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Traffic Grooming and Blocking Optimization in all-optical Networks

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Abstract— The paper proposed an efficient traffic grooming model for all optical networks. The model has low complexity and it can be easily implemented for traffic grooming problems. It is used to calculate the blocking probability of computer networks and then grooming problems are addressed based on the calculated blocking probability. Blocking probability is considered to be a major parameter during the analysis of network performance in optical network. It can be used to calculate some other network parameters such as busy traffic hour based on a fixed value of blocking probability. The results have shown that the proposed model can be implemented irrespective of the size of the network with equal efficiency.

Index Terms— Traffic Grooming, Blocking Optimization, All optical networks

1 INTRODUCTION

Traffic Grooming can be defined as the optimization of capacity utilization of any transmission systems. It can be achieved by means of cross connections of conversions between different transport systems or cross connections of conversions of different layers within the same system. The major aim of traffic grooming is to optimize the use of network resources and to improve the overall network performance. Different multiplexing techniques are used for traffic grooming in different domains of optical WDM networks [1]. It is expected that computer network must deliver maximum speed with significant reliability. It can be achieved only with efficient traffic grooming of networks. There are certain parameters which play important role in traffic grooming. Some of these parameters are network planner, topology design and dynamic circuit provisioning [2]. Traffic grooming can be further classified in two broad categories: traffic grooming for static traffic and traffic grooming for dynamic traffic. Static traffic is comparatively easy to handle, as the volume and nature of traffic is known in advance. But grooming of dynamic traffic is more challenging. Now the networks are shifting towards mesh topology from ring topology. This trend again offers various challenges for traffic grooming [3]. The ever increasing demand for higher capacity in terms of speed and reliability can be met only with the use of efficient groomed optical networks. Earlier the optical networks were limited only to point-to-point systems. At that stage multipoint and optical cross connect networks were rare in implementation. The success of any network depends upon its ability to share resources efficiently. Optical network can share resources within network and with other networks as well with required efficiency; it makes optical networks very successful. Earlier traditional communications concepts such as Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM) and CDMA network were used for in networking. Recently two major developments have changed the scenario significantly. One of them is wavelength division multiplexing (WDM) and another is erbium-doped fiber amplifier (EDFA). Many light beams of different wavelengths can be used in an optical fiber using WDM. Whereas, EDFA is capable to amplify signal at many different wavelengths simultaneously. A typical WDM link can be easily explained with Figure-I [4].

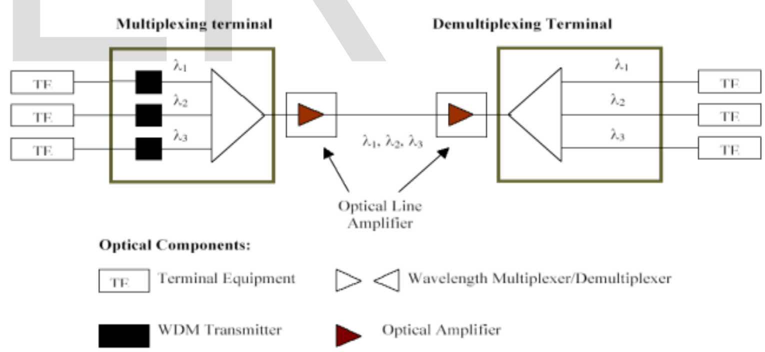

Figure 1: A Typical WDM Link

A typical WDM optical link consists of certain components such as WDM transmitters & receivers, WDM multiplexers & demultiplexers, optical amplifiers etc. Optical line terminals (OLTs), optical add/drop multiplexers (OADMs) and optical cross connects (OXCs) are key components of an optical network. OLTs are basically used at the ends of point to point WDM link. An OLT multiplexes multiple wavelengths into a single fiber and demultiplexes a set of wavelengths on to a single fiber into separate fibers. An OADM takes in signals at multiple wavelengths and selectively drop some of these wavelengths to the composite bound signal. The role of OXC is also similar to OADM but at much larger sizes. OXCs have a wide range of ports (ranging from few 10s to 1000s) and are able to switch wavelengths from one input port to another [4]. In this paper we have proposed an analytical model for traffic

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grooming and blocking optimization. The proposed model is used to calculate the blocking probability of network. Certain crucial parameters such as number of free wavelengths, numbers of channels, total number of call sources and path length are also considered while analyzing the blocking performance. The paper is organized as follows: In section 2, Research Background and Motivation has been discussed. In Section 3, Proposed Analytical Model has been discussed. Section 4 focuses on the results and discussions. The conclusions have been presented in Section 5.

2 Research Background and Motivation

The major strength of any optical network is its capacity to provide maximum bandwidth with high speed and significant reliability. Wavelength-division multiplexing (WDM) technology is the key approach to maximize the bandwidth of an optical network. The existing capacity of a WDM channel is much higher than the bandwidth required by a typical connection request. The significant capacity gap between WDM channel and connection request may lead to wastage of transmission capacity, if the entire bandwidth of a wavelength channel is allocated to a low speed connection. So, these low speed connection requests need to be efficiently groomed onto high speed lightpaths to maximize the capacity utilization. This bandwidth gap between the wavelength channels (high rate) and the connection request (low rate) is addressed as a two layer traffic grooming problem. One layer is optical layer and another layer is electronic layer [5, 6]. Efficient sharing of resources in any network optimizes the performance of the network.

Traffic grooming and blocking optimization are always major concern for any optical network. A network design for optical add–drop wavelength-division-multiplexed (OADM) rings has been proposed for traffic grooming. It minimizes the overall network cost and the number of wavelengths required [7]. Traffic grooming problem in WDM optical networks has been addressed. A blocking model has been devolved and the other performance related issues were discussed [8]. Traffic grooming in optical networks was analyzed. Low bandwidth traffic streams are aggregated to efficiently utilize high bandwidth media such as wavelength channels. A network design has been suggested where each traffic demand can follow a sequence of consecutive light paths. It minimizes the total cost of equipment required and minimizes the number of light paths required [9]. Dynamic traffic grooming is an important issue in optical networks. Various approaches are being proposed for dynamic traffic grooming. A heuristic approach was proposed to solve the dynamic traffic problem. It was implemented on WDM optical mesh networks [10]. Blocking probability is always a major parameter while calculating the blocking performance of a network. An optimum path has been proposed for routing depending upon the value of blocking probability [11].

3 Proposed Analytical Model

We have proposed an analytical model with following assumptions. It is given that:

– A physical topology Gp = (V, Ep) having a weighted bidirectional graph, where V represents the set of network nodes and Ep is set of physical links which connects the nodes. Nodes correspond to the network nodes of a particular network and links corresponds to the fiber links between these nodes. Each link is assigned certain weight, which may be a calculation of physical distance between nodes or it may represent some other parameter. We have assumed that all links have same weight 1, which correspond to the fiber hop distance. A network node i is assumed to equipped with optical cross-connects or wavelength-routed switch.
– N is number of nodes in network
– C is number of wavelength channels carried by each fiber.
– Nλ is number of free wavelengths
– w is total number of call sources
– R indicates the set of predetermined directed routes.
– r is the number of routes available where r R.
– l is the length of the route or the number of links in the route or path selected.
– Lrsd is load of the route r from source s to destination d.
– Offline line routing policy has been adopted for establishment of lightpaths

Assuming a network having l links, all having C channels (trunk or wavelengths). For each router R, the blocking probability B_{sd} for the connections along route r can be given by Eq. (1) as [12]:

$$B_{sd} = 1 - [1 - B(C, L_{sd}^{r})]^{l} \qquad (1)$$

Where, $B(C, L_{sd}^{r})$ represents the blocking probability along the path s-d with C as number of channels and load as Lrsd along the route r.

Erlangs loss formula can be substituted by Engset formula as given in Eq. (2):

$$B(C, L_{sd}^{r}) = \frac{\frac{(L_{sd}^{r})^{C}}{(w-C)!\,C!}}{\sum_{i=0}^{C} \frac{(L_{sd}^{r})^{i}}{(w-i)!\,i!}} \qquad (2)$$

From Eq. (1) and Eq.(2):

$$B_{sd} = 1 - \left[1 - \frac{\frac{(L_{sd}^{r})^{C}}{(w-C)!\,C!}}{\sum_{i=0}^{C} \frac{(L_{sd}^{r})^{i}}{(w-i)!\,i!}}\right]^{l} \qquad (3)$$

The load Lrsd for a route r, network having C channels and l as the route length can be given by Eq. (4) as:

$$L_{sd}^{r} = \frac{N\lambda}{l} \qquad (4)$$

Form Eq. (3) and (4), blocking probability can be calculated in Eq. (5) as:

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$$B_{sd} = 1 - \left[1 - \frac{\frac{(N\lambda/l)^c}{(w-c)!\ c!}}{\sum_{i=0}^{c} \frac{(N\lambda/l)^i}{(w-i)!\ i!}} \right]^l \qquad (5)$$

4 RESULTS AND DISCUSSIONS

The results of the proposed model have been verified on arbitrary networks. We have considered certain parameters such as number of free wavelengths, numbers of channels, total number of call sources, path length and total load on the network while analyzing the blocking performance of the optical network. First we have fixed total number of call sources as 100 and further assumed that each fiber has 80 channels. The path length or the number of nodes in the path is fixed as 10. The value of free wavelength is varied from 10 to 60 with equal interval of 10 each. The percentage blocking probability is calculated as shown in Table-I. It can be observed from the Table-I that percentage blocking probability keep on decreasing as the number of free wavelengths is increased. The same behavior can be shown graphically in Figure-I. . So it is concluded that blocking probability may be reduced significantly when there are sufficient free wavelengths available.Figure-2 reflects the behavior of percentage blocking probability with respect to the number of call sources.

TABLE-I: EFFECT OF FREE WAVELENGTHS ON PERCENTAGE BLOCKING PROBABILITY

Total no. of call sources (w)	Length of route (l)	No. of free wavelengths ($N\lambda$)	Percentage Blocking probability	
			C=80	C=50
100	10	10	4.000	1.020
100	10	20	2.020	0.510
100	10	30	1.350	0.340
100	10	40	1.012	0.255
100	10	50	0.810	0.204
100	10	60	0.675	0.170

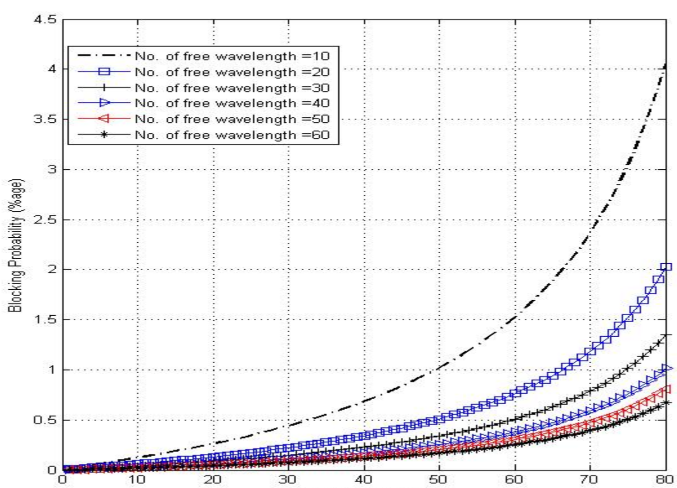

Figure 1: Effect of free wavelengths on percentage blocking probability

The percentage blocking probability was also analyzed with respect to number of channels. The blocking probability is keep on decreasing as the number of channels are decreased. This behavior is shown in Table-2 and Figure-3.

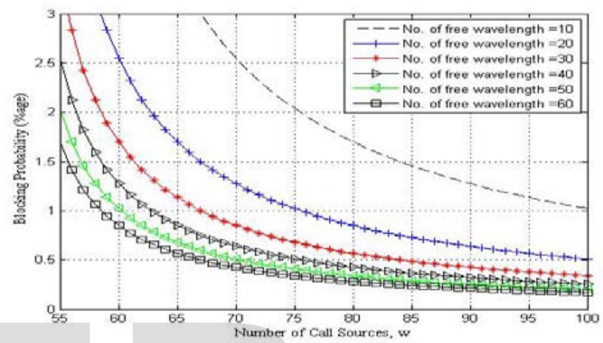

Figure 2: Number of call sources vs blocking probability

TABLE-2: EFFECT OF NUMBER OF CHANNELS ON PERCENTAGE BLOCKING PROBABILITY

Total no. of call sources (w)	Length of route (l)	No. of free wavelengths ($N\lambda$)	No. of channels (c)	Percentage blocking probability
100	10	20	50	0.510
100	10	20	40	0.342
100	10	20	30	0.221
100	10	20	20	0.131
100	10	20	10	0.061

Blocking probability is also calculated against the traffic or load on the network at a particular time. The total number of call sources and the number of channels is assumed as 100 and 10 respectively. It has been observed that blocking probability keeps on increasing as the offered traffic or load on the network is increased. Ideally blocking probability is zero when the load on network is one. It indicates that no call will be blocked at all if the load is one. The blocking probability is very near to one when load is 100. So, if load is 100, there is probability that almost 90% calls will be blocked. It can be shown in Table-3 and in Figure-4.

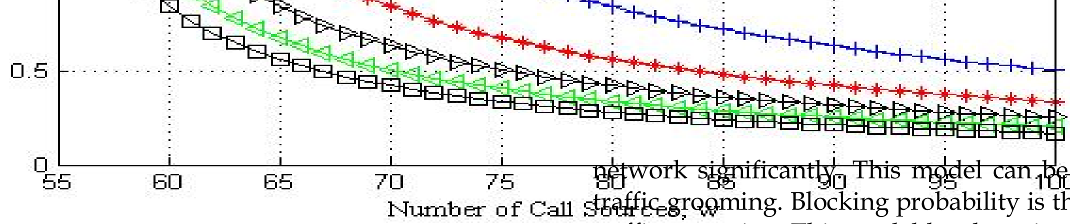

TABLE-3: TRADEOFF BETWEEN BLOCKING PROBABILITY AND TRAFFIC LOAD

Total no. of call sources (w)	No. of channels (C)	Traffic or load on the Network (Erlang)	Blocking Probability
100	10	01	0
100	10	10	0.214
100	10	20	0.538
100	10	30	0.681
100	10	40	0.758
100	10	50	0.805
100	10	60	0.837
100	10	70	0.859
100	10	80	0.877
100	10	90	0.890
100	10	100	0.901

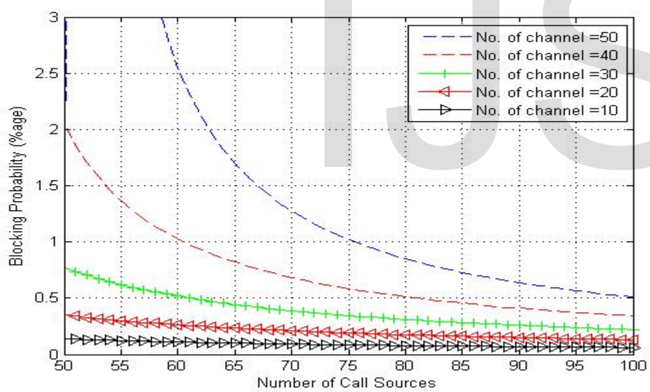

Figure 3: Effect of number of channels on percentage blocking probability

An analytical model was proposed regarding the blocking performance [11]. However, this model cannot analyze the blocking performance of network with respect to the load on network. The proposed model can analyze the network performance of any network with respect to the load on the network. Blocking probability varies significantly based on traffic load.

5 CONCLUSION:

The performance of all-optical network can be improved using proposed model for traffic grooming and blocking optimization. This model improves the blocking performance of the network significantly. This model can be used efficiently for traffic grooming. Blocking probability is the key parameter for traffic grooming. This model has been implemented on different networks and their blocking performance was evaluated. This model has low complexity and high efficiency. It can also be implemented for larger networks to yield a good blocking performance of the network.

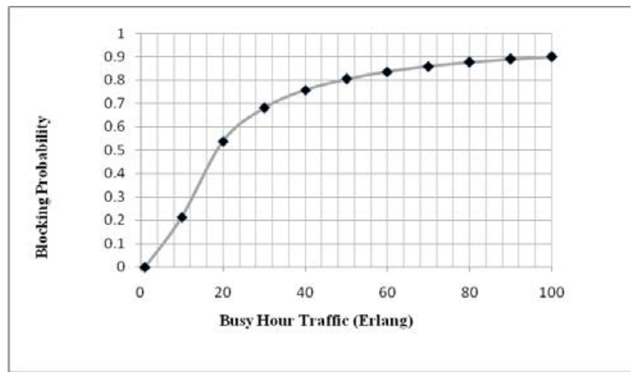

Figure 4: Tradeoff between Blocking Probability and Traffic Load

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