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A Review on Network Survivability in Optical Networks

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ABSTRACT
With the continuous advancement in technology data communication at higher data rates have become the need for the present and future technology. The data can be highly sensitive and loss of such data can hamper the communication which can cause huge loss to data, time and revenue. Thus survivability plays a very crucial role in optical networks. It is the ability of the optical network to overcome failure by pre reservation of resources (Proactive Approach) or by finding available resources after link failure (Reactive Approach) has occurred .Thus restoration of the failed link plays a very important role and is a very important area of research and efforts should be made to improve the survivability of optical networks. The objective of this paper is to analyze the existing survivability techniques.
Keywords – Survivability, Protection, Restoration, Optical Networks, Link Failure

I. INTRODUCTION

Optical networks are a high capacity network that uses optical technologies. They can operate on very high data rates exchanging terabytes of information in a second and hence they provide higher bandwidth. Thus any failure can cause loss of data which in turn can cause revenue loss and loss of sensitive information. There are many network components which can cause the failure of connection such as switches, fiber cuts, and transceiver and so on. But the most common failure is link failure Thus survivability plays a very crucial role in recovering from these failures. Survivability is the ability of the network to overcome failures. There are two approaches to overcome link failure for survivability Protection (proactive approach) and Restoration (reactive approach)[1].

II. TYPES OF SURVIVABILITY

Survivability techniques can be classified into two categories on the basis of type of approach used for surviving from network failure. They are:

2.1 Protection

Protection approach involves reserving the backup resources before a failure can occur. This involves reserving some of the network resources for failure at either connection establishment or network design time and these resources are activated only after failure has occurred. The protection approach has faster recovery time but it leads to the wastages of resources till the time there is no failure. Protection approach can be applied to link failures and path failures.

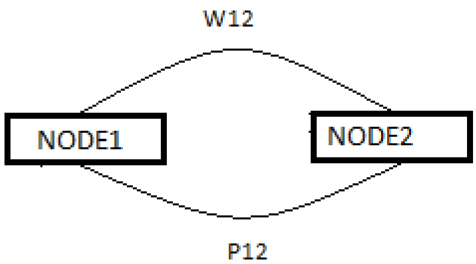

Fig. 1 Working and protection path

We can see the Fig. 1 that the working link between the node1 and node2 i.e. W_{12} has a protection link P_{12}. This is used in case the failure of link W_{12} occurs. The protection techniques are further categorized into two categories as discussed below.

2.1.1 Link Protection

Link protection involves reserving a protection path for each link between the nodes and this path is used upon network failure so that communication can be resumed using the reserved network resources.

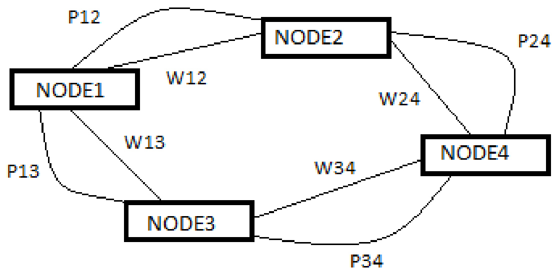

Fig. 2 Link protection

As shown in the Fig. 2 each working link has a corresponding protection link for.eg working link W_{12} has a protection link P_{12}. In case of the failure of the working link the entire traffic is routed over the protection link P_{12} as shown in the Fig. 3.

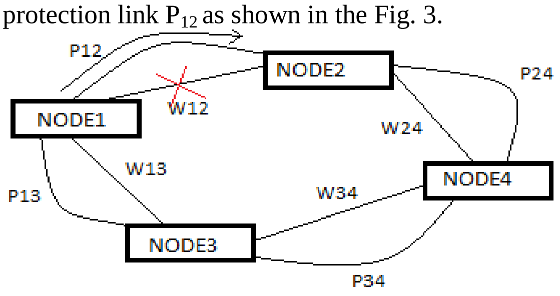

Fig. 3 Working path incase of failure

2.1.2 Path Protection

In path protection scheme the protection path of the working path is pre planned. Upon the failure of the link the source and destination nodes switches from the working path to protection path. As shown in the Fig. 4 suppose the source and destination nodes are 1 and 4 respectively and the working path is 1->5->4.

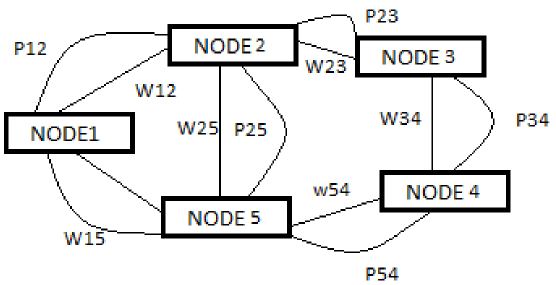

Fig. 4 Path Protection

and its protection path is 1->2->3->4 .In case of failure of any of link of working path the source and transmitter switches to the backup path 1->2->3->4. So in case of link protection only the adjacent nodes switches to the backup path while in path the source and the destination node switches to the backup path.

2.2 Restoration

Restoration is a reactive approach where network resources are not pre reserved to overcome failure. While on the occurrence of network failure a search is carried to find the available network resources so that by using these resources network functionality can be resumed[2]. Restoration can also be applied on link and path failure.

2.2.1 Link restoration

In case of link failure the adjacent nodes takes part in distributed algorithm to find a new path to resume the network functionality.

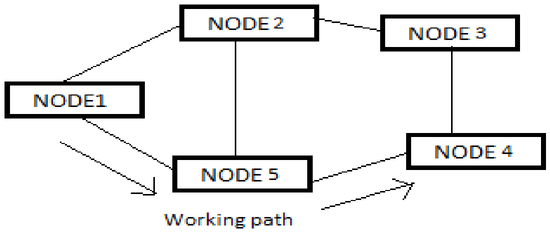

Fig. 5 Working path between node1 and 4

Then both the adjacent nodes switch to newly discovered path to restore network functionality. For .e.g. in Fig. 5 the source and destination nodes are 1 and 3 and the working path is 1->5->4.

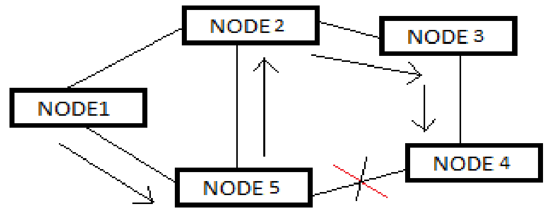

Fig. 6 Link restoration incase of failure

When the path between node 5 and node 4 fails both the nodes will switch to the new working path 5->2->3->4 . So the complete working path will be 1->5->2->3->4 as shown in Fig. 6 .But the time taken in finding the alternative backup path is very crucial as restoration time should be less.

2.2.1 Path Restoration

In path protection in case of failure of any of the link on the working path the source and destination nodes involves itself in distributed algorithm to find a backup path and switches over to it shown in the Fig. 7 after the failure of link 5->4 of the working link 1->5->4. The sources and destination nodes node 1 and node 4 switches to backup path 1->2->3->4. In this case the backup path can be on different wavelength channel.

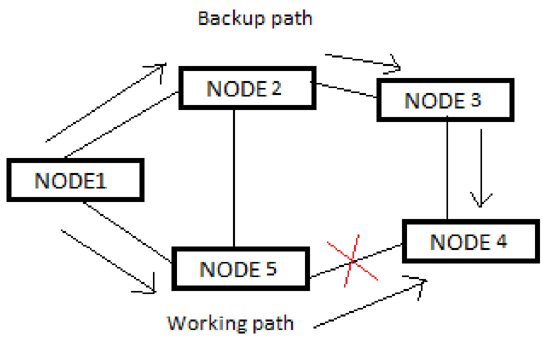

Fig. 7 Path Restoration

III. LITERATURE SURVEY

Various type of failures such as node failure, link failure etc. are there which can cause loss of information. So the survivability plays an important role in case of impaired networks. The survivability technique for WDM networks includes various predesigned protection and restoration techniques. Link failures are most common and the chosen survivability techniques should be such that it should have minimum restoration time from these failures [1],[3]. There is a tradeoff between resource utilization and restoration time for better network protection from failures[4]. Various link failure survivability techniques were analyzed by Dongyun Zhou [1] he concluded that survivability is one of the most important requirements of networks. Its importance is magnified in fiber optic networks with throughputs of the order of gigabits and terabits per second. He analyzed various techniques used to achieve survivability in traditional optical networks, and how those techniques are evolving to make next-generation WDM networks survivable. He also concluded that with the modification in APS (Automatic protection switching) and self-healing rings these techniques should be adopted for WDM networks as they provide better survivability against single link failures. A study was done by S. Ramamurthy [2] on different approaches to protect a mesh-based WDM optical network from failures. These approaches were based on two survivability paradigms: that are path protection/ restoration and link protection/ restoration. He examined the wavelength capacity requirements, routing and wavelength assignment of primary and backup paths for path and link protection and proposes distributed protocols for path and link restoration. He also examined the protection-switching time and the restoration time for each of these schemes, and the susceptibility of these schemes to multiple link failures.

Various survivability techniques were developed for ring and mesh networks using predesigned protection techniques one such technique was developed which could combine the benefits of both ring and mesh networks, they are known as p-cycles (predesigned protection cycles). The protection cycles are having both the speed and capacity benefits of ring and mesh networks[5]. Performance analysis on P-cycles was also done by D.A. Schupke [6] and it was analysed that p-cycles can easily withstand single link failure. They can also withstand multiple link failures if it occurs on different p-cycles. Multiple failures can also be survived using cycle reconfiguration while node failures can be survived using failure signalling. It was shown that p-cycles are also an attractive method to overcome multiple link failures which can happen in larger networks[6]. Thus it was concluded that p-cycles helps in better utilization of network resources and better restoration speeds since they combine the benefits of both mesh and ring networks[2],[6].The performance of p-cycles can further be enhanced by using intercycle switching (ICS). A method introduced by Raghav Yadav [7] to improve the length of p-cycle by taking into account the restored path length than the restoration segment during intercycle switching which was named as enhanced intercycle switching (EICS) . It was shown that the EICS restoration method is more effective than ICS method. By simulation results it concluded that the length of the restored path using the traditional CRP technique was more as compared to the EICS technique. In an optical mesh network p-Cycles have been designed for pre-planned 1: N protection. Even though the protection circuits are pre-planned but the discovery of a network failure and the routing of the network data takes time. Another protection technique to reduce this time is 1+1 protection in which a signal is transmitted on two disjoint links and the destination node chooses the strongest signal among the two this method is fast and ensures instantaneous recovery but the major disadvantage is large amount of protection circuits and wastage of network resources. In this paper the author presented a new concept for 1+N protection using p-cycles in which p-cycles can be used to protect duplex connections[8]. The maximum breakdown time is not more than double the propagation delay present in p-Cycles.

Mouftah, H.T.[9] listed various advantages and disadvantages of both the survivability techniques related to time complexity or restoration speed of an impaired network and he concluded that protection techniques have a better restoration speed but it causes wastage of resources as compared to restoration techniques so restoration schemes are an attractive alternative. *V*arious Survivability Strategies in Optical Networks were also studied by Manthoko G [10] and he concluded that with the increase in traffic, data rates have increased and any failure can cause tremendous loss of information which can effective many users. Therefore there is a need to design a network which can overcome failures efficiently. He then developed an IAR technique and concluded that in case of IAR the physical performance of backup path is better as compared to the traditional available routing algorithms. The results were obtained using COST239 and NSFNET network. His work presented two key finding one was the network performance taking into account resource utilization and blocking probability and the second was the network performance in the presence of dual link failures. *Then a modified* impairment-aware routing (IAR) was proposed to protect the network from single and dual link failures[11]. This scheme provided survivability through shared backup path protection scheme which is enhanced with a reinforced sharing mechanism. The results showed that the IAR is having low connection blocking as compared to traditional minimum hop routing. A new algorithm for protection of both single-link and single link/node failure scenarios were proposed by Divanshu Sharma [12]. This proposed algorithm was known as shortest path pair disjoint tree (SPP-DT). It was used for the development of an improved protection technique. It was very efficient way to overcome the link failure problem in network Graph. Various efforts were done in developing survivability one such technique was single node failure technique based on current IP over WDM static topology mapping methods[13]. The goal of the algorithm was to map the IP topology links into light paths in WDM topology to ensure IP topology remains connected after the failure of a single node in WDM topology. *P*erformance Analysis of First - Fit Wavelength Assignment Algorithm in Optical Networks was also done and a new technique was proposed using the First - Fit Wavelength Assignment Algorithm and found that this new proposed method reduces the blocking probability by taking into account the wavelength usage of that link [14]. This proposed method was found to be accurate in case a system is having a large number of wavelengths.

In an optical mesh network different networks can suffer from a common failure if it shares a common risk group. A new algorithm named as best effort SRLG was introduced to provide protection from these network failures. By doing performance analysis on 14-node NSFNET and 28-node WDM system it was analyzed that the proposed algorithm provided 98.5% for survivability NSFNET and 99% survivability for WDM system and the blocking probability was reduced[15]. The impact of shared risk link group (SRLG) failures on shared path protection was studied by calculating the percentage of connections that are effected after SRLG failures, thus investigating the advantages of backup reprovisioning after SRLG failures. Another Technique based on the behavior of ants for finding the shortest path between the source and destination nodes is ant colony optimization (ACO). Ying Lu and Wen Hu et.al [16]studied the behavior of ants in finding the shortest path from source to a desired destination. They analyzed ACO method to find various shortest paths and concluded that ACO can help overcome network survivability problems and can also reduce broadcast storms In a recent study by Mallika [17] analyzed the existing survivability techniques and proposed a modified approach for survivability in case of single link failure using ant colony organization (ACO). The proposed method improved the time complexity and also reduced the number of nodes involved in the recovered path. This proposed method showed improvement in results obtained from simple ACO technique and this proposed work can further be extended to double link failures. Ning-Hai Bao [18] have studied the impact of double link failure on optical mesh networks and they proposed an enhanced resource sharing scheme for double-link failures with resource contention resolution for surviving double failures in mesh networks. This newly proposed scheme can provide 100% protection from double link failures in optical mesh networks. Ina recent study by Md.Saifur Rahman [19] he proposed a new method based on predefined cycles which can help in surviving single link and dual link failures in optical WDM network. This newly proposed method decreases the restoration time from link failure thus decreasing the time complexity. He also analyzed the existing research and concluded that the maximum existing research focuses on single link failures while the dual link failures are still uncommon. Mariusz Dramski [20] studied and did the performance analysis of both Dijkstra and ant colony algorithm and concluded that Dijkstra algorithm assures 100% restoration and the recovery time is very less as compared to ant colony optimization which doesn't assures 100% recovery and the backup path is the shortest in case of Dijkstra algorithm. Thus any network impairment affects the QOS of the network and Tong Wang [21] has discussed about QOS and how network impairment affects the QOS of a network. He also discussed about the important efforts that are done in the field of survivability. After presenting the survivability research in WDM, Multiprotocol label switching(MPLS) and Synchronous optical networking(SONET) network, etc., he then move to the wireless network survivability. He discussed about the survivability of network in case of WSON and the present research efforts going on in this field.

Table 1: Comparison of Protection and Restoration schemes

Sr. No.	**Parameters**	**Protection Technique**	**Restoration Technique**
1	Resources	Pre-Reserved	Not Pre-Reserved
2	Resource Utilization	Low Resource Utilization	Better Resource Utilization
3	Hardware Requirement	More Hardware is Required	Less Hardware Requirement
4	Efficiency	Ensures100% Recovery From Single Link Failures	Depends On Available Network Resources
5	Recovery time	Minimum	Depends upon availability of resources

IV. CONCLUSION

With the advent of technology and the explosive expansion of internet, communication using higher data rates has become a need of the present and future generations and failure due to any reason can cause a large financial or revenue loss and thus survivability plays an important role. A lot of research has been done on survivability earlier particularly on single link failures and there is still a lot presently going one. Basically there are two methods for survivability protection and restoration both has their Advantages and disadvantages as discussed. A most appropriate survivability technique is the one in which the network restoration time from network failure is minimum and the backup path length should be minimum.

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