Meta Heuristic for WDM Optical Networks Without Wavelength Conversion

Arturo Rodríguez Garcia[1], Leonardo Ramirez López[2] Felipe Rodrigues Martinez Basile[3]
[1]*Universidad de Santiago de Chile, Centro Latinoamericano de Investigación en Nuevas Tecnologías – CLINT.*
[2]*School of Engineering, Centro Latinoamericano de Investigación en Nuevas Tecnologías - CLINT, Universidad Militar Nueva Granada,*
[3]*Instituto Federal de Educação, Ciência e Tecnologia de São Paulo*
arturo.rodriguez@usach.cl

***Abstract*—This paper presents the results of the algorithm Snake-Two, evolving from algorithm Snake-One, which showed important results in the blocking probability of transport networks under dynamic traffic, but poor results in the network utilization indicator. The strategy applied is called Saturated Link and it moves traffic to congestion zones, creating concentrated network utilization, thus improving blocking probability. This is achieved by monitoring congested links using the full saturation capacity of each link. This way, the ones least used are downloaded, which enables keeping the congestion zoned and saturated, significantly lowering the blocking probability with low network utilization cost for dynamic traffic scenarios.**

***Index Terms*—Heuristic Algorithms; National Science Foundation NETwork; Optical Networks; Snake One; Wavelength Division Multiplexing.**

I. INTRODUCTION

Information traffic on the internet has increased by the development of integrated video services based on streaming and buffering, which has generated growth in the demand of large transport networks that are subjected to increasingly more traffic through their lines. Today's transport networks are based on optical fiber known as WDM (Wavelength Division Multiplexing) on the various wavelengths used. These networks are based on switching and are exploited by SDH (Synchronous Digital Hierarchy) and SONET (Synchronous Optical Network) transport technologies, reaching speeds of up to 2.5 Gbps for each wave length [1-2].

The distance between nodes of this network is measured in kilometers and when amplifiers are used (EDFA, RAMAN, etc.), they cross borders and oceans, such as the TATA TGN-Pacific, of 22,300 km that joins Japan and USA crossing the Pacific Ocean, among others. The optical nodes called OXC (Optical Cross Connect) enable convergence of different links to switch wavelengths, band wavelengths, fibers, etc. In general, these OXCs are characteristically opto-electronic, establishing a delay in the internal processing of these devices [3][4].

The most extensively studied networks are the ones deployed in large countries where large cities need to be connected at large distances, such as the NSFNET (Network Science Foundation NETwork) in USA, the European Backbone Network in Europe, among others [5][6].

In the beginning, optical network traffic was static because its demand was lower than the installed capacity in the WDM network, enabling setting optimization processes in its use. However, over time, demand grew increasingly, determining dynamic traffic, so usage optimization was no longer a priority. Priority was set to meet the demand and avoid service request blocking, and to improve network utilization to provide greater capacity availability for future demand.

This new dynamic scenario made routing algorithms in the static scenario useless, giving way to heuristic algorithms allowing several routes (not necessarily optimum ones) in the same algorithmic process. This enabled improving blocking probability indicators of service requests and network utilization.

II. RWA – ROUTING AND WIRELESS NETWORK

The evolution of optical fiber networks is limited by the number of wavelengths that can be multiplexed on the same fiber. These networks are called WDM (Wavelength Division Multiplexing) networks. Depending on the number of wavelengths and distance between nodes, they may be DWDM (Dense WDM), used for long distances with a maximum of 160 wavelengths, and CWDM (Course WDM), used for short distances with a maximum of 18 wavelengths. The differences are mainly the network's economic cost, complexity, optic fiber transmission capacity of the devices and the transmission band width.

By multiplexing more wavelengths in a space from 50 to 200 Ghz (0.2 nm and 2,500 Ghz (20 nm) for the cases of the CDWM networks. This means that wider laser lines may be used, with the advantage of reducing the operative cost of the network, but the disadvantage of doing it at shorter distances [7].

This restriction affects two important indicators used in the study of these networks: the Blocking Probability (BP) and the Network Utilization (NU). The WDM networks may be the wavelength conversion (WWC-With Wavelength Conversion) this can be seen in Figure 1, and without wavelength conversion (NWC - No Wavelength Conversion) this can be seen in Figure 2. The WDM-WWC can reuse different channels in each link of their transport routes, while WDM-NWCs are restricted to using the same channel in each of the links of their routes. This condition is called WCC - Wavelength - Continuity Constraint) [1][8].

As observed in Figure 3, NWC can only use the same wavelength for each request, using different wavelengths associated to different systems, which generates a problem that has to be solved spatially or temporarily. Namely, to develop a route that does not use the same link or the session occurs at a different time. When two sessions need the same wavelength at the same link or at the same time, contention occurs.

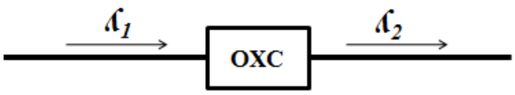

Figure 1: Optical cross connect with wavelength conversion.

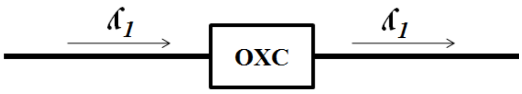

Figure 2: Optical cross connect without wavelength conversion.

In photonic (optical) networks, traffic can be static or dynamic. For the case of static Light Paths (LP), they are active for a long time, creating a scenario where the network availability is predictable and therefore, optimal exploitation.

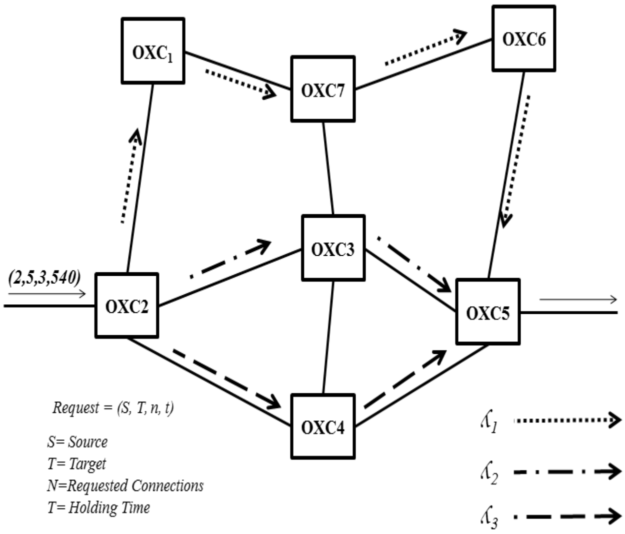

Figure 3: RWA Problem conceptualization.

In this scenario, the RWA solution is called Static LightPath Establishment (SLE). In the case of dynamic traffic, the LightPaths remain active for a finite time. This creates a scenario where network availability is not predictable and therefore exploitation is not optimizable. In these scenarios of heuristic algorithms are more efficient and have more and faster LPs. The RWA solution is called Dynamic Lightpath Establishment (DLE) [8-10]

III. Strategies and Algorithms

In scientific literature, the RWA problem in the DLE scenario has been approached by two strategies: the divided strategy and the integral strategy, this can be seen in Figure 4. The first strategy divides the problem in two, creating two algorithms, where the first part is in charge of obtaining the route between the origin and the destination of the request. The second part is in charge of assigning the wavelength associated to the found route. The second strategy solves the problem in one algorithm, finding the route and the wavelength.

In literature, relevant heuristics can be found, such as: Genetic Algorithm in [2], Artificial Bee Colony [17], Ant Colony [12], Simulated Annealing [13], Tabu Search [14-15], along with innovative and creative combinations and modifications such as those in [5-6][11]. The technologies research group (GINT-USACH, for its name in Spanish, Grupo de Investigación en Nuevas Tecnologías) proposes a new strategy to improve the Snake-One algorithm, called Snake-Two, which is described below.

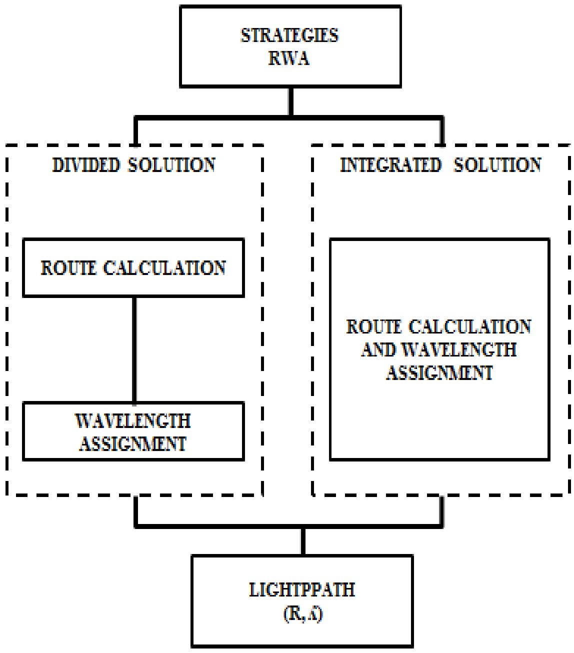

Figure 4: Strategies for solution of the RWA problem with heuristic algorithms

IV. Snake Two Algorithm

The new Snake Two strategy uses the Snake One algorithm to improve the NU indicator, because according to published results in [16], this algorithm improves the BP indicator, but with a high NU. The strategy strives to order congested traffic in the network using a traffic monitor represented by Matrix Congested Links (MCL). This matrix has two instant usage costs of each link of the network and it is ordered from most to least congested. Snake Two directs traffic toward the most used links ensuring that they work to the limits of their capacity (Saturated State), this can be seen in Figure 5. This way, the least used links will be less congested and therefore, available for service of future demand, thus reducing the blocking probability of incoming demand. Equation 1 represents MLC saving the characteristics of the current network traffic.

$$\mathrm{MCL} = \left\{ \begin{matrix} m_{ijk}/m_{ijk} = Instantaneous\ cost\ of\ the\ i-j\ link \\ for\ the\ k-th\ wavelength, \forall\ i \in [0, N(N-1)] \\ j = 3, k \in [0, n_W - 1] \end{matrix} \right\} \quad (1)$$

where:

N : Number of nodes of the network
n_W : Number of wavelengths for links in the network.

The rest of the intervening relations may be observed in Rodríguez (2015). Figure 5 shows the concept of the modification of Snake One to achieve Snake Two.

where:

So : Source Node
Ta : Target Node
n_{CX} : Number of Connections
t_{CX} : Holding Time

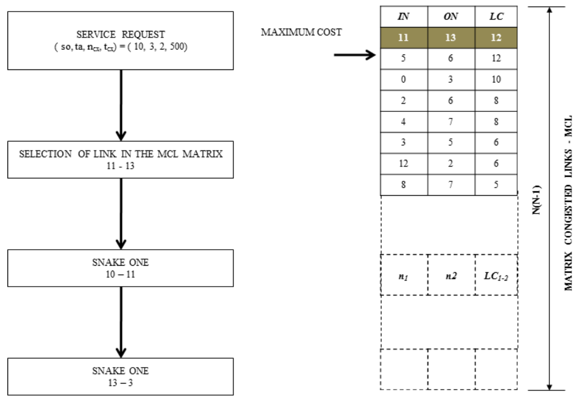

Figure 5: Conceptualization of the Snake-Two Algorithm, showing the Matrix congested links (MCL).

The Figure 6 shows the Flow Chart Snake-Two and the utilization of Snake-One Algorithm to obtain paths to links for each wavelength.

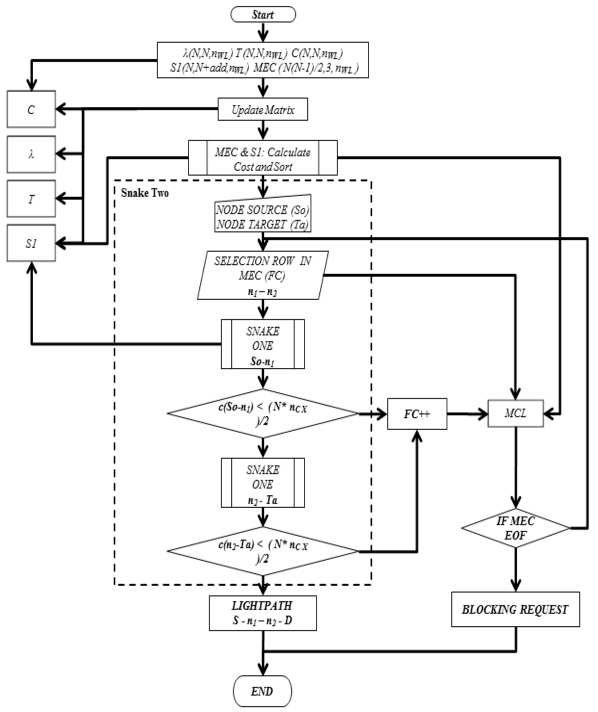

Figure 6: Flow chart of the Snake Two

V. Simulation Scenario

As mentioned above, the most studied networks are the ones deployed by large countries, where large cities must be interconnected at great distances. To compare results, the NSFNET (Network Science Foundation NETwork) network in USA was chosen, where fourteen nodes, twenty-one links and eight wavelengths were used (see Figure 7). Additionally, the demand is distributed uniformly among all the node pairs, the service demand has poisson features, there is no limit to the number of hops and there is no retry when a service request is blocked. These conditions are similar for algorithms that are studied in this article, which are shown in [8][10][16].

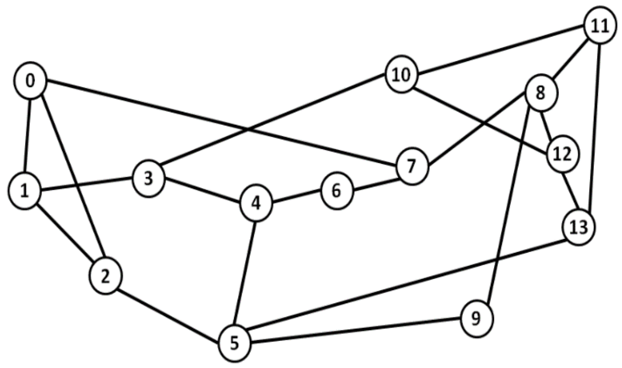

Figure 7: Simulation scenario, network NSFNET (National Science Foundation NETwork).

The network charge was obtained from the product of the mean arrival rate and the mean time of the connection request (holding time). The simulation was done varying the dynamic traffic conditions with charges of up to 180 erlangs each 10 erlangs.

VI. Comparison of Results

The compared heuristic algorithms are Snake One shows in [2] and Snake Two using generic algorithms as referential elements such as Simulated Annealing and Tabu Search shows in [16].

Table 1 shows the comparison between the mean values of indicators BP and NU for each heuristic algorithm.

Table 1
Comparison of mean values

	AG	SA	TS	SNK1	SNK2
Blocking probability	0.42	0.45	0.36	0.32	0.28
Use of the network (%)	42.17	45.30	55.17	68.2	72.2

It shows reduction of the blocking probability and a minor increase in network utilization. This behavior shows that the strategy of concentrating traffic in the most used sectors of the network (links working in saturation) produces greater availability for future demand and consequently decreasing the blocking probability, thus determining that incoming requests have a greater probability of being serviced.

To fine tune the heuristic comparison, another indicator was included (view Equation 2) called “blocking probability rate” (BPR) that relates the mean value of the BP and the mean value of NU (see Equation 2). The maximum BPR is 10,000 when BP is one (there is no service) and 100% of network utilization (saturated network).

$$\mathrm{BPR} = 10^6 \, \frac{\overline{\mathrm{BP}}}{\overline{\mathrm{NU}}} \qquad (2)$$

Table 2
Comparison of Blocking Probability Rate

	AG	SA	TS	SNK1	SNK2
BPR	9.995	9.976	6.477	4.631	3.915

According to Equation 2, the BPR shows the relation between the probability rate and network utilization (to see Table 2). This indicator helps to determine how much of the network resources the heuristic algorithms need to use to deliver their blocking probability. Figure 8 shows that SNK2

(Snake Two) has a lower value of TPB, indicating that it is the most efficient in terms of network resources.

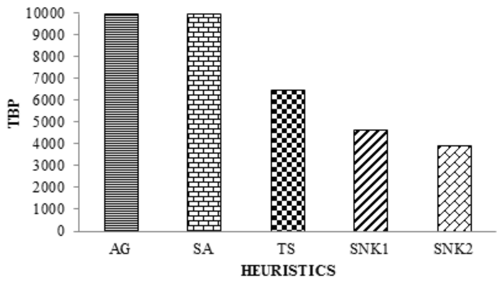

Figure 8: Comparison of the blocking probability rate (BPR) for every heuristic algorithm.

Figure 9 shows a slight improvement of SNK2, determining that the strategy of concentrating saturated traffic works, but not significantly.

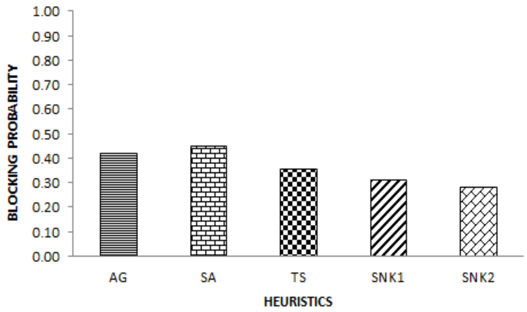

Figure 9: Comparison of the blocking probability (BP) for every heuristic algorithm

Figure 10 shows that the NU cost is relatively low, considering that as a dynamic traffic scenario without wavelength conversion, increasing the charge (erlangs) it increasingly uses more resources to respond to the incoming requests to control the blocking probability.

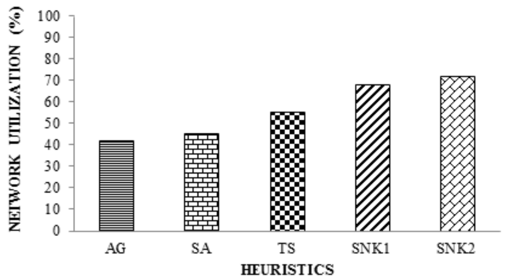

Figure 10: Comparison of the network utilization (NU) for every heuristic algorithm

In Figure 11, the blocking probability behavior of the SNK2 algorithm shows improvement that is not substantial; however it is important because the saturated traffic strategy does improve the performance.

Figure 12 shows the increase of network utilization of SNK2 below the levels of SNK1. This proves that the leverage of the Saturated Link strategy does not significantly increase resources usage, but it does reduce blocking probability.

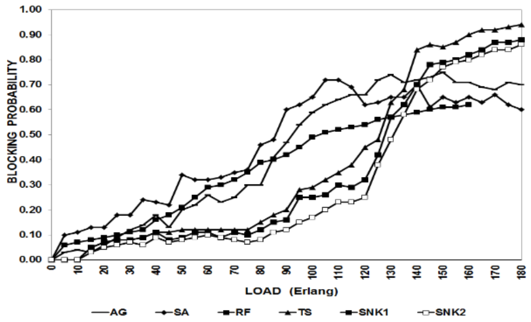

Figure 11: The blocking probability.

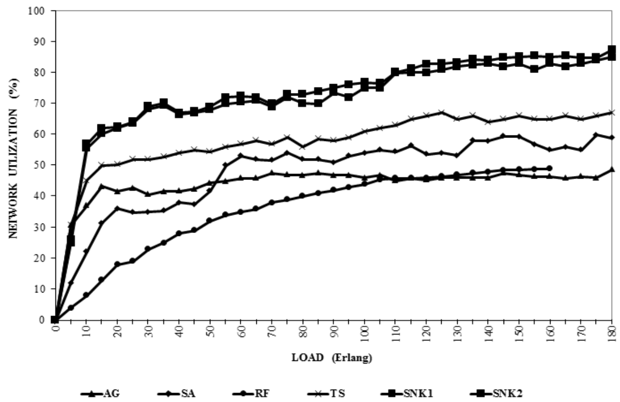

Figure. 12: The network utilization.

VII. Conclusion

The results show improvement of the blocking probability (decrease) at a low network utilization cost. This new strategy also establishes greater efficiency by using fewer resources than other heuristics to reduce blocking probability. It is noteworthy that the Saturated Link strategy does not significantly increase network utilization; however, it does reduce blocking probability. This indicator is significant because it ensures timely responses to transport requests of the network.

Acknowledgment

Special appreciation is expressed to the DICYT Program of Universidad de Santiago de Chile – USACH (Project DICYT N° 061572RG) and Project Basal USA1555 MECESUP-USACH, for its important support in research and development, and particularly to the New Technologies Research Group (Grupo de Investigación en Nuevas Tecnologías GINT-DTI-USACH).

References

[1] A. Rodriguez et al., "Comparing Genetic Algorithms and Simulated Annealing for dynamic traffic routing". LNEE Springer, vol. 315, 2014, pp. 3-14.

[2] H. Tantian et al., "A Genetic Algorithm Using Priority-Based Encoding for Routing and Spectrum Assignment in Elastic Optical Network", in Intelligent Computation Technology and Automation (ICICTA), 2014 7th International Conference on, 2014, pp.5-11.

[3] A. Rubio-Largo et al., "Multiobjective Metaheuristics for Traffic Grooming in Optical Networks", Evolutionary Computation, IEEE Transactions on, vol. 17, no 4, 2013, pp. 457-473.

[4] A. Kumar et al., "Optimization of wavelength converter in WDM networks using genetic algorithm. In: Electronics", in Computing and

Communication Technologies (CONECCT), 2013 IEEE International Conference on; Jan. 2013, pp.1-3.
[5] K. Assis et al., "Hybrid Algorithms for Routing and Assignment Wavelengths in Optical Networks", in Latin America Transactions, IEEE, vol. 8, no 3, 2010, pp. 214-220.
[6] A. Rubio-Largo et al., "Using a Multiobjective OpenMP+MPI DE for the Static RWA Problem", Computer Aided Systems Theory LNCS Springer-Verlag, vol. 6927, 2012, pp. 224-231.
[7] Y. Pan et al., "Cost-optimized joint resource allocation in grids/clouds with multilayer optical network architecture", Optical Communications and Networking, IEEE/OSA Journal of, vol. 6, no 10, 2014, pp. 911-924.
[8] H. Zang et al., "Dynamic lightpath establishment in wavelength routed WDM networks", Communications Magazine IEEE, vol. 39, no 9, 2001, pp. 100-108.
[9] R. Barpanda et al., "Solving large problem instances of the RWA problem using genetic algorithms", in Industrial and Information Systems (ICIIS), Mangalore, Karnataka, India, 2010, pp. 41-46.
[10] W. Zhang-liang et al., "An ant colony algorithm with tabu search and its application", in Intelligent Computation Technology and Automation (ICICTA), Shenzhen, Guangdong, China, 2011, pp. 412-416.
[11] A. Rubio-Largo et al., "A Multiobjective Gravitational Search Algorithm Applied to the Static Routing and Wavelength Assignment Problem", in Applications of Evolutionary Computation; Lecture Notes in Computer Science Springer-Verlag, vol. 6625, 2011, pp. 41-50.
[12] K. Bhaskaran et al., "Dynamic Anycast Routing and Wavelength Assignment in WDM Networks Using Ant Colony Optimization (ACO)", in Communications (ICC), 2011 IEEE International Conference on, vol. 1, no 1, 2011, pp. 1-6.
[13] S. Sakamoto et al., "Performance analysis of WMNs using simulated annealing algorithm for different temperature values", in Complex, Intelligent, and Software Intensive Systems (CISIS), Taichung, Taiwan, 2013, pp. 164-168.
[14] L. Khelifi et al., "A hybrid a|pproach based on multi-objective simulated annealing and tabu search to solve the dynamic dial a ride problema", in Advanced Logistics and Transport (ICALT), Sousse, Tunez, 2013, pp. 227-232.
[15] A. Rodriguez et al., "Routing wavelength assignement: A solution with tabu search in dynamic traffic", Ingeniare. Rev. chil. Ing, vol. 22, no 4, 2014, pp. 495-503.
[16] A. Rodriguez et al., "New heuristic algorithm for dynamic traffic in WDM optical networks", Revista Ingeniería e Investigación, vol. 35, no 3, 2015, pp. 100-106.
[17] A. Rubio-Largo et al., "Tackling the Static RWA Problem by Using a Multiobjective Artificial Bee Colony Algorithm", Advances in Computational Intelligence. Lecture Notes in Computer Science, Springer-Verlag, Berlin Heidelberg, vol. 6692, 2011, pp. 364-371.

.