Blocking Probability of Dijkstra Shortest and Least Congestion Routing Algorithm in Wavelength-Routed WDM Network

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Abstract- Routing and Wavelength Assignment (RWA) is important issue in a wavelength-routed all-optical network. There are two methods to tackle the RWA problem. One of them is taking routing and wavelength assignment problem as a single problem and the other method is taking routing and wavelength assignment as two separate problems. We focus on routing problem (as separate problem) in wavelength-routed optical WDM networks. This paper presents the various routing algorithms that can be used to route the connections in a wavelength-routed optical WDM network. Among them two different approaches; Dijkstra shortest routing algorithm and least congestion path routing algorithm are studied and analyzed their performance in terms of blocking probability of route. These two different routing approaches are used to find the cost of route for given node pair and blocking probability of route. The simulation results demonstrated that least congestion path algorithm has better performance than Dijkstra shortest routing algorithm.

Keywords: *routing and wavelength assignment, blocking probability, least-congested-path (LCR) routing*

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I.INTRODUCTION

WDM provides the tremendous bandwidth of an optical fiber to meet the growing network demand. In WDM network, the optical spectrum is divided into different channels. Therefore, WDM technique enables us to route multiple lightpath connections onto different wavelength channels in an optical fiber. Such networks where connections are routed on distinct wavelength channels of a fiber link are called wavelength-routed WDM networks. In wavelength routed WDM network, a connection is realized by a lightpath. In order to establish connection between a source destination pairs, a wavelength continuous route needs to be found between the node pairs. An algorithm use for selecting routes and wavelength to establish lightpaths is known as a routing and wavelength assignment algorithms.

When connection request arrives to network, the main problem is to provide route to the light-path requests and to assign a wavelength on each of the links along it is known as the routing and wavelength assignment (RWA) problem. The route must have same wavelength on its links. This constraint is known as wavelength continuity constraint. Here assume that there is no wavelength conversion in the network. The wavelength-continuity constraint degrades network performance. It increases the blocking probability of connections[1]. A connection can use only a wavelength continuous route. Therefore, it is mandatory to use a good routing and wavelength assignment algorithm to establish lightpaths in efficient manner. We studied different routing algorithms in WDM networks. In section II,III Dijkstra shortest routing and LCR algorithm are explained. These routing algorithms are analysed in section IV. In section V, blocking probability with simulations graphs are shown and conclude in section VI. All simulations results to find cost and blocking probability of algorithms are implemented in Matlab 7.3

A. Routing Algorithms

The important routing algorithms are fixed routing, alternate routing, exhaust routing and dynamic routing. In fixed routing method, only one route is provided for a node pair. Usually the shortest route is to be chosen. When a connection request arrives for node pair, the route fixed for that node pair is searched for the availability of a free wavelength. Fixed routing performs well for small networks with low nodal degree [2]. In alternate routing method, two or more routes are provided for a node pair. These routes are searched one by one in predetermined order. Usually these routes are arranged in increasing order of their hop length. The fixed routing method is simpler but yields poorer performance than alternate routing method.

In exhaust routing method, all possible routes are provided for a node pair. The network state is represented as a graph and shortest path finding algorithm is used on the graph. In dynamic routing, least-congested-path (LCP) routing method, a route with the least congestion is preferred. The least-congested-path is the one with the maximum number of free wavelengths. This technique performs well over fixed alternate routing by trying to maintain the network load balance. The cost of the route is computed based on the hop count, delay or congestion. The hop count of a route is the number of links traversed by it [9]. The cost of a route can also be measured by its congestion. The congestion of the route depends on the number of free wavelengths available on the entire route. The greater the number of free wavelengths, lesser the congestion[11].Among these routing algorithms, Dijkstra algorithm exhaust routing method and dynamic routing, least-congested-path (LCP) routing method are proposed to find cost of route between source and destination node in network.

B. Network Architecture and Assumptions

- A WDM network consists of nodes and links interconnected in an arbitrary mesh interconnection pattern. There are nodes in the network, labeled 1, 2, 3….N. The unidirectional links in the network are labeled l_0, l_1, $l_{2.......}$ L[10].
- Each link can have at least two or three wavelengths. A lightpath consists of a subset of l_0, l_1, $l_{2....}$ L. links that form a path and lightpath connection request is denoted by < s,d > pair.
- Load: For dynamic traffic, connection requests for node pair arrive according to a Poisson process. The holding time is exponentially distributed with mean,thus, load is expressed in units of Erlangs where 1 Erlang is defined to be the number of connection requests per unit call-holding time. The term "load" means the rate of connection requests per unit time [6].
- Routes are computed offline for least congestion path algorithm. R^p_0 , $R^p_{1.....}R^p_{k-1}$ is the ordered list of alternate routes for node pair When a connection request for node pair arrives, routes for it are attempted sequentially from R^p_0,$R^p_{1.........}R^p_{k-1}$, until a route with a free wavelength is found.
- It is assumed that there is no wavelength conversion in the network.

II.DIJKSTRA'S ALGORITHM

The algorithm proposed by Dijkstra to find a shortest path from a source node s to destination d on a directed graph. The edges are assumed to have non-negative weights. The nodes are numbered from 0 to N-1. This algorithm finds the length of the shortest path from s to d which can easily be modified to find the corresponding shortest path[4].

The Dijkstra algorithm goes through these steps:

1. The network is modeled as a graph and identifies source and destination nodes, as s and d.Then it builds a matrix, called the "adjacency matrix." In this matrix, a coordinate indicates weight.If there is no direct link between s_i and d_j, this weight is identified as "infinite."

2. Set the source node as permanently labeled and all other nodes as tentatively labeled.

3. Choose one node among all tentative nodes that are directly linked to the source node with least dist ( ) and labeled permanently. Let this node be y.

4. The dist ( ) value of every tentatively labeled node x is updated as:

$$\text{dist}(x) = \min[\text{dist}(x), \text{dist}(y) + wt(y,x)] \qquad [11]$$

5. If x node is destination, then go to step 8 and if not go to next step.

6. Select next tentative node and repeat all procedure until reach to destination node.

7. When x node reach destination, add up all weights of that path.

8. Display the shortest path between source and destination node with cost.

III. LEAST CONGESTED PATH ROUTING

In dynamic routing, the route decision is based on the current network state to ensure minimum connection blocking probability and maximum network resource utilization. Least congested path routing chooses the route with least congestion among the possible routes connecting a node pair p.

Following are the steps for this algorithm:

1. Connection request arrives for best route between source and destination node.

2. A set of candidates routes R^p_0, $R^p_{1.........}R^p_{k-1}$ are computed offline for requested connection.

3. Enter the number of nodes, total number of wavelengths in network and number of routes available for node pair.

4. Apply wavelength continuity constraint on all available routes.

5. Sort out the routes with free wavelengths and cost of all routes. The cost of a route is calculated as:

$$C = (w_t - w_f) / w_t$$

where C is the cost of a route, w_t is the total number of wavelengths in the network and w_f is the number of free wavelengths on a links of a given route.[5,7].

6. Select route with less congestion among other routes i.e. least cost route

7. Display the cost of route.

Least congested path routing algorithm assumes that each node in the network has the full knowledge of network topology and link state i.e. number of free wavelengths available on each link of the whole network. If more than one route has the same cost, then the route with shorter hop count is preferred. Once route is selected, one of the wavelength selection algorithms can be used to select the wavelength on this route. This algorithm tries to keep as many free wavelength continuous routes as possible. This will help to satisfy many future requests .A variant of LCR is proposed in [9] which only examine the first k links on each path, where k is a parameter to the algorithm. The main problems with this dynamic-routing method are longer setup delays and higher control overheads [3].

IV. ANALYSIS OF ROUTING ALGORITHMS

For analyses of these two approaches, case is considered in which network with nodes from 4 to 8 are taken i.e. four networks are considered with different nodes but number of

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wavelengths available on all network is 4. In simulations, the number of wavelengths available for all networks has fixed. By taking this case into consideration, cost of the route between source and destination node is found by above mentioned two routing approaches.

Then performance of two different routing algorithm is investigated in terms of blocking probability of route. The chance of being able to accept the route for further assigning the wavelength is blocking probability parameter. The blocking of route is caused by either the shortage of available wavelengths or by large cost or weight of route. The blocking probability which takes these causes into account is given by the following simple analytical method. The total number of wavelengths is known in WDM network.All N network nodes that are demanding connections, randomly selecting destination between all other nodes. In ideal case, it is assume that all these connections are routed on the shortest path or less congested path between source and destination in order to occupy the minimum possible amount of resources. The load is number of connections requests per unit time. The load is expressed in Erlang. which is traffic unit.One erlang of carried traffic refers to a single resource being in continuous use. So the blocking probability of route is calculated by:

P_b= 1–(W/N*L*C) [8]

where P_b is blocking probability parameter, W is total number of wavelengths available, L is load in Erlang and C is cost of route that is calculated by above mentioned two different routing algorithms. Hence performance analysis can be evaluated by substituting the cost of route in the formula of blocking probability. For analyses, the five networks with nodes 4, 5, 6, 7, 8 and fixed wavelength = 4 are shown and evaluate their cost that is calculated by two routing approaches as mentioned above.

The network topology with five, six, seven are taken from [5,11].

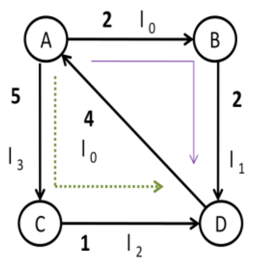

Figure 1. Network with 4 nodes, w = 4, Node pair <A,D>

Following are the wavelengths available on the links given by:

w_1 : l_0, l_1, l_2, l_3 w_2 : l_1, l_2, l_4

w_3 : l_0, l_2, l_4 w_4 : l_0, l_2, l_3

Two possible routes are available for pair<1,4>

$R^p{}_0$: $l_0 \rightarrow l_1$ $R^p{}_1$: $l_3 \rightarrow l_2$

By using Dijkstra routing algorithm:

Table 1: Matrix of Weights between Nodes for 4 Nodes Network

	A	B	C	D
A	0	2	5	Infinite
B	Infinite	0	Infinite	2
C	Infinite	Infinite	0	1
D	4	Infinite	Infinite	0

By simulation of Dijkstra algorithm, the best route for node pair is ABD and total cost is 4 (2+2).

By using Least congestion routing algorithm:

There are two routes for node pair as observed from fig 1.First route (ABD) has w_f = 1 , therefore cost = 0.75.Second route (ACD) has w_f = 2, therefore cost = 0.5

Least congestion routing algorithm incorporates link cost in path computation and computes a least cost path for a connection request. So, select the second route (ACD) with least cost 0.5.Thus, both routing algorithms find the best route with cost for connection request between source and destination node. The networks with 5,6,7,8 are shown below with weights and links with number of wavelengths in fig. 2,3,4,5.

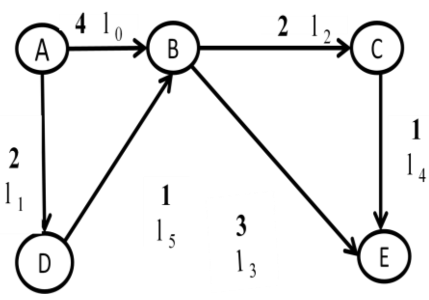

Figure 2.Network with 5 nodes, w =4,node pair <A,E>

Following are the wavelengths available on the links given by:

w_1 : l_0, l_2 w_2 : l_0, l_2, l_3, l_5

w_3 : l_1, l_3, l_5 w_4 : l_1, l_3, l_4, l_5

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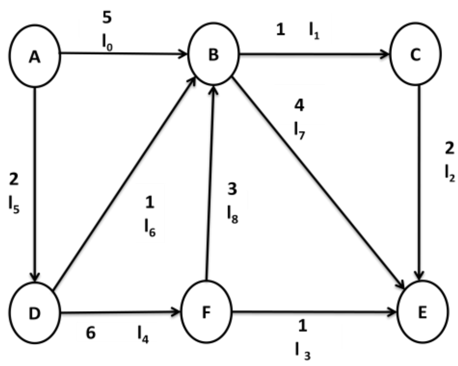

Figure 3.Network with 6 nodes, w =4, node pair <A, F>

The set of links on which each of the wavelengths is available is given by:

w_1: l_0, l_1, l_3, l_6, l_7, l_8 w_2: l_1, l_2, l_3, l_4, l_5, l_6, l_7

w_3: l_0, l_2, l_3, l_4, l_5 w_4: l_0, l_2, l_5, l_7, l_8

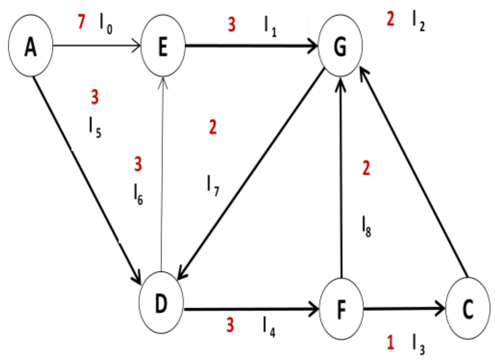

Figure 4. Network with 7 nodes, w=4,node pair <A,G>

The set of links on which each of the wavelengths is available is given by

w_1 : l_0, l_4, l_5, l_6, l_8 w_2 : l_0, l_1, l_2, l_3 ,l_6, l_8,

w_3 : l_1, l_2, l_4 , l_7 w_4 : l_2, l_3, l_4, l_5, l_6, l_9

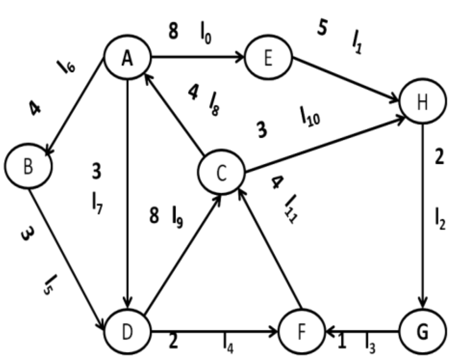

Figure 5. Network with 8 nodes, w=4, node pair <A,F>

The set of links on which each of the wavelengths is available is given by

w_1 : l_0, l_3, l_5, l_6, l_7, l_9 w_2 : l_0, l_5, l_9, l_{10}, l_{11}

w_3: l_0, l_1, l_3,l_4 ,l_6, l_9, l_{11} w_4: l_1, l_4, l_7, l_8, l_9, l_{10}

Simulation Results

Dijkstra Shortest Path Routing Algorithm:

Table 2: Calculated cost of routes for the networks by Dijkstra shortest path routing algorithm

Nodes	4	5	6	7	8
Cost	4	6	7	9	12

Least Congestion Path Routing Algorithm:

Table 3: Calculated cost of routes for the networks by Least congestion path routing algorithm

Nodes	4	5	6	7	8
Cost	0.5	0.5	0.5	0.75	0.75

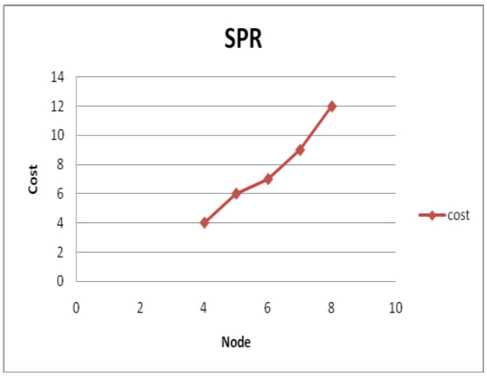

Figure 6. Graph of cost by Dijkstra SPR algorithm

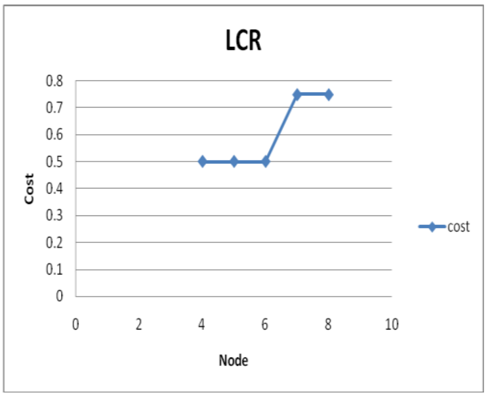

Figure 7. Graph of cost by Least congestion routing algorithm

It is analysed from above fig.6 that with Dijkstra shortest path routing algorithm, cost of the route increases with the

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increase in number of nodes in the network and fixed wavelengths. It is concluded that as network size increases, distance between nodes also increases i.e. cost increases. Fig.7. shows that with least congestion routing algorithm, there is the slightly rise in cost with the increase of node network with fixed wavelengths. It is analyzed that there is less availability of free wavelengths as network size increases.

V. BLOCKING PROBABILITY OF ROUTING ALGORITHMS

The performance of routing algorithms in terms of blocking probability of route is analyzed by substituting cost, network topology with nodes and total number of wavelengths available. The plots are generated for the network with nodes 4,5,6,7,8 with Load on x-axis and Blocking Probability on y-axis.

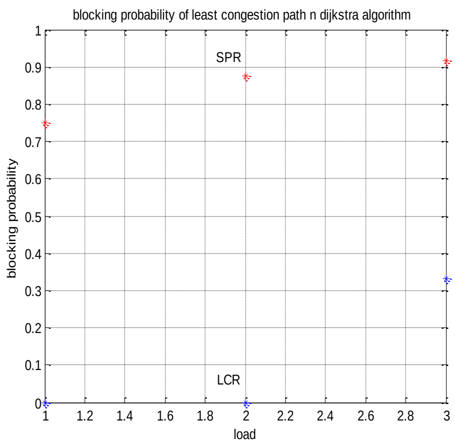

Figure 8: Plot of Blocking probability with load for fixed wavelength case (N=4,W=4)

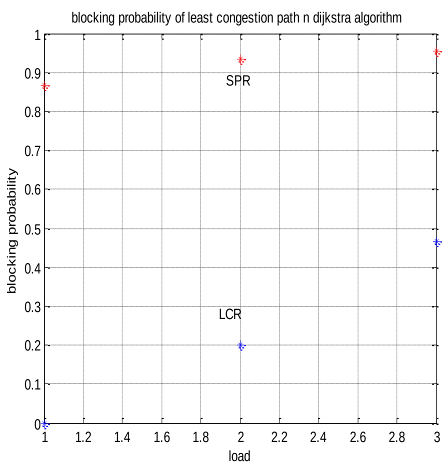

Figure 9. Plot of Blocking probability with load for fixed wavelength case (N=5, W=4)

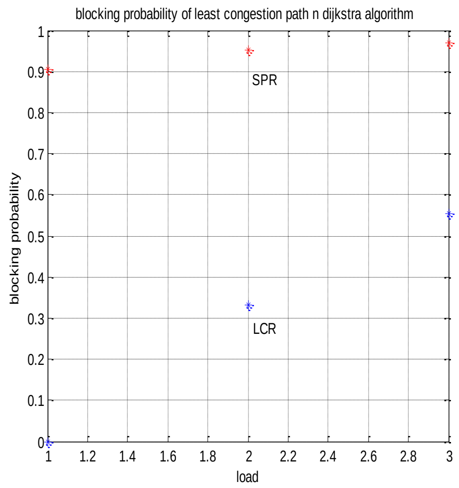

Figure 10. Blocking probability with load for fixed wavelength case (N=6,W=4)

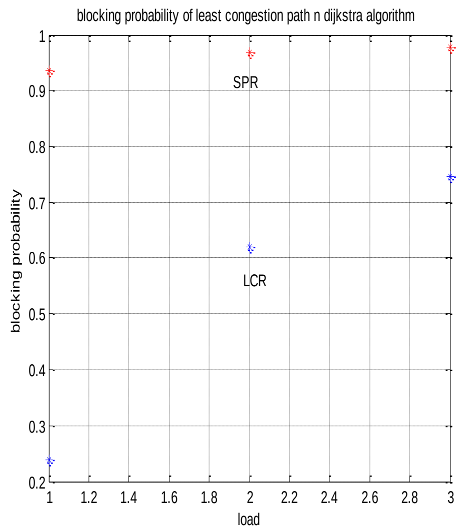

Figure 11.Plot of Blocking probability with load for fixed wavelength case (N=7, W=4)

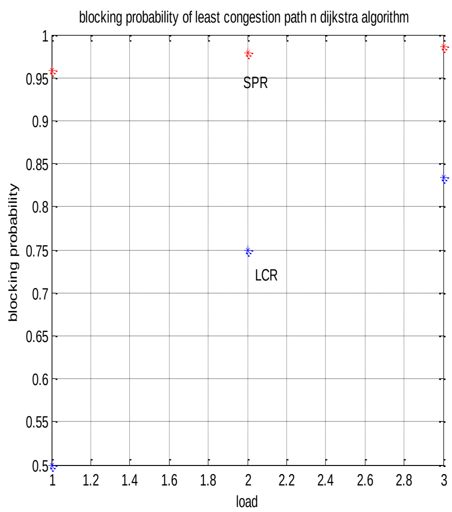

Figure 12. Plot of Blocking probability with load for fixed wavelength case (N=8, W=4)

Figure 9 to12 shows the blocking probability of node network varying from 4 to 8 nodes with fixed wavelengths for load ranging from 1 Erlang to 3 Erlang. It is observed that blocking probability increases from 0 to 0.5 with 1 Erlang in case of LCR algorithm and it increases from 0.75 to 0.96 with 1 Erlang in case of Dijkstra SPR algorithm. The blocking probability increases with the increase in load .LCR has less blocking probability as compared to Dijkstra SPR.

VI. CONCLUSION

In this paper, two routing algorithms are compared and analysed their performance in terms of blocking probability of route to solve the routing problem in WDM optical network. Both routing algorithms are implemented in Matlab 7.3.From the observations of simulation graphs, it is analyzed that Least congestion path routing algorithm has better performance than Dijkstra routing algorithm in terms of blocking probability of route. And also demonstrated that blocking probability increases as network increases with fixed wavelengths.

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