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Wavelength Assignment In WDM Optical Networks

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***Abstract*— This paper analyses the wavelength assignment problem in optical WDM networks. First, the random wavelength assignment algorithm is compared with the first-fit wavelength assignment algorithm, then the sparse wavelength conversion case is compared with no wavelength conversion and full wavelength conversion cases. These comparisons are done on the basis of blocking probability and number of links; numbers of channels are kept constant whereas the response is calculated by varying the load per link (in Erlangs). The blocking probability in case of random algorithm is always greater than first-fit wavelength assignment algorithm. 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 algorithm and also for multiple iterations. The throughput is achieved better compared to the previous works thereby increasing the performance.**

Index terms - Blocking probability, wavelength assignment and wavelength division multiplexing

I.INTRODUCTION

Transmitting light beams of different wavelengths in an optical fiber is known as Wavelength Division Multiplexing (WDM). A WDM optical network consists of wavelength routing nodes interconnected by point-to-point optical fiber links in an arbitrary topology[1]. In a wavelength routed network, a message is sent from one node to another node using a wavelength continuous route called a light path, without requiring any optical-electronic-optical conversion and buffering at the intermediate nodes 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 [2]

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 light path. 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. 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:

In the fixed routing method, only one route is provided for a node pair. Usually this route is chosen to be the shortest route. When a connection request arrives for anode pair, the route fixed for that node pair is searched for the availability of a free wavelength. In the alternate routing method, two or more routes are provided for anode pair. These routes are searched one by one in predetermined order. Usually these routes are ordered in non decreasing order of their hop length. In the exhaust method, all possible routes are searched for a node pair.

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.

II.BACKGROUND

During the last decade, Wavelength Division Multiplexing (WDM) Networks have emerged as an attractive architecture for backbone networks. WDM networks provide high bandwidth, on the order of tens of Gigabits per second per channel. However, recently two observations are driving the research community to explore the traffic grooming problem in WDM networks. First, the bandwidth requirements of most of the current applications are just a fraction of the bandwidth offered by a single wavelength in WDM networks. Second, the dominant cost factor in WDM networks is not the number of wavelengths but rather the network components, specifically, higher layer equipment, such as SONET Add/Drop multiplexers (ADMs), or MPLS or IP router ports. Therefore the cost effectiveness of WDM networks depends on the amount of the optical pass through provided by the network to the given traffic, thus reducing the number and cost of the higher layer equipment.

Optical wavelength-division multiplexing (WDM) is a promising technology to accommodate the explosive growth of Internet and telecommunication traffic in wide-area, metro-area, and local-area networks Using WDM, this bandwidth can be divided into multiple non-overlapping frequency or wavelength channels. Wavelength Division Multiplexing (WDM) systems have increasingly been deployed to increase the capacity of optical networks. The general problem of designing a WDM network (i.e., designing virtual topology on a given physical topology) to optimize system cost and system performance is known to be an NP-hard problem. In this paper, a very special case in which all costs except the cost of transceivers are neglected is studied. It is also assumed that all virtual topologies are implementable on the given physical topology. Although this assumption is very restrictive, it is satisfied in the following situation. In wide-area optical WDM networks, if the number of physical links (fibers) available between neighboring nodes is large, then the number of wavelengths in the system is not important and two light paths can always be routed on two different physical links even though they use the same wavelength.

Moreover, if any two nodes can be connected by a path of physical links, then between any two nodes any number of light paths can be implemented.

A WDM network consists of several nodes interconnected with fiber optical (physical) links. The traffic signals in the network propagate through the optical fiber at different wavelengths and therefore the network can be alternatively thought of as a set of nodes interconnected by light paths. A light path is a path of physical links in which a particular wavelength on each link is reserved for the light path. The traffic signals in the network remain optical (or almost optical) throughout their flow through a light path. They consider networks with fixed (static) full-duplex light paths. The light paths are terminated at each end by transceivers which are optoelectronic equipment that convert the optical signals into electronic signals for further processing. The cost of the transceivers is a dominant cost in the network. Therefore, in this paper network design to minimize the number of transceivers is studied. Since the number of transceivers is twice the number of light paths, minimizing the number of transceivers is equivalent to minimizing the number of light paths.

In a wavelength-routed WDM network, the wavelength-continuity constraint can be eliminated if we are able to use a wavelength converter to convert the data arriving on one wavelength on a link into another wavelength at an intermediate node before forwarding it on the next link. Such a technique is feasible and is referred to as wavelength conversion. Wavelength-routed networks with this capability are referred to as wavelength-convertible networks. If a wavelength converter provides the ability to convert from any wavelength to any other wavelength (such wavelength converters are said to have full-range capacity), and if there is one wavelength converter for each fiber link in every node of the network, then the network is said to have full wavelength-conversion capabilities.

III ANALYTICAL MODEL

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.

In case of a static traffic demand, connection requests are known a priori. The traffic demand may be specified in terms of source-destination pairs. The problems this type are categorized under the static light path establishment (SLE) problem. As the optimal-time algorithms are ideal, polynomial-time algorithms which produce solutions close to the optimal one are preferred to solve the SLE problem.

In case of a dynamic traffic demand, connection request arrive to and depart from a network one by one in a random manner. The light paths once established remain for a finite time. The dynamic traffic demand models several situations in transport networks. Unlike the static RWA problem, any solution to the dynamic problem is computationally simple. Dynamic RWA algorithms perform more poorly than static RWA algorithms because a dynamic algorithm has no knowledge about future connection requests, whereas all the connection requests are known a priori to a static RWA algorithm.

IV PROPOSED WORK

Blocking probability is an important performance parameter; it is the probability of blocking a request for a connection. When a new request for a connection comes to a node it searches for the available resources free wavelength, free route and if the appropriate resources are not free then it rejects the request for the connection that is it blocks the request. To minimize the blocking of a request in a WDM network there should be sufficient number of wavelengths, sufficient number of routes, an optimum number of wavelength converters placed at appropriate nodes and sufficient conversion capability of wavelength converter.

Blocking probability of the network is compared depending upon the number of channels, number of links and traffic load per link (in Erlang). The number of wavelengths on all the links is kept constant. A very important assumption is the consideration of a network with an arbitrary topology. Static routing is assumed i.e. the route is selected off-line. When a request arrives, it is processed on the basis of some heuristics. 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. The simulation figures show the blocking probability both with and without wavelength conversion as well as the case of limited conversion. The 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 algorithm. Also, for lower load values, sparse wavelength conversion and full wavelength conversion gives similar results but as load per link increases, sparse wavelength conversion has less blocking as compared to even full wavelength conversion.

The blocking probability is calculated for many iterations and the performance is measured. The throughput is calculated for the variation in the blocking probability and it is found to better compared to the previous works.

V RESULT ANALYSIS

A. Comparison of First-fit and Random Algorithms

In this section, we will present the simulation results for random wavelength assignment algorithm and first-fit wavelength assignment algorithm. These algorithms are compared with the case of wavelength conversion. In all the simulations, blocking probability of the network is compared depending upon the number of channels, number of links and traffic load per link (in Erlang). The number of wavelengths on all the links is kept constant. A very important assumption is the consideration of a network with an arbitrary topology Static routing is assumed i.e. the route is selected off-line.

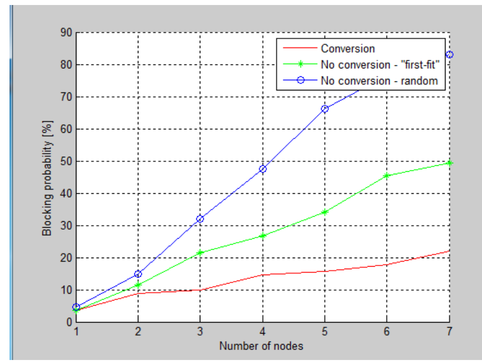

Fig 1: Blocking Probability for 10 links when load is 10 Erlangs per link .

The blocking probability increased with the increase in load. With no wavelength conversion the blocking probability is high. Compared to random wavelength assignment, first fit algorithm yielded a high blocking probability. According to the results random wavelength assignment was found to yield low blocking probability.

B.Effects of limited Wavelength Conversion

In this section, we will present the simulation results of comparison of sparse or limited wavelength conversion with no and full wavelength conversion. These algorithms are compared with the case of wavelength conversion.

In all the simulations, blocking probability of the network is compared depending upon the number of channels, number of links and traffic load per link (in Erlang). The number of wavelengths on all the links is kept constant. A very important assumption is the consideration of a network with an arbitrary topology. Static routing is assumed i.e. the route is selected off-line

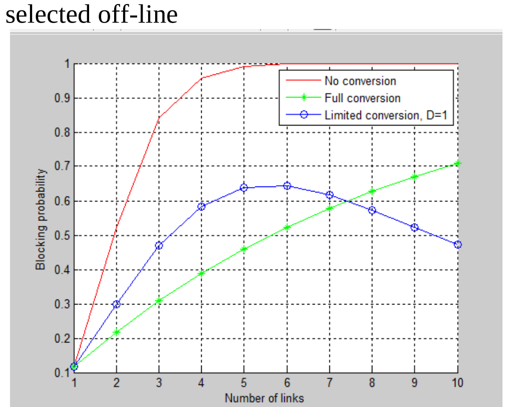

Fig.2: Blocking Probability for 10 links when load is 10 Erlangs per link

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. The simulation figures show the blocking probability of 10 links both with and without wavelength conversion as well as the case of limited conversion, for load ranging from 1 Erlang to 10 Erlang per link. The 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 algorithm. Also, for lower load values, sparse wavelength conversion and full wavelength conversion gives similar results but as load per link

C.Effects of iterations

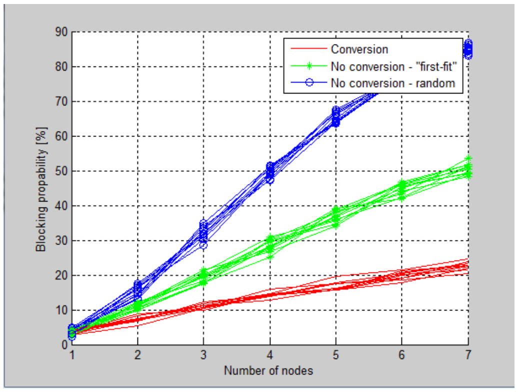

Fig:3 Blocking probability for many iterations

The blocking probability increased with the increase in load. With no wavelength conversion the blocking probability is high. Compared to random wavelength assignment, first fit algorithm yielded a high blocking probability for all iterations. According to the results random wavelength assignment was found to yield low blocking probability in all the iterations performed.

D.Throughput analysis

The blocking probability increased with the increase in load. So the throughput automatically increases.

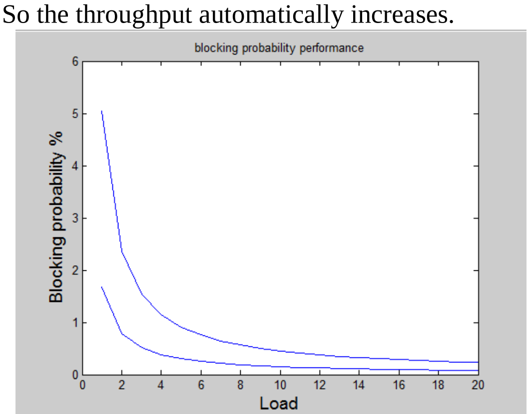

Fig:4 Performance of Blocking probability

VI. CONCLUSION

We have analyzed the response of blocking probability of a network having 10 links and for varying load. The simulation figures show the blocking probability of 10links both with and without wavelength conversion as well as the case of limited conversion, for load ranging from 1 Erlang to 10 Erlang per link. As load per link (in Erlang) increases, the blocking probability increases. The results show that the response of first-fit wavelength assignment algorithm is better than random wavelength assignment algorithm, whereas the response of wavelength conversion is much better than without conversion i.e. with first-fit and random algorithm. For lower load values, limited wavelength conversion and full wavelength conversion gives similar results but as load per link increases, sparse wavelength conversion has less blocking as compared to even full wavelength conversion and finally the throughput is also found to be better.

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