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Wavelength Assignment Techniques with Converters for All Optical Networks (AONs)

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***Abstract* - We present an optical routing and wavelength assignment (RWA) technique for the best placement of the wavelength converters. The wavelength converter placement was considered independently at the complete nodes and partial nodes. In comparison to existing approaches, our technique performs better and requires fewer wavelength converters to get the required performance. As much as 7%, the likelihood of blocking is decreased. The study also demonstrates that the top four nodes have the biggest influence over the blocking performance of the network. It is clear that placing the converters in the right location is just as crucial to improving performance as simply adding more converters.**

***Keywords:* Wavelength Assignment, RWA Algorithms, Blocking Probability, Optical Wavelength Converters**

I. INTRODUCTION

Wavelength division multiplexing (WDM) and dense WDM in optical networks allows exceptionally high transmission speeds with very high QoS for real time and non-real time applications. All Optical Networks (AONs) combine data from distribution and access networks and send it across the optical domain from beginning to end [1]. The development of a lightpath allows for the avoidance of electronic processing at intermediate nodes between any two nodes along the route or from end to end. After figuring out the best way for each connection, the sender node chooses a wavelength from the available pool of free wavelengths. In this case, routing and wavelength assignment, or RWA, is carried out [2]. A lightpath employs the identical transmission wavelength for end to end transmission whenever it is practical to do so. A limitation known as a single wavelength continuity constraint typically results from the availability of exactly same wavelengths on each and every links and sections of that route. Overall, it raises the prospect that call blocking could reduce the effectiveness of the network. The wavelength converters (WCs) can be incorporated into the network to lessen the effects of this constraint.

Despite the fact that there have been numerous research on AON, it has proven challenging to design the optimum RWA method when WCs are present [3-6], which convert input signal wavelength to another available wavelength, reducing the blocking. AONs can be equipped with WCs at few node. Figure 1 (a) shows how optical nodes can convert wavelengths at each node in accordance with the specifications (b).

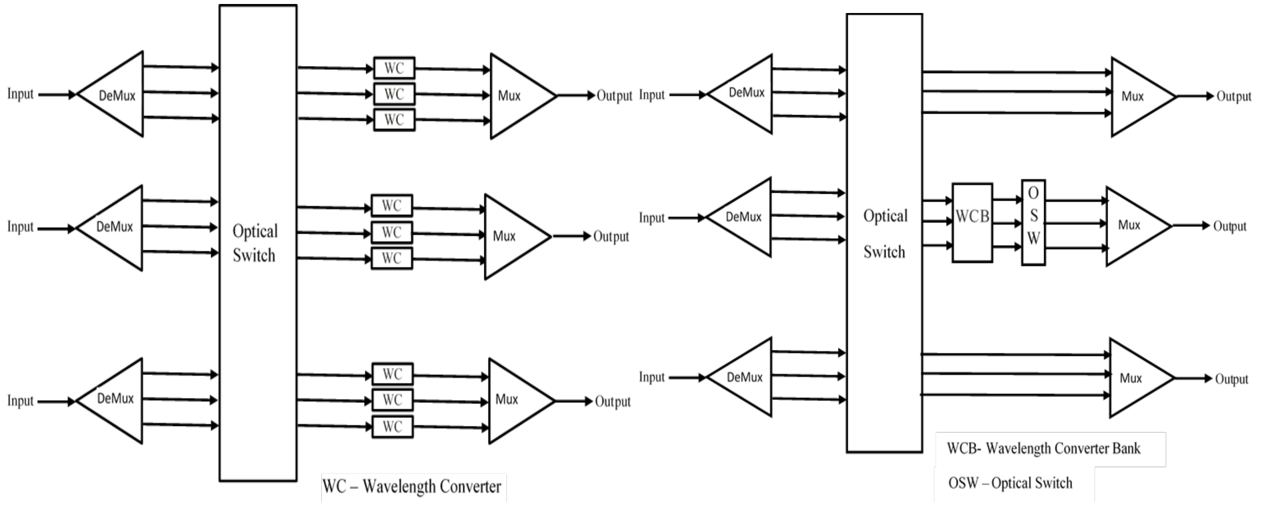

Fig. 1 Full (a) and partial (b) wavelength converters placement

Full-wavelength converters, each of which has a dedicated WC, are used to simultaneously convert all entering wavelengths to any other wavelengths. The system cost is reduced because the WCs are only used at a select few nodes in partial wavelength converters. Waveband switching [7], [8] makes it possible to switch and route numerous wavelengths to the same place, but it is still challenging to guarantee that each node has access to a certain wavelength in a waveband. In multi hop carrier class optical networks, it has challenges to have the optimal number of partial wavelength converters (WCs) without sacrificing performance, increasing complexity, or increasing costs. The unique RWA algorithm proposed in this research is used to put the fewer WCs in the networks. The rest of the manuscript covers literature review, proposed technique, results and discussion.

II. LITERATURE SURVEY

Network blocking can be efficiently avoided with wavelength converters (WCs) than in networks without WCs in optical networks. The topology and scale of the network, the volume of traffic, the number of wavelengths and hops needed for each connection, and the presence and placement of WCs are the key determinants of how well AON blocks traffic. Because there are so few nodes that can convert wavelengths, there is less chance of a network breakdown. The performance can be enhanced by positioning these converters ideally using heuristic and metaheuristic techniques, according to studies on the location of wavelength converters [9], [10], and [11]-[14]. In order to find wavelength convertible routers for partial wavelength conversion, least blocking probability first (MBPF) is used [12]. Weighted Least Congestion Routing First Fit (WLCR-FF) [11] with MBPF determines the location for the lowest blocking probability each time a converter is added to a simulation by calculating the blocking probability. It has been shown that WLCR-FF improves blocking performance for both full and partial WCs, although it adds computational time.

The graph [15] technique only chooses the nodes that have access to the whole range of WCs. It does not, however, take into account nodes with few WCs, currently accessible wavelengths, or uneven traffic. The integer linear programming method for best WC placement for static traffic [16] takes into account both RWA and WC simultaneously, which makes it complex and challenging to use in real-time networks. A maximum of 5% wavelength converters are needed at any given moment under Minimum Converter Allocation (MCA) [17], which enhances the utilisation of wavelength converters. WC placement is on the auxiliary graph thanks to the link state data [3]. Depending on how they were used previously, intermediate node WCs are assigned. The least loaded routing (LLR) is utilised to choose the path. Comparisons are made between the accuracy of the blockage probability for various traffic classifications and patterns [18]. According to [19], sparse partial WCs only need 2.4% converters under various load circumstances. Numerous scenarios are considered in the study of adaptive alternate routing [20]. By adjusting the wavelength in optical networks, the bandwidth utilisation rate can be increased. The performance of the network is enhanced by sparse wavelength conversion or tweaking. Having additional pathways available can also lessen calling blockage. The analysis of the literature reveals that although many forms of research have been done to enhance AON's blocking performance, the best location for WCs is still an open problem that needs more investigation. To further enhance the performance of AONs, we provide a novel weight dependent RWA method with ideal weight coefficients (WCs).

III. PROPOSED RWA TECHNIQUE

The goal is for minimising WC numbers needed in the AON and lower the likelihood of a call being blocked. In the WDM NSFnet topology, there are 14 nodes, 21 bidirectional links, and 21 links. The network traffic is analysed using the memoryless Poisson distribution.

Currently, a non-negative random sequence is defined as the inter-arrival call method for a random variable with a known probability distribution function. The nth inter-arrival time is described by an exponential distribution with a mean arrival rate parameter. The network traffic is analysed using the memoryless Poisson distribution. The inter-arrival call procedure for a random variable $X(t)$ with a known probability distribution function at the time t is defined as a non-negative random sequence $A(n)$. The exponential distribution with mean arrival rate parameter describes the nth inter-arrival time λ as

$$P\{A(n) \le t = \left(1 - e^{-\lambda t}\right)\} \qquad (1)$$

Number of arrivals for interval t, described by

$$P\{N(t) = n\} = \frac{(\lambda t)^n e^{-\lambda t}}{n!} \qquad (2)$$

Number of network nodes are

$$N := \{n \mid n \in N, \quad 1 \le n \le 14 \ \} \qquad (3)$$

The number of bi-directional links in the networks as

$$L := \{l \mid l \in N, \quad 1 \le l \le 21\} \qquad (4)$$

$$:= \{(s_{i,} d_i)\} | s_i \ne d_{i,} i \in N \qquad (5)$$

where s and d are the source and destination nodes, respectively. Total number of paths for each source and destination pair,

P_n can be written as

$$Paths := P_n := \{\{p\}\}$$

$$:= \{(s_1,d_1),(s_2,d_2),(s_3,d_3)...........(s_n,d_n)\} | s_i \ne d_{i,} n \in P_n, i \in N \qquad (6)$$

The traffic distributed uniformly for exponential call holding time with an average of 1/μ. We use the weighted dynamic routing algorithm to select the route with the maximum weight value. By computing *K*-shortest routes offline and weight values by considering the availability of resources, the selected route is written as

$$P^{k}{}_{W,\max} = \arg\max_{k=1\ to\ 18} \left(\frac{\left(W^{a}\right)\left(T_{e}\right)\left(\sum_{i=1}^{PI} S_{c}(i)\right)}{\left[\left(\sum_{i=1}^{PI} S_{c}(i)\right)+\left(\sum_{i=1}^{PI} B_{c}(i)\right)\right]\left(\sum_{i=1}^{PI} H_{t}(i)\right)} \right) \quad (7)$$

where total available wavelengths are W^{a} for *k* routes, T_{e} is time elapsed, $S_{c}(i)$ is served calls, $B_{c}(i)$ is blocked calls, and $H_{t}(i)$ is total call holding time of served calls. W^{s} is selected wavelength as $W^{a}(1)$. The quickest paths for new requests are determined. The route with the highest weight along the K-shortest path is chosen. If the wavelength is not accessible, the dynamic routing and first fit as wavelength assignment system uses wavelength converters. The shortest path is taken while using the converters. For alternative values of, it might necessitate more hops, which would change the required wavelengths and increase complexity. In order to compare performance between the created technique and the previously published literature, we applied it to both scenarios, WCs at all nodes and at chosen nodes. With an average of 1/, the traffic was spread equally for exponential call holding time. In order to choose the route with the highest weight value, we employ the weighted dynamic routing method. The chosen route is expressed as K-shortest routes offline with weight values taken into account for resource availability.

A. Wavelength Converters at each Node

In this scenario, WC nodes are deployed at all nodes. As a result, the call is successful and the wavelength continuity constraint is lifted, decreasing the likelihood of blockage. The problem with installing WCs at every node is that they are not all used at once, adding to the expense and complexity of the system.

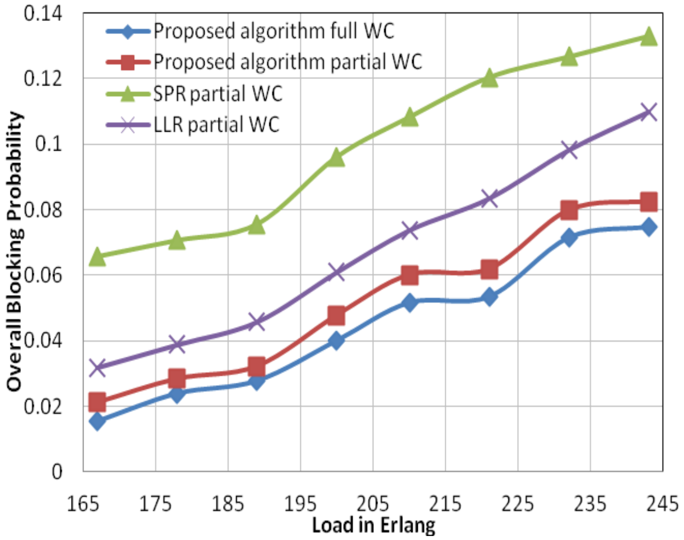

Fig. 2 (a) Blocking probabilities for low load - 40 wavelengths (b) a high load - 120 wavelengths

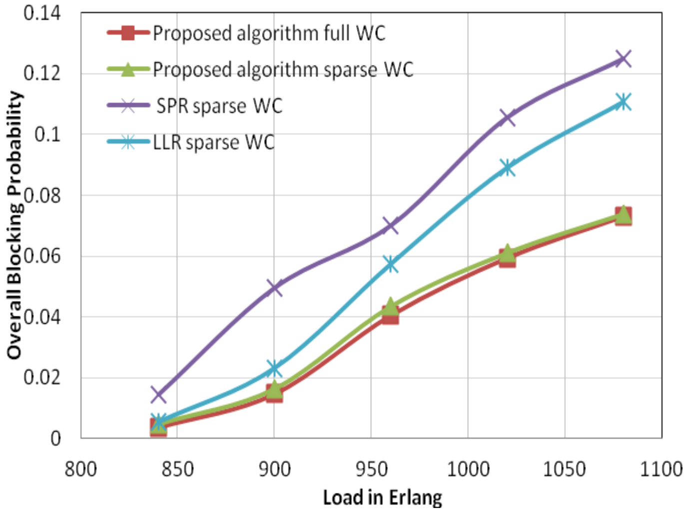

Fig. 2 (b) Blocking probabilities for high load - 120 wavelengths

B. Partial Wavelength Conversion

A very small number of chosen nodes have the capacity to convert wavelengths instead of all the nodes having WCs. Finding the best places for WCs is a very important task for placement. To create clusters that matched the requirements, we employed the K-means clustering technique. The K-means clustering approach is initially utilised as input to reduce the objective function as call blocking probability without WCs. To place the converters, follow these steps: Set the hours' worth of traffic in motion, Run a new dynamic RWA algorithm without WC on the network for one hour, Identify the nodes and their likelihood of blocking, To determine the two distinct groups of blocking probabilities from all nodes, use the K-Means clustering technique. The blocking probabilities of each node, which were computed without the use of wavelength converters, are the algorithm's inputs, For the deployment of WCs, choose the cluster containing the nodes with the highest likelihood of blocking, Restart the network after installing the WCs at the aforementioned nodes.

IV. RESULTS AND DISCUSSION

We run thorough simulations for the WDM NSFnet. Blocking probability for both full and partial wavelength converters is calculated and examined using the dynamic RWA method. With the shortest path routing first fit wavelength assignment [11] and least loaded routing first fit wavelength assignment [12] algorithms, the outcomes for partial WCs are compared. As shown in Fig. 2(a), the simulation results were obtained for modest traffic loads from 170 E to 240 E for 40 wavelengths. The findings demonstrate that the suggested method outperforms SPR-FF [11] with partial WC and lowers the blocking probability by 5%. The blocking probability decreases by up to 5.4% compared to SPR at the high load of 840 E to 1080 E for 120 wavelengths, as shown in Fig. 2(b). It also demonstrates how little there is in terms of blocking probabilities when WCs are placed partially versus fully, and how properly placing partial WCs leads to improved outcomes.

We have chosen the first four nodes that refuse the most call requests to place the partial WCs. According to the findings in Fig. 3, the blocking probability does not significantly deviate when WCs are simply increased. As can be shown, the maximum improvement in blocking efficiency for a 2 to 14 converter increase is about 1%. Therefore, adding more restrooms to the network may not be advantageous if they are not located in the proper locations. The outcome also demonstrates that, despite the deployment of a greater number of converters, there is a little fluctuation in blocking caused by a lack of a wavelength or route to the destination or a rapid rise in network traffic [21].

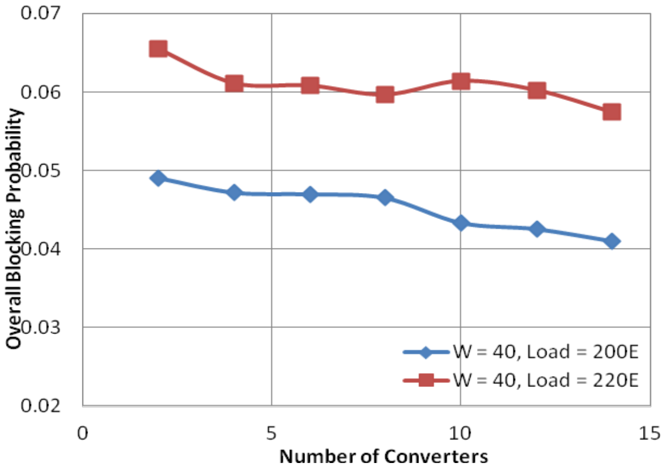

Fig. 3 Blocking probability vs number of WCs for lower load and 40 wavelengths

TABLE I COMPARISON OF BLOCKING PROBABILITIES FOR DIFFERENT ROUTING ALGORITHMS

Wavelengths	Load	SPR	LLR	WLCR	Proposed RWA
W=40	190E	0.07566	0.034586	0.04335	0.035126
W=40	210E	0.109771	0.069797	0.06775	0.062877
W=120	840E	0.051969	0.005510	0.006213	0.00510
W=120	960E	0.095301	0.054825	0.053413	0.04501

Fig. 4 shows the overall blocking probability for a low load with 40 wavelengths as a function of the number of WCs. One must take into account the total amount of wavelengths that are available in the network in addition to where to deploy WCs. Simulations were run for blocking probability to examine their effects. Figure 5 illustrates how the number of wavelengths affects the likelihood of blocking in a network using the First-fit wavelength assignment techniques [12] and the proposed RWA and WLCR algorithms.

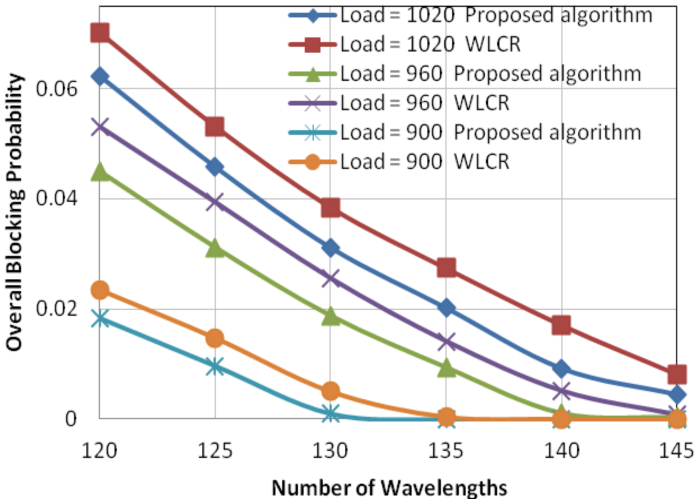

Fig. 4 Overall blocking probabilities versus the number of wavelengths for high load

According to the findings, increasing the network's wavelength count reduces blocking likelihood from 6.2% (with 120 wavelengths) to 1% (with 140 wavelengths), which is a significant improvement over previously published findings [22]. This reduces the blocking and hence the QoS improves. With the increase in number of the wavelengths, however, computational complexity increases at node level. Therefore, number of wavelengths should increase only to have optimal performance [23] [24]. Additionally, it can be demonstrated that further increasing the number of wavelengths does not significantly lower the likelihood of blocking.

V. CONCLUSION

In this study, we propose a new RWA algorithm with full and partial wavelength converters that is dynamic weight based. The findings demonstrate that, as long as wavelength converters are installed at the appropriate network nodes, blocking likelihood does not significantly differ between full and partial wavelength converter scenarios. Blocking likelihood decreases as the number of converters rises, however beyond the first four converters, the decrease is not as significant. According to the study, our algorithm has a low complexity and cheap cost and lowers the blocking probability by 5.4% in comparison to earlier studies that have been published. It demonstrates that the amount of wavelengths in the networks determines blocking performance, and that adding more wavelengths has little effect on performance enhancement.

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