Bio-inspired Routing and Wavelength Assignment Algorithm for Optical Mesh Networks

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Abstract. Optical networks have been widely implemented and they are usually used as the backbone of high-capacity telecommunication infrastructures. However, the nowadays traffic demand over these networks has increased in a way that congestion over the architecture is considerable. Due to the high costs of implementing new optical links, the routing and wavelength assignment process become an important point of analysis. This paper presents a time-efficient routing and wavelength assignment algorithm for optical mesh networks by applying bio-inspired calculation methods. The algorithm's main goal is to reduce computational costs and time during lightpath selection and wavelength assignment.

Keywords: Bio-Inspiration, Genetic Algorithms, Optical Mesh Networks, Routing, Wavelength Assignment.

1 Introduction

Optical networks work over a wavelength-division multiplexing –*DWM*– technology which allows a single optical channel to carry multiple signals and enable bidirectional communication links by multiplexing carrier signals into different wavelengths of laser light [1].

An optical network is usually composed by a mesh of interconnected routing nodes. For each new request between source and destination nodes it must be given a route and a wavelength. This optical network's challenge is known as the routing and wavelength assignment –WRA– problem [2,3]. The main goal of a *WRA* algorithm is to maximize the number of established connections within the optical mesh network [4].

2 A Useful Representation of Optical Mesh Networks

Optical mesh networks can be easily represented by using matrices. For a given network, a matrix is built in order to represent the presence or absence of

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direct links between nodes. The links –L– matrix is then given by the conditions represented in (1).

$$L_{(i,j)} = \begin{cases} 0 & if \;\; n_i \; and \; n_j \; are \; the \; same \; node \\ 1 & if \;\; there \; is \; direct \; link \; between \; n_i \; and \; n_j \\ 1000 & if \;\; there \; is \; no \; direct \; link \; between \; n_i \; and \; n_j \end{cases} \quad (1)$$

Then, $L = 1$ means that two different nodes are directly communicated and $L = 1000$ represents the absence of direct link between nodes. The final representation of a n-nodes optical network is finally given by (2).

$$L = \begin{bmatrix} 0 & L_{(1,2)} & L_{(1,3)} & \cdots\cdots & L_{(1,n)} \\ L_{(2,1)} & 0 & L_{(2,3)} & \cdots\cdots & L_{(2,n)} \\ L_{(3,1)} & L_{(3,2)} & 0 & \cdots\cdots & L_{(3,n)} \\ . & . & . & 0 \cdots\cdots & . \\ . & . & . & .\,0 \cdots & . \\ . & . & . & ..\,0 \cdots & . \\ . & . & . & \cdots 0 .. & . \\ . & . & . & \cdots . 0 . & . \\ . & . & . & \cdots\cdots 0 & . \\ L_{(n,1)} & L_{(n,2)} & L_{(n,3)} & \cdots\cdots & 0 \end{bmatrix} \quad (2)$$

3 Routing and Wavelength Assignment Algorithm

The *RWA* problem is approached by dividing the algorithm into two parts. The first one solves the routing issues and the second part deals with the wavelength assignment process.

3.1 Routing Algorithm

Let us assume there is an optical network with n routing nodes and a communication request between a source node –n_s– and a destination node –n_d– is received.

In order to find the best path –BP– throughout the network, the routing algorithm defines an initial matrix, which we will refer to as BP matrix. The BP matrix is given by a $m \times n$ array, where m represents the number of initial possible solutions to the problem.

The matrix's content is set under the criteria given by (3).

$$BP_{(i,j)} = \begin{cases} n_s & if \;\; j = 1 \\ random(1 \sim n) & if \;\; 1 < j < n \\ n_d & if \;\; j = n \end{cases} \quad (3)$$

Every single row, in fact, represents a possible path between n_s and n_d and this is why the first and last columns of the matrix are fixed and respectively identify the source and destination nodes. The remaining data on the *BP* matrix is then filled with random values between 1 and n. The final representation of *BP* matrix is shown in (4).

$$BP = \begin{bmatrix} n_s & r_{(1,2)} & r_{(1,3)} & \cdots\cdots & r_{(1,n-1)} & n_d \\ n_s & r_{(2,2)} & r_{(2,3)} & \cdots\cdots & r_{(2,n-1)} & n_d \\ n_s & r_{(3,2)} & r_{(3,3)} & \cdots\cdots & r_{(3,n-1)} & n_d \\ n_s & . & . & \cdots\cdots & . & n_d \\ n_s & . & . & \cdots\cdots & . & n_d \\ n_s & . & . & \cdots\cdots & . & n_d \\ n_s & r_{(m,2)} & r_{(m,3)} & \cdots\cdots & r_{(m,n-1)} & n_d \end{bmatrix} \quad (4)$$

Once the initial matrix is defined, the algorithm compute the path cost –*PC*– over every single proposed solution.

The *PC* mainly depends on the network links matrix represented by (2) and is given by the total sum of the cost for each hop between nodes, as shown in equation (5).

$$PC_i = \sum_{k=1}^{n-1} L_{\left(BP_{(i,k)}, BP_{(i,k+1)}\right)} \quad (5)$$

The algorithm's main goal is to minimize the *PC* and indeed three genetic operators are applied over the *BP* matrix. **Selection:** the $m/2$ paths that present the lowest costs are selected to be part of a new generation of best paths. **Crossover:** $m/2$ new paths are obtained by crossing the previously selected paths at a random point within its second and (n-1)-th column. **Mutation:** the nodes within the paths matrix have a given probability of changing.

After the process, a new *BP* matrix has been created and its average *PC* is lower than the previous one's. The whole process can be iterated as many times as required in order to get closer to the best path solution.

3.2 Wavelength Assignment Algorithm

The second part of the *RWA* problem is solved by applying the well-known First Fit algorithm [5]. First Fit is one of the most common methods for wavelength assignment and consists on simply choosing the available wavelength with the lowest index. It has to be here considered that the assigned wavelength must be defined for the entire lightpath.

4 Conclusion

The bio-inspired routing and wavelength assignment algorithm represent a time-efficient solution for the optical mesh network's *RWA* problem. The goal of maximizing the number of possible connections within an optical telecommunication architecture is finally achieved by minimizing the time taken during the genetic algorithms-based calculation of best paths and wavelength assignments.

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