Fuzzy Logic Based Alternate Routing Scheme for the Minimization of Connection Set up Time and Blocking Rate in WDM Optical Network

Abdur Rahaman Sardar, J. K. Sing, Subir Kumar Sarkar

Abstract— ***An alternate routing can improve the blocking performance of an optical network by providing multiple possible paths between source and destination nodes. Wavelength conversion can also improve the blocking performance of an optical network by allowing a connection to use different wavelengths along its route. But wavelength conversion scheme is not an economical proposition. We perform simultaneous study of the relationship between traditional alternate routing scheme and fuzzy logic based alternate routing scheme for comparative studies of those two schemes. Connection set up time and blocking rate reduction are the two important parameters of any optical data communication networks. These two parameters are computed in the present work. It is observed that fuzzy logic based alternate routing scheme provides better performance by reducing the connection set up time and blocking rate in optical network. The effect of the variation of number of wavelengths is also studied to see their effects on connection set up time and blocking rate.***

Keywords- Alternate routing, connection set up time, blocking rate, Fuzzy Logic, Wavelength Division Multiplexing.

I. INTRODUCTION

In optical network information is transmitted by light pulse through an ultra thin fiber of glass known as optical fiber. Conventionally a pulse of light indicates a 1 bit and absence of light indicates 0 bit. Today optical fiber provides a very high bit rate of 10 Gb/s. Because of its high bandwidth, low cost, extremely low bit error rates, low signal attenuation, low distortion and low power requirements it is widely used to establish very high speed communication network [1,3].

With this optical network, Wavelength Division Multiplexing has been rapidly gaining acceptance as a means to handle the ever increasing bandwidth demand. Wavelength Division Multiplexing (WDM), which is a method of sending many light beams of different wavelengths simultaneously down the core of an optical fiber[l]. WDM is conceptually similar to Frequency Division Multiplication (FDM), in which multiple information signals modulate optical signal at different wavelengths, and the resulting signals are combined and transmitted simultaneously over the same optical fiber.

In wavelength-routed network, a connection is set up by a light path. A light path is similar to an end-to-end circuit switched connection. In this paper we have considered that a message is transmitted from source to destination without any optical to electronic conversion.

Such type of light path is called all optical light path. In order to establish a connection between source and destination a wavelength continuous route needs to be found between node pairs. The same wavelength is to be maintained through the entire path of the selected route from source to destination. This is called wavelength continuity constraint. Routing and Wavelength Assignment (RW A) algorithm follows another constraint i.e distinct wavelength assignment, which states that if two connections share any link they have to assign two different wavelengths. One way to overcome the bandwidth loss caused by the wavelength continuity constraint is to use wavelength converters at the routing node. But wavelength converters are very expensive for this reason most proposed network do not use wavelength converters. In this paper we also assume previously mentioned two constraints and we do not allow wavelength converters.

The Routing and Wavelength Assignment (RW A) problem can be classified into two types:-i) Static RW A problem and ii) Dynamic RW A problem. In static RW A problem the set of connection is known in advance, the problem is to set up light paths for the connections, which minimize network resources such as number of wavelengths and number of fibers. On the other hand in dynamic R W A problem a number of wavelength is given and our objective is to maximize the number of connection set up and minimize the blocking probability. We consider dynamic RW A problem in this paper.

Wavelength Selection Algorithm

Wavelength selection algorithm selects a wavelength from the free wavelength list. Various wavelength selection algorithms like Most Used (MU), Least Used (LU), First Fit and Random Wavelength selection are used based on different selection criteria. The MU selects a wavelength which is used on the largest number of links. The LU algorithm attempts to select a wavelength which is used on the least number of links. In First Fit algorithm all the wavelengths are indexed and wavelength of least index will be selected from the free wavelength list on a selected route. In Random Wavelength Selection algorithm all wavelengths are indexed and a wavelength is selected from the free wavelength list randomly.

Various RW Algorithms

1. <u>Fixed Routing(FR):</u> The fixed routing is the simplest one. For every node pair a route RP is computed offline. When there is a request for a connection for a node pair it will then search for free wavelengths on that route. If there is more than one free wavelength then it will select a wavelength on that route by using pre-specified

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wavelength selection algorithm. If there is no free wavelength on that path then that call will be blocked. The main advantage of this algorithm is that it is easiest and faster. So the connection set up time is shorter. But the main disadvantage of this algorithm is that even if there are free wavelengths on some other route between that node pair, the call may block due to non-availability of wavelength on the fixed route. Under light load condition this algorithm performs slightly better, as the load increases the performance starts degrading.

2. Fixed Alternate Routing(FAR): It is the extension of fixed routing which uses a set of k candidate routes between each set of node pairs. The candidate route are denoted as R_o^p, R_1^p ,R^2_p,………R_{k-1}^p. This routes are computed offline. These candidate routes are sorted with a finite cost. The hop counts and delays are normally used as a cost. If no wavelength is found free on any of the candidate route, then the request is blocked. If more than one wavelength are found free on a chosen route, a wavelength is selected by using pre-specified wavelength selection algorithm. It performs better than fixed routing in case of blocking. But the main disadvantage of this algorithm is that connection set up time increases slightly as more number of links are to be searched.
3. Exhaust Routing: Exhaust routing yields quite better performance than FR and FAR algorithm. Exhaust routing does not predetermine the candidate routes for any node pair. It keeps network state information in the form of table and this state information is dynamic and will keep changing dynamically depending upon dynamically changing traffic. When a new connection request arrives for node pair p; it chooses some best route (based on some cost criteria) among all possible routes. Thus by exploring all the possible routes, it attempts to increase the acceptance rate of connection. This algorithm is more suitable for centralized implementation but less amenable to distributed implementation.
4. Adaptive Routing Based on Global Information: Adaptive routing approaches establish a connection by taking into account network state information. Routing decision is made with the full information that which wavelengths are available on each link. A cost is assigned to each link based on availability of wavelengths on a link and lengths of that link.

   Adaptive routing based on global information can be implemented in either centralized or distributed manner. In a centralized approach only one route has the responsibility to find out the least cost route and to set up or take down a connection. As the centralized node manages the entire network so there is a large chances to failure the network due to one link failure.

   A distributed adaptive routing based on global state information may be implemented in a number of ways. In link state approach each node in the network must maintain the complete network state information. Whenever there is a connection request it will find a route in a distributed manner. The establishment or removal of any light path must updates the state information of all nodes in the network[8]. When the light path are being established or removed at a higher rate, it requires a significant control overhead to broadcast the update message to all nodes.

   A distance vector or distributed routing approach to routing with global information is also possible[4]. This approach does not require complete link-state information. Each node maintains a routing table which indicates for each destination and on each wavelength, the next hop to the destination and the distance to the destination. This scheme also requires nodes to update their routing table information whenever a connection is established or removed. This update is accomplished by sending update message to their neighbors periodically or whenever the node's outgoing links change.

   Least Congested Path (LCP) routing is another type of adaptive routing based on the congestion on each link of the network. LCP chooses the route with least congestion among the routes connecting a node pair. The number of free wavelengths available on the entire route determines the congestion of a route. The greater the number of free wavelengths, the less congested is the route. It is also an alternate routing approach where the route is selected based on the least congestion. Similar to an alternate routing approach a set of candidate route Rt_1, Rt_2 , Rt_n.. are computed offline. When a connection request arrives between a node pair p, the cost of each candidate route is computed. If more than one route has the same cost then the route of less hop count will be selected. The performance in terms of blocking probability is poorer than Exhaust Routing but the algorithm performs better than FR and FAR.
5. Adaptive Routing Based in Neighborhood Information: In this method for each source-destination pair, a set of preferred paths are precomputed and stored at the source node. Instead of searching all the links on the preferred route only the first k links on each route are searched[7]. A route is selected based on the availability of free wavelengths on the first k links on the preferred route. If several wavelengths are free on the selected route, a wavelength is assigned according to pre-specified wavelength selection algorithm. If there is no free wavelength on k links of all preferred route then that request will be blocked [4]. The value of k depends on the diameter and topology of the network and the network performance requirement.

Different Types of Wavelength Reservation Algorithm

To set up light path, it is required to exchange different control information among the nodes. The signaling protocols are closely related to the different types of routing and wavelength assignment protocols. The signaling protocol may reserve the resources in parallel, hop by hop basis along the forward path or hop by hop basis along the reverse path.

i) Parallel reservation: In this scheme each node maintains a global information of the current state of the network regarding the wavelength being used on each link. Each node then calculate an optimal route between a source-destination pair on a wavelength. After that the source node attempts to reserve the wavelength on each link by sending a separate control message on each link on that route.

Receiving the request message each node sends back an acknowledgement or negative acknowledgement to the source. When the source node receives a positive acknowledgement from all nodes in a route, it establishes a light path and begins communicating with the destination node. As the nodes process information in parallel so it shortens the light path establishment time. But the main disadvantage of this method is that it requires global information.

ii) Hop-by-Hop Reservation: In hop-by-hop reservation a control message is sent along a selected route one hop at a time. At each intermediate node the control message is processed and forwarded to the next node. When the control message reaches the destination, it is processed and send back another message toward the source node. The actual reservation of link resources may be performed while the control massage is traveling towards the destination i.e. forward reservation or while the control message is traveling towards the source from the destination i.e. backward reservation.

The routing and wavelength assignment problem has been widely studied in literature. Chalamtec et al. had proven that it is a NP-complete problem[11]. Several heuristic approaches have been developed to solve it sub optimally.

In[12] Ramaswami and Sivarajan has given a mixed integer linear formula for solving the RWA problem. In [13] the author suggests a multicommodity flow formulation for routing and then rounding using a randomized approach.

In [14] Zhang P. developed a genetic algorithm based fitness function to solve the routing sub problem of RWA problem. The main objective was to route all lightpath in such a way that would minimize the number of wavelengths needed to establish all the lightpath in the demand matrix and also to minimize the lightpath in the demand matrix and also to minimize the total cost in setting all light paths. The cost was calculated in terms of route length traversed by a light path from source to destination node.

In [15] D. Bisbal et al proposed a novel genetic algorithm based routing and wavelength assignment algorithm in all optical WDM network. They had shown a low average blocking probability and a very short computation time using simulation study.

II. FUZZY LOGIC

Fuzzy logic is a mathematical tool that allows modem digital computers to model systems that are imprecisely defined. This technology allows the computer to make a decision from vague or imprecise data.

A fuzzy logic based system reduces the inaccuracy that occurs at crisp or traditional set boundaries by substituting fuzzy sets. A set consists of a collection of elements. In crisp set the elements have the membership value either zero or one. One represents the completes membership and zero represents null membership in the set. The boundaries of the crisp sets are clearly defined. On the other hand, in a fuzzy set, a set element can have a membership value between zero and one. There is a gradual transition from membership to non membership in a fuzzy set and not the sharply defined boundaries as in the crisp set. The grade of membership in the fuzzy set is expressed by a membership function. Linguistic variables or labels may be used to represent a fuzzy set. For example "small", "medium" etc. Production rules for control applications are used to map input variable to output variables using IF THEN statements. The rule has the general form

IF (condition), THEN (action), the ith control rule appears as follows

IF X_l is Ai AND X_2 is Bi AND X_3 is Ci THEN Y is Oi ; where Xn is the input and Y is the out put and Ai, Bi . Ci , Oi are the membership functions and n is the number of antecedents. Multiple input systems may exist and the system may have several rules firing in parallel at the same instant to produce a single output. The firing strength of the i^{th} rule is used to determine a control decision.

Membership functions are combined using an inference method based on the compositional rule of inference for approximate reasoning suggested by Zadeh. The inference is used to derive a conclusion from implications and premises. The final fuzzy output level is found using max min or max dot method.

The fuzzy output that results from inference must be defuzzified to obtain a crisp result for the physical out put.

III. PROBLEM DEFINITION

The routing and wavelength assignment problem can be described as follows:

Given a set of nodes **V** and set of bidirectional edges **E** representing a fibre in each direction, we have a set of lightpath demand **D** $=\{(s_1,d_1), \ldots\ldots(s_i,d_j),\ldots\ldots\ldots(s_n,d_n)\}$ where s_i and d_j are in **V** and i=1………n and j=1……..n are the source and destination node respectively. We are to establish a number of light paths $P=\{p_1,p_2,\ldots\ldots\ldots p_n\}$ and assign to each a wavelength from the set of given wavelengths **W**$=\{w_1,w_2,\ldots\ldots\ldots w_m\}$ by following wavelength continuity constraint and distinct wavelength assignment constraint. In order to establish a connection between source and destination a wavelength continuous route needs to be found between node pairs. The same wavelengths need to be maintained through the entire path of the selected route from source to destination. This is called wavelength continuity constraint. Routing and Wavelength Assignment algorithm follows another constraint i.e. Distinct Wavelength Assignment constraint which says that if two connection share any link they have to assign two different wavelength.

Here our objective is to set up a lightpath from a source to destination node by following above mentioned constraints with minimum blocking rate and connection set up time.

IV. PROPOSED METHODOLOGY

In this paper we present an alternate routing and wavelength selection mechanism based on fuzzy logic in which best three paths are computed previously between each pair of source-destination node. The shortest paths are calculated based on hop-counts or link distance. The algorithm for finding three best shortest paths is given below.

Procedure Path_finding:

Data structures maintained:

A singly linked linear list in which the pointer to the first node is start node.

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An integer array named path is maintained in each node of the link list as data element.

The chosen five paths are finally stored in the two dimensional array named way which is initially declared as way [5] [node numbers].

```
Initialization: start = NULL
        Source = s        // s is the source node
Procedure:
    begin
    repeat
    for all nodes in the network do
    begin
    if a link exists between source and
            the current node then do
            begin
            if source = s then do
            begin
            getnode(temp);
assign the current node number to temp -> path[0];
    temp -> next = star;
    star = temp;
    end
    else
    begin
    newpath = start-> next;
    getnode(temp);
assign all the array elements of the array start -> path
    to the array temp -> path;
    add the current node number as the last element
    of the array temp -> path ;
    temp -> next = newpath;
    newpath = temp;
    end
    end if
    end for

    if source != s then start = newpath;
    if in any node in the list, it is found that
the path list that it contains, has no outgoing path
    then  removed that node from the link list;


if any node in the list, it is find that
 we have reached the dimension node
    then do
    begin
    store  the array path as one of our
possible path;
    remove that node from the link list;
    end
    source = the last element of the array
      start-> path;
    until the link list is empty;

    calculate the path lengths for each path;
    sort the paths according to their length;
    choose the first three paths from the
sorted lists and store them in the two
dimensional array way ;
    end
```

After that a "COLLECT" message is sent from source to destination through the control channel in each shortest path parallelly. The "COLLECT" message collects information about the wavelength uses and the free wavelengths in each shortest path between source destination nodes. This is done by taking intersection of free wavelengths on the link between source and next node and free wavelengths on the link between next and next-to-next node in the forward path. This process continuous until destination node reaches. At the destination node the fuzzy controller will take the decision which path will be selected based on two things i.e. the number of free wavelengths and the total delay to process the control message.

After selecting a path a wavelength is selected from free wavelength list based on the first fit algorithm and a "RESERVE" message is sent from the destination node to source node. The "RESERVE" message reserve a wavelength and update the table information of all node in that path. There is one problem in this backward reservation protocol i.e. if multiple connections are set up simultaneously which uses common link then one connection will set up and another will be blocked due to the fact that this wavelength will be unavailable in that path. But the probability of this is very less. This problem can be solved by sending an N-RESERVE message from the intermediate node (where the wavelength is not found free) to the destination node and tries to reserve another wavelength from the free list. This process increases the connection set up time slightly but decreases the blocking probability. After successful reservation of wavelength the source node starts to transmit the message to that wavelength through the data channel. At the end of the transmission a "RELEASE" message is sent from the source node to the destination node through the control channel. The "RELEASE" message contains the connection-id and wavelength. The "RELEASE" message then release that wavelength in that path by adding that wavelength in the free wavelength list in the table of each node.

Fuzzy logic controller select a path based on the following criteria:

i) The shorter hops or less delay paths are assigned an idle wavelength. This leaves some wavelengths free on links, which can be used by longer hop connections.

ii) Least congested paths are selected frequently. The congestion of a route is determined from the number of free wavelengths available on the entire route.

If the free wavelengths in a path are very few then that path will be suspended or that path will be selected for very small delay and for a massage whose hold time is very small such that within a very small time it can be freed.

iii) For very large message whose hold time is large. A least congested path will be selected because for very large message the release time is also large and so if a path in which very less number of wavelengths are free is selected then that path may be blocked.

Design criteria

In our design we have considered two input membership functions i.e Delay and No. of free wavelengths and one output membership function.

Control rules that maps input space to the output space are: Here we have applied two rules Rule 1 and Rule 2. If message hold time is small then we follow rule 1 otherwise follow rule 2.

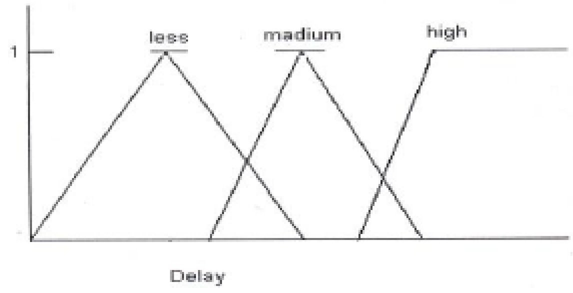

Figure 1

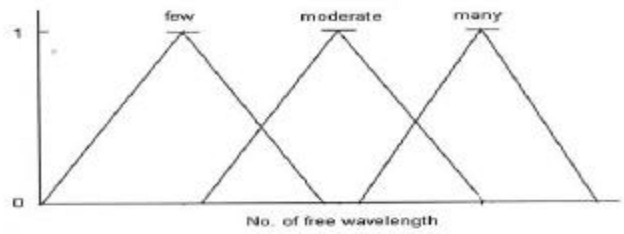

Figure 2

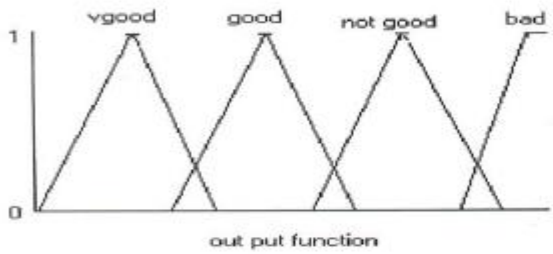

Figure 3

Rule 1:

If Delay is less AND No. of free wavelength is few THEN Output is bad.

If Delay is medium AND No. of free wavelength is few THEN Output is bad. If Delay is high AND No. of free wavelength is few THEN Output is bad.

If Delay is less AND No. of free wavelength is moderate THEN Output is good.

If Delay is medium AND No. of free wavelength is moderate THEN Output is not good. If Delay is high AND No. of free wavelength is moderate THEN Output is not good.

If Delay is less AND No. of free wavelength is many THEN Output is vgood.

If Delay is medium AND No. of free wavelength is many THEN Output is vgood.

If Delay is high AND No. of free wavelength is many THEN Output is good.

Rule 2:

If Delay is less AND No. of free wavelength is few THEN Output is bad.

If Delay is medium AND No. of free wavelength is few THEN Output is bad.

If Delay is high AND No. of free wavelength is few THEN Output is bad.

If Delay is less AND No. of free wavelength is moderate THEN Output is not good.

If Delay is medium AND No. of free wavelength is moderate THEN Output is not good.

If Delay is high AND No. of free wavelength is moderate THEN Output is not good.

If Delay is less AND No. of free wavelength is many THEN Output is vgood.

If Delay is medium AND No. of free wavelength is many THEN Output is good.

If Delay is high AND No. of free wavelength is many THEN Output is good.

V.PERFORMANCE STUDY

In this paper alternate routing scheme is compared with fuzzy logic based alternate routing scheme. For the comparison two things: i) connection set up time and ii) blocking rate are studied through simulation of the network shown in fig. 4. The number shown in each link indicates the length of the link in numbers of 10k.m.

We assume the following:

i) The number of wavelength on each link, w, is either 8 or 12.
ii) The traffic is uniformly distributed among all node pairs.
iii) The connection holding time is exponentially distributed.
iv) Message processing time at a node, P, is $10\mu s$.
v) The time to configure, test and set up a cross connect, C, is 500Jls.
vi) The time to transmit or switch a packet in the control network, R, is 0;
vii) Average propagation delay between two nodes D, D=0.l 0665 ms.
viii) Flows (connections) arrive at a node according to a Poisson's process with rate λ[9,1O].

i) Connection set up time: In alternating routing approach connection set up time is calculated as follows: CST=2*D+N*P+C [where N is the total number of node traversed].

But in fuzzy logic based alternate routing scheme, the searches are done parallely, so "COLLECT" message processing time is equal to the processing time of the largest path of the three paths between any source-destination pair and "RESERVE" message is processed by all the nodes on the selected path.

So connection set up-time is=2*D+(no. of nodes in the 3rd path + no. of nodes in the selected path)*P + C.

ii) Blocking Rate: Blocking rate is calculated as

BR=(No. of connection blocked/No. of connection requested) * 100

Here the performance between alternate routing schemes with the fuzzy logic based alternate routing scheme is studied. The topology used is shown in Fig. 4.

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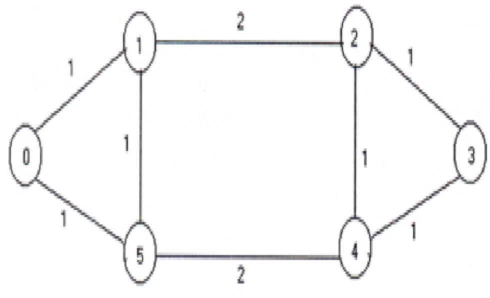

Fig.4 Topology

The results are obtained through C++ program. Blocking rate and connection set up time are calculated for different set of loads. Firstly blocking rate and connection set up time are studied for a set of 8 wavelengths in each link and then for a set of 12 wavelengths.

Fig.5 and fig.7 shows the load vs. blocking rate for a set of 8 wavelengths and for a set of 12 wavelengths accordingly. The continuous line indicates the load vs. blocking rate for alternate routing scheme and dotted line indicates load vs. blocking rate for fuzzy logic based alternate routing scheme. Fig. 5 and 7 shows that fuzzy logic based alternate routing scheme has blocking rate much less than the blocking rate of alternate routing scheme.

Fig. 6 and fig. 8 shows the load vs. connection set up time for a set of 8 wavelengths and for a set of 12 wavelengths accordingly. The continuous line indicates the load vs. connection set up time for alternate routing scheme and the dotted line shows the load vs. connection set up time for fuzzy logic based alternate routing scheme. The connection set up time for alternate routing scheme is widely varies with the load while the connection set up time for fuzzy logic based alternate routing scheme varies very less with the load of the network.

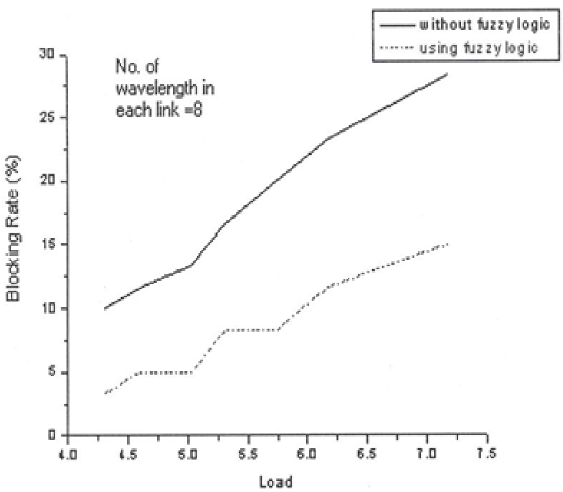

Fig.5 load vs Blocking rate for 8 set of wavelength

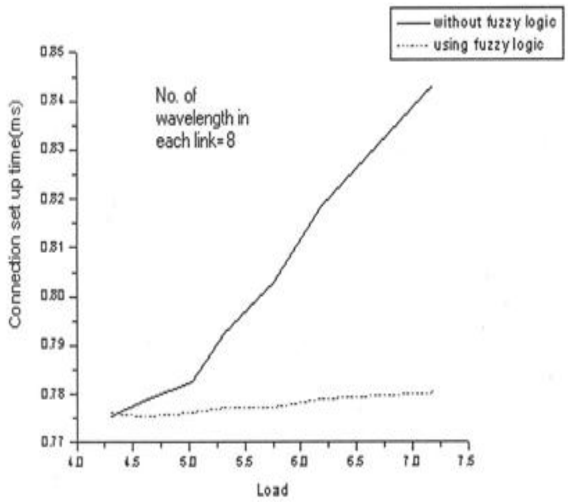

Fig 6. load vs connection set up time for 8 set of wavelengths

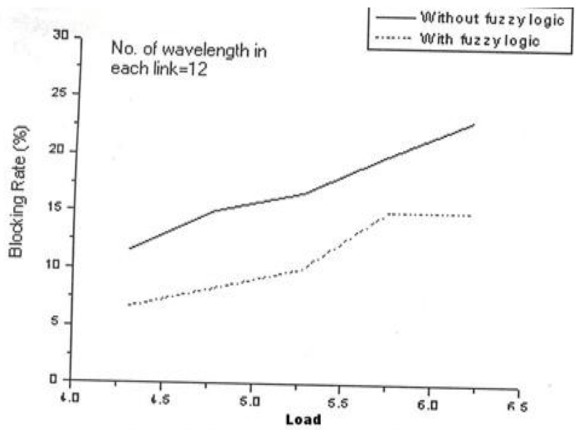

Fig.7 load vs blocking rate for set of 12 wavelengths

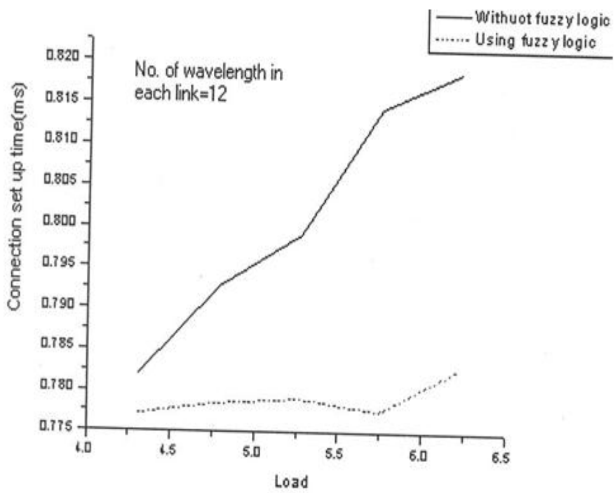

Fig.8 load vs connection setup time for set of 12 wavelengths

VI. CONCLUSION

An alternate routing can improve the blocking performance of an optical network by providing multiple possible paths between source and destination nodes. Connection set up time and blocking rate reduction are the two important parameters of any optical data communication networks.

Here a simulation study between traditional alternate routing scheme and fuzzy logic based alternate routing scheme is performed. From the simulation result we conclude that the connection set up time for alternate routing scheme is widely varies with the load while the connection set up time for fuzzy logic based alternate routing scheme varies very less with the load of the network. The result also shows that the fuzzy logic based alternate routing scheme has blocking rate much less than the blocking rate of the traditional routing scheme.

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