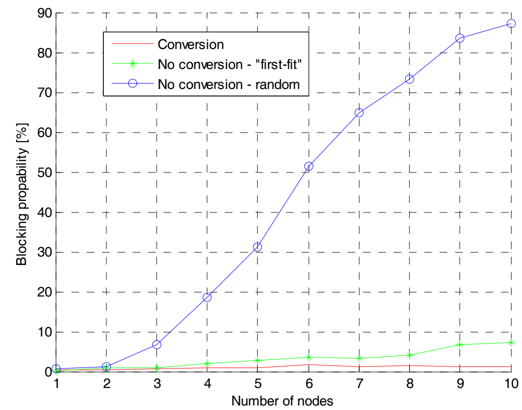

Fig. 5 Blocking Probability of 10 nodes for load 4 Erlangs per link

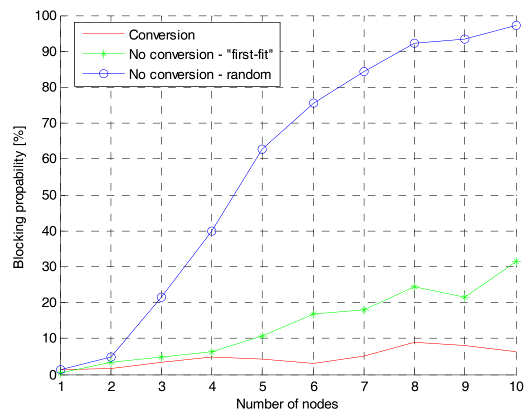

Fig. 6 Blocking Probability of 10 nodes for load 5 Erlangs per link

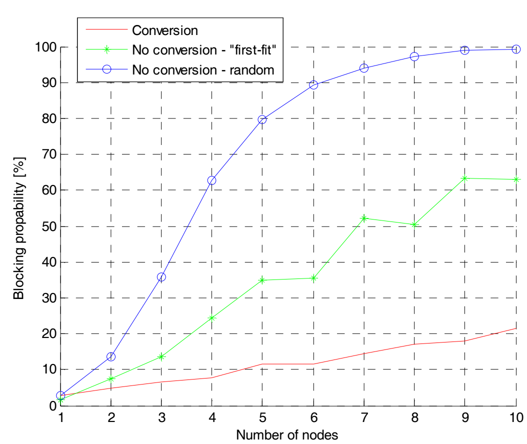

Fig. 7 Blocking Probability of 10 nodes for load 6 Erlangs per link

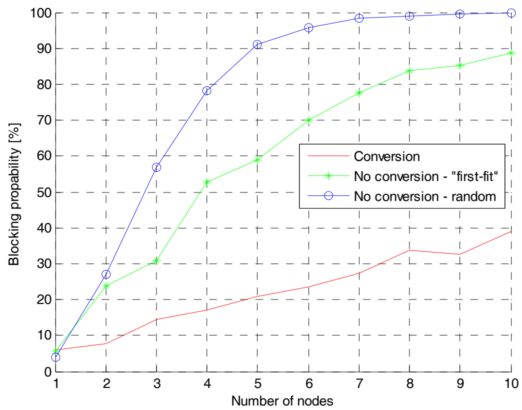

Fig. 8 Blocking Probability of 10 nodes for load 7 Erlangs per link

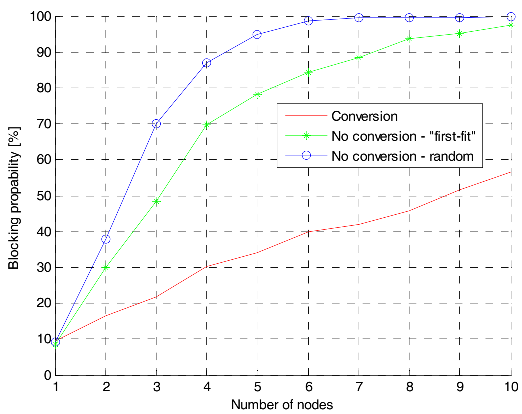

Fig. 9 Blocking Probability of 10 nodes for load 8 Erlangs per link

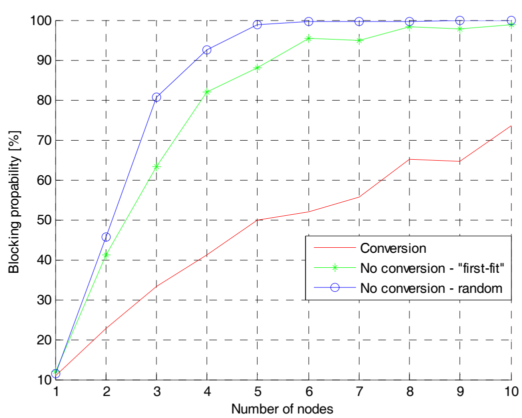

Fig. 10 Blocking Probability of 10 nodes for load 9 Erlangs per link

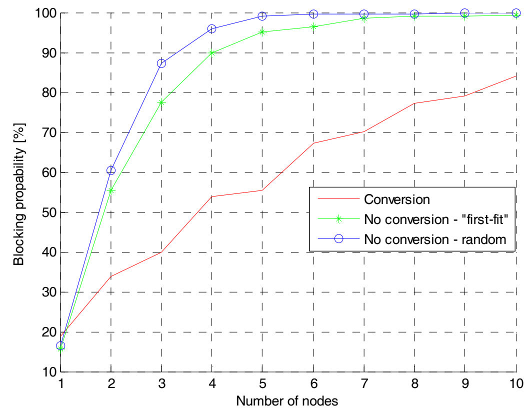

Fig. 11 Blocking Probability of 10 nodes for load 10 Erlangs per link

The above shown simulation results shows how the blocking probability (%) increases with the number of nodes. The blocking probability in case of random algorithm is always greater than that of First-fit wavelength assignment algorithm. Fig. 2 – fig. 11 shows that the blocking probability of 10 nodes both with wavelength conversion and with no conversion, for load ranging from 1 Erlang to 10 Erlang per link. The blocking probability is minimum in case of wavelength conversion, whereas in case of no conversion the first-fit algorithm has better results as compared to that of random wavelength assignment algorithms.

4. Conclusion

We have analyzed the response of blocking probability of a network having 10 nodes and for varying load. As the load per link (in Erlangs) increases the blocking probability increases. The results shows that the response of first-fit is better than random algorithm whereas the response of wavelength conversion is much better than without conversion i.e. with first-fit and random algorithm

5. References

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