Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems)
Pp. 247- 251 (2016)

OPTIMIZATION OF ROUTING AND WAVELENGTH ASSIGNMENT IN PASSIVE OPTICAL NETWORKS

[1]Roshni.V.V, [2]R.Hemalatha and [3]R.Mahalakshmi

Department of EEE, Kumaraguru College of Technology, Coimbatore, Tamilnadu
[1]roshnidvkrn52@gmail.com; [2]hemalatha.r.ece@kct.ac.in; [3]mahalakshmi.r.eee@kct.ac.in

ABSTRACT

This paper presents the implementation of a metaheuristic algorithm on optical network to fix Routing and Wavelength Assignment (RWA) problem.RWA is one of the important optimization problems in optical networks. RWA problem are of two types, static and dynamic. In static RWA the set of connections is known in advance where as in dynamic RWA connection request arrive sequentially. Here we examine the dynamic routing and wavelength assignment problem. The goal is to minimize the number of wavelengths and blocking probability. Evolutionary programming algorithms are used to optimize the routing and wavelength assignment. The RWA problem can be fixed by number of algorithms like GA, ACO etc. In this paper, Shuffled Frog Leaping Algorithm (SFLA) has been implemented in optical networks to fix the RWA problem.. Cost, number of wavelengths, hop count and blocking probability are the optimization parameters. In WDM network, for the given set of connection requests, routing and wavelength assignment problem involves the task of establishing lightpaths (routing) and assigning a wavelength to each connection request. The problem is analyzed for different wavelength assignment methods such as first fit, random, round robin and wavelength ordering. Fitness function is calculated in terms of cost, number of wavelengths, hop count and setup time. SFLA algorithm produce less blocking probability, less cost and less computational complexity than existing methods.

*Index Terms: R*outing and Wavelength assignment, Genetic Algorithm, Shuffled Frog Leaping Algorithm, Fitness function

INTRODUCTION

Optical networks plays major role in high capacity telecommunication networks. It provides routing, grooming and restoration at the wavelength based services. Fiber optics mainly used for conversion of light signals to transmit data. The transmitted data moves across a fiber. There should be a way to separate it so that it gets to the proper destination. The basic important types of systems in optical networks are active and passive optical networks. An active optical system is applicable to electrically powered switching equipment, such as a router or a switch aggregator. It is used to regulate signal distribution and also it directs signal to different users. This switch opens and closes in various ways to control the incoming and outgoing signals to the proper place. On the other hand, a passive optical network will not have electrically powered switching equipment. It uses optical splitters to isolate and collect optical signals. For each portion of the network, a passive optical network shares fiber optic strands. Powered equipment is required only at the two ends of the signal.

An optical WDM network can be defined as a network with optical fiber transmission links and with an architecture that is designed to make use the features of fibers and WDM. Such networks offer the guarantee of all optical information capable of supporting a wide range of applications [13]. Wavelength-division multiplexing (WDM) have high band width demand. Traffic grooming, Optimal routing and wavelength assignment, survivability, Quality of service(QoS) routing , physical layer impairment aware (PLI aware) routing and wavelength assignment are different problems that exist in optical wavelength division multiplexing (WDM) [1]. The idea of lightpath is introduced in wave length routing. A lightpath is an optical connection between two nodes. According to their wavelength, data flowing through a lightpath are optically routed at intermediate nodes [2,15]. The methods that have been employed to solve the above problems include classical approaches and heuristics or metaheuristics based approaches. Conventional techniques are able to give accurate results for simple problems; but, to solve complex problems, these techniques have too much computational time [3, 6]. Multiobjective evolutionary algorithms are used to solve the RWA problem which is based on swarm intelligence in real-world optical networks [4,5]. In the proposed method Shuffled Frog Leaping Algorithm is used to solve this problem.

The paper is arranged as follows. In section II we present the routing and wavelength assignment problem model in detail. The description of two optimization algorithms, genetic algorithm and shuffled frog leaping algorithm are detailed in section III. In section IV we include the analysis and simulation results. Finally, in section V, we review conclusions of this study and discuss possible lines of future work.

ROUTING AND WAVELENGTH ASSIGNMENT PROBLEM

A. Problem Definition

In dynamic routing and wavelength assignment the lightpath requests are arrived dynamically. A lightpath can be defined as a path in the network that satisfies the wavelength continuity constraint (that is, a lightpath must use the same wavelength on all the links along its path).Source node, destination node and holding time define each lightpath for the request. Time taken during which a lightpath and the associated resources remain occupied is defined as holding time. Once the holding time elapses, the resources become free and handle other lightpath requests. Fig.1 shows the model to solve the problem [10].

Fig.1.Block diagram of the optimization method

B. Network Model

The N node network can be modeled as a graph G (V,E), in which V is the set of nodes representing routers or switches, and E is the set of edges representing connectivity between the nodes. The link between the nodes is assumed to be bidirectional in nature, that is, if a link can be represented as e = (i,j) from node i to j implies the existence of another link e' = (j, i) for nodes (i,j) ∈ E. For the dynamic routing and wavelength assignment problem, V is the set of nodes representing routers or wireless routing networks, and E is the set of fiber links representing physical connectivity between the nodes.

C. Routing Model

Routing and Wavelength Assignment (RWA) problem is major optical networking problem with the goal of maximizing the number of optical connection. Each connection request must be given a route and wavelength. The wavelength must be same for the entire path, unless the usage of wavelength converters is assumed. If different wavelength is provided then two connections requests can share the same optical link [12].

Fitness function is to maximize

$$f_x = \frac{W_x}{\sum_{j=1}^{k_x-1} C_{gx(j),gx(j+1)}} + \frac{W_x}{\sum_{(i,j)\in E} H_{i,j}^x} + \frac{W_x}{T_x} \quad (1)$$

In the fitness function, W_x is the free wavelength factor. If the same wavelength is available in all links of the path x then it is one and zero otherwise. The other term in the first function defines the sum of the link costs in the path. The denominator of the second term represents the total number of hops the path passes through. The variable $H^x_{i,j}$ equals one if link (i, j) is a part of path x; otherwise, it is equal to zero.. The variable T_x represents the set up time of path x. The variable k_x represents the length of the x-th chromosome or number of memeplexes. A route is considered to be optimal when it maximizes this objective function while satisfying the following constraints:

$$\sum_{(i,j)\in E} I_{ij}^{lp} - \sum_{(j,i)\in E} I_{ij}^{lp} = 1, \text{ if i=S, } lp \in LP \quad (2)$$

$$\sum_{(i,j)\in E} I_{ij}^{lp} - \sum_{(j,i)\in E} I_{ij}^{lp} = -1, \text{ if i=D, } lp \in LP \quad (3)$$

$$\sum_{(i,j)\in E} I_{ij}^{lp} - \sum_{(j,i)\in E} I_{ij}^{lp} = 0, \text{ if i}\neq\text{S, i}\neq\text{D, } lp \in LP \quad (4)$$

$$\sum_{\substack{i\neq j \\ (i,j)\in E}} I_{ij}^{lp} \leq 1, \text{ if i}\neq\text{D, } lp \in LP \quad (5)$$

$$\sum_{\substack{i\neq j \\ (i,j)\in E}} I_{ij}^{lp} = 0, \text{ if i=D, } lp \in LP \quad (6)$$

$$\sum_{(i,j)\in E} I_{ij}^{lp} \leq h_0, \text{ for } t \leq T \quad (7)$$

$$h_0 < \sum_{(i,j)\in E} I_{ij}^{lp} \leq (N-1), \text{ for } t > T \quad (8)$$

Equations from (2) to (6) represent the flow conservation constraint. Equation (7) and (8) represents the hop count constraint.

D. Wavelength Assignment Model

First fit and Random fit are two generally used wavelength assignment techniques. First Fit decides the available wavelength with the lowest index while random fit determines which wavelengths are available and then chooses randomly amongst them. The complexity of both algorithms is O(w), where w is the number of wavelengths. First Fit outperforms Random Fit. The other wavelength assignment techniques used here are round robin and wavelength ordering. In the proposed fitness function, a free wavelength factor, Wx, is updated after the wavelength assignment phase. In the wavelength assignment model, the variable I_{ij}^{lp} is equal to one when the link (i, j) is used by the lightpath lp, and zero otherwise. The additional variables used are, I_{ijw}^{lp}, the lightpath wavelength indicator that shows whether the lightpath lp uses wavelength 'W' on link (i, j), $I_{ijw}^{lp(x,y)}$. It is one when the lightpath uses wavelength 'W' on link (i, j) between the nodes x and . $l^{(x,y)}$ equals to one if a physical link exists between the nodes x and y [11].

The wavelength continuity constraints are

$$I_{ij}^{lp} = \sum_{w=0}^{W-1} I_{ijw}^{lp}, \ \forall \text{ (i,j)} \quad (9)$$

$$I_{ijw}^{lp(x,y)} \leq I_{ijw}^{lp}, \ \forall \text{ (i,j)}, \ \forall \text{ (x,y)}, \ \forall \text{ w} \quad (10)$$

$$\sum_{i,j} I_{ijw}^{lp(x,y)} \leq 1, \ \forall \text{ (x,y)}, \ \forall \text{ w} \quad (11)$$

$$\sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(x,y)} l^{(x,y)} - \sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(y,x)} l^{(y,x)} = I_{ij}^{lp}, \text{ y=j} \quad (12)$$

$$\sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(x,y)} l^{(x,y)} - \sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(y,x)} l^{(y,x)} = -I_{ij}^{lp}, \text{ y=i} \quad (13)$$

$$\sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(x,y)} l^{(x,y)} - \sum_{w=0}^{W-1}\sum_{x} I_{ijw}^{lp(y,x)} l^{(y,x)} = 0, \text{ y}\neq\text{i, y}\neq\text{j} \quad (14)$$

OPTIMIZATION ALGORITHMS

A. Genetic Algorithm

The step by step methodology of Genetic Algorithm is shown in Fig.2. This iteratively works on an initial solution set, referred to as a population, and finally converges to the best solution [7].

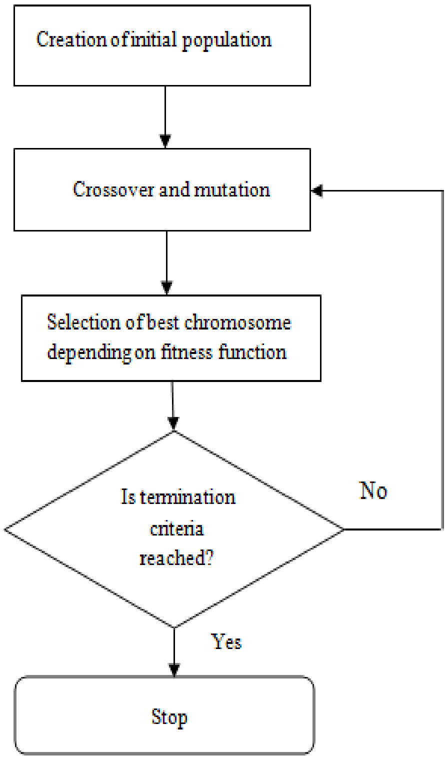

Fig.2. General Flow of GA

1) *Representation of chromosome*

A chromosome represents a route or a path encoded from source to destination. A sequence of nodes creates each chromosome that is randomly generated while satisfying the topology of the particular network. The chromosomes are of variable length, each of which is the encoding of a path from the source node, S, to the destination node, D.

2) Initialization of population

An initial population is created from a random selection of solutions. Each chromosome is represented by these solutions. The initial population consists of only a single individual.

3) Crossover and Mutation

Crossover examines the current solutions in order to find better ones. Crossover does not dependent on the position of nodes in routing paths. One pair is randomly taken and the locus of each node becomes a crossing site of each chromosome. The crossing points of two chromosomes may be different from each other [14]. When a chromosome undergoes mutation, mutation site of the parent chromosome is chosen randomly and a different path is chosen from that site to the destination. A different path is generated from that site to the destination node based on the topology database.

4. Calculation of fitness function

The fitness function is to evaluate the quality of the chromosomes. It is formulated as in equation (1).

B. Shuffled Frog Leaping Algorithm

Shuffled Frog Leaping Algorithm (SFLA) is a natural inspired metaheuristic algorithm. The most distinguished benefit of SFLA is its fast convergence speed .The Shuffled frog leaping algorithm combines the advantages of the both the genetic-based memetic algorithm and the behavior-based Particle Swarm Optimization(PSO) algorithm. In the Shuffled frog leaping algorithm, possible solutions are defined by a group of frogs which is referred to as population. The group of frogs is partitioned into several communities referred to as memeplexes. Local search is performed by each frog in the memeplexes. The individual frog's behavior can be influenced by behaviors of other frogs within each memeplex and it will develop through a process of memetic evolution. The memeplexes are forced to mix together after a certain number of memetics evolution steps and new memeplexes are formed through a shuffling process. The local search and the shuffling processes continue until convergence criteria are satisfied.Fig.3 shows the general flow of SFLA method.

The various steps are as follows:

1) The Shuffled frog leaping algorithm involves a population 'P' of possible solution, defined by a group of virtual frogs (n)

2) Frogs are sorted in descending order according to their fitness and then partitioned into subsets called as memeplexes(m).

3) Frog i is expressed as $X_i = (X_{i1}, X_{i2},...X_{is})$ where S represents number of variables.

4) Within each memeplex, the frog with worst and best fitness is identified as X_w and X_b.

5) Frog with global best fitness is identified as X_g.

6) The frog with worst fitness is improved according to the following equation.

$$D_i=rand\ (\ )\ (X_b - X_w) \quad (15)$$

$$X_{neww}=X_{oldw}+ D_i \quad (16)$$

where rand is a random number in the range of [0,1] [8]. Di is the frog leaping step size of the i-th frog and D_{max} is the maximum step allowed change in a frog's position. If the fitness value of new X_w is better than the current one, Xw will be accepted. If it isn't improved, then the calculated (9) and (10) are repeated with Xb replaced by X_g. If no improvement becomes possible in the case, a new Xw will be generated randomly. Repeat the update operation for a specific number of iterations. After a predefined number of memetic evolutionary steps within each memeplex, the solutions of evolved memeplexes are replaced into new population. This is called the shuffling process. The shuffling process promotes a global information exchange among the frogs. Then, the population is sorted in order of decreasing performance value and updates the population best frog's position, repartition the frog group into memeplexes, and progress the evolution within each memeplex until the conversion criteria are satisfied [9].

SIMULATION RESULTS

The optimization algorithms have been carried out in MATLAB R2012b. In the simulation work, fig.4 and

5 depict the fitness of the genetic algorithm and shuffled frog leaping algorithm with the execution time. The fitness function involves cost, number of hop counts and holding time. Better fitness is achieved for a smaller execution time.

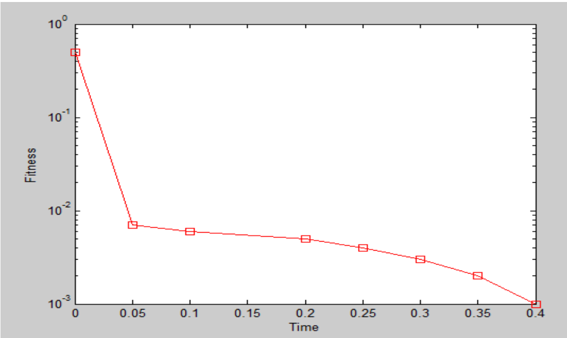

Fig.4.Fitness function of GA

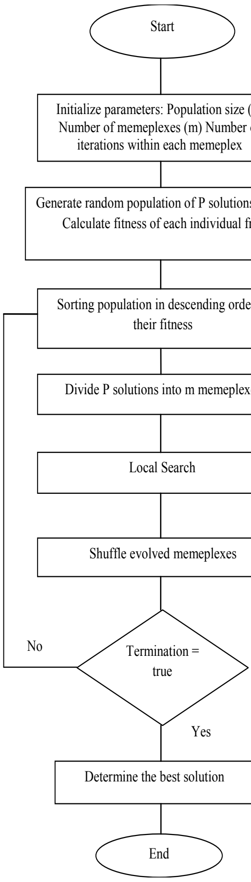

Fig.3.General Flow of SFLA

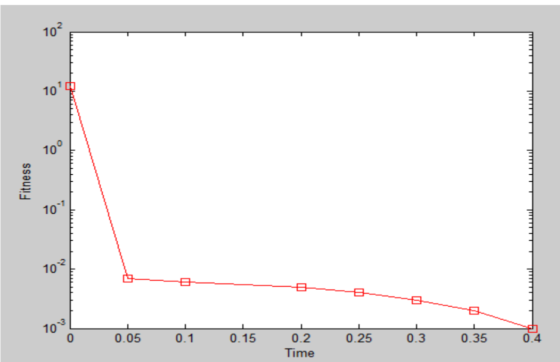

Fig.5.Fitness function of SFLA

Fig.6 and 7 shows the variation in the blocking probability assuming different values of adjacent wavelength rejection ratios. In each case by executing the program several times and then by computing the average, mean blocking probability is estimated. In wavelength ordering assignment, the mean blocking probability decreases for a reduction in each of the adjacent wavelength rejection ratio.

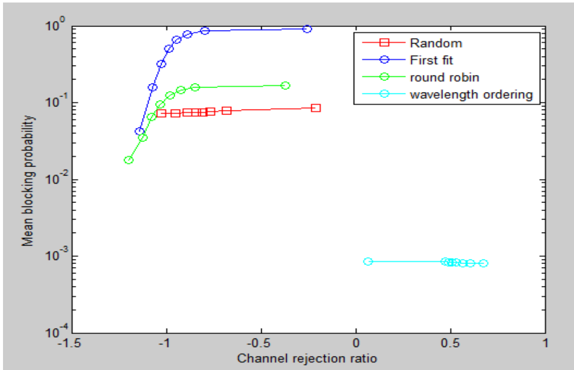

Fig.6.Mean blocking probability or a fixed network load using GA

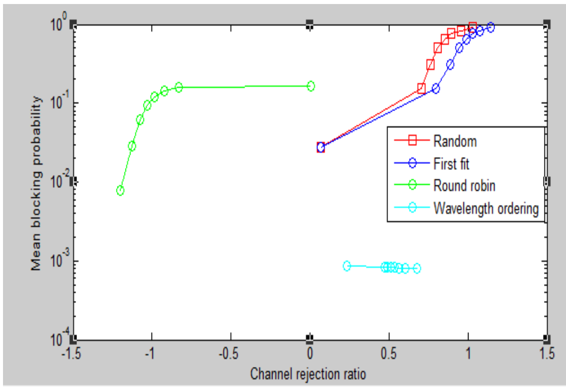

Fig.7.Mean blocking probability for a fixed load using SFLA

Fig.8 depicts the rate of convergence of genetic algorithm and shuffled frog leaping algorithm for first fit, random, round robin and wavelength ordering wavelength assignment techniques. By randomly selecting an individual and fixing the best fitness value, the curves can be plotted. The average fitness score decreases with increase in generations.

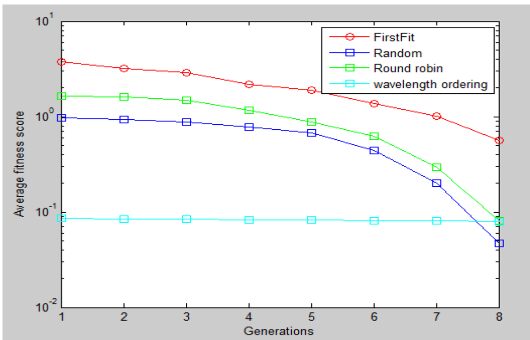

Fig.8 Average fitness for a fixed network load

Fig.9 and 10 show the mean blocking probability exhibited by the genetic algorithm and SFLA which is a performance metric of dynamic routing and wavelength assignment. The mean blocking probabilities obtained by GA and SFLA for the three wavelength assignment techniques are plotted assuming exponential holding times distribution.

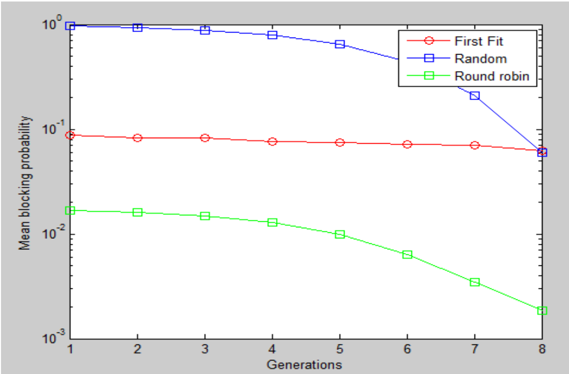

Fig.9.Mean blocking probability of GA

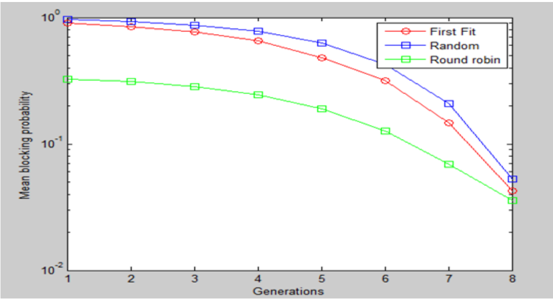

Fig.10.Mean blocking probability of SFLA

CONCLUSION

Routing and Wavelength Assignment (RWA) problem is the most complex optimization problem in optical networks. Genetic Algorithm and Shuffled Frog Leaping Algorithm are used to solve the RWA problem. The fitness function minimizes the cost, number of hops and blocking probability. The four wavelength assignment techniques such as first fit, random, round robin and wavelength ordering are used while evaluating the performance of GA and SFLA. SFLA approach has a lower time complexity compared to Genetic Algorithm. The proposed scheme provides certain degree of flexibility in the network design.

REFERENCES

[1] Urmila Bhanjaa and Sudipta Mahapatra, A metaheuristic approach for optical network optimization problems. Applied Soft Computing **13**(2): 981–997 (2013)

[2] David Bisbal, Ignacio de Miguel and Fernando Gonzalez, Dynamic Routing and Wavelength Assignment in Optical Networks by Means of Genetic Algorithm. Photonic Network Communications**7**(1); 43-58(2004)

[3] Wang, X., M. Brandt-Pearce and S. Subramaniam, Distributed Grooming, Routing, and Wavelength Assignment for Dynamic Optical Networks Using Ant Colony Optimization. IEEE/OSA Journal of Optical Communications and Networks **6**(6): 578-589 (2014)

[4] lvaro Rubio-Largo, A., Miguel A. Vega Rodr´ıguez, Juan A. Go´mez-Pulido and Juan M. Sa´nchez-Pe´rez, A Comparative Study on Multi objective Swarm Intelligence for the Routing and Wavelength Assignment Problem, IEEE Transactions on systems, man, and cybernetics **42**(6): 1644-1655 (2012)

[5] Yousef S. Kavian, Arash Rashedi, Ali Mahani and Zabih Ghassemlooy, Routing and wavelength assignment in optical networks using Artificial Bee Colony algorithm. Optik **124**: 1243-1249 (2013)

[6] Joan Triay and Cristina Cervell´o-Pastor, An Ant-Based Algorithm for Distributed Routing and Wavelength Assignment in Dynamic Optical Networks, IEEE journal on selected areas in communications **28**(4): 542-552 (2010)

[7] Kavian , Y.S., W. Ren , H.F. Rashvand, M.S. Leeson and M. Naderi, E.L. Hines, Genetic Algorithm for Designing DWDM Optical Networks under Demand Uncertainty, ICTON Mediterranean Winter Conference Pp. 1-4 (2009)

[8] Muzaffar, Kevin and Fayzul Pasha, Shuffled frog-leaping algorithm: a memetic meta-heuristic for discrete optimization. Engineering Optimization **38**(2): 129–154(2006)

[9] Giftson Samuel, G. and C. Christober Asir Rajan, A Modified Shuffled Frog Leaping Algorithm for Long-Term Generation Maintenance Scheduling. Proceedings of the Third International Conference on Soft Computing for Problem Solving, Advances in Intelligent Systems and Computing **1**: 11-24(2014)

[10] Urmila Bhanjaa, Sudipta Mahapatra and Rajarshi Roy, An evolutionary programming algorithm for survivable routing and wavelength assignment in transparent optical networks. Journal International Sciences: An International Journal **222**: 634-647 (2013)

[11] Urmila Bhanjaa, Sudipta Mahapatra and Rajarshi Roy, A novel solution to the dynamic routing and wavelength assignment problem in transparent optical networks. International Journal of Computer Networks and Communications **2**: 119-130 (2010)

[12] Urmila Bhanjaa, Sudipta Mahapatra and Rajarshi Roy, FWM aware evolutionary programming algorithm for transparent optical networks. Photonic Network Communications **3**: 285-299 (2012)

[13] Ramaswami, R., K.N. Sivarajan, Optical Networks: A Practical Perspective,Morgan Kaufmann Publishers, San Francisco (2000)

[14] Ahn, C.W. and R.S. Ramakrishna, A genetic algorithm for shortest path routing problem and the sizing of populations. IEEE Transactions on Evolutionary Computation **6**: 566–579 (2002)

[15] Le, V.T., X. Jiang, S.H. Ngo and S. Horiguchi, Dynamic RWA Based on the Combination of Mobile Agents Technique and Genetic Algorithms in WDM Networks with Sparse Wavelength Conversion. IEICE Transactions on Information and Systems **9**: 2067-2078 (2005)