Link Failure Recovery in WDM Networks

Mallika, and Neeraj Mohan

Abstract— The explosive growth of Web-related services over Internet is bringing millions of new users online, thus feeling enormous demand for bandwidth. Optical communication networks employing WDM(Wavelength Division Multiplexing) are deployed to satisfy our increasing bandwidth requirements. WDM is an important technique which allows transport of large quantities of data. All optical WDM-based networks have been used to improve overall communication capacity and provide an excellent choice for the design of backbone networks. Because of the large amount of traffic a fibre carries, a single failure in a WDM system would cause severe service loss.So survivability against failure becomes very important issue. The survivability of a network refers to a network's capability to provide continuous service in the presence of failures since a failure can lead to huge data loss.. . In our proposed method whenever link in network fails, adjacent shortest cycle is used as its backup path. Shortest path is calculated using ACO (Ant Colony Optimization) algorithm. Then these adjacent cycles are updated using restoration method. It can survive link failure and theoretically provide better performance than existing restoration methods.

Keywords— Survivability, Wavelength Division Multiplexing (WDM) Networks, Restoration, Link failure.

I. Introduction

OPTICAL Fiber communication systems offer a huge bandwidth as compared to copper cables. They are also less susceptible to electromagnetic interferences. The first transatlantic optical communication system, TAT-8, was installed in 1988, operating at 140 Mbps. Since then, in almost 16 years, advances in optical communication technology have facilitated transmission speeds exceeding 1 Tbps [1].

First generation optical networks employ fiber only as a transmission medium. These networks essentially replace copper cables with optical fibers. The key feature of first generation optical networks is that all processing is carried out in the electronic domain. The electronics at a node must handle all data intended for that node as well as all data passing through the node and destined to other nodes in the network. [2]

Second generation optical networks use WDM technology to split the huge bandwidth provided by a fiber into multiple wavelength channels, that can be used to support multiple transmissions simultaneously. Also, some of the switching and routing functions that are performed by the electronics in first generation optical network can be carried out in the optical domain in second generation optical networks. [3] These are also known as WDM optical Networks.

With the growth of communication technology at high speed, WDM optical networks are the future network, because these type of networks offers many advantages and can handle large amount of data for communication. WDM is the most important technique that allows for expanding the inherent great capacity of optical fibers.

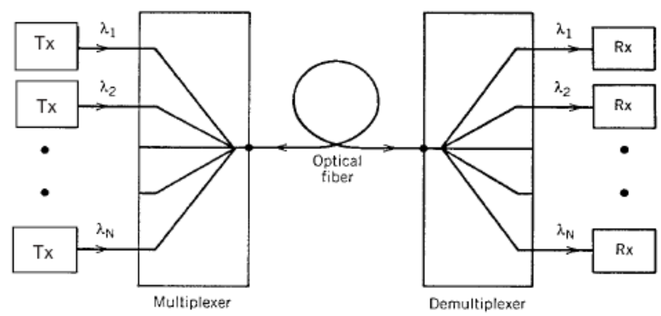

Fig. 1 WDM (Wavelength Division Multiplexing)

WDM refers to the technology of combining multiple wavelengths onto the same optical fiber. Each wavelength is a different channel. At the transmitting end, there are *W* independent transmitters. Each transmitter *Tx* is a light source, such as a laser, and is independently modulated with a data stream. The output of each transmitter is an optical signal on a unique wavelength λ_i , i = 1, 2, . . . , W. The outgoing signal from different transmitters are multiplexed together using a multiplexer. Then power amplifieramplifies the combined signal. Due to attenuation signal may need amplification whic is carried out by amplifier. Finally at destination, the combined signal is amplified agaian and de-multiplexed. Due to de-multiplexing,the signal is split into different wavelenghts which are converted to electronic domain using photodetectors.

II. Failure Occurrence

As WDM optical networks are becoming more and more popular for today's fast telecommunication networks and the Internet, the demand for a fault free or fully fault tolerant network system is also increasing. Since a huge amount of data can travel at a tremendous speed through the fibers of the optical networks, interruption of any component of the network system can cause the loss of a large amount of data.
As optical networks are being rapidly deployed on a global scale, protecting a network from different types of faults and failures have become particularly important

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In a WDM network, failure may occur in any component of the network. Optical networks also suffer different kind of failures. [4] Link, node and channel failures are very common. Node failures occur because of equipment failure at network nodes & link failures are normally caused by fiber cuts which impair service continuity to countless number of users. A channel failure is usually caused by the failure of transmitting and/or receiving equipment operating on that channel. [5]

One of main services of operation network that must be deployed efficiently is reliability. In order to deploy a reliable networking strategy, one needs to protect transmitted signal over unreliable links.

Network capable of protecting itself against failure is called survivability.

A. Survivability

Survivability of a network refers to a network's capability to provide continuous service in the presence of failures. Network Restoration refers to ability of network to restore or recover from failure. Different restoration techniques have been proposed to ensure survivability. But an efficient restoration scheme is a demanding request in this field.

There are essentially two main strategies to achieve survivability of a network: protection and restoration. Protection preplans backup routes that are used in the event of a failure. Restoration addresses failures by locating free wavelength channels for backup after a failure occurs. [6] In our paper we are focusing on restoration techniques.

III. Restoration Scheme

Restoration in optical networks refers to the process of rerouting the affected traffic after component failure. Lightpath is a connection in all optical networks, which is totally optical except at the end nodes. There are two types of lightpaths: primary lightpath and backup lightpath. Primary lightpaths are those lightpaths upon which data transmission takes place under normal conditions. Backup lightpaths are those lightpaths which carries the data when primary lightpath cannot be used due to failure occurrence.

Restoration methods can be categorized as proactive and reactive.[7] *In proactive scheme* alternate routes are pre calculated. After the fault occurs, the connection is simply rerouted to the previously calculated route. *In reactive scheme* alternate routes are calculated after the actual fault occurs.

Typical reactive schemes flood packets into the network after the fault to look for free capacity and to set up the new path. The proactive or reactive schemes can be either link-based or path-based.

In *link based methods*, the end nodes of the failed link participate in a distributed algorithm to dynamically discover a new route i.e. demands is rerouted around the failed link. [8] This alternate path is used for recovery. The method is illustrated in Fig.2. The figure shows a primary lightpath P1, 1-2-6 and a backup lightpath 1-4-5-2-6 is used when link 1-2 fails while retaining the working segment of 1-2-6.

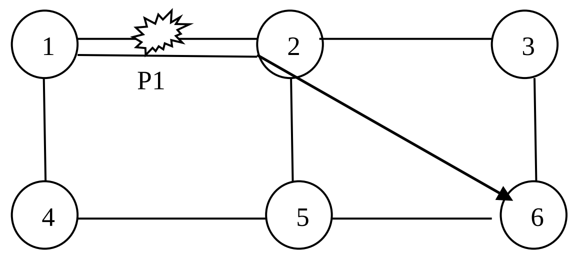

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Fig. 2 link-based backup path reservations

In path-based restoration, a complete new path is used as alternate path. Schemes with dedicated backup reserve the backup route for the particular demand. The path-based restoration method is illustrated in Figure 3. Figure shows a primary lightpath, 1-2-6 and it uses backup lightpath as 1-4-5-6 on a given wavelength. Note that 1-4-5-6 is established between end nodes of 1-2-6 and the working segment of 1-2-6 is not utilized by 1-4-5-6.

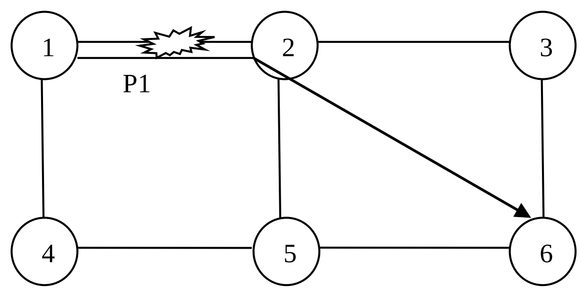

Fig.3 path-based backup path reservation

Our approach is to implement efficient algorithm for survivability of network failure. We want to improve the performance of existing restoration schemes & propose method that can be able to :

i. Reduce the restoration time taken to recover from failure.
ii. To select shortest backup path in case of network failure

IV. Proposed Method

In our proposed method to transmit traffic from source to destination, Ant Colony Optimization is used to establish primary path between source & destination. After selecting primary path source transmit data to destination. To survive link failure all independent cycles are determined. Every node stores its all adjacent cycles. Every link can be attached to one or more cycles. To restore backup path of failure link the shortest adjacent cycle of this failure link is used. After restoring failure link all nodes of this link adjacent cycles update their cycles.

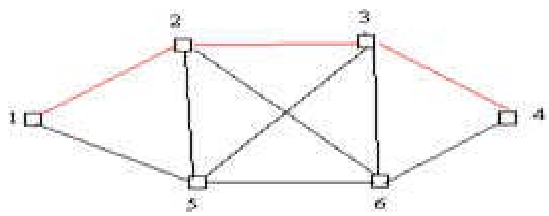

Fig. 4

According to our proposed method fig. 4 consists of the independent cycles 1-2-5-1, 2-5-3-2, 3-5-6-3 and 3-6-4-3.Here node 1 contains the cycles 1-2-3-1 and all the link backup paths of these cycles. Similarly other nodes contain their adjacent cycles and their link backup paths. Here 1-2-5-1 cycle can provide the backup path for link 1-2 by 1-5-2, 1-5 by 1-2-5 and 2-5 by 2-1-5. As 1-2 is external link so it is adjacent to one independent cycle and has one backup path. On the other hand 2-5 is internal link so it is adjacent with two independent cycles and has two backup paths, one is 2-1-5 and other is 2-3-5. The shortest cycle is used to recover backup path.

A. *Algorithm for proposed Method*

Ant colony optimization is a meta-heuristic technique that uses artificial ants to find solutions to combinatorial optimization problems. ACO is based on the behaviour of real ants and possesses enhanced abilities such as memory of past actions and knowledge about the distance to other locations. In nature, an individual ant is unable to communicate or effectively hunt for food, but as a group, ants possess the ability to solve complex problems and successfully find and collect food for their colony. Ants communicate using a chemical substance called pheromone. As an ant travels, it deposits a constant amount of pheromone that other ants can follow. Each ant moves in a somewhat random fashion, but when an ant encounters a pheromone trail, it must decide whether to follow it. If it follows the trail, the ant’s own pheromone reinforces the existing trail, and the increase in pheromone increases the probability of the next ant selecting the path. Therefore, the more ants that travel on a path, the more attractive the path becomes for subsequent ants. Additionally, an ant using a short route to a food source will return to the nest sooner and therefore, mark its path twice, before other ants return. This directly influences the selection probability for the next ant leaving the nest [6]

In our work, the ACO is used for finding the shortest path using the distance value assign to the each node The host of the ant is considering as the source node and their food is representing as the destination. The current node is act as an ant in routing process for finding the next shortest node in network. [9]

In general the ACO assign two ants such as forward and backward ant. The forward ant is used while searching the food and the backward ant is used when the ant get back to host. But in transferring the information, only the forward ant can be used. There is no use of backward ant in the transferring process, but it can be used for the acknowledgement purpose. Here the current node is assign as a forward ant during the transformation; it can be also act as backward ant during the acknowledgement. [10]

The sequence of steps in proposed algorithm is as follows:

Step 1: Forward ants to all destinations are launched by each network node in regular time intervals.

Step 2: The ant calculates a path to the destination based on the current routing tables.

Step 3: The stack is created by forward ant, pushing in trip times for every node as that node is reached.

Step 4: When the destination is reached, the backward ant inherits the stack.

Step 5: The stack entries are then pop by backward ant and follows the path in reverse.

Step 6: The node tables of each visited node are updated based on the trip times.

Step 7: The message ant is generated as link failure occurs.

Following pseudo code describe the functions of a node when it behave as forward/backward ant during path finding between source to destination:

```
if (Forward ant)
{
Get the next node based on the pheromone value

if (the link is available and no loop caused)
   then
{
Update forward ant with network status (stack)

Send forward ant to the next node
}
else if (no such link exist)
{
Create backward ant and load contents of forward

ant to backward ant (queue)

Send backward ant towards source along the same path as
forward ant
}
}
if (backward ant)
{
 if current node is source node
{
Store path, kill backward ant and update routing table
 }
else
{
Forward backward ant on to link available on queue

update routing table
}
if (next node is not available)

Kill backward ant
Else
 {
```

if (link failure)
then
Update forward ant with network status as failure and stop sending information (data)

Send message ant to the previous node regarding link failure and update of table for alternative path till path is recovered or restore
}
}

At first we have to find all independent cycle in the network graph G (i , j). In our approach every node contain all its adjacent independent cycle. Only one or two cycles can be adjacent with a link. Whenever a primary path fails we find its adjacent shorter backup path. In case of multiple link failure always active cycle works for surviving iteratively.
All independent cycles in the network are determined and every node has to store its adjacent cycles. By using this cycle backup path nodes adjacent links can be protected.

1. Calculate the shortest path p(l) between source and destination using Ant Colony algorithm.
2. If a link failure is detected by p(i) node on the primary path
   Then set check=0,Max=number of adjacent cycles to p(i) node

2.1 For *(j=1 to Max)*
Find shortest backup path,bp among adjacent cycles.
Set *check=1* and break
Set *length*=active backup cycle length
End loop
2.2 if *(check=1)*
Set a new backup path =bp
Else No path available
End If

3. Then the node by which the failure is detected, send the setup message to source using bp and send lost data from the source.

4. Then affected traffics are retransmitted along the selected new backup path.

5. Then all the nodes on adjacent cycle to the failure link just update their affected cycle.

V. Results & Discussions

To analyse the result we have considered node 1 as source and node 13 as destination. In this network we have primary path as 1-5-4-10-17-13. We have considered a case when link 10-17 fails.

In proposed method, node-17 detects the failure and link 10-17 is protected by its adjacent cycle 10-15-17. Then node-17 sends FNM (Failure Notification Message) to source by using 17-15-10-4-5-1. When FNM reaches source node traffic is retransmit using restored path 1-5-4-10-15-17-13. .

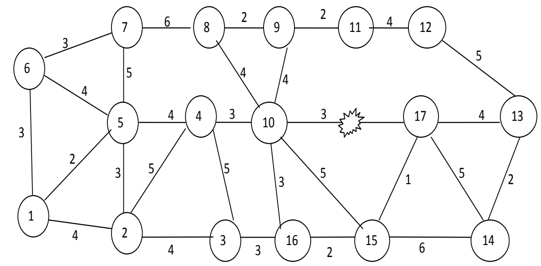

Fig 5

TABLE I
RESULT FOR FAILURE RECOVERY IN CASE OF SINGLE LINK FAILURE FROM ABOVE FIGURE

Restoration Scheme	No. of nodes to recover path	Nodes used to acknowledge	Nodes used to resend data
Proposed method	6	17-15-10-4-5-1	1-5-4-10-15-17-13

VI. Conclusion

The proposed method is able to reduce the failure recovery time. The number of nodes involved in the solution are also reduced. This proposed method is applied to single link failure. It may be extended to multiple link failures in future.

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