MULTILEVEL FEEDBACK QUEUE WAVELENGTH ASSIGNMENT ALGORITHM IN SURVIVABLE OPTICAL WDM NETWORKS

M. Arunachalam[1] and V. Rajamani[2]

[1]*Department of Computer Science and Engineering, K.L.N College of Information Technology, Tamil Nadu, India*
E-mail: er.arun80@gmail.com
[2]*Department of Electronics and Communication Engineering, Indra Ganesan College of Engineering, Tamil Nadu, India*
E-mail: rajavmani@gmail.com

Abstract
In survivable optical WDM networks, finding physical routes and assigning wavelengths to light paths plays a vital role in the information transmission systems. Wavelength assignment (WA) problem is a major concern than assigning routes to the light paths. Earlier wavelength assignment algorithm suffers from unbalanced utilization of wavelength that leads to blocking probability for any connection request. Our aim is to achieve better protection without the need for extra resources. In this paper, we propose a new multilevel feedback queue wavelength assignment algorithm (MFWA) to minimize the blocking probability of the connection requests considerably. Simulation results indicate that the proposed MFWA algorithm achieves reduced connection drop rate and delay with increased bandwidth utilization and throughput.

Keywords:
Optical WDM Networks, MFWA Wavelength Assignment, Connection Drop Rate, Channel Utilization, Average Queuing Delay

1. INTRODUCTION

To face the growing traffic demands in optical networks, wavelength division multiplexing (WDM) technologies provide the increase in network capacity [1]-[2]. In optical WDM network, routing of traffic sessions is subjected to the wavelength continuity constraint, which dictates that the light path corresponding to a given session must travel on the same wavelength on all links from the source node to the destination node. Using wavelength converters potentially allows the network to support a larger set of traffic. However, such converters are likely to be expensive. Hence, we focus on the problem of routing and wavelength assignment (RWA) without wavelength converters. Routing and wavelength assignment (RWA) problem determines the routes and assignment of wavelengths to the light paths, using the available number of wavelengths. The RWA problem is an important problem in resource management for WDM networks. Detailed surveys on the subject are available in [3]–[12]. In the routing process, the routes are chosen based on shortest-path sets. So, we are concerned only with the wavelength assignment (WA) problem here.

1.1 VARIOUS HEURISTIC WAVELENGTH ASSIGNMENT APPROACHES

Various heuristic wavelength assignment approaches are described below:

1.1.1 First Fit (FF) Wavelength Algorithm:

This strategy is implemented by predefining an order on the wavelengths. The list of used and free wavelengths is maintained.

The basic principle of FF strategy always chooses the lowest indexed wavelength from the list of free wavelengths and assigns it to the connection request. When the request is completed the wavelength is added back to the free wavelength set. The disadvantage of this approach is that the lower indexed wavelengths are much more used than the higher indexed wavelengths. Hence certain wavelengths are utilized very low. Since all the nodes in the network use the lower numbered wavelengths, contention for these wavelengths increases which results in higher connection drop rate in the network.

1.1.2 Random Fit (RF) Wavelength Algorithm:

Random fit algorithm determines which wavelengths are available and then chooses the wavelength randomly amongst the available set of wavelengths. Even though random fit assignment works better than first fit assignment as it can choose any of the free wavelengths, it suffers from lack of definite approach for wavelength assignment and that may not yield good results in some cases.

1.1.3 Most Used (MU) and Least Used (LU) Wavelength Algorithm:

In Most used wavelength strategy, the connection request is assigned with a free wavelength that is used on the greatest number of fibers in the network. If several available wavelengths share the same maximum usage, the wavelength with a specific index is chosen. Least used wavelength assignment is similar to the most used wavelength strategy, but in this strategy the least used wavelength in the network is assigned.

Of the above strategies, first fit and random fit techniques are the most practical, as these are simple to implement. Unlike most used and least used they do not require global knowledge of the network. They simply depend on the state of the node at that instant and choose the wavelength from the set of free wavelengths at that output link. As they are unaware of the state of the network, this assignment strategy will not yield optimum results.

1.1.4 Round Robin (RR) Wavelength Algorithm:

In Round robin wavelength assignment, the wavelengths are indexed. The assignment of wavelength starts with assigning the first indexed wavelength for the first requested light-path. With every subsequent request, the node chooses the next numbered wavelength and so on. This process continues in a round robin manner and the first wavelength is reached again after all the wavelengths in the available set have been assigned. In this manner all the wavelengths are utilized equally which reduces the blocking probability considerably. Blocking probability in the network increases when the requested wavelength is not available for any connection request. In round robin wavelength

assignment approach, the light-path can be routed with next indexed wavelength in the list. This approach is possible only if wavelength converters are placed at or near the mesh. This research work focuses on wavelength assignment without wavelength converters. Since wavelength converters are found to be expensive, it is not possible to route the light-path into another wavelength without wavelength converter. So the connection request has to wait indefinitely for the requested wavelength. This overhead will make the average queuing delay still more.

To overcome the problems addressed in the existing strategies, a multilevel wavelength assignment algorithm is proposed. The goal of this paper is to develop a wavelength algorithm which minimizes the average connection drop rate for a new session request given a fixed number of wavelengths in the network. The paper is organized as follows. In Section 2 we review the literature work done earlier. In Section 3 we propose a multilevel feedback wavelength assignment (MFWA) algorithm for survivability in optical WDM networks. Simulation results and evaluation of the proposed algorithm performances are presented in Section 4. Finally we conclude the paper in Section 5.

2. RELATED STUDY

Anpeng Huang et al [3] developed little-arc-first (LAF) routing algorithm, first matching (FM) wavelength assignment, and sharing peer protection (SPP) to achieve high-level performance in Africa TWO. From the simulation results that their proposed algorithms proved better resource distribution and achieved load balancing in the network.

Yvan Pointurier et al [4] compared and presented two classes of adaptive Quality of transmission ie., QoT-aware routing and wavelength assignment algorithms for networks with physical impairments. When networks are heavily loaded, calls are blocked because of poor QoT, measured by BER. The proposed fair QoT-aware adaptive RWA algorithms decrease BER and improve fairness in blocking probability and BER without any connection drop in the network.

Based on the combination of given First fit (FF) list with a dynamic constraint on Cross Phase Modulation (XPM)incidence, Raul C. Almeida et al [5] implemented a wavelength assignment algorithm. It has been shown that the use of dynamic constraint on XPM incidence on the wavelength assignment improves the blocking performance obtained by strict FF assignment with carefully selected impairment-aware lists.

Jun He et al [6] discussed and presented a new heuristic offline wavelength ordering algorithm for wavelength allocation. Also they studied the impact of guaranteeing QoS, by combining both BER and latency constraints, on the performance of wavelength assignment algorithms in shortest path (SP) and fixed alternate (ALT) routing. From the results, it is observed that their heuristic algorithm minimizes the crosstalk due to adjacent wavelength power leaking through the WDM demultiplexers.

The analysis of the RWA problem was topologically defined, and the behavior of the corresponding algorithms was explained in detail by Tarek Hindam [7] to solve a large and scalable problem in reasonable time. The algorithm has explained the dependence between the number of representation graphs and the shortest light path in terms of hops.

To solve the dynamic wavelength assignment problem in wavelength-convertible networks, Ching-Fang Hsu et al [8] presented a heuristic algorithm, named Least weighted configuration cost (LWCC). Simulation results show that LWCC outperforms the existing algorithm significantly in terms of blocking performance. Also, the performance of LWCC is not as sensitive to waveband granularity as that of the existing algorithm.

Nina Skorin-Kapov et al [9] investigated the problem of routing and wavelength assignment in transparent optical networks. They presented a novel objective criterion, called the maximum Lightpath Attack Radius (max LAR). Comparison results with existing approach indicate with the obtained improvement in network security.

To serve a connection request, Konstantinos Manousakis [10] developed a Impairment-aware routing and wavelength assignment (IA-RWA) algorithm and described the the mechanisms required to compute them. The IA-RWA algorithm calculates all the cost-effective and feasible light paths for the given source-destination of the network.

Kiyo Ishii et al [11] developed the optimal wavelength assignment for concatenated ring networks that minimizes the number of wavelengths used. They also described three schemes, traffic separation, hierarchical switching for inter-ring traffic, and restriction to only the end-node switching protection scheme, that can reduce the switch scale of the ring-concatenating node(s).

Namik Sengezer et al [12] investigated the light path establishment problem in the presence of physical layer impairments. They presented an efficient heuristic solution for the light path establishment problem: Reordered light path establishment (ROLE) by comparing ROLE with Pre-ordering least impact offline routing and wavelength assignment (POLIO-RWA), a heuristic algorithm for the same problem that is shown to be superior to the previous heuristic algorithm.

3. PROPOSED MFWA ALGORITHM

In this section, the suggested MFWA algorithm is described in detail. MFWA algorithm is a dynamic wavelength assignment algorithm which minimizes the average connection drop rate in the network. MFWA algorithm overcomes the problems of wavelength assignment algorithms (addressed earlier).In MFWA approach, the scheduler determines the queue to which the light-path request should be sent. For wavelength assignment, new connection requests are sent to Queue Q_3, while the intermediate connection requests are sent to Queue Q_1 and Queue Q_2 depending on the availability of wavelengths. Fig.1 shows the block diagram of the MFWA algorithm:
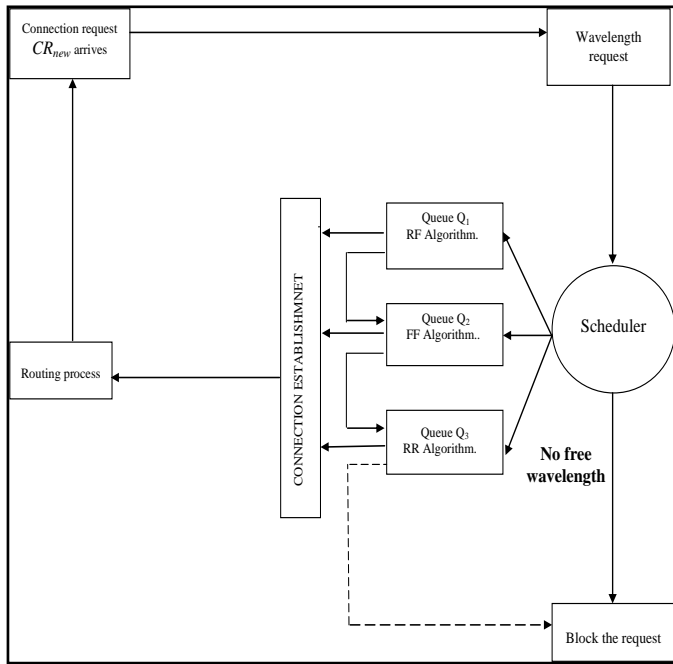
Fig.1. Block diagram of MFWA algorithm

The suggested MFWA algorithm implements two or more scheduling queues. The processing steps of the MFWA algorithm are given below:

Let, w denotes the set of wavelengths and w = {λ_1, λ_2, λ_3. . . λ_y}

Let, Q_1, Q_2, Q_3 be the queues and each queue assigned with w_1, w_2, w_3 wavelength sets.

Let, $X=x$, $Y=y$ and $M=m$ where x, y and m are number of queues, number of wavelengths and number of wavelength sets respectively.

Step 1: Calculate the shortest path 'k' for every source-destination pairs.

Step 2: Connection requests are queued in First In First Out (FIFO) fashion.

Step 3: If the scheduler receives the new connection requests CR_{new}:

Step 3.1: if any free space in the Q_1 is available

Step 3.1.1: if any free wavelength λ_y in the wavelength set w_m, is available, assign the wavelength λ randomly from the wavelength set w.

assign $CR_{new} = RF(\square_y, w_m)$

Step 3.2: else if any free space in the Q_2 is available

Step 3.2.1: if any free wavelength λ_y in any wavelength set w_m is available, assign the lowest indexed wavelength λ from the wavelength set w

assign $CR_{new} = FF(\square_y, w_m)$

Step 3.3: else if any free space in the Q_3 is available

Step 3.3.1: if any free wavelength λ_y in any wavelength set w_m is available, assign the first indexed wavelength for the connection request. The connection request chooses the next numbered wavelength λ and so on for every subsequent request.

assign $CR_{new} = RR(\square_y, w_m)$

Step 4: else go to Exception.

Step 5: Exception:

if all the paths has been tried

then

connection request is blocked;

else

select an alternate path and go to step 1;

3.1 SIMULATIONS

The experiments are carried out to analyze the performance of suggested MFWA algorithm. The performances of the existing algorithms are also presented for comparison. The parameters used for simulations are number of wavelengths, link bandwidth, link delay, traffic arrival rate, traffic holding time and number of session traffics. A mesh topology with 19-nodes NSFNET is shown in Fig.1.
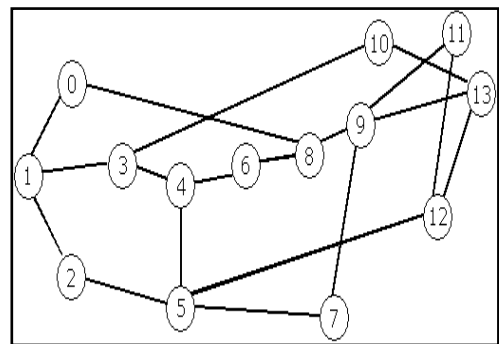

Fig.2. NSFNET

3.1.1 Results and Discussion:

Here, the simulation results for the suggested MFWA compared with the existing FF, RF and RR wavelength algorithms are presented. From this simulation, traffic load of the network is compared with connection drop rate, packets received, average queuing delay and channel utilization. The load is assumed as 2MB, 4MB, 6MB, 8MB, 10MB, 12MB and 14 MB.
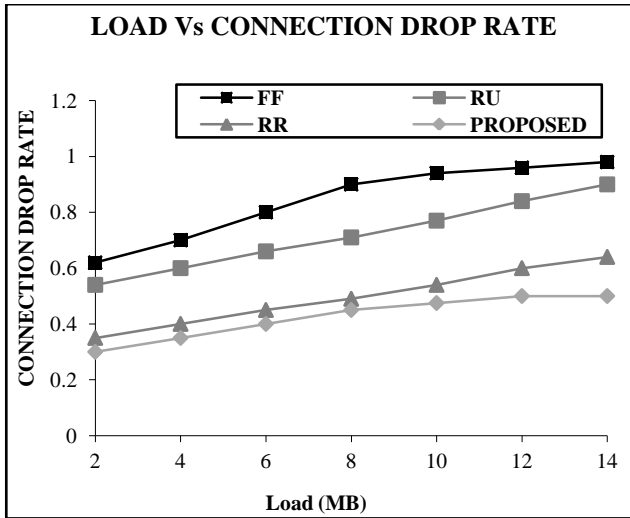
Fig.3. Variation of Connection drop rate with load

Fig.3 shows the connection drop rate with traffic load for the suggested MFWA with reference to the existing algorithms for various traffic loads viz., 2MB, 4MB, 6MB, 8MB, 10MB, 12MB and 14 MB. It is seen from the Fig.3 that the connection drop rate for the suggested MFWA algorithm is significantly less than the existing algorithms. This improvement is due to the balanced utilization of wavelengths achieved in the suggested algorithm. In MFWA, the wavelength blocked demands and unutilized wavelengths move between the queues so that the wavelengths are utilized uniformly. For example, when the load is 8 MB, the connection drop rate with MFWA algorithm is only 0.44, whereas the drop rate achieved by the existing FF, RF and RR wavelength algorithms are 0.9, 0.66 and 0.47 respectively.
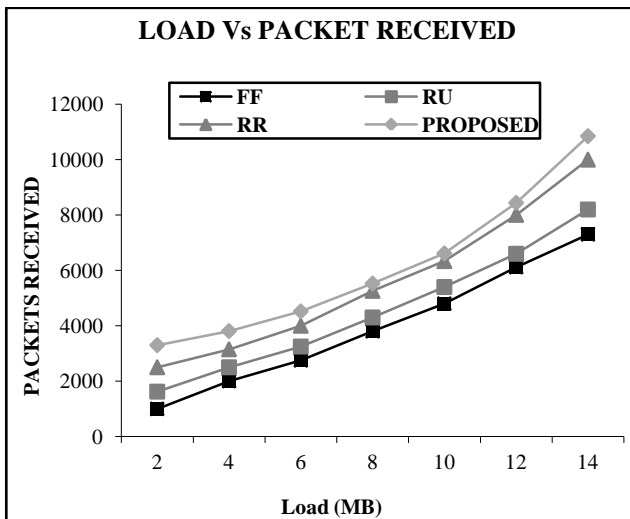

Fig.4. Variation of Packets received with load

The variation of packet received with load is presented in Fig.4 for MFWA algorithm with the existing algorithms for various loading conditions. For a network load of 8 MB, it is observed that number of packets received by the suggested MFWA algorithm is 5500, whereas the existing FF, RF and RR algorithm receives only 3760, 4220 and 5140 packets respectively. Since the MFWA algorithm achieves reduced connection drop rate due to balanced wavelength utilization, this

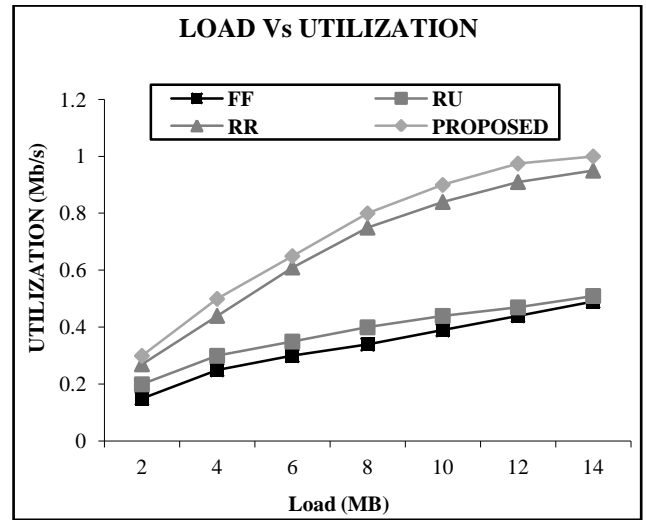higher packet receiving capacity is possible than the existing wavelength algorithms.

Fig.5. Variation of Channel utilization with load

Fig.5 shows the utilization of channel by the suggested MFWA algorithm with reference to the existing wavelength algorithms. For a traffic load of 8 MB, the Fig.5 shows that the MFWA algorithm achieves utilization as 0.8 Mbps, whereas the existing FF, RF and RR wavelength algorithms achieves 0.34 Mbps, 0.38 Mbps and 0.72 Mbps respectively. From Fig.5, it is proved that MFWA algorithm achieves comparatively better utilization than the existing algorithms, since all the available wavelengths are utilized uniformly.
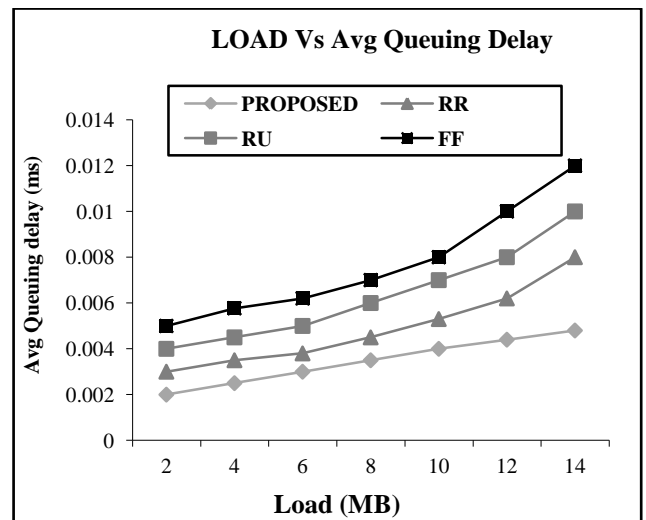

Fig.6. Variation of Average queuing delay with load

Fig.6 shows the variation of average queuing delay with load for the suggested MFWA algorithm with reference to the existing algorithms. It is observed from the Fig.6 that the average queuing delay using MFWA algorithm is significantly less than the existing algorithm. For example, when the network load is 8 MB, the average queuing delay using MFWA algorithm is 0.003 ms, whereas the average queuing delay for FF, RF and RR wavelength assignment algorithms are 0.007ms, 0.006ms and 0.0038ms respectively.
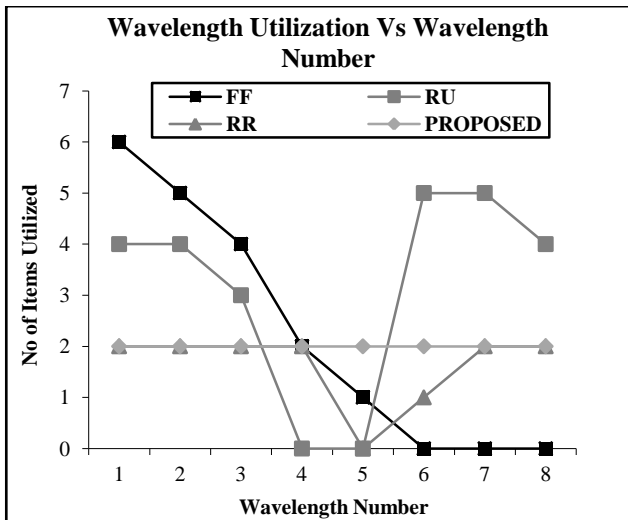
Fig.7. Variation of Wavelength utilization with wavelength number

Fig.7 shows the wavelength utilization by the suggested MFWA algorithm with reference to the existing wavelength algorithms. From the Fig.7, it is seen that the MFWA algorithm achieves uniform wavelength utilization, whereas the existing FF, RF and RR wavelength algorithms achieves unbalanced wavelength utilization than the suggested MFWA algorithm. The unbalanced wavelength utilization in the existing system is due to connection drop rate involved in FF and RF approaches, indefinite waiting time for the requested wavelength in RR approach. This improved wavelength utilization is due to uniform distribution of all available wavelengths in the suggested MFWA approach.

4. CONCLUSION

In this paper, the performance of the suggested Multilevel Feedback queue Wavelength Assignment (MFWA) algorithm has been analyzed for various performance metrics such as connection drop rate, packets received, average queuing delay and channel utilization. In MFWA approach, the scheduler determines the queue to which the light-path request should be sent. For wavelength assignment, new connection requests are sent to Queue Q_3, while the intermediate connection requests are sent to Queue Q_1 and Queue Q_2 depending on the availability of wavelengths. So, the computational overhead will be less for assigning wavelengths for any connection request thereby reducing the cost. MFWA algorithm improves the balanced and uniform utilization of wavelengths in the network. The uniform utilization of resources minimizes the average connection drop rate for the session requests in the network. By the simulation results, it is shown that the suggested algorithm achieves reduced connection drop rate and delay with increased channel utilization and throughput.

REFERENCES

[1] A. Rajkumar and N.S. Murthy Sharma, "A Distributed Priority Based Routing Algorithm for Dynamic Traffic in Survivable WDM Networks", *International Journal of Computer Science and Network Security*, Vol. 8, No. 11, pp.192-198, 2008.

[2] Vinh Trong Le, Son Hong Ngo, Xiaohong Jiang, Susumu Horiguchi and Yasushi Inoguchi, "A Hybrid Algorithm for Dynamic Lightpath Protection in Survivable WDM Optical Networks", *IEEE Proceedings of the 8th International Symposium on Parallel Architectures, Algorithms and Networks*, pp. 484-489, 2005.

[3] Anpeng Huang, Suman Sarkar, and Biswanath Mukherjee, " Africa TWO: A Proposal for a Concentric Two-Ring Network for the African Continent", *IEEE Journal on Selected areas in Communications*, Vol. 26, No. 6, pp. 2-11, 2008.

[4] Siamak Azodolmolky, Mirosław Klinkowski, Yvan Pointurier, Marianna Angelou, Davide Careglio, Josep Solé-Pareta, and Ioannis Tomkos, "A Novel Offline Physical Layer Impairments Aware RWA Algorithm With Dedicated Path Protection Consideration", *Journal of Lightwave Technology*, Vol. 28, No. 20, pp. 3029-3040, 2010.

[5] Raul C. Almeida Jr., Divanilson R. Campelo, Adolfo V. T. Cartaxo, Kenneth M. Guild and Helio Waldman, "Efficient Wavelength Assignment Policy for XPM-Impaired WDM Networks", *IEEE Communications Letters*, Vol. 12, No. 10, pp. 791-793, 2008.

[6] Jun He, Maïté Brandt-Pearce and Suresh Subramaniam, "QoS-Aware Wavelength With BER and Latency Constraints for All-Optical Networks", *Journal of Lightwave Technology*, Vol. 27, No. 5, pp. 462-474, 2009.

[7] Tarek Hindam, "Solving the Routing and Wavelength Assignment Problem WDM Networks for Future Planning", IEEE *Communications Magazine*, Vol. 47, No. 8, pp. 35-41, 2009.

[8] Ching-Fang Hsu and Fang-Sheng Lin, "On Dynamic Wavelength Assignment in Wavelength-Convertible Multi-Granular Optical Networks", *IEEE Transactions on Communications*, Vol. 57, No. 8, pp. 2221-2224, 2009.

[9] Nina Skorin-Kapov, Jiajia Chen and Lena Wosinska, "A New Approach to Optical Networks Security: Attack-Aware Routing and Wavelength Assignment", *IEEE/ACM Transactions on Networking*, Vol. 18, No. 3, pp. 750-760, 2010.

[10] Konstantinos Manousakis, Panagiotis Kokkinos, Konstantinos Christodoulopoulos, and Emmanouel Varvarigos, "Joint Online Routing, Wavelength Assignment and Regenerator Allocation in Translucent Optical Networks", *Journal of Lightwave Technology*, Vol. 28, No. 8, pp.1152-1163, 2010.

[11] Kiyo Ishii, Hiroshi Hasegawa, and Ken-ichi Sato, "Wavelength Assignment for Concatenated ROADM Ring Networks and Switch Scale Reduction in a Concatenating Node", *Journal of Optical. Communication Network*, Vol. 2, No. 1 pp.67-79, 2010.

[12] Namik Sengezer and Ezhan Karasan "Static Lightpath Establishment in Multilayer Traffic Engineering under Physical Layer Impairments", *Journal of Optical. Communication Network*, Vol. 2, No. 9, pp. 662-677, 2010.