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PATH RESTORATION TECHNIQUE OF OPTICAL NETWORK WITH APPLICATION OF BIT ERROR RATE (BER) PERFORMANCE EVALUATION AND GENETIC ALGORITHM

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Abstract: Optical Fiber communication is one of the vital communication technologies preferred by broadband service provider which is spread all over the world with worldwide data infrastructure. It is preferred not only for the less expenditure required for its installation and maintenance but also for its other advantages. The optical fibers are the main attraction because of high data rates and large bandwidth having the capacity to support large number of users at same time. This high end technology may also become interrupted due to sudden fiber cut or link failure which causes problem to the users. So, faster recovery of the network system with seamless connectivity is highly appreciable to any broadband service provider. In our research work, the restoration technique with seamless communication is proposed which uses BER evaluation of the alternative link and connects those links for data communication to overcome single link failure within network. This proposed method uses BER evaluation to find the least BER value of the adjacent path between two nodes in a given network and in case of failure occurred on any link of the working network, all the adjacent cycles between end nodes of the failed link are determined. Then Genetic Algorithm (GA) is applied to get the fittest path. Here the basic parameter to select the fittest path is BER performance of the link. This is served by marking adjacent cycles of the failed link having the least BER value and that adjacent cycle consists of the source and destination nodes of the failed link which finally help to bypass the failed link to stay connected all the time.

Index Terms **- Optical Networks, Survivability, BER, Link failure, Restoration.**

I. INTRODUCTION

Optical fibres are highly preferred over copper cables because not only for the fastest data carrying capacity but also for many other advantages over conventional copper cable. So, optical fibres are most dominant technology today in long haul broadband communication services [1]. In present scenario, all the broadband service providers around the world emphasize on the need for faster, cheaper and more reliable deployment of broadband networks, for which hardware manufacturers pursue innovative solutions that helps to drives down the component complexity, installation time, required skill set etc. With the invention of Erbium Doped Fiber Amplifier (EDFA), Semiconductor Optical Amplifier (SOA) etc, the communication technology for long haul broadband communication became upgraded and compatible for high speed data communication that dramatically increase in the Fiber-to-the-Home (FTTH) deployment pace along with the desire to eventually migrate completely to these systems. It puts the Optical Network deployment and maintenance issues in the spotlight of current academic and network system research. With the explosive growth of internet it has certainly affected the need to provide not only high unparalleled, accelerating demand for bandwidth requirement and speed with seamless connectivity, but also requires faster networking infrastructure deployed over different technologies and faster restoration if any failure happens [2- 3]. Any failure in an optical network may result in significant data and revenue loss due to large amount of traffic communicated over optical links.

In today's scenario, link failure issues of optical networks are one of the main problems to both the customer and service provider. Problems like link failure, node failure and failures due to other reasons are increasing and surviving from this kind of failure is very important objective in an optical network, otherwise the failure may cause disruption of entire network which ultimately affects the users on the network or the society at a large. So in different layers of network such as the SONET/SDH, WDM, IP and MPL layers survivability is one of the important criterions which can be provided. Even though for the higher layers of the network, there are also own recovery methods incorporated in the system. It is important to confirm survivability on the WDM layer because the WDM layer has numerous advantages in comparison with the higher layers i.e. maximum utilization of existing resources, faster recovery time from failure and protocol transparency. To protect the network from failures, survivability may be the pathway which may be provided through either protection or restoration techniques or application of both. First, protection technique which uses a proactive approach where backup resources are pre-reserved for the time of failure and are only utilized when a failure occurs. But for the next case of restoration, this method uses a reactive approach where both the end nodes whose link has failed passes through a distributed algorithm after the failure occurred, to find out the possible alternative path to restore the network from link failure. In protection approach, as alternative backup paths are reserved during the time of network design and these reserved network resources are only utilized at the time a failure so resource utilization is high which further increases the cost of network deployment. On other hand for restoration technique it has very less resource utilization. 'Overcome network failure' is also known as survivability and the time of survivability is very small. So, the restoration approach has better resource utilization in comparison with protection technique as no resources are preserved and after the occurrence of failure, the network is restored fast using the current available resources of the network. This technique, may take time to restore a network from failure and the restoration time from the failure condition depends on the time to search the current available resources using which network can be restored. [5-6] after the search, the adjacent node corresponds to the failed link switches from the failed link to the newly found working link to re-establish the network link. After restoration of failed link all adjacent nodes of the failed link update their cycles of operations. Restoration times are also calculated to find out the time required to restore failed link [6]. These proposed techniques are checked by MATLAB with comparing the results between our proposed techniques and existing technique by which the improvements can be understood.

II. PROBLEM STATEMENT

Any failure of the Optical Network may cause loss of high speed data communication which in turn also causes revenue loss and loss of sensitive information. There are many network components which exist under physical layer of the network system and failure of any one/ many of them can cause the failure of connection such as router operation failure, optical fibre cuts, and transceiver module fault etc. But the most vulnerable area of network failure is link failure. Thus survivability plays the most crucial role to recover the system from these failures. For survivability of the networks, protection and restoration become the inevitable part of network design planning. In our work, we focused to develop an effective and efficient solution of this problem. In our proposed work Genetic algorithm is applied to find the path between the source and destination nodes having the lowest BER figure. After link failure happens, the proposed algorithm will search and find all adjacent cycles and out of the various adjacent cycles the adjacent cycle with the best BER figure connecting the end nodes of the failed link to serve the restoration purpose.

III. NETWORK RESTORTION WITH BER CALCULATION AND GENETIC ALGORITHM

There are various survivability techniques having with different types of criteria. From the study about all of them it is clear that the reliability of communicating link and the time required for survivability of collapsed network are the most important issues. So our aim is to propose the survivability technique which is reliable and fast. In our proposed technique we have used Genetic Algorithm to find the path between source and destination with least BER value as it has been found that the lower BER values determine better and reliable communication. BER values are also dependent on the received power levels from different distances. A considerable interplay has been observed between the transmitting power and distance variation of the optical network units while evaluating the data loss and BER characteristics purpose. But to calculate the BER value of different links and find out the corresponding path between two nodes, we have to follow a set of organized rules. To serve the purpose we have to apply Genetic Algorithm on the network.

A. BER PERFORMANCE EVALUTION

In this scheme, first need to sort the nodes according to their distance from other nodes, and then used to compute the BER figure of the communicating line that exist between the two nodes. This scheme is capable to compute BER of the node to node links and it helps to reduce the variance. The BER performance of any channel depends on the signal power received in any port and the power received by any port may be calculated as:

$$P^i_{sig} = L_f\,(d_{feeder} + d^i_{drop})\,L_P L_S G P_t \qquad (1)$$

Where P^i_{sig} is the signal power at the i-th port. Here:

L_f is the insertion loss at the feeder section

L_p is the propagation loss per km

L_s is the loss at the drop section

d_{feeder} is the distance of the feeder section

d^i_{drop} is the distance of the drop section for i-th port

G is the Gain

P_t is the transmission power

Now, Noise variance for the bit transmission of '0' and '1' are:

$$\sigma_0^2 = \sigma_{th0}^2 + \sigma_{sh0}^2 \qquad (2)$$

$$\sigma_1^2 = \sigma_{th1}^2 + \sigma_{sh1}^2 \qquad (3)$$

Where σ_{th} noise variance due to thermal is noise, and σ_{sh} is noise variance due to shot noise.
Further, the decision threshold set at the receiver end is:

$$I_{th} = \left[\frac{R_\lambda P^i_{sig}\,\sigma_0 + \epsilon\, R_\lambda P^i_{sig}\,\sigma_1}{(\sigma_0 + \sigma_1)}\right] \qquad (4)$$

Where R_λ is the photo-detector responsivity ($R_\lambda = 0.8$) and ϵ is the laser extinction ratio ($\epsilon = 0.1$)
Finally the BER at the receiver end may be computed as follow:

$$BER = \frac{1}{4}\left\{ erfc\left[\frac{R_\lambda P^{i}{}_{sig} - I_{th}}{\sqrt{2}\sigma_1}\right] + erfc\left[\frac{I_{th} - \epsilon R_\lambda P^{i}{}_{sig}}{\sqrt{2}\sigma_0}\right] \right\} \quad (5)$$

Here in Fig. 1 and Fig. 2, the BER figure along with the Received Power (dbm) is shown for the optical network line having fixed distance of less than 5 km. This BER calculation done here is based on the mathematical derivations described 1 to5.

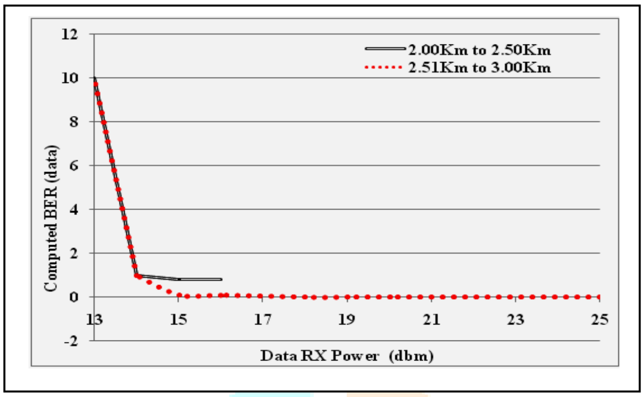

FIGURE 1. BER VS RECEIVED POWER FOR DISTANCE OF 2 KM.

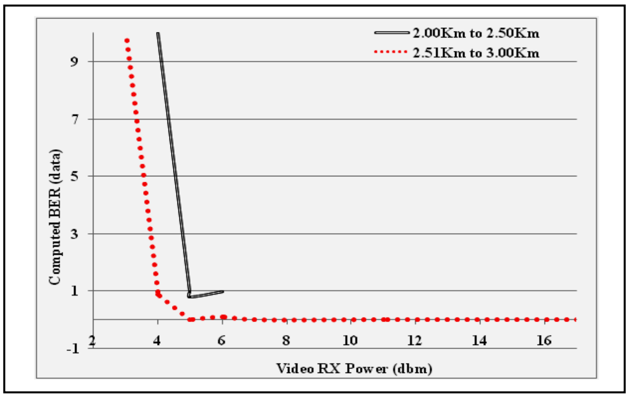

FIGURE 1. BER VS RECEIVED POWER FOR DISTANCE OF 3 KM.

So from Fig. 1 and Fig. 2, it clears that by applying the above mentioned computation procedure, we can obtain the BER figure of each link of the network. Now we need to apply this computation in an organized manner for each link, adjacent to the failed link of the network to get the path as alternative of the failed link to restore the network. To serve the purpose we have to apply Genetic Algorithm as described below.

B. GENETIC ALGORITHM

Genetic algorithm encodes a potential problem solution into a chromosome-like data structure and then applies a number of recombination operators (crossing and mutation processes), in order to preserve critical evolutionary information and discard any unwanted characteristics. The genetic algorithm optimization for the BER performance evaluation of the restoration path searching process is selected due to its rapid convergence of the algorithm which provides faster operation. Another approach to the problem includes construction of spanning network with description of all possible combinations of paths, which become complex when considering the number of resources, obstacles and other map elements which need to be accounted for. Once constructed, a shortest path searching algorithm may be applied (Dijkstra, Bellman-Ford, A* search or Floyd-Warshall algorithm), though the required processing grows exponentially with the network map complexity, making any attempt to scan the whole solution futile. In the case of the optimization process, the basic data set describing the problem is limited to a single signal path connecting two predefined nodes. The said path is composed of a series of interconnected and ordered links, spanning between pairs of access points. The selection of the chromosome for a GA process is therefore straightforward. An example of a simple chromosome for network optimization process based on a GA mechanism is depicted in Fig. 3.

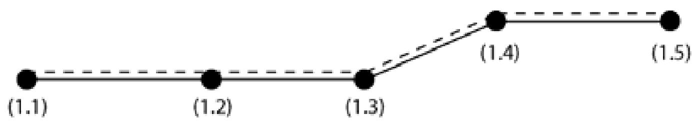

FIGURE 3. A SIMPLE CHROMOSOME FOR A GA BASED PON OPTIMIZATION PROCESS

The said chromosome is thus a simple path representation, composed of a series of ordered spanning points (1.1) through (1.5), creating a series of links (1.1) → (1.2), (1.2) → (1.3) etc., which in turn create a complete signal path (1.1) → (1.5).

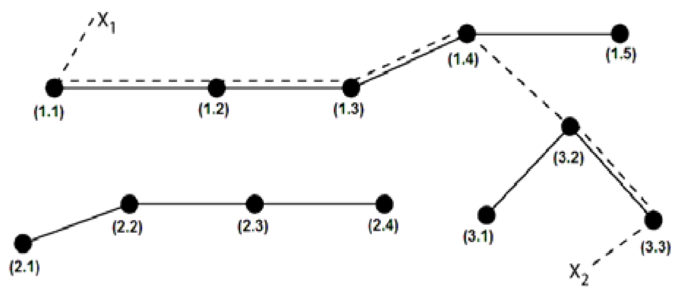

Figure 4. A selected chromosome, connecting points X_1 and X_2, spanning on 3 different resources and creating new interconnections.

Fig. 4 depicts chromosome selection for a more complex system, with several resources, interconnecting points X_1 and X_2 and creating several new connection sections, traversing in the following way:

$X_1 \rightarrow (1.1) \rightarrow (1.2) \rightarrow (1.3) \rightarrow (1.4) \rightarrow (3.2) \rightarrow (3.3) \rightarrow X_2$.

The said PON chromosome is thus the basic data structure for the network path optimization process, containing genetic information in the form of an ordered list of spanning points and path fitness. Additional information stored in the path includes traversed resources and total resource and non-resource lengths etc. In the network builder framework, we optimize one path at a time. A logical choice for the chromosome is thus a path spanning between the two points we want to connect. For each network segment, a path contains information about, whether the segment in question reuses an existing resource.

First, we create the initial set of chromosomes (termed initial population) of paths using randomized path finding procedure in order to include as much varied genetic material as possible. Each chromosome represents a potential solution of the given problem (a complete path spanning between two points on the map, traversing a number of existing and newly created resources), the fitness, performance of which is evaluated applying a problem specific fitness function, which describes the appropriateness of the given solution in numerical terms. The next step consists creation of the so called 'gene pool' where the chromosomes with the highest fitness entry with higher probability. Having a gene pool, the new generation is created through crossing and optional mutation processes. The chromosome crossing process is used to introduce variability in the genetic material of the chromosome population, mainly through exchange of sections of genetic encoding between individuals from the same or different populations. The mutation process is used to maintain high diversity of the genetic material and introduce randomness. We have developed two different crossing and three mutation processes since we did not find any already existing that could be applied directly to our problem.

Since the chromosomes with the highest fitness level can enter the gene pool many times, they are more likely to create offspring in the result of the crossing process, and thus are more likely to pass their genetic material to the next generation. Once the offspring pool is created through the crossing process, a new gene pool is created, this time picking from both offspring and parent chromosomes. The above described process is repeated until the end condition is met the path finding process ends when the fitness function for the best chromosome in the population does not improve for a certain predetermined number of generations. Since the whole network structure is created one path at a time, whenever a path is established, all its non-resource segments are added to the set of existing resources. That way all the resources that must be built for that path can be reused for all the subsequently calculated paths. It means that the resource map may change after establishing every new path which will be helpful in future when the link cut or the fault will be repaired and it will start its function again.

IV. RESTORATION TECHNIQUE

There are various survivability techniques having with different types of criteria. From the study about all of them it is clear that the reliability of communicating link and the time required for survivability of failed network are the most important issues. So our aim is to propose the survivability technique which is reliable and fast. In our proposed technique we have used Genetic algorithm to find the path between source and destination with least BER value as it has been found that the lower BER values determine better and reliable communication. BER values are also dependent on the received power levels from different distances. A considerable interplay has been observed between the transmitting power and distance variation of the optical network units while evaluating the data loss and BER characteristics. After finding out the path having least BER value, which is the primary path for the source to transmit data towards the destination. In case of a failure of link occurs on the primary path, all the independent cycles are determined. Out of all independent cycles on the cycle with least BER will be identified that consist of both the end nodes of the failed link. Then the end nodes will switch to the newly found path of restoration. The restored time will also be calculated to find out the time taken in searching the protection path. The results of the proposed technique are evaluated her by help of MATLAB, and the results are compared with the existing techniques to find out the improvements with existing technique. The sequence of steps for finding out the restored path:

Step 1: All the faulty link of the network is denoted by L_{ij}. Definitely at the two ends of the link, two nodes are located. If the nodes are faulty then, the nodes are marked by N_{kl}. We need to have the BER value of each link of the network counted as B_{ij}. When the network works properly, then the number of faulty link or faulty node is zero.

Step 2: When any link failure occurs initially that causes to hamper the communication which is possible to detect easily because the BER value of that link becomes infinity.

Step 3: After detecting the faulty link, the two end nodes of the link are identified. Now, our purpose will be served by restoration of the network with as minimum time by finding out the alternative path of the disrupted link. We start our work by marking any one node of the two end nodes of failed link as node '0' and this source node is counted as active node.

Step 4: Then from this starting node the BER value to all the adjacent links are determined up to the next end node of adjacent links. The least BER value from the possible links of the entire neighboring node is found out. This is known an update cycle.

Step 5: Now set the link from the node with least BER figure from the starting node and count as current and permanent node.

Step 6: By this way in the case of the network, active path restoration process, the basic data set describing the formulation process stated above are limited to a single signal path connecting two pre-defined nodes. The defined path consists of a series of interconnected and ordered links, spanning between pairs of access points. Finally this may be interpreted with application of Genetic Algorithm (GA) that depicts chromosome selection for a network system with several resources, interconnecting points N_1 and N_2 and creates new connections. This said network chromosome is thus the basic data structure for the network restoration optimization process, containing genetic information in the form of an ordered list of spanning points and path fitness.

Step 7: Now with application of the GA, the steps described in step 4 to step 6 are repeated till no nodes are left to be searched in between the final two end point nodes of the failed link, i.e. Source Node and the Destination Node.

V. FLOWCHART OF THE PROPOSED TECHNIQUE

The above mentioned seven steps for application of BER evaluation and application of Genetic Algorithm are shown in the flowchart below (Fig. 5) -

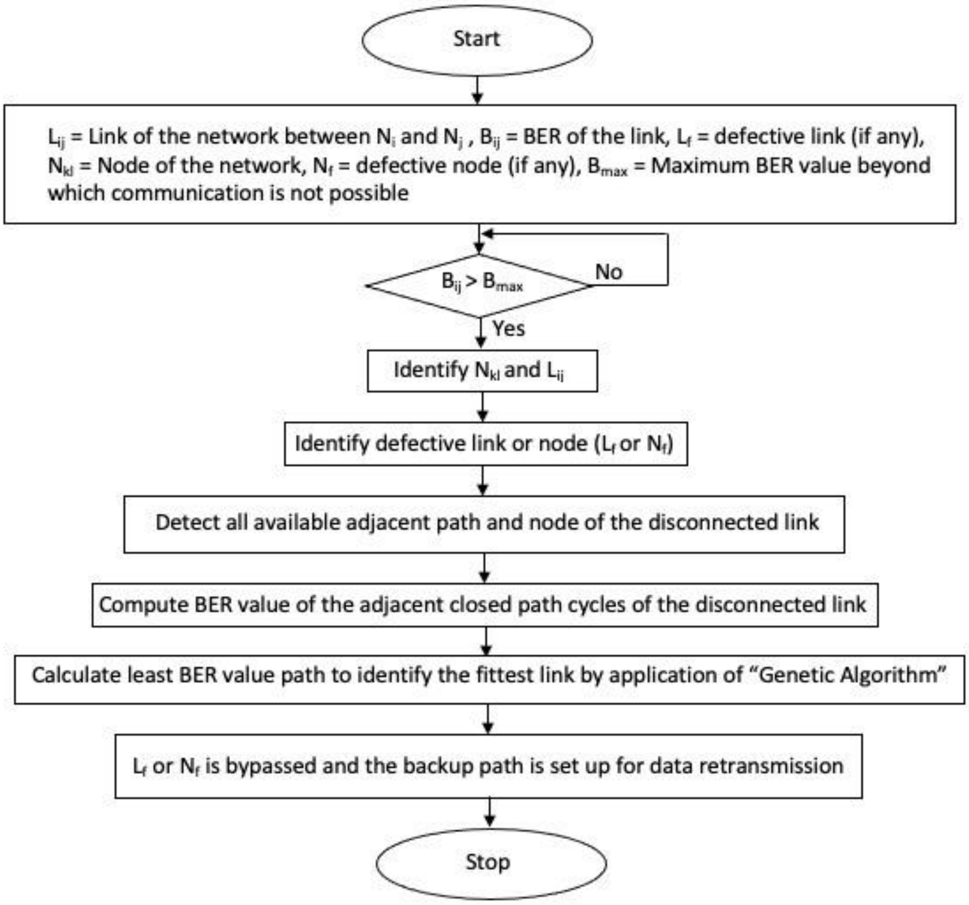

Figure 5. Flowchart representation of the proposed BER evaluation and Genetic Algorithm application technique.

VI. DISCUSSION ON SIMULATION AND RESULTS

For simulation and result purpose we have selected the network diagram given in Fig. 6. Here all the nodes are marked correspondingly and the links joining them are also shown in the diagram. For the simulation purpose we presume that the distances between two nodes, i.e. the link length is given. Now we also presume that the link between node 11 and node 18 become faulty. Similarly the link between node 18 and node 23 become faulty (marked with red color).

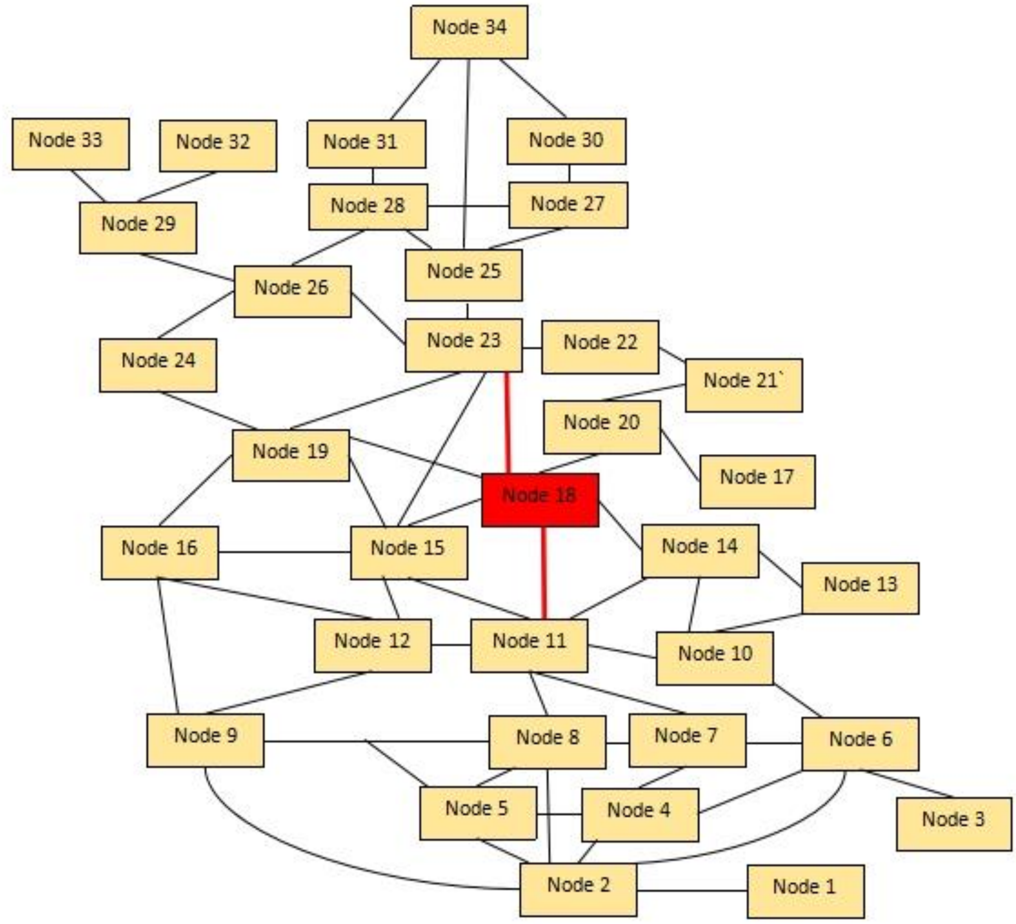

Figure 6. Node Network Diagram.

Improvement in the survivability of the network by application of the proposed Technique

Case 1: a) If Path between 11 and 18 fails

Now consider a case when link 11->18 fails while transmitting data from source to destination. In proposed method, failure is detected by node-11 and link 11->18 is protected by adjacent path 11->14->18 or path 11->15->18. Then BER value of the two paths will be computed and the path having least value will be selected. Then node-11 sends the FNM to the source node by using the lowest BER valued path. When FNM reaches source node traffic is retransmit using the restored path having the lowest BER value. If the lowest BER valued path is 11->14->18, then that path will be used instead of 11->18. Otherwise 11->15->18 will be used instead of 11->18.

Case 2: a) If Path between 11 and 23 fails

Now consider a case when link 11->23 fails while transmitting data from source to destination. In this case node 18 has two numbers of links faulty and so marked red. By the proposed method, failure is detected by node-11 and link 11->23 is protected by adjacent path 11->15->23; path 11->15->18->19->23; path 11->14->18->20->21->22->23; path 11->15->19->23 or 11->12->16->19->23. Then BER value of the different paths will be computed and the path having least value will be selected. Then node-11 sends the FNM to the source node by using the lowest BER valued path. When FNM reaches source node traffic is retransmit using the restored path having the lowest BER value. As BER value is dependent on the distance, the major chances are there to get the outcome result as the path having least distance.

A. COMPARISON OF THE PROPOSED TECHNIQUE WITH THE EXSISTING TECHNIQUE

The results of the simulation of the proposed network is given in the Table I below -

Table 1 Path Restoration results

Path through which link is failed	Alternative Path Searched by the Algorithm	Total No of Nodes traversed for the Restoration of the failed link	BER Value Range	Final Path of Retransmission based on total BER figure	Restoration Time	
					By conventional Method (µs)	By proposed Algorithm (µs)
11->18	11->14->18 OR	1 (Node 14)	10^{-9}	11->14->18	2070.336	1936.566
	11->15->18	1 (Node 15)	10^{-8}			
11->18->23	11->15->23 OR	1 (Node 15)	10^{-9}	11->15->19->23	4070.336	3886.536
	11->15->18->19->23	3 (Node 15, 18, 19)	10^{-9}			
	11->14->18->20-> 21 ->22->23	5 (Node 14, 18, 20, 21, 22)	10^{-6}			
	11->15->19->23	2 (Node 15, 19)	10^{-10}			
	11->12->16->19->23	3 (Node 12, 16, 19)	10^{-8}			

From the above table, the time consumption of restoration of the network can be observed and the bar chart representation of both case 1 and case 2 can be observed from Fig. 7 and Fig. 8; as shown below.

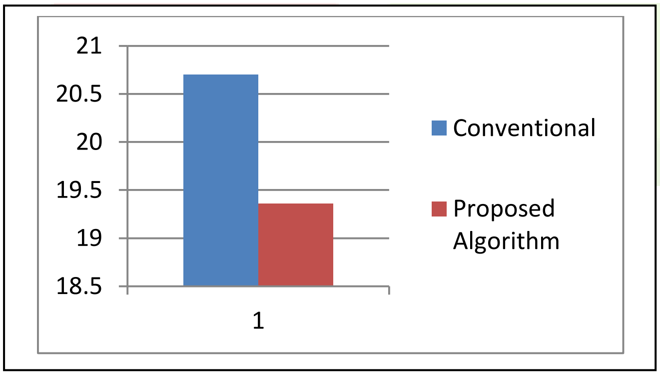

Figure 7. Comparative Study of Case 1.

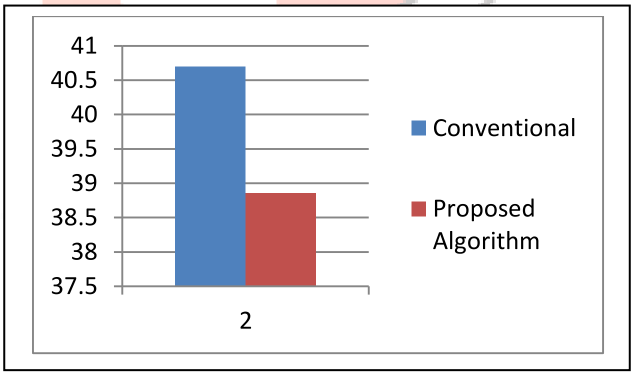

Figure 8. Comparative Study of Case 2.

From Fig. 7 and Fig. 8, the representation of the comparative study of time consumption to restore the network for both conventional method and the proposed method, this is evident that the proposed technique works faster than conventional technique.

VII. CONCLUSION

The main emphasis of this work is to search for seamless network connection with restoration and protection methods to survive during link failure in optical network. Our focus is on restoration method that dynamically allocates path to failed link. In this work we have proposed a quick and effective survivability method for surviving failure of single link in WDM networks because failure of single links is the main cause for network failure. The objective is to keep number of nodes required to overcome from failure minimum and time to restore link also as minimum as possible with maintaining the reliability.

VIII. ACKNOWLEDGMENT

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