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# REDUCTION OF BLOCKING PROBABILITY OPTIMIZATION ALGORITHM FOR ALLOCATION OF WAVELENGTH CONVERTER

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## ABSTRACT

In all-optical network, the Wavelength conversion is one of the key that has been shown to improve blocking performance in a wavelength-routed. In this paper the different techniques Partial Wavelength Conversion, Sparse Wavelength Conversion are analyzed. A performance indication of an All Optical Network is the call blocking probability. The blocking probability is reduced at an affordable cost and at the same time to make sure that other performance measures are within reasonable limits is also achieved. The blocking probability is calculated varying number of channels and load (in Erlangs) on each link in network. It has been observed that the selection of nodes to be equipped with wavelength converters is crucial. The blocking probability should be minimal at those particular nodes chosen to place the Wavelength Converter. The placement of Wavelength Converter will be easy for the decrease in the blocking probability by a large margin. In this paper, Sparse-Partial Wavelength Conversion (SPWC) network architecture is proposed to support wavelength conversion. The performance of an different Optical backbone Network for different parameters such as number of links, number of channels, number of Wavelengths associated between source to destination are analyzed.

**KEYWORDS:** Links, Nodes, Channels, Wavelength Converters, Optimization, Blocking probability.

## I. INTRODUCTION

An Optical Network is built by interconnecting various optical switches with Wavelength Division Multiplexing (WDM) fibers, that can simultaneously transmit data over different wavelength. On Optical Technologies and components that provide routing, grooming, and restoration at the wavelength level as the Optical Networks are high capacity communications networks. A tremendous growth in the traffic carrying capability of All Optical Networks (AON)[1–4] has led to the concept of Wavelength Division Multiplexing (WDM) allows several optical channels (wavelength) to be allocated simultaneously in an optical fibre, improving its transmission capacity. The same wavelength is used throughout the path of a channel in the absence of any wavelength converter. A channel can be established only if there exists a free wavelength that is not used on all links of the path.

The channel is blocked only, when there is no wavelength available on a link which give rise to the equipping the node with the allocation of Wavelength Converter. It is obvious that the minimum blocking probabilities of channels is referred as the optimal for the Placement of Wavelength Converters. Wavelength Converter will convert the Wavelength of the incoming signal into a desire wavelength at the output and the optical delay line will hold the incoming signal for a certain time. It is not possible that every network node can be equipped with such a device. Wavelength Converters can be either full-range or limited-range with respect to their ability to converting the incoming wavelengths to outgoing wavelengths. An incoming wavelength to any outgoing wavelength is referred to as Full Wavelength Converter. An incoming wavelength to only a subset of outgoing wavelengths is referred to as Limited range Wavelength Converter. When a cross connect node is equipped with as many FWCs as the number of outgoing wavelengths, it is said to possess full wavelength conversion capability. A node equipped with LWCs is said to have limited wavelength conversion capability. Since WCs are likely to remain costly devices, the cost of equipping all the nodes in the network with full conversion capability is high. Hence, a network in which some nodes are equipped with full conversion capability is more practical. This network is referred to as a sparse wavelength conversion network. Other wavelength conversion scenarios such as having a fewer number of FWCs per node or equipping some (or all) nodes of the networks with LWCs are also viable alternatives. In this paper, concerned about deciding which of the nodes in a sparse conversion network should be equipped with full wavelength conversion capabilities so as to optimize the blocking performance. Specifically, given the number of nodes with full wavelength conversion capability, the traffic demand, the network topology and the number of available wavelengths. The main goal is to achieve optimization and allocations with full wavelength conversion so as to obtain optimum blocking performance. Henceforth, the phrase 'placing a wavelength converter at a node' is defined as providing the node with full wavelength conversion capability. Such a node is referred to as a wavelength converter node. The networks in which only some nodes are equipped with Wavelength Converters are referred to as Sparse Wavelength Conversion networks. In this paper, discussions to a network with sparse wavelength conversion are done. The number of converters in a network and the traffic demand decide which network nodes should be equipped with converters such that the overall blocking probability of the network is minimized. This is the Converter Placement problem.[14] Throughout this paper, "Allocate the Wavelength Converter on a precise node" means equipping a node with a Wavelength Converter. The Network considered is assumed that on a node either only one converter is placed, or none is placed. The analysis is also based on the optimized the converter placement with various algorithm.

The rest of the paper is organized as follows. Review, problem definition and Objectives are explained in section II. Mathematical modeling, Implementation of Proposed Algorithm and Experimental results are presented in section III. Simulation Results and Conclusion are given in section IV.

## II. REVIEW

**2.1** Many works have proposed and evaluated identifying the nodes which are to be equipped with wavelength converters such that the network blocking probability is minimized. Usually, these studies compare their proposed schemes with the full-complete wavelength conversion architecture, the lower limit regarding blocking probability. Recent literature shows that there are many bio-inspired algorithms proposed to solve blocking probabilities. The calculation of blocking probability in wavelength routing networks has been a foremost concern since their inception in the last decade.[3-6] Since these networks resemble in many aspects the circuit-switching networks of many decades before, it was only natural to reuse, as much as possible.

In[7] this paper the sparse wavelength conversion architecture is used with some WCs it was possible to achieve a good performance close to the full-complete conversion one. Since studied earlier the wavelength converters placement problem is concerned in optical network design and planning. This problem decides in which nodes the available WCs can be placed, considering the network topology and the expected traffic load characteristics. Algorithms for optimal position of WCs, in simple topologies, were proposed in,[7] but in more realistic topologies the placement problem was shown to be more complex.

In,[8] it was proposed Total Outgoing Traffic - TOT, a wavelength converter placement scheme. The TOT goal is to distribute WCRs between the nodes of the network which have the largest number of routes crossing them. An analytical model was modified to be used in MBPF algorithm of wavelength converter placement.

In,[9] the wavelength converter placement problem is investigated along with RWA (routing and wavelength assignment) algorithms. Two schemes for wavelength converter placement problem in sparse wavelength conversion network were proposed. The first, called Minimum Blocking Probability First - MBPF, has the ability to place a limited number of WCs in an arbitrary mesh network with FAR-FF (fixed alternative routing-first fit) RWA algorithm; and the second, named Weighted Maximum Segment Length (WMSL), is proposed to work under LLRFF (least loaded routing-first fit) RWA algorithm.

In,[10] it was proposed an analytical model to incorporate FAR and wavelength conversion.

In,[11] Xiaowen Chu et al. redefined the wavelength converters placement problem for an SPWC architecture. The goal was to identify which network nodes should be WCRs and how many WCs each WCR should have, based on an specific number of available Wavelength Converters. Ramaswami and Sivarajan,[12] showed that use of WCs resulted in a 10–40% increase in the amount of wavelength reuse. In addition, they also established lower bounds on the blocking probability for a network using any routing and wavelength assignment algorithm.

In,[13] it was shown that wavelength conversion can improve performance in large mesh networks where a path consists of many hops.

Barry and Humblet,[14] also studied the effects of path length, switch size and the hop number on the blocking probability in networks with and without WCs.

Subramanian et al.[15] studied sparse wavelength conversion and its effects on the blocking performance. They showed that the performance of the network improved as the conversion density (probability that a node in the network is capable of full wavelength conversion) was increased from 0 to 1. But, they also found that the rate of improvement decreased with increasing conversion density. This means that it may not be necessary for all the nodes to have WCs for obtaining sufficiently high performance. On the other hand, they pointed out that it was more important to perform a detailed analysis of a given network topology in determining the number and node placement of the WCs.

### 2.2 Problem Description

The problem that has been studied in this work is based on a general WDM network. In general, in an optical network, the fiber optic links connecting the nodes are unidirectional. This means that adjacent nodes have two fiber optic cables between them providing the double duplex conditions.

Our objective is to transfer information over an optical network with the minimum number of wavelength conversions. In fact, the network will have a maximum number of wavelength conversions allowed, which will henceforth be denoted by C. If the number of implemented wavelength conversions is more than C, it will not be possible for the receiver to correctly decode the incoming signal. Every network in the sequence is evaluated separately analytical technique. Then, a procedure combines the results of these evaluations in a way that captures the dependencies that occur in real systems due to the competition for bandwidth between the different connections. The evaluation of the blocking probability of all users (connections) for network topologies. The use of this procedure in the dimensioning of a WDM network is illustrated, in calculating the number of wavelengths on every network link, by considering the traffic load of every user, the routing algorithm and the maximum connection blocking probability acceptable by every user (quality of service).

In this paper, a new fast and accurate methodology to evaluate the blocking probability in dynamic WDM networks without wavelength conversion is presented. The proposed model considers different traffic loads at each network connection (heterogeneous traffic). To take into account the wavelength continuity constraint, the method sees the network as a sequence of networks where all the links have capacity.

### 2.3 Objective of the Work

Wavelength converters are key components in advanced WDM networks. A Wavelength Converter is not cost-effective to equip all nodes with Wavelength Converters. Hence, it is desirable that just a limited amount of Wavelength Converters are used in the whole network.

This motivated to do the research in the Wavelength Converter Placement problem.

- To minimize network congestion
- To distribute the load uniformly by employing congestion control using dynamically varying state of the network
- To determine a near optimal placement of wavelength
- Minimize average blocking probability
- Assign a channel (or wavelengths) to the selected route
- The ultimate purpose of the efficient network is having minimum blocking probability and Maximum connectivity

### 2.4 Blocking Probability

The real time back bone network is done for the evaluation of the blocking probability which determines whether or not each network user (each connection) is being treated with the required quality of service. One of the main parameter is blocking probability that has been used to evaluate the performance of dynamic WDM optical networks. Generally the blocking probability is evaluated through simulation.[4,6] The mathematical modelling is done for the analysis. Nevertheless, in general simulations is very slow with the solution obtained compared with the mathematical approach.[7] The evaluation speed is more concern, because when solving problems of higher order. To calculate the blocking probability a large number of times is necessary. Thus, mathematical computational method is extremely useful as it is a fast and accurate. However, to obtain a mathematical modelling with such characteristics is a difficult task, the parameters considered are traffic load, wavelengths capacity, wavelength continuity constraint (because the network operates without wavelength conversion), network topology, etc. Therefore, to simplify the model in order to facilitate its analysis, several hypotheses are typically introduced. This blocking probability can be affected by many factors such as network topology, traffic load, Routing and Wavelength Assignment (RWA) Algorithm employed and whether Wavelength Conversion is available or not. Blocking probability on a link is calculated by using famous Erlang B formula. For a mathematical modelling the Erlang-B formula is proposed with the purpose of evaluating the link blocking in the network.

$$E(A,C) = \frac{A^C}{C!}\left[\sum_{n=0}^{C}\frac{A^n}{n!}\right]^{-1} \quad (1)$$

Where $E(A,C)$: blocking probability;

$A$: load in Erlangs

$C$: Number of nodes

**III.Mathematical Modelling**

**3.1 Mathematical approach**: The system model is based on the network and traffic models. The network is modelled as a directed graph $G = (V, E)$ which consists of a set of nodes, V, and a set of directed links, E. The state vector $(x_1, x_2, \ldots, x_n)$ indicates the placement of converters on a network with n nodes. The blocking probability on a link $lij$ connecting node $i$ and $j$ is defined as the probability that a specific wavelength on this link is occupied. The blocking probability $\rho ij$ can be computed.

The traffic matrix of the network is given by $\{\lambda sd\}$, where $\lambda sd,\ s \neq d,$ denotes the mean number of calls that arrive per unit time at source node s destined for node d. The call durations are assumed to be exponentially distributed with a mean equal to unity. Let W be the number of wavelengths on each direction of every link in the network. Every call occupies a full wavelength on each link it traverses. Let $lij$ denote the directed link from node $i$ to node $j \in V$. The link load $\rho ij$ per wavelength for link $lij$ is defined as the probability that a given wavelength is occupied by a lightpath on link $lij$. It is given by

$$Pij = \frac{\sum_{sd} \lambda sd}{w} \quad (2)$$

Where the summation is taken over all (s,d) pairs for which the path from s to d includes link $lij$. It is assumed for the stability of the network that $\lambda_{sd}$ 's are small enough so that $\rho ij < 1$ for all $i, j \in V$.

Let **N** be the number of nodes in the network, out of which K nodes are to be equipped with wavelength converters. Thus there are $N_K^C$ converter placement combinations. When a call arrives at a source node, a lightpath is established if at least a single common wavelength is available on every link between the converter nodes occurring on the path to the destination node. Otherwise the call is blocked, since there is no alternate path. The evaluation of blocking probability is carried out assuming that the wavelength occupancy on each link is statistically independent of the occupancy of other wavelengths on the same link as well as that on other links.

Consider the path from node *i* to node *j* which contains no converter nodes. Suppose that this path consists of successive links $l_{ii1}$, $l_{i1i2}$ ,……,$l_{inj}$. Where $l_{ij}$ is the number of wavelengths on each link *ij*, *sd* is the end-to-end traffic load from node *s* to node d, which also represents the arrival probability of a call from *s* to *d*, where $i_1, i_2, \ldots i_n$ are the nodes between *i* and *j* along the path. Let $l_{ij}$ denote the directed link from node i to node $j \in V$. The link load $\rho_{ij}$ per wavelength for link $l_{ij}$ is defined as the probability that a given wavelength is occupied by a lightpath on link $l_{ij}$.

It is given by $\rho_{xy}= 1- \overline{\rho_{xy}}$ for the link $l_{xy}$, which is the probability that a given wavelength on link $l_{xy}$ is unoccupied at an arbitrary time as well as at the time when a call arrives.

Then $\rho_{ii1}\, \rho_{i1i2,} \ldots\ldots\ldots \rho_{ini}$ is the probability that a given wavelength is available on all links over the path from i to j. Hence the probability that a call successfully finds a lightpath from i to j is given by

$$f(i,j)=1- (1- \overline{\rho_{ii1}}\ \overline{\rho_{i1i2}} \ldots\ldots\ldots \overline{\rho_{ini}}\,)^{w} \qquad (3)$$

The probability of successfully establishing a lightpath on the path from s to d is the probability of successfully establishing a lightpath in each of the segment constituting the path from node s to node d.

Let $C = \{ c(1), c(2),..,c(K)\}$ be the converter placement vector such that $1 \leq c(i) < c(i+1) \leq N,\ 1 \leq i < N$. Thus, C represents one of the $N_K^C$ converter placement combinations. The entries of *C* denote the placement of converters among the nodes 1, 2, .., N. Consider the path from source node s to destination node d that includes converters at nodes $c(1), c(2) \ldots\ldots c(k)$. The set of these nodes is a subset of given converter placement C in the entire network. The presence of wavelength converters divides the path into k + 1 segments. A segment is defined as the set of links on the path between two consecutive converter nodes or between the source (or destination) and a converter node. If the path contains no converter nodes, then it consists of a single segment between the source and the destination.

### 3.2 Success Probability

The probability of successfully establishing a lightpath on the path from *s* to *d* is the probability of successfully establishing a light path in each of the segment constituting the path from node *s* to node *d* this is given by

$$S_{sd}(C) = \prod_{i=0}^{k} f(c(i), c(i+1)) \qquad (4)$$

Where $c(0) := s$ and $c(k+1) := d$. Thus the blocking probability for the path

From *s* to *d* is given by

$$P_{sd}(C) \;= 1 - S_{sd}(C) \qquad (5)$$

The overall success probability of this model is

$$S(P_{sd}) = (1 - (1 - q)^{F}) \qquad (6)$$

The probability of successfully establishing a lightpath on the path from *s* to *d* is the probability of successfully establishing a lightpath in each of the segment constituting the path from node *s* to node *d.*

### 3.3 Implementation of Proposed Algorithm

The algorithm for proposed technique is explained as shown below:

*Step 1-Start.*

*Step 2-Initialize the number of channels in the optical fiber.*

*Step 3-Initialize the number of links in the network.*

*Step 4-Enter the traffic load per link (in Erlangs) value.*

*Step 5-Number of simulation value is stored*

*Step 6-Parameters like Number of channels, Number of Links, Load per link to calculate the blocking probability without wavelength conversion*

*Step 7-Step 6 is repeated,*

*Step 8-No. of channels and load per link (in Erlangs) are passed through bpfxn(L(i),C(i)) function*

*Step 9-By varying the METHOD parameter, blocking probability is calculated for no, full and limited wavelength conversion.*

*Step 10-If Sparse or Limited Wavelength Conversion is used, then enter the number Channels keeping load per link(in erlangs) constant*
*Step 11-The above mentioned steps are repeated by varying the value of traffic load per link (in Erlangs) keeping channel constant.*

This model allows different traffic loads on each network link, but since it is based on the Erlang-B formula The technique for calculating the number of wavelengths on every network link for dimensioning the WDM network. The final network dimensioning results show that the proposed method obtains the same results as the ones obtained by simulation (which in general are based on the sequential execution of simulation experiments) much faster.

## IV. SIMULATION RESULTS

The simulation is carried out on simulation software MATLAB 13A of Mathworks. The blocking probability of the network; which is illustrated by eq. (1), compared depending upon the number of channel or wavelength, load and number of nodes.

**Case 1**: Varying the number the channels, Load (in erlangs) is Constant
In this graph number of the channel is varied as 4,5,6,7 and load (in erlangs) is kept constant, on increasing the number of channel the blocking probability is also increased.

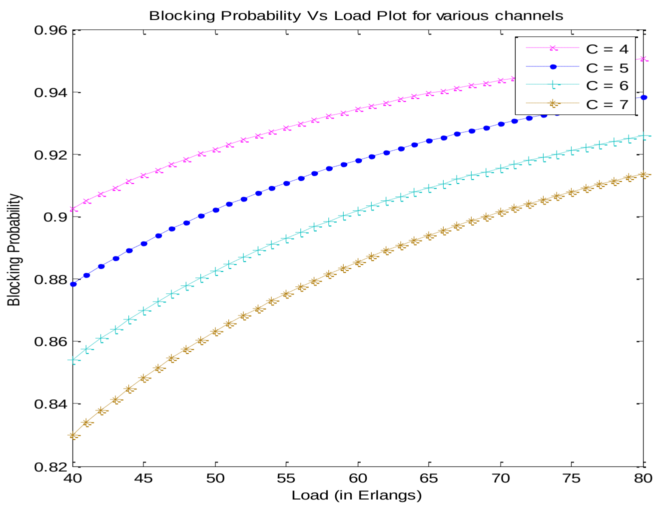


**Fig. 1: Blocking Probability with load constant varying number of channel 4, 5, 6, 7.**

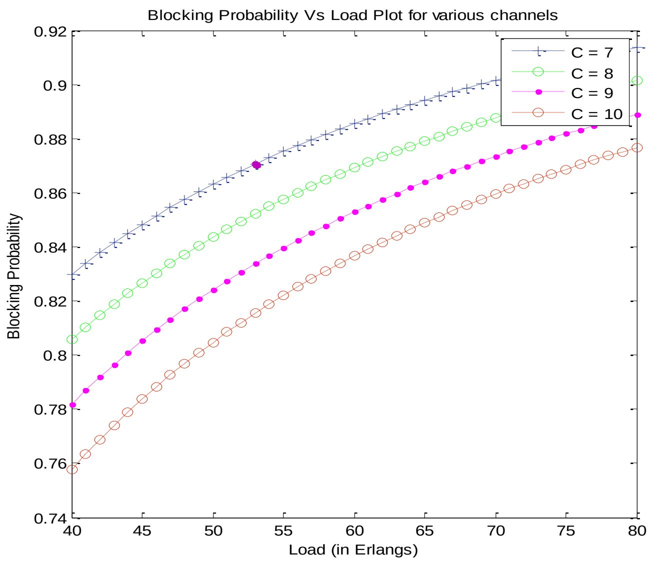


**Fig. 2: Blocking Probability with load constant varying number of channel 7, 8, 9, 10.**

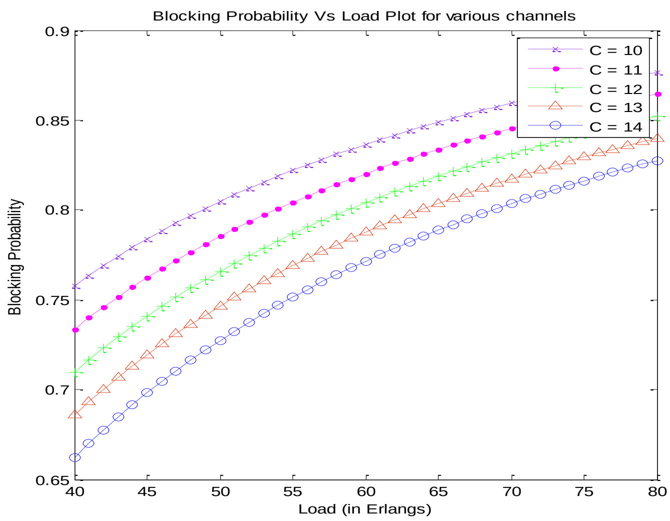


**Fig. 3: Blocking Probability with load constant varying number of channel 10,11,12,13,14.**

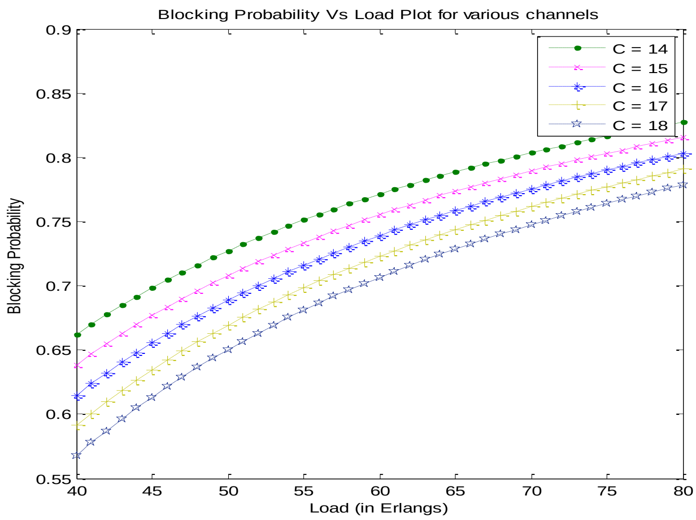


**Fig. 4: Blocking Probability with load constant varying number of channel 14,15,16,17,18.**

## V. CONCLUSION

The paper finally makes some suggestion as a contribution to the upcoming researchers for considering while performing novel investigation in the area of optical network. The future work will be on the direction of evolution of simple and novel mathematical technique for the purpose of modelling the uncertain traffic condition in optical network. The future study will also adopt various other performance parameters e.g. throughput, packet delivery ratio, BER, blocking probability etc. The prime objectives will be towards i) evolution of an algorithm for better traffic management, ii) coming up with new implementation with enhanced characteristics, iii) adoption of new algorithm for the purpose of improving the switching operation of the optical network. The evaluation of such study will be carried out by transmitting real-time files through optical node in presence of uncertain traffic and evaluate its performances based on the above mentioned strategies.

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