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NEW WEIGHT DEPENDENT ROUTING AND WAVELENGTH ASSIGNMENT STRATEGY FOR ALL OPTICAL NETWORKS IN ABSENCE OF WAVELENGTH CONVERTERS

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Abstract
In wavelength division multiplexed all optical networks; lightpath establishes a connection between sending and receiving nodes bypassing the electronic processing at intermediate nodes. One of the prime objectives of Routing and Wavelength Assignment (RWA) problem is to maximize the number of connections efficiently by choosing the best routes. Although there are several algorithms available, improving the blocking performance in optical networks and finding optimal solutions for RWA problem has still remained a challenging issue. Wavelength conversion can be helpful in restricting the problem of wavelength continuity constraint but it increases complexity in the network. In this paper, we propose new weight dependent routing and wavelength assignment strategy for all optical networks without use of wavelength converters. Proposed weight function reduces blocking probability significantly, improving the network performance at various load conditions. Further, due to absence of wavelength converters, the cost and complexity of network reduces. Results show that the proposed strategy performs better than earlier reported methods.

Keywords:
WDM, Lightpath, RWA, NSFnet, Blocking Probability

1. INTRODUCTION

Due to emergence of bandwidth intensive applications such as IPTV, cloud computing, Big Data, Internet of Things, there is unprecedented growth in Internet data. To support such rapid demand of high transmission and reception, and fast processing, optical fiber has become a natural choice for transmission because of its exceptional transmission capabilities, low attenuation, and low Bit Error Rate (BER). Wavelength Division Multiplexing (WDM) in optical network provides high speed data transmission by transmitting multiple wavelengths simultaneously within an optical fiber. In today's networks, electronic devices such as switches and routers are interconnected by optical fiber links. The information carried in optical fibers must be processed at electronic data rates that are compatible with electronic circuitry, hence limiting network throughput. In All Optical Networks (AONs), information is transmitted entirely in optical form and there are no optical-to-electronic and electronic-to-optical conversions within the network. One of the major advantages of AONs with respect to networks with electro-optic devices is its high speed transmission and huge processing abilities. Various AON test-beds and laboratory experiments have achieved an aggregate network throughput of over 1 Terabits per second and higher throughputs are expected in the near future. In these networks, a lightpath establishes a connection between two nodes which bypasses the electronic processing at intermediate nodes. A lightpath consists of the same wavelength from source to destination called wavelength continuity constraint. Two lightpaths sharing the same link cannot be assigned with same wavelength.

For any connection request, a route has to be found, and a wavelength has to be assigned. Searching and assignment of route and wavelength to the connection request with minimum network resources is called Routing and Wavelength Assignment (RWA) Problem. Though numerous researches have been carried out on WDM based optical networks, finding optimal solutions for RWA problem is still remains a challenge.

Important objective of RWA algorithm is to maximize the number of connections by taking the best route. When the new lightpath requests arrive at the network, the RWA algorithm determines the routes and selects the wavelengths depending on the availability of the wavelengths. Each connection request has to be given a route and wavelength from the available resources. There are three approaches to tackle this problem. First approach deals with the routing initially and then assigning a wavelength along the path. The second approach considers both route selection and wavelength assignment jointly. The third approach is RWA with wavelength converters (WCs). In this paper, we have proposed a new RWA strategy based on new dynamic weight routing for AONs in absence of WCs.

The paper is organized as follows: Section 2 discusses various route selection techniques. Section 3 describes wavelength assignment techniques. Section 4 covers RWA schemes without WCs. Section 5 presents proposed RWA strategy and results, whereas paper is concluded in Section 6.

2. ROUTE SELECTION TECHNIQUES

Route selection algorithms can be of fixed routing, fixed alternative routing or adaptive routing. In fixed routing, for each source and destination a fixed single path [1] is used whereas in fixed alternate routing [2], there is provision for alternative routes. It is similar to fixed routing method but has more than one alternating routes. Upon the connection request, it checks for the first free route and if it is not available then it takes the alternative route and hence reducing the blocking probability. These routes are pre-calculated and do not consider the current network state information. Routing is done depending on the free wavelengths on the route [3]. They have proposed a routing technique named fixed path least congestion routing (FPLC) which gives better results as compare to fixed alternative routing (FAR). In [4] they have analyzed that fixed alternate routing with most used wavelength assignment technique gives better results as compared to fixed routing. In Adaptive Routing, route is chosen adaptively depending on the current status of the network. Upon the route request, the route with minimum or maximum weight depending on the weight cost function considered for transmission. There are several adaptive routing schemes like least loaded routing (LLR) [3], least congested path routing [6], weighted least congested routing (WLCR) [7] etc. The major advantage of adaptive routing is that it often results in higher resource utilization and lower connection blocking than static routing. Link load [3], [5] is taken into account while determining a new path without any wavelength converters. Least congested path routing [5], dynamically switches the light path between the primary and alternate route according to the network traffic distribution.

WDM aware weight functions [6], [7] consist of free wavelengths available on each link, total number of wavelengths and number of hops. The effect of different weight function on the network performance was studied and the best results are achieved for the weight combination of less number of hops, free available wavelengths and total number of wavelengths. Adaptive alternate routing (AAR) [8] with more than one alternate route and without wavelength converters shows the reduction in blocking probability for low load. It is not much beneficial for high load because of restricted number of alternative routes. Amongst the above routing techniques, fixed routing is simple and having less complexity. The adaptive routing is complex but has lesser blocking. Fixed alternate routing is the trade-off between fixed and alternate routing. Adaptive alternate routing shows the better results in all routing techniques.

3. WAVELENGTH ASSIGNMENT TECHNIQUES

Selection of wavelength plays very important role in determining the performance of any algorithm. There are various approaches used in optical networks for wavelength assignment.

First Fit: All the available wavelengths are indexed in an increasing order. While assigning the wavelength from the available set of the wavelengths, lower indexed wavelength is first selected for the path. This does not require any global information for assignment thus it is less complex. With adaptive routing, it gives better results in terms of blocking probability [9], [10].

Random Wavelength Assignment: In the random wavelength selection [11] a group of available wavelengths is maintained. For the new request, randomly wavelength is selected and assigned. Used wavelength is removed from the list and free wavelength is added to the list again. This list is updated whenever new connection required and any current connection ends. The first-fit has better performance as compared to random assignment [12].

Least Used Wavelength Assignment: The least used wavelength algorithm [9] selects the least used wavelength from the set of the available wavelengths. In this, global information is required for least usage of the wavelengths and hence the computational cost is high for this algorithm. If more than one wavelength is having less usage then first fit wavelength is selected.

Most Used: The most used algorithm [9], [10] selects the wavelength which is used maximum times in the network. Like least used algorithm, this requires global information and is computational costly. If more than one wavelength is having more usage then first fit wavelength is used.

4. RWA WITHOUT WAVELENGTH CONVERTERS

An efficient RWA without wavelength converter algorithm is needed to improve the blocking performance. For improving the blocking performance, a new technique called weighted least congested routing (WLCR) [7] with first-fit wavelength assignment was suggested. In WLCR, current traffic load as well as route length is considered jointly. The routes are calculated off-line for every source and destination and the weight is assigned to each route. For every new connection request, the weight value is calculated and then assigned to each route. The route is selected with maximum number wavelengths and less number of hops. From the set of routes, upon the new connection request, it calculates the weight for a route as

$$W(T) = \frac{W(F)}{\sqrt{L(R)}} \quad (1)$$

where, $W(F)$ is number of free wavelengths whereas $L(R)$ is number of hops on the route. Maximum weight value is selected from all computed values and the corresponding route is chosen for the new connection. The route with more number of free wavelength and less hop count is selected as the probability of successful connection with large number of free wavelengths on shorter route will be larger than that of longer routes. Dynamic Wavelength Routing (DWR) [13] uses an adaptive routing and has two approaches, viz. least congestion with least nodal degree routing (LCLNR) and dynamic two-end wavelength routing (DTWR). The routes for each source and destinations are pre-calculated using modified Dijkstra's k-shortest algorithm. The routes are calculated with the help of computed weight function. Basically maximizing the utilization of wavelengths and thus minimizing the blocking probability. The DWR gives better performance than LLR [6] and WLCR [7]. Because the routing technique exclusively considers the route from the pre-calculated routes, it may happen that one of the route may be missed from the expedient routes. The DTWR [13] is used when call gets blocked in LCLNR, it finds the maximum available wavelengths between the nodes and then uses the wavelength converters. This increases wavelength utilization and reduces blocking probability. The LCLNR with first fit avoids the routes which goes through the congested links and therefore reduces the blocking probability. For the new connection request, the route is selected with maximum value of the function,

$$W = \frac{\lambda}{h} \quad (2)$$

where, λ is free wavelength of the route and h is number of hops of the route. If more than two routes have the same values then minimum nodal degree is considered avoiding the congested node. Minimum coincidence routing (MCR) [14] selects the path with minimum number of hop length and more number of free wavelengths, at the same time it balances the network load. MCR selects the shortest path between the source and destination node from the pre-computed routes with minimum value of parameter called minimum shared link (MSL),

$$MSL = H_L \times L_S \tag{3}$$

where, H_L is the number of hops and L_S is the number of links shared between a corresponding path and the path which has been previously selected. This method is selected for getting k-shortest paths. The lightpaths will be selected with first-fit wavelength assignment algorithms.

A new routing and wavelength assignment [15] reduces the blocking probability and also gives better resources utilization. By combining routing and wavelength assignment, route is jointly selected with wavelength assignment. If the route cannot find with wavelength then another wavelength is selected. It uses combination of shortest path routing and load balancing. A suitable route selection is depends on the weight cost function. For each route a weight is assigned to every link of the network and is given as

$$W_{ij} = \left(\frac{P_{ij}}{T}\right) l_{ij} \tag{4}$$

where, P_{ij} is total number of presently available wavelengths on the link, T is total number of wavelengths and l_{ij} is the length of the link. The route with minimum value is selected. For the wavelength assignment, first fit is considered. Amongst the above routing and wavelength assignment algorithms, WLCR-FF [7] gives better results as it considers the route with more number of free wavelengths as well as the route length.

5. PROPOSED WORK

Considering the importance of weight function and dynamic RWA, we propose a new dynamic weight function for computing best path for new connection requests with lesser blocking probability. Our weight function is based on common available wavelengths, number of calls served, number of calls blocked, average number of call requests and holding time of served calls.

5.1 MODEL ASSUMPTIONS AND NOTATIONS

NSFnet network topology is considered for the simulation purpose by using MATLAB. It consists of N nodes, L links and W total number of wavelengths in the network and all the links are bidirectional.

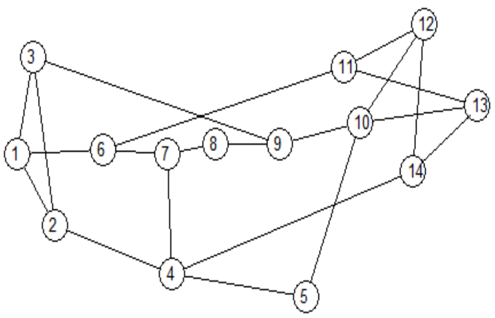

Fig.1. NSFnet Network

5.2 STEPS FOR PROPOSED ALGORITHM

5.2.1 *Traffic Generation:*

The call arrival process is Poisson with mean rate λ uniformly distributed and the holding times are exponential with average length $1/\mu$, then the state probabilities are determined by the birth and death process. Considering W as maximum wavelengths per fiber and C as active wavelengths. The traffic load behavior depends on Erlang's model [16].

$$P_c(C) = \left(\frac{\lambda}{\mu}\right)^c \frac{P(0)}{c!}, c = 0,1,\ldots,C \tag{5}$$

where, $P_c(C)$ is probability density function of C under the normalized condition $\sum_{C=0}^{W} P_c(C) = 1$, $P(0)$, is obtained as

$$P(0) = \left[\sum_{c=0}^{C} \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c\right]^{-1} \tag{6}$$

5.2.2 *Weight Calculation:*

In our new dynamic weight routing and first fit wavelength assignment (NDWR-FF), k-shortest paths are calculated for every source and destination by Dijsktra's modified algorithm. Dynamic weight function calculates the routes online for every source and destination. Whenever the new connection request comes then at that particular instant the weight is calculated and assigned to each route. Weight function is the ratio of common free available wavelengths to the average served traffic intensity per unit time. The route with maximum weight is selected. So maximum free available wavelengths and at the same time, the offered traffic, number of served calls, number of blocked calls and total holding time of the served calls for that whole route is also considered. The weight value is calculated as

$$W_t^k = \frac{W_a^k}{A^k} \tag{7}$$

where, W_a^k is free available wavelengths on each calculated path k and A^k is traffic intensity on path k, calculated as $A^{k} = \lambda.h$. λ is average number of call requests per unit time, given by $\lambda = \frac{C_s + C_b}{T_e}$, where C_s is total number of served calls, C_b is total number of blocked calls, T_e is time elapsed during which C_s and C_b calls were handled and h is average duration of calls in seconds calculated as $h = \frac{T_h}{C_s}$, where T_h is total call holding time of served calls. The final weight function becomes,

$$W_t^k, \max = \arg\max_{k=1to18} \left(\frac{\left(W_a^k\right)\left(T_e\right)\left(\sum_{i=1}^{Pl} C_s(i)\right)}{\left[\left(\sum_{i=1}^{Pl} C_s(i)\right) + \left(\sum_{i=1}^{Pl} C_b(i)\right)\right]\left(\sum_{i=1}^{Pl} h_t(i)\right)} \right) \tag{8}$$

The route with maximum weight value is selected. If wavelength is not available, i.e. $W_a^k = 0$ on the routes then the request is blocked. Once the route is decided, the wavelength assignment is done on the basis of first-fit wavelength assignment technique. The wavelengths are numbered in an ascending order and the lowest indexed is first assigned.

5.2.3 Computing Blocking Probability:

The overall blocking probability is calculated for proposed routing and wavelength assignment algorithm as the total number of blocked traffic divided by the total number of offered traffic to the NSFnet network as,

$$P_N^b = \frac{A_N^C - S_N^C}{A_N^C} \tag{9}$$

where, A_N^C is offered traffic to the network and S_N^C is total carried traffic by the network.

5.3 RESULTS AND PERFORMANCE COMPARISON

For every link, 40 bidirectional wavelengths are considered and k-shortest paths are calculated for every source and destination. Initially, we have computed the blocking probability for different values for *k* between 1 to 25, for low and high traffic conditions. The Fig.2 shows the results obtained for low load and its corresponding blocking probability for *k* = 2, 10, 18, and 25. It illustrates that with increase in load, blocking probability increases and it is lesser for *k* = 18 and 25 than that of *k* = 2 and 10. Blocking probabilities for *K* = 18 and 25 are almost same as merely calculating large number of routes for a destination is not going to help in avoiding blocking but at the same time, sufficient number of calculated routes helps in reducing the blocking instances. The Fig.3 shows similar results for large load wherein for *k* = 10, 18, and 25, blocking probabilities are almost same.

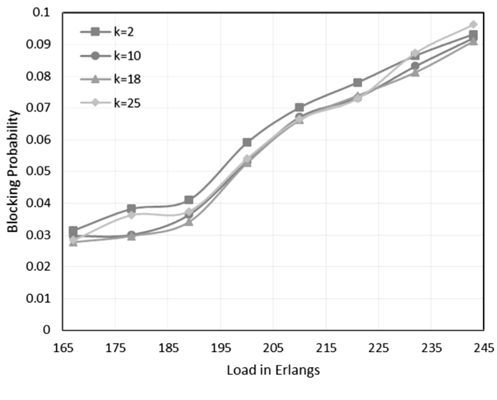

Fig.2. Traffic load versus blocking probability for low load conditions

After studying the above results and considering other values of k-shortest routes, we choose optimum value of *k* as 18 for our further study.

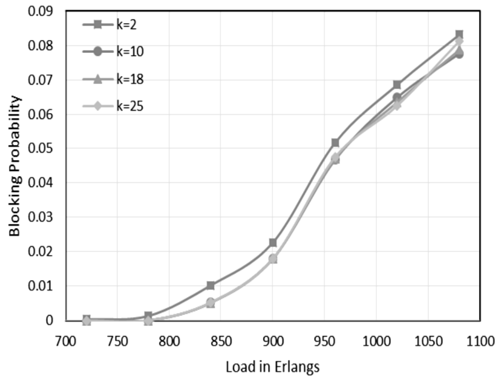

Fig.3. Traffic load versus blocking probability for high load conditions

With our proposed strategy, a new dynamic weight routing and first fit wavelength assignment (NDWR-FF), a new dynamic weight is calculated. Path with maximum weight function is chosen for the connection. The blocking probabilities obtained with first fit approach for different number of wavelengths for varied load conditions are compared with shortest path routing (SPR), least loaded routing (LLR), weighted least congested routing (WLCR) and is as given in Table.1 and Table.2. For SPR-FF, only one route is considered whereas for others, the route is selected from the k-shortest paths. The results show that NDWR-FF gives lesser blocking probabilities and it performs better as compare to SPR-FF, LLR-FF and WLCR-FF.

Table.1. Comparison of Blocking probabilities for different routing algorithms for wavelengths = 40, 50

Wave lengths	Load	SPR	LLR	WLCR	NDWR
W=40	190E	0.07566	0.03458	0.0433	0.03312
	210E	0.10977	0.06977	0.0677	0.06287
W=50	220E	0.04313	0.01239	0.0137	0.00593
	240E	0.05464	0.01926	0.0154	0.00915

Table.2. Comparison of Blocking probabilities for different routing algorithms for wavelengths = 120, 140

Wave lengths	Load	SPR	LLR	WLCR	NDWR
W=120	840E	0.05199	0.0055	0.0062	0.0051
	960E	0.09530	0.0548	0.0534	0.0450
W=140	1020E	0.05837	0.0100	0.0103	0.0093
	1080E	0.0689	0.0274	0.0267	0.0200

The Fig.4 shows the effect of traffic load on blocking probabilities for NDWR-FF and WLCR-FF for low load conditions. It demonstrates that our proposed strategy improves the blocking performance as compare to earlier reported methods. In case of low load for *W* = 40, the difference in blocking probability with proposed strategy and WLCR is more as compare to that of for *W* = 45 and 50, demonstrating that the proposed strategy performs even better with the lesser wavelengths. Similarly, Fig.5 shows that for high load conditions and with $W = 120$, the blocking performance is better than that of $W = 130$ and 140. It also shows that if the number of wavelengths in the network is increased, the blocking probability is reduced up to certain extent.

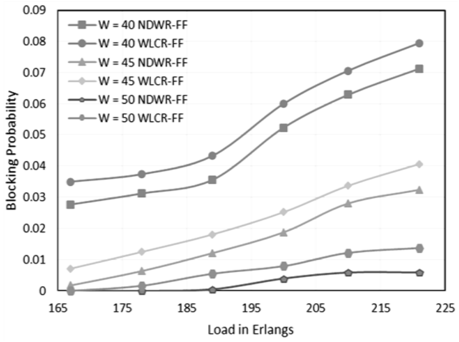

Fig.4. Traffic Load versus blocking probabilities for NDWR-FF and WLCR-FF for low load conditions

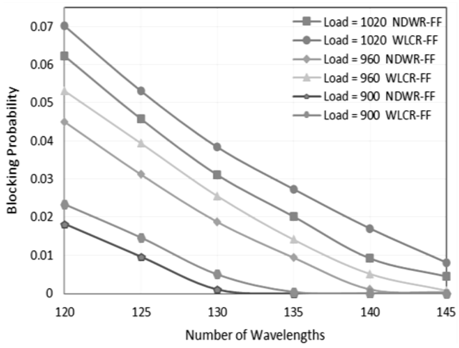

Fig.5. Number of wavelengths versus blocking probabilities for NDWR-FF and WLCR-FF for high load conditions

6. CONCLUSION

New routing and wavelength assignment strategy for all optical networks without use of wavelength converters is proposed. Simulations were carried out on NSFnet optical network. The new weight function gives better results and reduces the blocking probabilities as compare to earlier results. In proposed weight function, few shortest paths are calculated for every source and destination by Dijsktra's modified algorithm. For connection request, the weight is calculated for each route and route with maximum weight is selected. The blocking probabilities obtained with first fit approach for different number of wavelengths for varied load conditions are compared with the existing available techniques. The results show that the proposed strategy gives better blocking performance and it performs well as compare to other reported techniques. The proposed strategy can also be extended with partial and sparse partial wavelength converters for further improvement in network performance.

REFERENCES

[1] G. S. Arora and S. S. Subramaniam, "Converter placement in wavelength routing mesh topologies", *IEEE International Conference on Communications*, Vol. 3, pp. 1282-1288, 2000.

[2] H. Harai, M. Murata and H. Miyahara, "Performance of alternate routing methods in all-optical switching networks", *Proceedings IEEE Sixteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Driving the Information Revolution*, Vol. 2, pp. 516–524, 1997.

[3] Jun Zhou and Xin Yuan, "A study of dynamic routing and wavelength assignment with imprecise network state information", *Proceedings of International Conference on Parallel Processing Workshops*, pp. 207-213, 2002.

[4] Ravi Teja Koganti and Deepinder Sidhu, "Analysis of Routing and Wavelength Assignment in Large WDM Networks", *Procedia Computer Science,* Vol. 34, pp. 71-78, 2014.

[5] Ling Li and Arun K. Somani, "Dynamic wavelength routing using congestion and neighborhood information", *IEEE/ACM Transaction on Networking*, Vol. 7, pp. 779-786, 1999.

[6] Kit-Man Chan and T. P. Yam, "Analysis of least congested path routing in WDM lightwave networks", *Proceedings of 13th IEEE Conference on Networking for Global Communications,* Vol. 2, pp. 962-969, 1994.

[7] Xiaowen Chu and Bo Li, "Dynamic Routing and Wavelength Assignment in the Presence of Wavelength Conversion for All-Optical Networks", *IEEE/ACM Transactions on Networking*, Vol. 13, No. 3, pp. 704-715, 2005.

[8] Iyad Katib and Deep Medhi, "Adaptive alternate routing in WDM networks and its performance tradeoffs in the presence of wavelength converters", *Optical Switching and Networking*, Vol. 6, No. 3, pp. 181-193, 2009.

[9] Hui Zang, Jason P.Jue and Biswanth Mukherjee, "A review of routing and wavelength assignment approaches for wavelength-routed optical WDM networks", *Optical Networks Magazine*, pp. 47-60, 2000.

[10] Ahmed Mohkhtar and Murat Azizoglu, "Adaptive wavelength routing in all optical networks", *IEEE/ACM Transaction on Networking*, Vol. 6, No.2, pp. 197-206, 1998.

[11] R. A. Barry and P. A. Humblet, "Models of blocking probability in all optical networks with and without wavelength changers", *IEEE Journal of Selected Areas in Communication*, Vol. 14, No. 5, pp. 867-878, 1996.

[12] Rajneesh Randhawa and J. S. Sohal, "Blocking probability analysis of survivable routing in WDM optical networks with/without sparse-wavelength conversion", *Optik - International Journal for Light and Electron Optics*, Vol. 121, No. 5, pp.462-466, 2010.

[13] Kungmeng Lo, D. Habibi, Q. V. Phung and H. N. Nguyen, "Dynamic Wavelength Routing in all optical mesh networks", *Asia-Pacific Conference on Communications*, pp. 178-182, 2005.

[14] X. Masip-Bruin, M. German, A. Castro, E. Marin-Tordera, R. Serral-Gracia, S. Sanchez-Lopez, M. Yannuzzi, R. Gagliano, E. Grampin, "The Minimum Coincidence Routing Approach in Wavelength-Routed Optical WDM Networks", *Latin American Network Operations and Management Symposium* , pp. 1-5, 2009.

[15] Vladica Tinto and Jovan Radunovic, "Multihop Routing and Wavelength Assignment Algorithm for Optical WDM Networks", *International Journal of Networks and Communications*, Vol. 2, No. 1, pp. 1-10, 2012.

[16] Hamzeh Berranvand and Jawad A. Salehi. "Multiservice Provisioning and Quality of Service Guarantee in WDM Optical Code Switched GMPLS Core Networks", *Journal of Lightwave Technology*, Vol. 27, No. 12, pp. 1754-1762, 2009.