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Performance Analysis of Wavelength Assignment Algorithms in Optical Mesh Network using Hegon Simulator

Shilpa Arya *
CSE Department , Kurukshetra University
India

Kamal Chhabra
CSE Department , Kurukshetra University
India

Abstract— ***The main aim of this research paper is to analyse the performance of wavelength assignment algorithms such as First Fit , Random Fit, Most Used, Least Used, Least Loaded , Most Loaded and to find their effect on the blocking probability in optical mesh network with traffic grooming. Hegons simulator is used to find the results. In wavelength routed networks the wavelength assignment is a unique feature as it distinguishes them from the conventional networks. In this paper , placement of traffic grooming devices with varying number of wavelength converters and varying traffic types is studied and results are obtained on their effect on blocking probability. Simulation is done for the 32 node optical mesh network. The experimentation results indicate that the most used algorithm achieves reduced network blocking rate in two out of the four scenarios used in the network.***

Index Terms— Blocking Probability; First-Fit method; Random-Fit method; Most Used; LeastUsed; Least Loaded; Most Loaded; Hegons; Traffic Grooming.

I. INTRODUCTION

1.1 Optical Networks: Optical networks are high-capacity telecommunications networks based on optical technologies and components that provide routing, grooming, and restoration at the wavelength level as well as wavelength-based services. Optical networks, based on the emergence of the optical layer in transport networks, provide higher capacity and reduced costs for new applications such as the Internet, video and multimedia interaction, and advanced digital services. Lightpath is used for data communication in optical fibers. A lightpath is an optical connection carried end to end, from a source to a destination over a wavelength on each intermediate link.

1.2 The Future of Optical Networks Continued advancements in optical technology promise continued change as the optical network evolves to the ultimate goal of end-to-end wavelength services. The impact of the new optical layer in the telecommunications network is astounding. It can be measured in two ways—economic impact and carriers' ability to offer new services. Optical layer technology will increase network capacity, allowing network providers to transport more than 40 times the traffic on the same fiber infrastructure. That will ultimately lead to lower prices, and competition in the local exchange (as a result of the 1996 Telecommunications Act) will ensure that bandwidth becomes more affordable. Consumers will have access to new high-bandwidth services made possible by the increased capacity afforded by the optical layer. Services that today are considered prohibitively expensive, such video conferencing to the desktop (or home), electronic commerce, and high-speed video imaging, will become commonplace because they will be technologically and economically feasible. In essence, optical layer technology will improve the way we live.[20]

1.3 WDM networks: WDM(wavelength division multiplexing) network came into scenario to meet the demand of high bit rate. WDM enables the efficient utilization of optical fibre by dividing its tremendous bandwidth into a set of disjoint wavelength bands , which are referred as wavelengths. Each of these wavelengths supports one communication channel which corresponds to an end user operating at an arbitrary speed and helping in overcoming the optoelectronic mismatch between multiple terabit per second bandwidth of optical fibre and gigabit per second electronic processing speeds at end user. WDM based optical network enables the fibre to provide the large throughput as each of these multiple channels have assigned different wavelengths and transmitted over the same fibre simultaneously. Wavelength Division Multiplexing also solves the problem of dispersion which came into the effect during transmission in the fibre by keeping the transmission rates of each channel at reasonably low levels and achieving a high data rate by combining many channels.

WDM networks provide concurrency by multiplexing more than one wavelength and transmit them simultaneously within the same fiber. A lightpath is an optical connection, from a source to a destination over a wavelength on each intermediate link. These end to end all-optical circuits offer bandwidths equivalent to the bandwidth provided by single wavelength. Such optical networks are referred to as the wavelength division multiplexing networks [1]. WDM networks can carry more than 160 wavelength channels, with the advancement in technology supporting over 160 channels, with each channel having 10 Gbps of transmission capability. A lightpath may span multiple fiber links and is identified by the wavelengths that it carries [21].

1.4 Wavelength continuity constraint and wavelength conversion: If a lightpath occupies the same wavelength on all the fiber links that it traverses, then this is called as the wavelength continuity constraint [22]. This constrained is relaxed using wavelength conversion technique. The wavelength conversion feature is used when a lightpath cannot be established using a single wavelength channel on all intermediate links between source and destination [23].

1.5 Connection blocking: The connection blocking is the probability that an incoming connection or call request is blocked or denied, due to insufficient resources between the source and destination [8]. For every dynamic connection request, a lightpath is needed to be established. Otherwise the connection is blocked. Blocking probability is also a measure of performance in dynamic wavelength routed networks. A network's performance is inversely proportional to the amount of connection blocking in the network. Common causes of connection blocking within a network:

- Insufficient network resources. (Unavailable Link Bandwidth or Wavelengths)
- Lack of wavelength converters in the network.
- Routing and wavelength assignment decisions made on outdated network state information.[25]

1.6 Wavelength Converter: A wavelength converter is a device that converts data from one incoming wavelength to another outgoing wavelength [18]. A device that can change the carrier wavelength of the channel without affecting its bit pattern that contains the information being transmitted [19]. It is also called as frequency changer, shifter or translator. It is called as up-converter and down-converter when it changes the original wavelength to a shorter wavelength or longer wavelength respectively.Wavelength conversion increases the routing choices for a given light path , resulting in better performance in terms of less blocking probability .It also reduces the bandwidth loss that results in better bandwidth utilization . However such converters are expensive . The routing and wavelength assignment(RWA) can be split up into two parts: first choosing the route then assigning the wavelength/channel to that route. In routing process the routes are choosen based on shortest path selected . Assignment of wavelength to the connection request is depicted in figure 1[1].

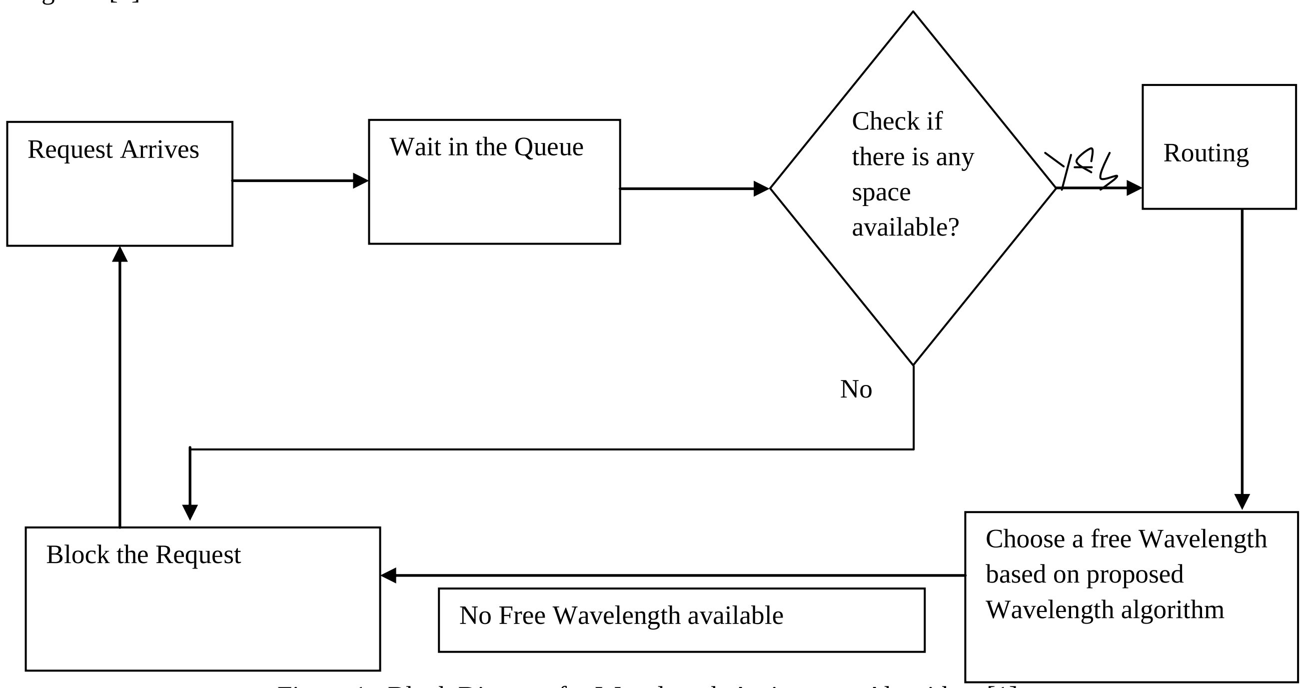

Figure 1 : Block Diagram for Wavelength Assignment Algorithms[1]

II. LITERATURE SURVEY

Vikas Kaushik et. al. [1] analyzed the performance of various wavelength assignment algorithm and their effect on the blocking probability of the connection request in the optical network with traffic grooming. The experimentation results indicate that the most used algorithms achieves reduced network blocking rate with and without Traffic Grooming.

Yvan Pointurier et. al. [2] presented an analytical method to evaluate blocking probability in all-optical networks, accounting for several physical layer impairments: intersymbol interference (ISI), amplifier noise (both are static effects that only depend on the network topology only) and node crosstalk (a dynamic effect that depends on the network status) Model was successfully validated through simulations on large scale networks with realistic physical layer parameters.

Bijoy Chand Chatterjee et. al. [3] proposed a priority based routing and wavelength assignment scheme with incorporation of a traffic grooming mechanism (PRWATG) to reduce call blocking.Results showed that using the PRWATG scheme, the blocking probability and the congestion of the network were significantly reduced compared to NPRWATG , also the performance of the proposed scheme was better compared to NPRWATG when the number of connection requests increases in the network.

Jun He et. al. [4] derived analytical expressions for the total blocking probability for first-fit wavelength assignment fornetworks suffering from transmission impairments.

Yvan Pointurier et. Al. [6] presented an analytical method to evaluate blocking probability in all-optical networks, accounting for physical layer impairments. Simulations show that this technique is suitable for quick and accurate dimensioning of all-optical networks: the accuracy of the blocking rates computed with the analytical method, taking only seconds or minutes to run, is the same as that of simulations, which take hours to run.
Dr. Aditya Goel et. al. [7] evaluated the effects of varying number of wavelength converters, different traffic types on fiber link utilization and network blocking probability and results showed that the blocking probability is minimum with wavelength conversion factor of 0.5. Thus a network with 32 and 64 wavelengths and 50 % wavelength convertible nodes was proposed.
Tushar Tripathi et. al. [8] proposed a method to calculate the average blocking probability in all-optical networks using limited-range wavelength conversion. Comparisons to simulations show that this analytical model is accurate for a variety of networks, for various values of the conversion degree (d = 1, 2, 3), and hop length (1–4), and over a wide range of blocking probabilities (> 0.0001). The method is also accurate in estimating the blocking probabilities on individual paths (and not just the average blocking probability in the network).
Ning-Hai Bao et. al. [10] investigated some representative sharing schemes and proposed an enhanced resource sharing scheme with resource contention resolution for double-link failures in survivable optical mesh networks. Simulation results show that this enhanced resource sharing scheme can achieve satisfactory performance in terms of resource utilization ratio and blocking probability.
Xuehong Sun et. al. [11] This paper proposes a new analytical technique for the performance analysis of all optical networks which use the first-fit algorithm for wavelength assignment.The wavelength usage on the links to calculate the blocking probability of a source destination pair, taking into account wavelength correlation and load correlation between links is analysed .The model is accurate even in a system with large number of wavelengths.
M. Arunachalam et. al. [12] analysed the performance of the wavelength assignment strategies to reduce the network block rate of the request considerably. Simulation results indicate that the round robin assignment algorithm achieves reduced network block rate and delay with increased bandwidth utilization and throughput.
Wei Yang et. al. [14] proposed an analytical model to iteratively compute blocking performance of single-fibre networks and presented RWTA algorithms for multi-fibre networks based on an indexed fibre designation scheme in order to enhance network blocking performance in all-optical metro networks .Results showed that packed algorithms reduce blocking probability and also that the indexed fibre designation scheme enhances performance.

III. PROPOSED WORK/SIMULATION

The experiment is carried out to analyze the performance of various wavelength assignment algorithms.The parameters used for simulation are variable traffic and fixed wavelength. The mesh topology with thirty two nodes is used.The simulation is done on the optical mesh network model which is having 32 nodes with the fixed wavelength 9 and the variable offered traffic on each of the link between the nodes.The nodes used in the model are of grooming type.The link capacities matrix which is of [32][32] in the case of mesh network and the arrival rate matrix of order [32][32] is also used in the proposed model.The blocking probability of network depends on length of the route , free wavelengths, and number of channels.The wavelength is fixed as 9 and traffic load varies from 0 to 7.Here the total traffic blocked and maximum blocking probability probability of algorithms such as first fit, random fit, most used , least used ,least loaded and most loaded is compared with each other.

IV. SIMULATION TOOL

Hegon(Heterogeneous Grooming Optical Network Simulator) Simulator is used for performing analysis of various wavelength assignment algorithms with traffic grooming mechanisms. A HEterogeneous Grooming Optical Network Simulator, supportes mixed routing & wavelength assignment algorithms and optional wavelength conversions capability on each node.

V. RESULTS

The blocking probability of network depends on length of the route , free wavelengths, and number of channels.The wavelength is fixed as 9 and traffic load varies from 0 to 7.
In Table 1 and figures 2 and 3, the total traffic blocked and maximum blocking probability of algorithms such as first fit, random fit, most used , least used, least loaded and most loaded are compared with each other when when multihope alternate nodes are used in the network.

Table 1: Blocking Probabilities

Algorithm	First Fit	Least Loaded	Least Used	Most Loaded	Most Used	Random fit
Total Blocked	256177	256177	257104	256177	256480	255871
Total Arrived	467422	467422	467520	467422	467638	466925
Average of Averages Blocking Probability	0.290248	0.290248	0.291687	0.290248	0.29073	0.290679
Maximum Blocking Probability	0.934621	0.934621	0.939435	0.934621	0.944895	0.95257
Average Number of attempts	10.1433	10.1433	8.86737	10.1433	10.8598	9.29144

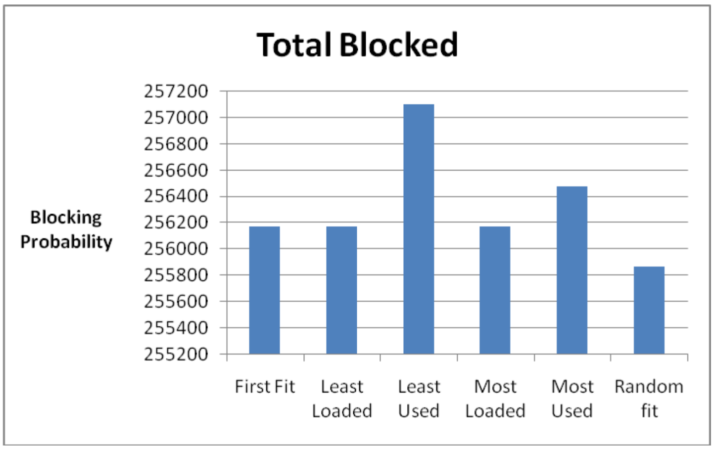

Figure 2: Total Blocked

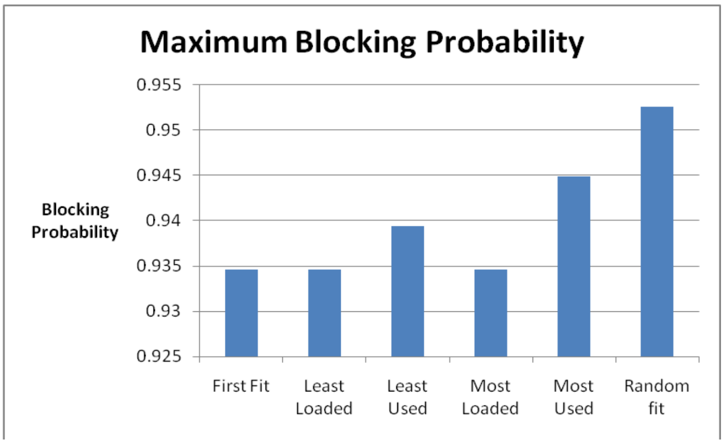

Figure 3: Maximum Blocking Probability

In Table 2 and figures 4 and 5, the total traffic blocked and maximum blocking probability of algorithms such as first fit, random fit, most used , least used, least loaded and most loaded are compared with each other when multihope full grooming nodes are used in the network.

Table 2: Blocking Probability

Algorithm	First Fit	Least Loaded	Least Used	Most Loaded	Most Used	Random fit
Total Blocked	254149	254149	254149	254149	254149	254149
Total Arrived	468904	468904	468904	468904	468904	468904
Average of Averages Blocking Probability	0.27813	0.27813	0.27813	0.27813	0.27813	0.27813
Maximum Blocking Probability	0.912184	0.912184	0.912184	0.912184	0.912184	0.912184
Average Number of attempts	12.8254	12.8254	10.3227	12.8254	14.0089	10.7598

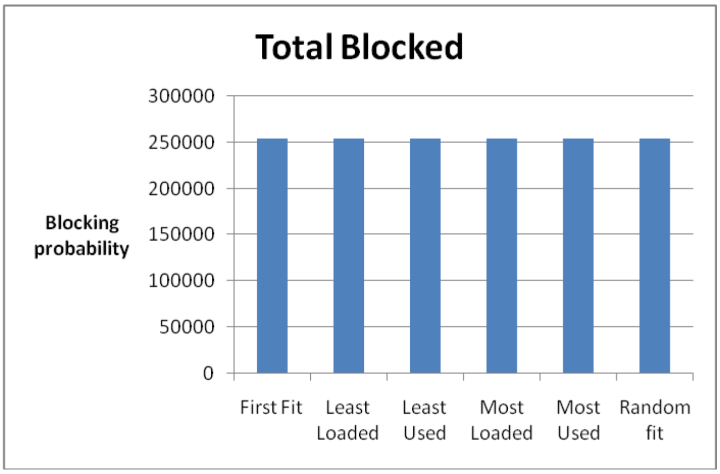

Figure 4: Total Blocked

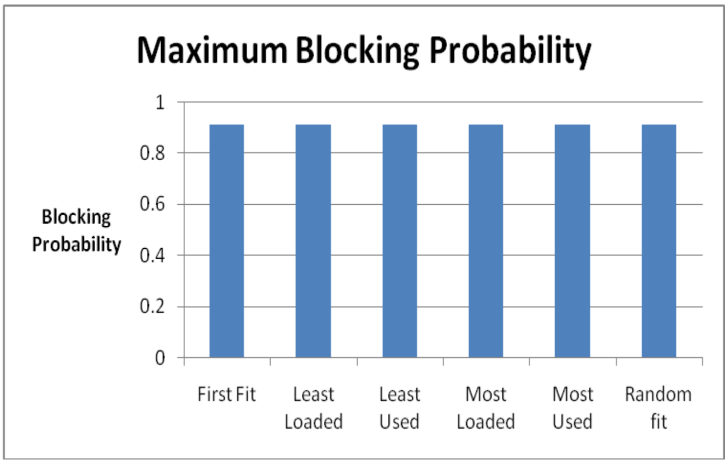

Figure 5: Maximum Blocking Probability

In Table 3 and figures 6 and 7, the total traffic blocked and maximum blocking probability of algorithms such as first fit, random fit, most used , least used, least loaded and most loaded are compared with each other when first and last full grooming nodes are used in the network.

Table 3: Blocking Probability

Algorithm	First Fit	Least Loaded	Least Used	Most Loaded	Most Used	Random Fit
Total Blocked	261164	261164	262423	261164	261125	261663
Total Arrived	465363	465363	465655	465363	465490	465358
Average of Averages Blocking Probability	0.288186	0.288186	0.289314	0.288186	0.288155	0.288612
Maximum Blocking Probability	0.981372	0.981372	0.983833	0.981372	0.981707	0.98203
Average Number of attempts	8.16661	8.16661	7.65682	8.16661	8.55729	7.98595

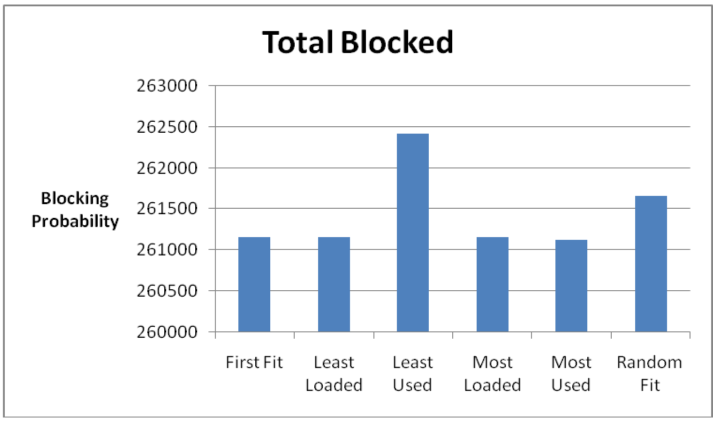

Figure 6: Total Blocked

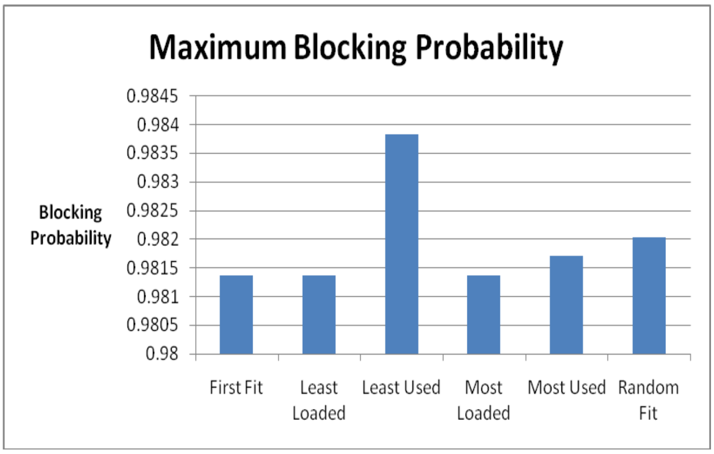

Figure 7: Maximum Blocking Probability

In Table 4 and figures 8 and 9, the total traffic blocked and maximum blocking probability of algorithms such as first fit, random fit, most used , least used, least loaded and most loaded are compared with each other when no wavelength converters are used in the network

Table 4: Blocking Probability

Algorithm	First Fit	Least Loaded	Least Used	Most Loaded	Most Used	Random Fit
Total Blocked	266051	266051	266050	266051	264723	266079
Total Arrived	471593	471593	470953	471593	471150	471409
Average of Averages Blocking Probability	0.291413	0.291413	0.291513	0.291413	0.29047	0.291607
Maximum Blocking Probability	0.98046	0.98046	0.982213	0.98046	0.97505	0.977192
Average Number of attempts	7.97536	7.97536	7.58041	7.97536	8.35241	7.8886

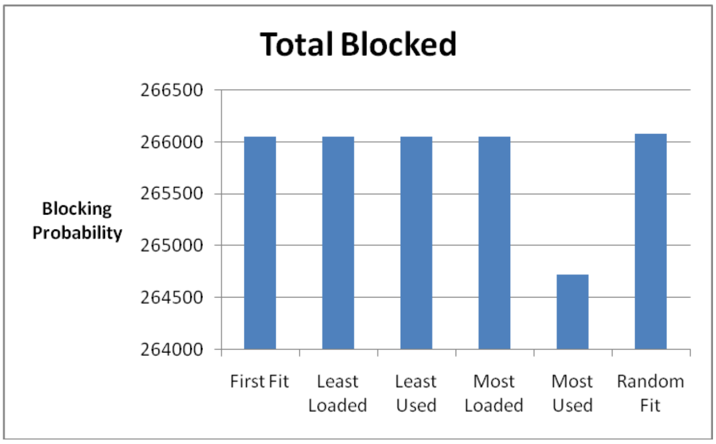

Figure 8: Total Blocked

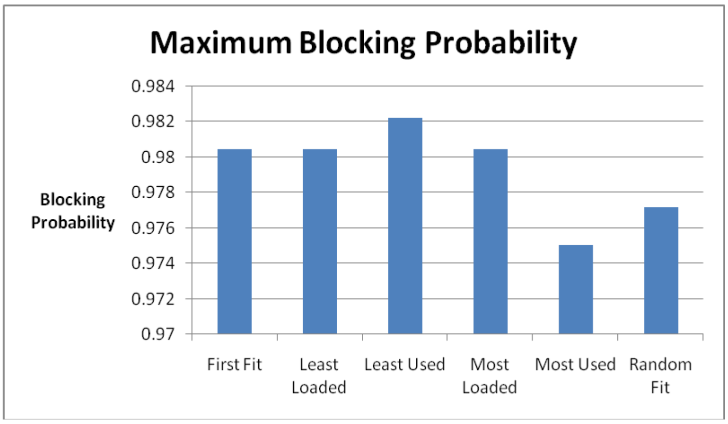

Figure 9: Maximum Blocking Probability

VI. CONCLUSION

The blocking probability in an optical network depends on the Network hierarchy as well as the offered Traffic to that network. Hegons simulator is used for performance analysis of optical network using first fit, random fit, most used, least used, least loaded and most loaded wavelength assignment algorithms. Simulation is done for four scenarios. In the first scenario performance analysis is done with multihope alternate node scheme. In the second scenario the performance analysis is done with multihope full grooming node scheme. In the third scenario the performance analysis is done with multihope first and last full grooming node scheme and in the fourth scenario the performance analysis is done without wavelength converters.

The blocking performance of WDM network was analyzed for optical mesh network having 32 nodes with fixed wavelength 9 and varying traffic load from 0 to 7. Simulation results obtained for calculating the total blocked and maximum blocking probability for each of the algorithm are compared in each scenario and it is analyzed that the most used wavelength assignment algorithm offers least connection blocking of 261125 and 264723 in schemes where multihope first and last grooming nodes were present and where no wavelength converters were used in the network respectively.Random fit wavelength assignment algorithm offers least connection blocking of 255871 in scheme when multihope alternate nodes are used in the network and finally when multihope full grooming node scheme was used in the network then all of the six wavelength assignment algorithms performed similar with connection blocking of 254149.

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