ADEQUATE WAVELENGTH ASSIGNMENT IN WDM SYSTEMS

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Abstract**—**One of the important requirements in control plane of a wavelength-routed optical network is to set up and take down optical connections which are established by lightpaths between source and destination nodes. When the wavelength conversion is not possible at intermediate routing nodes a lightpath must occupy the same wavelength on each link over its physical route. This restriction is known as the wavelength-continuity constraint. Wavelength continuity constraint is an important constraint which uses same wavelength on every link of the path to make a lightpath. This is true when OXCs in wavelength-routed optical network do not have wavelength conversion capability. The number of available wavelengths in a fiber link plays a major role in these networks which is increasing day by day. In this paper the Least Used Wavelength Conversion algorithm has been proposed for wavelength assignment and the performance of this wavelength assignment algorithm is evaluated in terms of blocking probability and fairness. In the first phase we have varied the number of wavelengths by keeping the other parameters constant. The results prove that the blocking probability of the proposed algorithm decreases with the increase in the number of wavelengths. As the number of wavelength is increased the blocking probability is decreased. In the second phase, the load per unit link is increased keeping the other parameters constant. The results show that as the load is increased the blocking probability of the network increases for the proposed algorithm keeping other parameters constant. Further, the blocking probability of proposed algorithm is compared with algorithms such as first-fit, best-fit, random and most-used wavelength assignment algorithm. The results have proved that as the load is increased keeping all other parameters constant the blocking probability is increased many times but the blocking probability is minimum for the proposed algorithm. This proposed algorithm gives the blocking free environment.

Keywords—*Wavelengths division Multiplexing; Wavelength Assignment; First Fit Algorithm; Least used wavelenth Algorithm.*

I. INTRODUCTION

The rapid growth of Internet traffic has been the driving force for faster and more reliable data communication networks. Networking is a very promising technology to meet these ever increasing demands. Broadly speaking a computer network is an interconnected collection of interdependent computers that aid communication in numerous ways. Apart from providing a good communication medium, cost effectiveness and sharing of available resources (programs and data) are some of the advantages of networking. This rapid growth of internet traffic has been the driving force for faster and more reliable computer and data communication networks. Wavelength division multiplexing (WDM) is a very promising technology to meet the ever increasing demands of high capacity and bandwidth. In a WDM network several optical signals are sent on the same fiber using different wavelength channels. Sometimes, the term dense wavelength division multiplexing (DWDM) is used to distinguish the technology from the broadband WDM systems where two widely separated signals (typically 1310nm and 1550nm) share a common fiber. In DWDM up to 40 or 80 signals are combined on the same fiber. WDM networks are a viable solution for emerging applications, such as supercomputer visualization and medical imaging, which need to provide high data transmission rate, low error rate and minimal propagation delay to a large number of users [1]. Traditionally, only a small fraction of the fiber capacity was used, but by using WDM it is possible to exploit this huge capacity more efficiently [2]. The possibility to use the existing fibers more efficiently makes WDM a very attractive alternative commercially, as it is very expensive to install new fibers in the ground. This is the case especially in densely populated areas like cities, where fibers must be dug under streets etc. WDM technology has been recognized as one of the key components of the future networks. The commercialization of WDM technology is progressing rapidly. Most important for the development of the WDM technology was the invention of Erbium Doped Fiber Amplifier, (EDFA) an optical fiber amplifier in 1987. The optical fiber amplifier is a component capable of amplifying several optical signals at the same time without converting them first to electrical domain (opto-electronic amplification). It is also important to note that EDFAs can be used to amplify signals of different bit rates and modulations. Other important WDM components include lasers, receivers, wavelength division multiplexers, wavelength converters, optical splitters and tunable filters amongst others. There is also wide interest towards the optical networking in academic community as it offers a rich research field for scientists from the component level up to the network protocols.

II. LTERATURE SURVEY

Abhisek Mukherjee *et. al.* [28], proposed a new wavelength conversion algorithm in a DWDM network using online routing. The model for the algorithm has been theoretically developed and the corresponding call connection probability has been calculated. The limitation on the number of wavelength conversions has been addressed by fixing the maximum number of wavelength conversions allowed for the transmissions of a single packet over the network.

Anwar Alyatama [24], used random and first-fit wavelength assignment approach for presenting an approximate analytical method and evaluated the blocking probabilities in wavelength division multiplexing networks without wavelength converters. The new approach viewed the WDM network as a set of different layers (colours) in which, blocked traffic in one layer is overflowed to another layer. Analysing blocking probabilities in each layer of the network is derived from an exact approach. A moment matching method was then used to characterise the overflow traffic from one layer to another.

Arun K. Somani *et. al.* [34], addressed the wavelength assignment issues in interconnecting optical local area networks in which a wavelength could not be reused for local connections. Static and dynamic approaches for partitioning of wavelengths were analysed and compared by simulations for local and global traffic. Several dynamic wavelength assignment algorithms were also developed and architectural issues interconnecting optical networks were also discussed. The objective was the development of a simple yet accurate model to predict approximate blocking performance with an arbitrary number of LANs.

D. Guo *et. al.* [41], presented an optimal wavelength assignment algorithm and three different adaptive wavelength routing algorithms. This wavelength assignment algorithm was used to minimize the number of wavelengths used in the network. The performance of these proposed algorithms was evaluated in terms of call blocking probability. They also presented a method for minimization of call blocking probability with a fixed number of transceivers per node. A scalable multi-hop WDM passive ring architecture for local area or metropolitan area networks was also presented.

F. Matera *et. al.* [23], showed how to obtain a wavelength assignment in a wide geographical transport network connecting the main cities of Europe, when all optical wavelength converters are introduced in the network nodes. They also reported an investigation on 40 Gb/s transmission performance in the presence of all optical wavelength converters based on four wave mixing in semiconductor optical amplifiers and on different frequency generation in periodically poled lithium niobate waveguides.

Guangzhi Li *et. al.* [42], studied the off-line wavelength assignment problem in star and ring networks for optical wavelength division multiplexed networks. The results showed that the ability to switch between fibers increases wavelength utilization. Additionally, the complexity of the problem was studied and several constrained versions of the problem were also considered for star and ring networks.

H. Ghafouri-Shiraz *et. al.* [37], presented a series of wavelength optimization and wavelength assignment algorithms with the objective to optimize the number of required SONET add–drop multiplexers. The other objective of these algorithms was to minimize the number of wavelengths in both unidirectional and bidirectional rings under an arbitrary grooming factor. Both uniform and general non-uniform all-to-all network traffic were considered for these algorithms.

I. Alfouzan *et. al.* [27], introduced two new wavelength assignment reconfiguration algorithms, the One-Directional Transfer (1DT) and the Two-Directional Transfer (2DT) algorithms. The simulation results for both these algorithms were shown to outperform the existing algorithms in terms of the trade-off.

Jian Liu *et. al.* [36], proposed two different wavelength assignment algorithms for the network. These wavelength assignment algorithms were proposed for minimization of blocking probability of the network.

Jianping Wang *et. al.* [33], studied the problem of wavelength assignment for multicasting in order to maximize the network capacity in all-optical wavelength-division multiplexing networks. Two efficient greedy algorithms were also proposed for general multi-hop networks. The objective of this work was to minimize the call blocking probability by maximizing the remaining network capacity after each wavelength assignment.

Jianping Wang *et. al.* [44], studied wavelength assignment for WDM multicast network to cover the maximum number of destinations for minimizing the network cost. The computational complexity of the problem was also studied. Three heuristic algorithms were proposed and the worst-case approximation ratios for some heuristic algorithms were given. They also derive a lower bound of the minimum total wavelength cost and an upper bound of the maximum number of reached destinations. The efficiency of the proposed heuristic algorithms and the effectiveness of the derived bounds were verified by the simulation results.

Junjun Wan *et. al.* [22], proposed a wavelength assignment algorithm, which was based on the method called Dynamic Preferred Wavelength Sets (D-PWS). Also, they described the basic architecture of the optical burst switching network based on Dynamic Wavelength Routing (DWR), under which the guarantee of the quality of service in the DWR-OBS network was discussed. Then they focused on two aspects: the transmission latency of the data packets and the blocking probability, which leads to a quantitative description of the transmission latency and the size of the edge node buffer.

Kuo-Chun Lee *et. al.* [38], developed wavelength assignment algorithms for hierarchical networks and wavelength-routing algorithms for arbitrary network topologies. Signal to noise ratio was also analysed for in-band/out-band WDM signals.

III. PROPOSED MODEL

In this phase, we have investigated the analysis and development of wavelength assignment algorithms. The model has also been suggested in this chapter to develop better wavelength assignment strategies. The effective algorithm is proposed in this chapter and the performance of new wavelength assignment algorithm is evaluated in terms of blocking probability and fairness. In the first section of this chapter, the analysis of proposed wavelength assignment algorithms has been discussed. In the second section, proposed wavelength assignment algorithm is compared with conventional wavelength assignment algorithms such as first-fit, best-fit, random and most-used wavelength assignment algorithms. These algorithms are compared on the basis of blocking probability, number of channels and number of links. For the comparison the number of links is kept constant whereas the response of algorithms is calculated by varying load (in Erlangs) per unit link. These simulation results show that the proposed approaches are very effective for minimization of blocking probability of optical WDM networks. Many analytical models have been proposed in the literature but some of them are very complex and lots of simulation statistics are required to evaluate the performance of the system by using these models. The models proposed in literature are such that the mathematical computations used are very complicated. Further, computation time of these models is also quite large. In this chapter, we have identified a low complexity mathematical models which do not require any simulation statistics. These models have low implementation complexity and computation is also quite efficient. These models suggest an optimum path as a solution to routing and wavelength assignment problem.

In this section, conventional wavelength assignment strategies are analysed and compared with each other on the basis of blocking probability and fairness. The performance of conventional wavelength assignment algorithms is calculated in terms of blocking probability and fairness. Erlang's-B formula is used to compute the blocking probability. We have developed approximate analytical models for clear channel blocking probability of the network with arbitrary topology, both with or without wavelength translations. The goal of our analysis is to calculate and compare blocking probability of different algorithms. In order to do the analysis following assumptions are made:

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

We have considered blocking probability for wavelength non-convertible networks. The two constraints which are followed for the wavelength assignment are:

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

If there is no free wavelength available on any link the call will be blocked. In simple terms blocking probability as per *Poisson's formula* can be calculated as the ratio of calls blocked to the total number of calls generated as given in equation (1.1).

$$P_{Bavg} = \frac{Total\ number\ of\ calls\ blocked}{Total\ number\ of\ calls\ generated} \qquad (1.1)$$

Also, the blocking probability on the link can be calculated by famous Erlang-B formula as given by Milan Kovacevic [45] equation (1.2)

$$P_{b(L,W)} = \frac{\frac{L^W}{W!}}{\sum_{i=0}^{W} \frac{L^i}{i!}} \qquad (1.2)$$

Where $P_{b(L,W)}$ is blocking probability for L load and W wavelengths.

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

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

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;

Figure 1.1: First-fit Algorithm

The algorithm for the random wavelength assignment is very simple and is limited to the generation of a random number but algorithm for first-fit is a bit complex. The algorithm for the first-fit wavelength assignment can be illustrated by figure (1.1).

A. Proposed Least-Used Wavelength Conversion Algorithm

In this section, we have proposed an efficient wavelength assignment algorithm for dynamic provisioning of lightpath. This proposed algorithm is an improvement of Least-used wavelength assignment algorithm. We have used mathematical model for WDM optical networks for minimization of blocking probability. The results of proposed algorithm and Model given by equation are then compared with conventional wavelength assignment algorithms such as first-fit, best-fit, random and most used wavelength assignment algorithms. Simulation results proved that these proposed approaches are very effective for minimization of blocking probability of optical WDM networks.

B. Analytical Model

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

- Each station has an 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.

A. Analysis of wavelength assignment algorithms

For no wavelength translation; the two constraints are to be followed for wavelength assignment these are wavelength continuity constraint and distinct wavelength assignment constraint. If there is no free wavelength available on any link the call will be blocked. The blocking of calls can be calculated by blocking probability which can be calculated by equation (1.1). In addition, blocking probability on a link can be calculated by the famous Erlang-B formula as in equation (1.2). The algorithms which are used for simulation are first-fit algorithm, best-fit algorithm, most-used algorithm and random algorithm.

B. Least–used wavelength conversion (LUWC) algorithm

This algorithm is an improvement of least used wavelength assignment algorithm. In this algorithm least–used wavelength assignment algorithm is executed until blocking. When the call is blocked wavelength conversion is introduced and hence blocking probability is reduced. If the full wavelength conversion is used after least–used wavelength assignment algorithm the blocking probability is reduced to a very large extent and its value reduces to a minimum possible value. As full wavelength conversion is costlier than sparse wavelength conversion so the sparse wavelength conversion is employed in this proposed algorithm. The least–used wavelength conversion algorithm can be easily explained with figure (1.2).

IV. RESULTS AND DISCUSSION

In this section, the simulation results of proposed Least Used Wavelength Conversion algorithm have been shown. Also, the blocking probability of proposed algorithm is compared with the conventional algorithms. The simulation is carried out on simulation software MATLAB 7.2 of Mathworks. The blocking probability of network is compared depending upon number of channels, load and the number of links.

The Least Used Wavelength Conversion algorithm has been proposed for wavelength assignment and the performance of this wavelength assignment algorithm is evaluated in terms of blocking probability and fairness. In the first phase we have varied the number of wavelengths by keeping the other parameters constant. We have fixed the number of channels to 20; total number of links in the network to 20 and maximum load per unit link to 10 Erlangs and increased the number of wavelengths used from 20 to 50 respectively in figure 1.2 to 1.5.

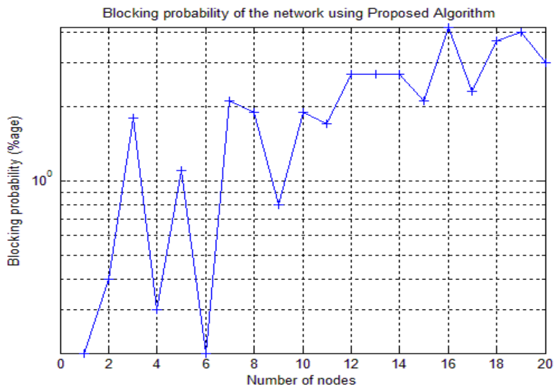

Figure 1.2: Blocking probability of the proposed Algorithms for W=10.

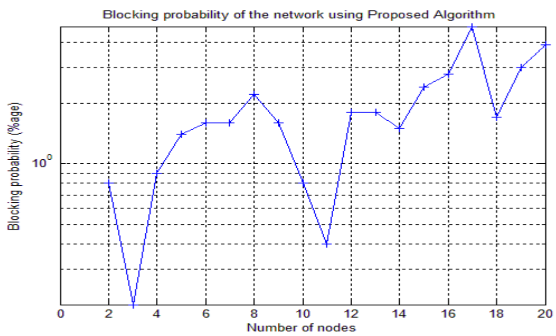

Figure 1.3: Blocking probability of the proposed Algorithms for W=20.

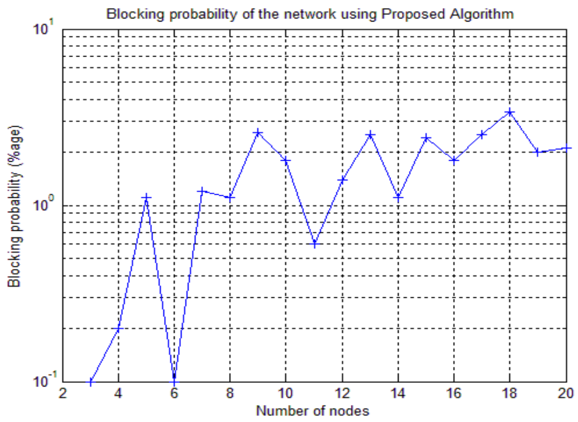

Figure 1.4: Blocking probability of the proposed Algorithms for W=30.

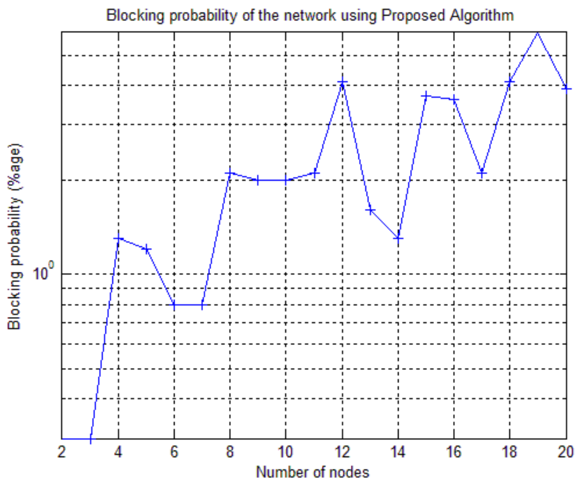

Figure 1.5: Blocking probability of the proposed Algorithms for W=40.

The results shown in figure 1.2 – 1.5 prove that the blocking probability of the proposed algorithm decreases with the increase in the number of wavelengths. As the number of wavelength is increased the blocking probability is decreased.

Comparison of proposed wavelength assignment algorithm with the conventional algorithm

Further, the blocking probability of proposed algorithm is compared with algorithms such as first-fit, best-fit, random and most-used wavelength assignment algorithm and are shown in figure (5.6). For this comparison we have fixed the number of channels to 20; the total number of links used in the network is also fixed to 20; and the total number of wavelengths used along with the load per unit link is varied. The results shown in figure (5.10) – (5.9) show the results when the other parameters kept constant and number of wavelengths used is 20 and the load per unit link is increased from 10 Erlangs to 40 Erlangs. The results have shown that as the load is increased keeping all other parameters constant the blocking probability is increased many times but the blocking probability is minimum for the proposed algorithm amongst all the algorithms.

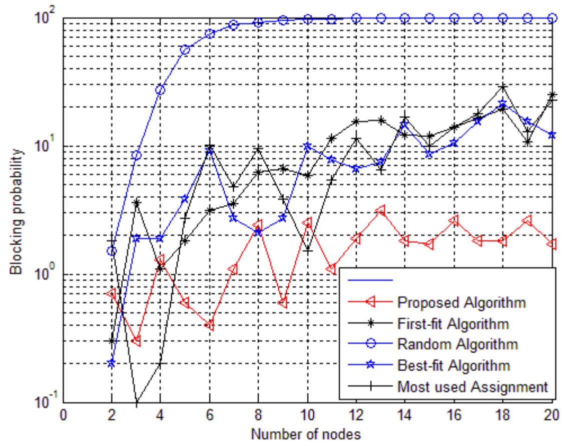

Figure 1.6: Comparison of the algorithm for load=10 Erlangs; W=20

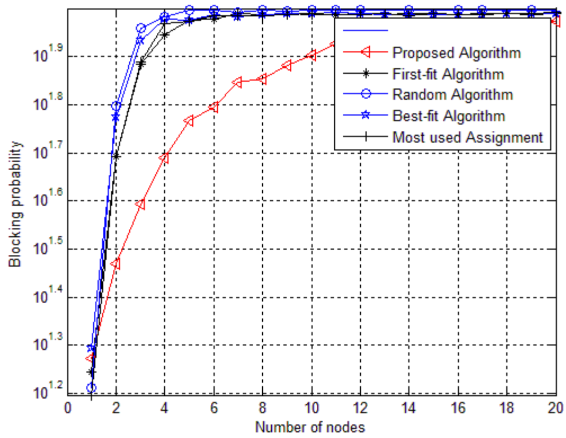

Figure 5.7: Comparison of the algorithm for load=20 Erlangs; W=20

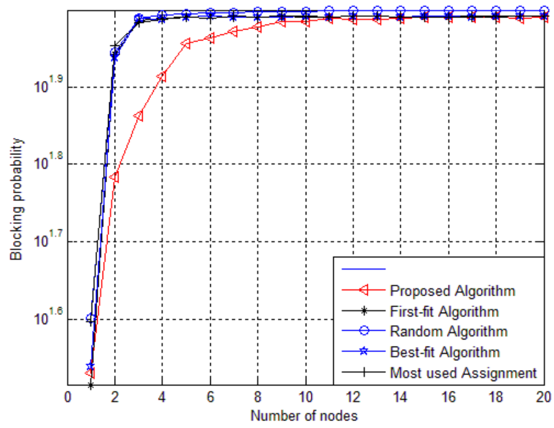

Figure 5.8: Comparison of the algorithm for load=30 Erlangs; W=20

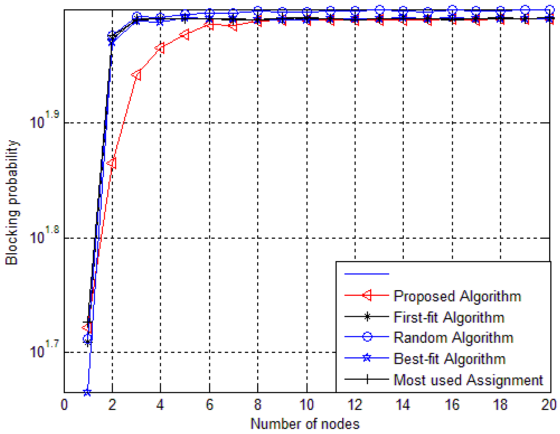

Figure 1.9: Comparison of the algorithm for load=40 Erlangs; W=20

V. CONCLUSION

The template is designed so that author affiliations are not repeated each time for multiple authors of the same affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization). This template was designed for two affiliations. The results prove that the blocking probability of the proposed algorithm decreases with the increase in the number of wavelengths. As the number of wavelength is increased the blocking probability is decreased. In the second phase, the load per unit link is increased keeping the other parameters constant. The results show that as the load is increased the blocking probability of the network increases for the proposed algorithm keeping other parameters constant. Further, the blocking probability of proposed algorithm is compared with algorithms such as first-fit, best-fit, random and most-used wavelength assignment algorithm. For this comparison we have fixed the number of channels to 20; the total number if links used in the network is also fixed to 20; and the total number of wavelengths used along with the load per unit link is varied. The results have shown that as the load is increased keeping all other parameters constant the blocking probability is increased many times but the blocking probability is minimum for the proposed algorithm. This algorithm proposed gives the blocking free environment.

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