

# Using of Latin Router for Routing Wavelength with Configuration Algorithm

A.Habiboghli, R.Mostafaei, M.R.Meybodi

**Abstract**— Optical network uses a tool for routing which is called Latin router. These routers use particular algorithms for routing. In this paper, we present algorithm for configuration of optical network that is optimized regarding previous algorithm. We show that by decreasing the number of hops for source-destination in lightpath number of satisfied request is less. Also we had shown that more than single-hop lightpath relating single-hop lightpath is better.

**Keywords**— Latin Router, Constraint Satisfied, Wavelength, Optical Network

## I. INTRODUCTION

A lightpath is used in a wavelength-routed, optical network to establish highspeed, all-optical, channels which can span multiple fiber links without undergoing electronic processing at the intermediate nodes of the network. For example, in Fig. 1, optical lightpath LP4 is established directly connecting nodes 4 and 2 through an all-optical channel. In the absence of wavelength conversion devices at the intermediate nodes of the network, a lightpath will be on the same wavelength on all the fiber-links through which it traverses; the lightpath will be switched optically at the intermediate nodes, e.g., lightpath LP4 is optically switched at node 5 and node 1 before it finally terminates at node 2. A lightpath is typically a unidirectional channel of communication, i.e., a lightpath from node 4 to node 2 does not necessarily mean that there will be a lightpath from node 2 to node 4.

Using all-optical lightpaths in the network architecture considerably reduces the processing time at intermediate switching nodes, by optically switching forwarded traffic. If two lightpaths traverse one or more common fiber links, the lightpaths must necessarily be operated on different wavelengths. For example, in figure 1 lightpaths LP1 and LP4 traverse a common fiber 4-5, and hence should be on different wavelengths. Typically the number of wavelengths available in the network is fixed at some maximum number, and is

limited by the technology used to build the network. [4].

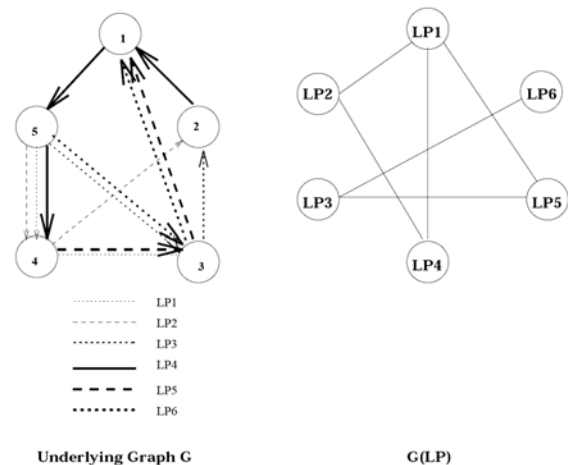


Fig. 1. From G to G(V C).

A routing node in this network employs an optical component for wavelength routing of all optical lightpaths. We use a Latin Router as a passive wavelength router in the optical component of the router, because of its low cost and robustness.

A  $K \times K$  Latin Router [1] (LR) (shown in Fig. 2) provides complete connectivity between every input and output port, by passively routing  $K^2$  optical connections on  $K$  wavelengths. A certain router, called the Shift Latin Router (SLR), has a fixed cyclical-permutation-based interconnection pattern between its input and output ports, e.g., wavelength  $k$  on input port  $i$  is always routed to the same wavelength on output port  $(i + k) \text{ modulo } K, \forall i, k \in [0, 1, 2, \dots, N - 1]$ . A particular feature of the Latin Router is that the number of wavelengths supported in the router is equal to the size of the Latin Router that in [3] have been referred to this.

A common problem in optical network design is: given a physical network topology and a numbers of available wavelengths (hereafter called colors), can we establish a given set of lightpaths? Requested lightpaths are given as source destination pairs of nodes in the underlying physical topology. Previously proposed algorithms typically solve this problem in two distinct phases: routing and coloring. The routing algorithm uses traditional shortest-path-based algorithms to generate a set of routes for each lightpath. Each lightpath is

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then assigned a color, such that no two lightpaths passing through a common link are assigned the same color.

Most existing network designs are based on the Wavelength Routing Switch (WRS), which is a reconfigurable router allowing any wavelength to be switched from any input port to any output port, and hence does not impose any restrictions on the routing algorithm. The advantage of this scheme is that routing and coloring are both well-studied problems, and therefore a large number of existing techniques can be employed to solve the problem.

While the above techniques work well in WRS-based networks, we must find different solutions for LR-based networks. In particular, Shift Latin Routers make it difficult to separate the algorithmic process into routing and coloring stages. The constraints that are imposed by a Shift Latin Router on the wavelength assigned to a lightpath needs to be accommodated by the routing algorithm; otherwise unacceptably small.

Numbers of lightpaths will have colorings which obey those constraints. Modifying the routing algorithms to minimize the impact of those constraints is difficult and substantially complicates the routing process (this is explained later in the Appendix). It is important to develop schemes to handle the constraints that these routers impose on optical routing.

In this paper, for configuration of optical network we present an algorithm that is optimal than previous way. In section2 we provide the problem formulation.

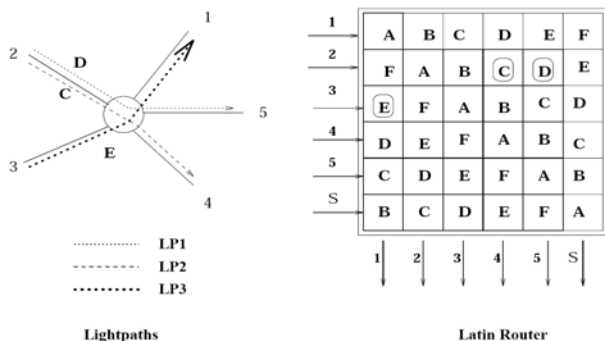


Fig 2. Latin Square Router.

In section3, we discuss LONCA, which is based on the well-known local search paradigm. We explain our proposed algorithm in section4. We present simulation results for this algorithm on randomly generated problem instances in section5. Our result is showing that CSONCA is better than LONCA. In section6 we conclude and discuss future work.

## II. ROUTING IN OPTICAL NETWORKS

We discuss the problem formulation, and briefly mention the traditional routing algorithms used to satisfy a set of lightpath requests. In the Appendix, we discuss how different parameters in the underlying graph and the chosen router can affect the constraint-satisfaction problem.

### A. Problem Formulation

The input to the problem is a graph  $(G, V, E)$ , a number of available wavelengths  $k$  and a set of  $i$  requested lightpaths  $C = \{s_i, d_i\}$ . The number of wavelengths available restricts the number of lightpaths which can traverse a single link. Lightpaths are directed; in other words, we may desire to have a directed lightpath from  $s_i$  to  $d_j$ , without a lightpath from  $d_i$  to  $s_j$ .

Traditionally we employ a routing algorithm which takes the list  $C = \{s_i, d_i\}$  and produces a set of uncolored routes  $LP = \{lp_{i1}, lp_{i2}, \dots, lp_{ij}\}$  such that  $\forall i, lp_{i1} = s_i \wedge lp_{ij} = d_i$ . Two lightpaths  $lp_a, lp_b$  can't have the same color if they share an edge  $(i, j) \in G$ . This motivates a graph coloring problem where each connection is isomorphic to a node of an auxiliary graph; two nodes have an edge between them in the auxiliary graph if their corresponding lightpaths share an edge in the underlying graph  $G$ . We shall refer to this auxiliary graph as the graph induced by LP and denote it as  $G(LP)$ . Fig. 1 shows an example of constructing  $G(LP)$  from  $G$ . We observe, for example, that  $lp_1, lp_2$  and  $lp_4$  all use edge 4 - 5 in the graph, and so they form a 3-clique in  $G(LP)$ . Given  $N$  nodes in  $G$ ,  $G(LP)$  has  $|LP| \leq N(N-1)$  nodes. The number of edges in  $G(LP)$  is dependent on the routing of the lightpaths. Intuitively, shorter routes for lightpaths result in the fewer edges in  $G(LP)$ , because fewer lightpaths share the fiber links. The network topology, and the size of the router used, has also been shown to impact lightpath routing.

### B. Physical Network

The characteristics of the network topology represented by  $G$ , and the router used at the network nodes, influence the solution to the problem. It is clear that the more edges  $G$  has, the less constrained the graph coloring problem is likely to be, because there will be fewer lightpaths sharing a fiber, thus decreasing the number of edges in  $G$  (LP). If the underlying graph is a multigraph, i.e., there are multiple fibers connecting adjacent nodes in the physical topology, then more connections can pass between two heavily congested nodes without an increase in the number of colors the fiber must support. In a simple graph this would result in a 3-clique in  $G$  (LP); however, clever selection of the edges the lightpath uses can result in a less restrictive constraint graph.

In figure 3 we show an example of a 3 node network composed of 3x3 Latin Routers. Each undirected edge of the graph is represented by 2 directed edges between the routers. As before, an S by the input port (row) denotes the port at which connections originate at the node, while an S at the output port (column) denotes connections terminating at the node. Let us suppose we want a lightpath established between nodes 1 and 2. Input port 3 of node 1 is the designated port where connections originate, and the edge from output port 2 runs from node 1 to node 2. This edge enters port 1 of node 2, and output port 3 of node 2 terminates this lightpath. In order

for this to be a valid lightpath, table entry (3, 2) of node 1 and table entry (1, 3) of node 2 must have the same wavelength; if we look at the circled table entries we see that both entries have wavelength C. So this edge denotes a lightpath. If we want to establish a lightpath from 3 to 1, we can't take the edge from 3 to 1 since entry (3, 1) of node 3 is B and entry (1, 3) of node 1 is C. In fact, we can't establish a lightpath from node 3 to node 1 in this configuration at all.

### III. PREVIOUS PROPOSED ALGORITHM

An alternative approach to constraint satisfaction is local search which has proven successful at rapidly solving a variety of constraint problems. Local search makes small changes to a complete assignment of variables in a constraint problem in order to improve the quality of the solution.

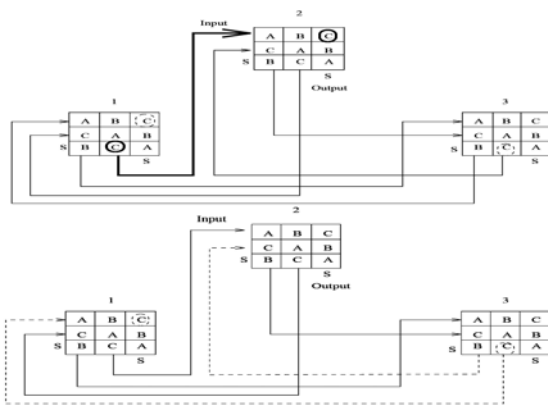


Fig3. Interconnection using Latin Squares.

We have devised an algorithm called the Local-search Optical Network Configuration Algorithm (LONCA) which routes static requests for an optical network built using Latin Routers. This algorithm has been shown in Fig4. LONCA addresses two problems, which are as follows.

- Establish the maximum number of a set of requested lightpaths in a network.
- Establish the maximum number of single-hop connections in a network.

LONCA operates by performing local search on the space of virtual topologies (i.e. possible interconnections of routers) to find such topologies which satisfy the maximum number of lightpath requests or which establishes the maximum number of single-hop in an optical network. It is not possible to set up a complete graph as a virtual topology by establishing lightpaths to provide single-hop connectivity between every pair of nodes.

In this case, traffic might need to go through multiple lightpaths, while undergoing electronic switching at the endpoints of adjacent lightpaths. Minimizing the average number of optical hops that traffic has to traverse in the network to reach from a source node to a destination node is a related optimization problem.

```

procedure LONCA( $G, VC, RouterSize, MaxSwap$ )
Begin
    Connect all in G at random
    for  $i=1$  to  $MaxSwap$ 
        Pick a router at random
        for each row and column swaps
            evaluate the number of connection satisfied
            update set of best swaps
        endfor
        pick one of the best swaps and do it
        if all connection satisfied exit
    endfor
End

```

Fig4. LONCA Algorithm

```

procedure CSONCA( $G, RouterSize$ )
Begin
    Generate the request for network at random
    repeat for  $I=1$  to number request
        select one request
        evaluate each request respectively that satisfied
        connect the connection satisfied.
    Endfor
    connect the remaining connection at random
End

```

Fig5. CSONCA for Network Configuration

LONCA does not handle this problem directly, but we investigate the virtual topologies maximizing the number of single-hop connections to see how many optical hops are necessary to establish all connections in the network.

### IV. PROPOSED ALGORITHM FOR NETWORK CONFIGURATION

Consider the request for lightpath established. For every request both source and destination should be specified. For example, see the LP5 in Fig1. We know where source is and where the lightpath is finished and which are the middle nodes, too.

For every request, connection should be established. For this reason, constraint search algorithm should find the solution. Otherwise, in lightpath should be found middle node. Now, algorithm should satisfy constraint source node to middle node and satisfy constraint middle node to destination node i.e. lightpath established with two connections. If constraints do not satisfy, find third middle node and try. Finally, if constraints do not satisfy then all middle nodes have been tested otherwise the connection will fail. For other request, connection should be satisfied and so. Figs 5 show the proposed algorithm that is called Constraint Search Optical Network Configuration (CSONCA) Algorithm.

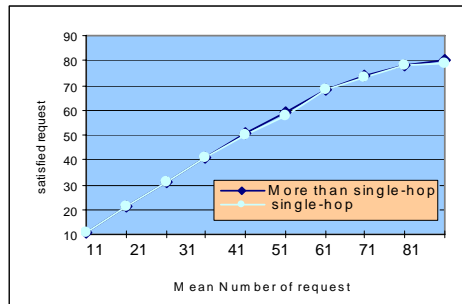


Fig7. Mean number of requested than total requested

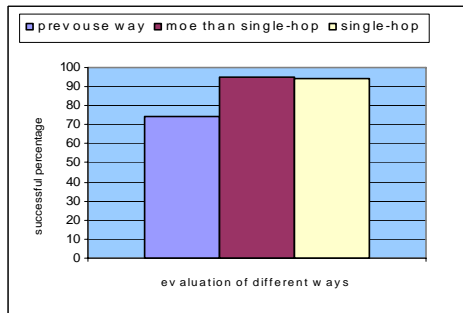


Fig8. Evaluation of performance of three ways

## V. EXPERIMENTAL RESULT

Since common network simulation tools have some limitations in this case, we implement a new simulation tool by Visual Basic programming language for simulation of proposed idea and previous method. We simulated CSONCA and executed different experiments; we got results that explained it. If number of nodes in particular topology has direct concern with number of requests then number of total requests of lightpath is satisfied. Also, with ascending of network size, number of established connections increase and therefore, number of satisfied lightpath directly relate to network size. For more than single-hop network, with ascending network size, number of established connections increase. Fig7 shows mean number of requests regarding the total requests that more than single-hop is better than single-hop. Fig8 shows mean successful percentage for three different ways. With evaluations of previous way, single-hop and more than single-hop, we had shown that more than single-hop is better than other two ways and single-hop is better than previous way, too.

## VI. CONCLUSION AND FUTURE WORK

The constraint paradigm is a useful and well-studied framework expressing many problems of interest in Artificial Intelligence and other areas of Computer Science. In this paper, we present new approach for optical network configuration. We show that number of connection established directly relate to router size in network. Also we show that number of established connections, is more than single-hop connections which are greater than single-hop connections.

In future work, we optimize CSONCA or present new algorithm that has more performance. We believe new

algorithm should be hybrid of LONCA and CSONCA.

## REFERENCES

- [1] C. Chien and S. Banerjee, "Optical switch configuration and lightpath assignment in wavelength routing multihop lightwave networks." Proceedings of the 14th IEEE INFOCOM, 1995
- [2] D. Banerjee and J. Frank, "Constraint Satisfaction in Optical Routing for Passive Wavelength-Routed Networks", Department of Computer Science University of California, 1998.
- [3] Carla P. Gomes and D. Hmays, "Completing Quasigroups or Latin Squares: A Structured Graph Coloring Problem", In Proc. Computational Symposium on Graph Coloring and Generalizations, Cornell University, Dept. of Comp. Science, 2002
- [4] D. Banerjee and J. Frank, and B. Mukherjee, "Passive Optical Network Architecture Based on Waveguide Grating Routers" IEEE Journal on selected areas in communications, september 1998
- [5] M.H. Saqalli, L. Purvis and E.C. Freuder "Survey of Application Integrating Constraint Satisfaction and Case-Based Reasoning" university of New Hampshire, pages 3-4, 2000
- [6] K. Vermirovsky, "Algorithms for Constraint Satisfaction Problems", Master Thesis of Purdue University, 2003