Design of Restorable Routing Algorithm in Optical Networks

Navneet Kaur
Department of Computer Science and Engineering
Department of Computer Science and Engineering

Raman Kumar
D A V Institute of Engineering and Technology, Jalandhar.
D A V Institute of Engineering and Technology, Jalandhar.

ABSTRACT
In current WDM networks, it is possible to support hundreds of WDM channels on a single fiber. Therefore, the cost of the transmitters and the receivers, and hence the number of light paths, is becoming the main factor in determining the cost of a WDM network. Researchers tried to keep the number of light paths required to implement a topology as low as possible. This paper presents a restorable routing algorithm that reduces blocking probability and suggested a mathematical model and compares the proposed work with the conventional algorithms such as first fit and best fit routing algorithm. In this work, we have presented a quick and efficient heuristic for restorable routing.

Keywords
OXCs, BP, WDM, Optical network., lambda routers

1. INTRODUCTION
There is need to send more information or data through a channel is one of the motivating factors for the research to establish more efficient communication systems. In the past conventional copper and wireless methods were good for transporting data from one place to another. But they had certain limitations of a finite bandwidth and higher the electrical inference of signals. Optical fibers are thin glass cables are immune to electrical interference of noise. Optical fibers provides higher bandwidth and high transportation rate than copper cables. As a result, optical fiber is a preferred medium for transmission of data more than a few tens of megabits per second over any distance more than a kilometer. It is also preferred medium of realizing short-distance, high-speed interconnections inside large systems. Optical network uses wavelength division and multiplexing (WDM) technology. With WDM technology, multiple optical signals can be transmitted simultaneously and independently in different optical channels over a single fiber, each at a rate of a few gigabits per second, which significantly increases the usable bandwidth of an optical fiber.

A light path is an "optical communication path" between two nodes, established by assigning the same wavelength throughout the route for transmitting the data. A light path is uniquely identified by a wavelength and a physical path. Two light paths can share the same fiber link, if they are using different wavelengths. If two nodes are connected by a light path, a message can be sent from one node to the other without requiring any buffering [2].

1.1. Wavelength (Lambda) Routers
Wavelength routers (Figure1)-which are also called Lambda Routers, or Optical Cross-Connects (OXC) - are normally placed at network junction points or router nodes. The lambda router takes in a single wavelength of light from a specific optical fiber and recombines it into another fiber that is set on a different path, without going through any optoelectronic conversion.

1.2. Routing Algorithm
Routing is the process of selecting the best paths in a network. A routing algorithm establishes the paths that messages must follow to reach their destination used. Routing algorithms can be broadly classified into three types that are:

In the Fixed Routing, for every node pair only one candidate route is provided. This candidate route for the node pair is fixed and does not change with changing network traffic demand.

In the Alternate Routing, for every node pair a set of K candidate routes is provided. The set of K routes provided for a node pair is a subset of all possible routes. When a connection request arrives for a pair p, one of the candidate routes is selected

In Exhaust Routing, there is no restriction on the selecting a path, for a given node pair p, a route among all possible routes is chosen

1.3. Faults in WDM Optical Networks
In a WDM network, failure may occur in any component of the network. This includes link failures, node failures, channel failures and software failures. Link failure is the most common type of fault where the fiber constituting a link between two nodes in the network does not permit data transmission. Since a single fiber can carry100 or more light paths, and each light path can carry data at the rate of 2.5Gbps to10Gbps, even a brief disruption of this traffic is a serious matter

Two major techniques that are used to handle link failures in optical networks give below:

1. Protection based techniques[23]
2. Restoration based techniques [23]

1. Protection-based techniques are based on the provisioning of back up path store cover from a failure. During the period of establishing light paths, network resources are kept reserved, such that, when a failure occurs, data can be rerouted around the links that are affected. In case of a network failure, such as a broken link on the primary path from node, the primary light path from node i to node j is disrupted. In this situation the data from node it node j are sent through the corresponding backup light path. Since a primary light path and the corresponding backup light path are link-disjoint. The drawback of this approach is that there sources allocated to the backup paths remain idle, and are wasted under normal conditions.

2. Restoration-based techniques, on the other hand, dynamically search for the spare capacity in the network to establish new light paths in order to restore the affected services after a network failure is detected [23].

2. ROUTING ALGORITHMS

There are a number of wavelength routing techniques proposed in literature. The important routing schemes considered in literature are WLCR-FF, Shortest path routing algorithm, Genetic Algorithm, MSPP (Mixed shared path protection).

WLCR-FF is a type of fixed alternate routing algorithm. In the Fixed Alternate Routing, for every node pair p, a set of K candidate routes are provided [1]. Fixed alternate routing techniques have been proposed for the minimization of blocking probability that establishing light paths dynamically.

In **Shortest Path Routing** for every unit of traffic, we follow the shortest feasible path where the Path length is defined as the number of links in it.

A Genetic algorithm (GA) as shown in figure 1 provides the combination of alternative shortest paths for the given multicast requests in order to minimize the number of required split-capable nodes.[1] A node that has splitting capability can forward a message to more than one output link. In this algorithm randomly created the initial population. Feasible solutions are generated after repeating genetic operators such as crossover and mutation. [17].

MSPP routing algorithm defines three types of resources: 1) Primary resources that can be used by primary paths; 2) Spare resources that can be shared by backup paths; and 3) Mixed resources that can be shared by both the primary and the backup paths. In this MSPP scheme, each connection has assigned a primary path and a backup path. Differing from pervious protection schemes, MSPP allows some primary paths and backup paths to share the common mixed resources if the corresponding constraints can be satisfied. [7]

3. PROBLEM FORMULATION

The literature survey suggests that several algorithms have been proposed for joint working and spare capacity planning in optical networks. These methods are based on static traffic demand and then optimize the network cost. Wavelength conversion is also used for the reduction of blocking probability. But sometimes cost of the wavelength converters is very high. Wavelength conversion can eliminate the wavelength continuity constraint and can thus improve the blocking probability. The main task of proposed work is to develop a routing algorithm and a mathematical model that reduces the blocking probability to certain extent and improves network efficiency.

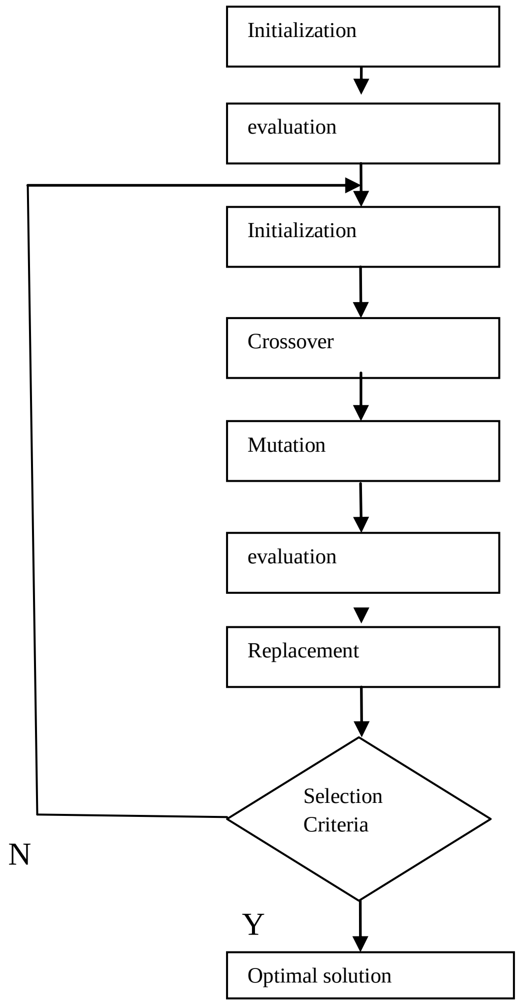

Figure 1. Genetic Algorithm Flow chart

4. PROPOSED WORK

4.1. Routing algorithm

In this paper a routing algorithm (improved fixed alternate routing algorithm that is a type of alternate routing algorithm) is proposed. This algorithm is used for the reduction of the blocking probability and the advantage of the proposed model and algorithm is that the user has the complete knowledge of the blocking probability in advance for a particular path in the given network. A low-complexity mathematical model has been developed which is used for the calculation of the blocking probability of network and this model does not require any simulation statistics [2]. The routing algorithm has been proposed depending upon the proposed model, which is efficient in the calculation of the blocking probability. In this a methodology for the design of restorable routing algorithm in optical networks has been proposed, that is based on the concept of restorable routing. In this approach, route the light paths over the physical topology in such a way that the logical topology remains connected even in the event of a link failure. This algorithm assures that the restorable logical topology, after any single link failure, will have sufficient reserve capacity to accommodate the entire traffic demand.

4.2 Mathematical Model

In this paper a mathematical model has been suggested, which is used for the calculation of blocking probability. Given N node WDM network, all the nodes forms a set V, and all directed links are contained in a set E. Suppose fixed path routing policy is adopted the light path establishment, the predetermined directed routes are indicated with a set R and r Є R.

Notations used:
Following notations are used:

- *s* and *d* denotes source and destination of an end-to-end traffic request. The end-to-end traffic may traverse through a single light path or multiple light paths.
- *N*: Number of nodes in the WDM network.
- *l* : Number of links in the route or path selected, and all links have *C* channels.
- *r* : Number of routes available where *r Є R.*
- $\mathbf{B(C,L^{r}_{sd})}$**:** Erlang loss formula for $\mathbf{L^{r}_{sd}}$ load and **C** channels.
- $\mathbf{B_{sd}}$: Blocking probability; $\mathbf{B_{sd}} = 0$ if the request from node *s* to node *d* has been successfully routed; otherwise, $\mathbf{B_{sd}} = 1$, call blocked.
- $\mathbf{B^{r}_{sd}}$: Blocking probability of *r* routes
- $\mathbf{L^{r}_{sd}}$: Load of the route *r.*

Given

- **N** node WDM network
- All the nodes forms a set **V**.
- **E** is the set of all directed links.
- Fixed path routing policy is adopted for the establishment of light path.
- **R** indicates the set of predetermined directed routes.

For each router **r** ∈ **R**, the blocking probability for the connections along route *r* can be given by eq. (1).

$$\mathbf{B_{sd} = 1-[1-B(C, L^{r}_{sd})]^{l}} \quad \mathbf{(1)}$$

We can substitute the value of Erlang's loss formula in eq. (1) as.

$$\mathbf{B(C, L^{r}_{sd}) = \frac{(L^{r}_{sd})^{C} / C!}{\sum^{c}_{i=0}(L^{r}_{sd})^{i} / i!}} \quad \mathbf{(2)}$$

$$\mathbf{B_{sd} = 1- \left[\frac{1-(L^{r}_{sd})^{C} / C!}{\sum^{c}_{i=0}(L^{r}_{sd})^{i} / i!} \right]} \quad \mathbf{(3)}$$

Equation (3) is used mathematical model which can be used for blocking probability calculation in restorable optical networks.

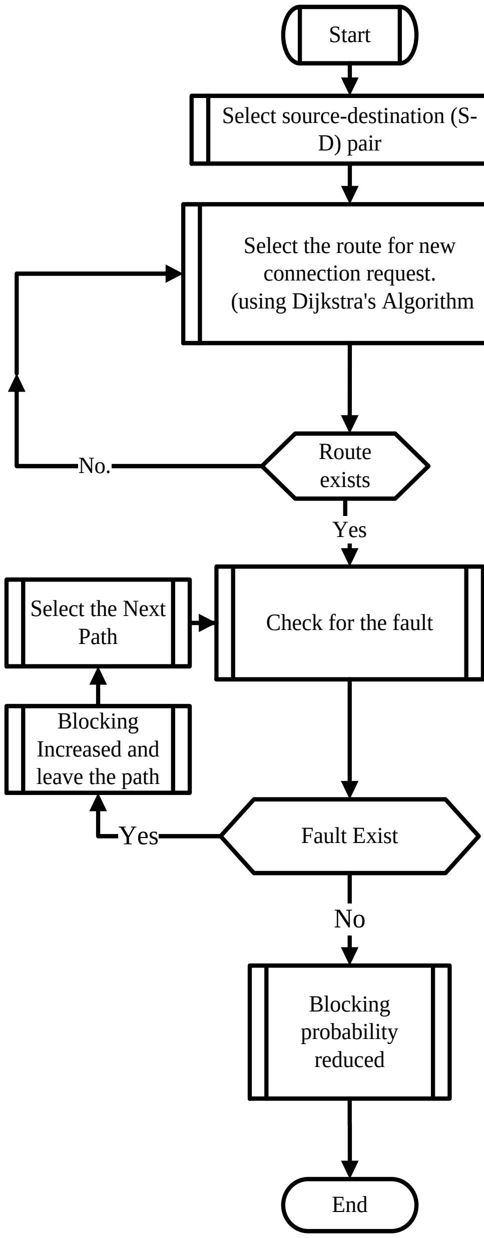

Figure 2: Proposed Algorithm

5. RESULTS AND DISCUSSIONS

The routing algorithm has been proposed for restorable networks and the performance of this routing algorithm evaluated in terms of blocking probability and fairness. The results are shown in figure 5-9. The proposed algorithm was applied on the random network topology shown in figure 4**.**

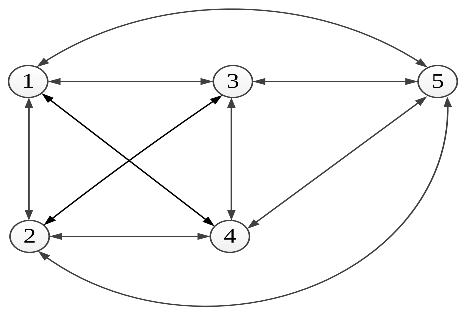

Figure 3 Network Topology

The proposed algorithm applied on the network topology as shown in figure 4. In the algorithm some of the values are fixed and varied others to find the output. In the simulation results value of the channels fixed to 10 and for the given network topology the number of paths is fixed to 11 as per the table 1. For the given values we have varied the value of load (in Erlangs) and calculated the results for the given routing algorithm. The path sequence was entered as per the table 1 and the load was varied from 10 Erlangs to 1000 Erlangs respectively.

Table 1: Physical Route and number of wavelengths

S-D Pair	Physical Route	Wavelength	Route Length
1-5	1-5	λ1	1
	1-4-5	λ1	2
	1-3-5	λ1	2
	1-2-5	λ1	2
	1-2-4-5	λ1	3
	1-2-3-5	λ1	3
	1-3-2-5	λ1	3
	1-3-4-5	λ1	3
	1-4-3-5	λ1	3
	1-4-2-5	λ1	3
	1-2-3-4-5	λ1	4

For figure 4 the Load was dynamically assumed to be [10 10 5 9 2 5 108 10 7] respectively by the algorithm and path {1-2-5} was found having minimum load and then this path was selected and was checked for faulty path also this path was fault free and was selected for connection. The value of blocking probability in this case was calculated nearly 0%. Figure 4 shows that as the number of channels is increased the value of blocking probability is increased but still its value is very low.

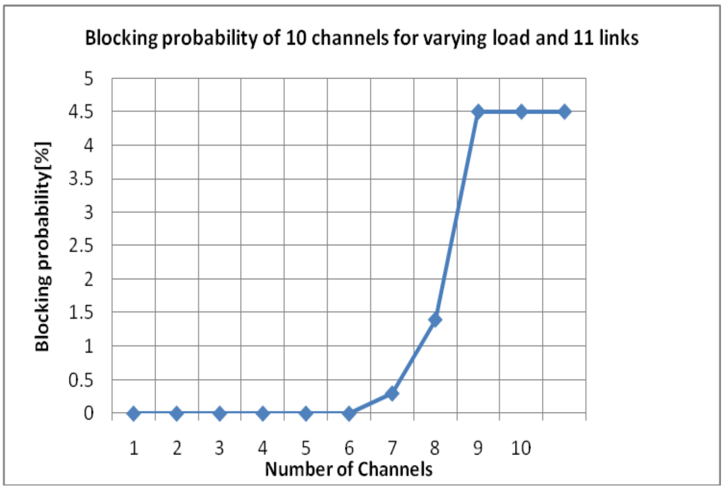

Fig 4: Blocking probability vs Number of channels for the network load = 10 (Erlangs)

Keeping on increasing the maximum value of load to 100 and fixing dynamically the values as [46 9 23 92 16 83 54 100 8 45] then the path {1-4-5} was selected and the value of blocking probability was increased up to 8.6431 x 10-009%, the results are shown in figure 6. Again increasing the maximum value of load up to 1000 and fixing dynamically as [962 5 775 818 869 85 400 260 801 432] then path {1-2-3-4-5} was selected and the average value of blocking probability was calculated as 25.7221%

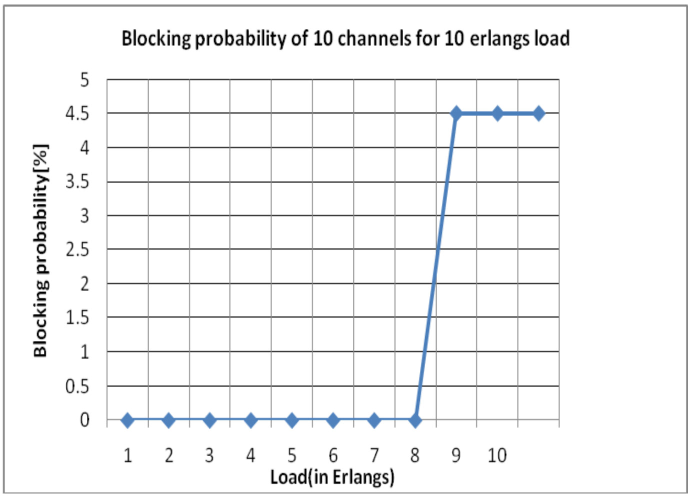

Figure 5: Blocking probability vs Load for 10 channels and Load =10 Erlang's

Now when the value of maximum value of load is increased up to 11 and keeping all other values constant the dynamic load was fixed to be [10 11 8 9 9 5 8 2 8 1] and path {1-4-3-5} was selected and the average value of blocking probability was calculated as 0% as shown in figure 6-7.

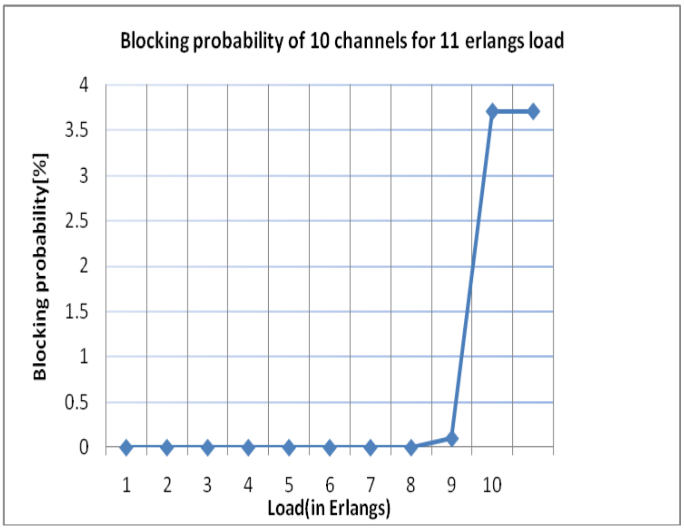

Figure 6: Blocking probability vs Load for 10 channels and Load =11 Erlangs

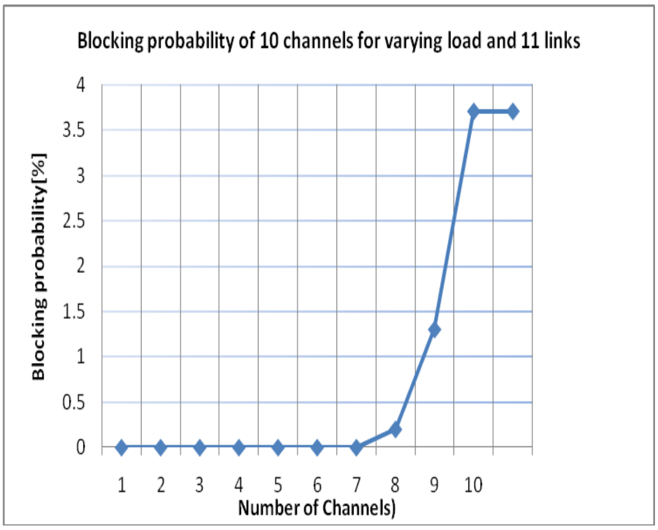

Figure 7: Blocking probability vs Number of channels for the network load = 11 (Erlangs)

When the maximum value of load was increased to 14 and was dynamically assumed to be [7 14 5 9 4 11 4 8 10 13] then path {1-2-5} was selected and results are shown in figure 8-9. Further, keeping on increasing the value of maximum value of load to 100 and fixing dynamically the values as [46 9 23 92 16 83 54 100 8 45] then the path {1-4-5} was selected and the value of blocking probability was increased up to 8.6431 x 10^{-009}%

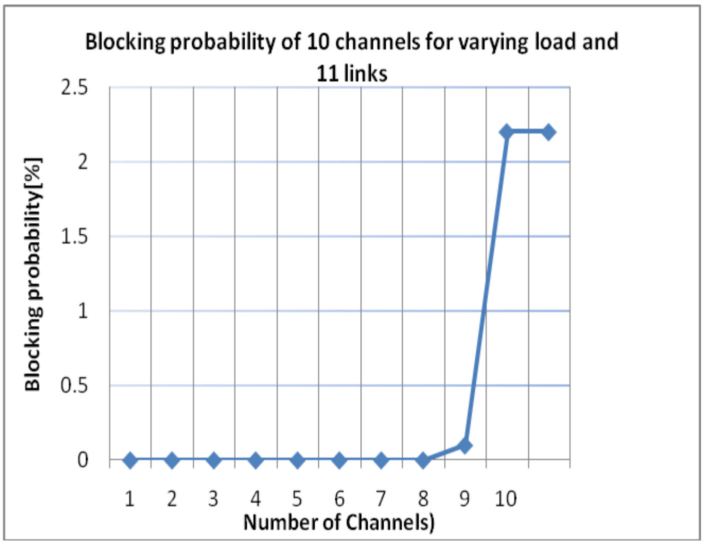

Figure 8: Blocking probability vs Number of channels for the network load = 14 (Erlangs)

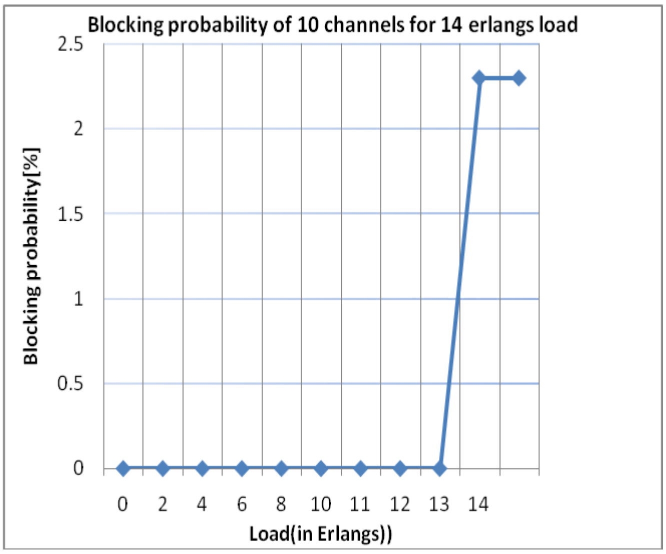

Figure 9: Blocking probability vs Load for 10 channels and Load =14 Erlangs

The results shown in figure 4- figure 12 shows that the blocking probability of the proposed algorithm increased with the increase in the offered load per unit link. In this paper proposed algorithm also compared with two conventional algorithm first fit routing algorithm and best-fit routing algorithm which are shown in figure 12. The figure shows that value of blocking probability is in the range of 4 x 10^{-2} % whereas we have shown in figure 10 that by using the proposed algorithm the value of blocking probability was reduced up to 8.6431 x 10^{-009}%. This shows that the proposed algorithm is effective and it can be used for the networks with larger load

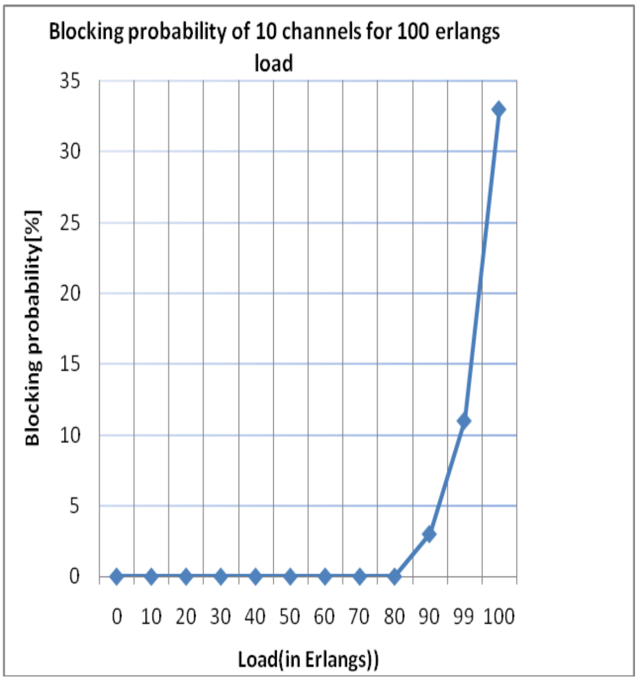

Figure 10: Blocking probability vs Load for 10 channels and Load =100 Erlangs

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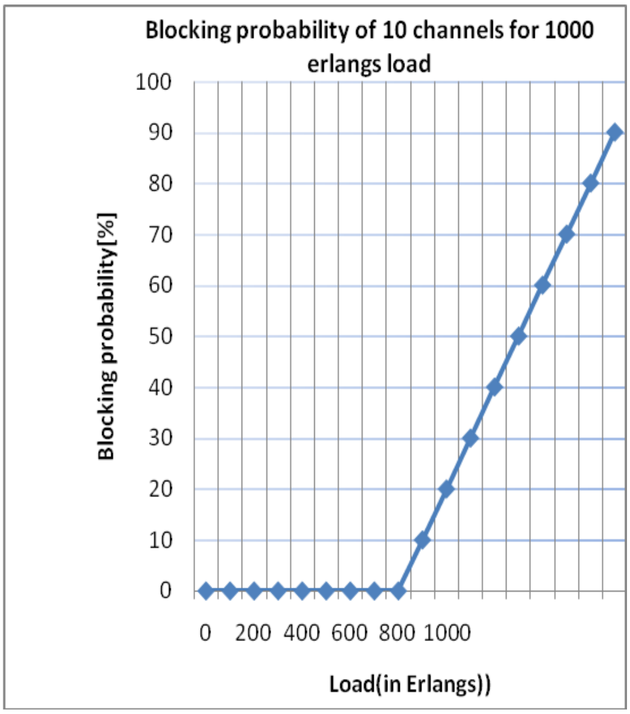

Figure 11: Blocking probability vs Load for 10 channels and Load =1000 Erlangs

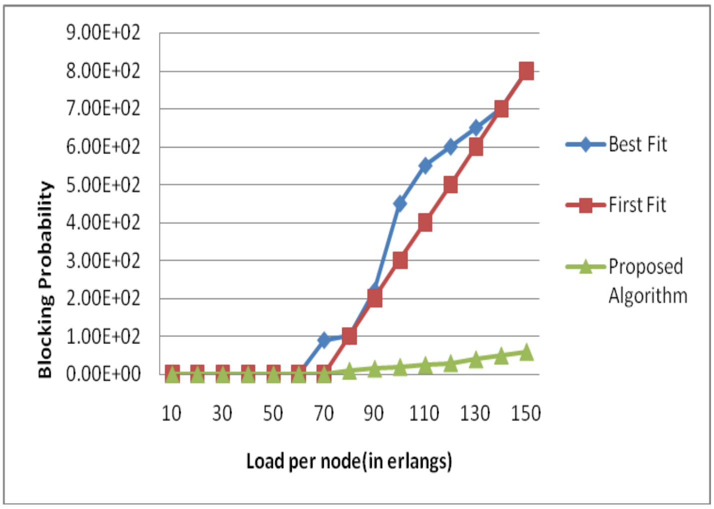

Figure 12: Blocking probability of best-fit and first-fit routing algorithm as a function of load, with14 nodes and 23 links.

6. CONCLUSION

In this research paper, an efficient technique designed for restorable routing schemes in optical networks and comparison of the proposed work with the conventional algorithms. This paper presented a quick and efficient heuristic for restorable routing. In current WDM networks, it is possible to support hundreds of WDM channels on a single fiber. Therefore, the cost of the transmitters and the receivers, and hence the number of light paths s, is becoming the main factor in determining the cost of a WDM network. The authors have tried to keep the number of light paths s, required to implement a topology as low as possible. The results shown in this work prove that the blocking probability of the proposed algorithm increased with the increase in the offered load per unit link. We have also compared the two conventional algorithm first fit routing algorithm and best-fit routing algorithm. The comparison clears that the blocking probability of the network for proposed algorithm is 8.6431 x 10^{-009}% for proposed algorithm whereas its value is 4 x 10^{-2} % in case of conventional algorithm, which proves that the proposed algorithm is effective routing algorithm and it can be used for the networks with larger load.

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