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FAULT TOLERANT FIBER TO VILLAGE USING PASSIVE OPTICAL NETWORK

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ABSTRACT

Fiber occupied networks are coming out with a performance is supporting the ongoing demands for very huge connections. One best technology that has evolved in the previous few course of time is Passive Optical Networks. Fiber to the X is in very huge demand all over the world. To contend the demands of the rural and semi urban areas FTTX networks need to be upgraded. In this paper we propose a inexpensive solution for fulfilling the demands of rural area using the existing passive splitter based infrastructure.

The basic idea of the paper is to construct a network architecture that would be the optimal design for this network. In this paper, an aspect of Fiber based Passive Optical Network Technology will be presented.

The need of higher capacity Networks in the rural areas is to be developed on the basis of day to day emerging high data rate demands in rural and semi urban areas. FTTV for broadband application may be considered an effective solution for higher capacity networks. PON based technologies are new for Indian telecom network and will grow extensively in near future for higher capacity applications.

Furthermore, the maintainers issue will be a critical factor for designing a Fiber to the village Network. The paper will analyze the fault tolerance in a Passive Optical Network and the results will be used for Design of Fault tolerance FTTV.

Secondly, the paper analyzes the loss budget and transmission capacity which both are crucial in design of a network. This will give the basic design concepts and technical tradeoffs we need to assess in the system. Furthermore, the future work will be to make FTTV cost effective and provide the best optimal design of FTTV network.

1. INTRODUCTION

As we breathe in the 21st era, the age of 'Information technology' there should be no ambiguity that information technology has an exponential increase through the recent telecommunication systems. Talking particularly, optical fiber communication shows a major role in the advancement of very good quality and huge-speed telecommunication systems.

Today, both in urban and rural areas there is a need of high speed data rate for use of internet and other data services. To fulfill the need of high speed data in the rural areas it is necessary to pave the path of Fiber to the X (FTTX) technology for supplying broadband access in the semi urban and rural areas. The Technology named Fiber to the Village (FTTV) will provides sufficient bandwidth and will be presenting Triple Play services (Data, Voice, Video) on a single fiber at long distances .FTTV will be ready to meet potential future requirements for supplying additional services such as Video on demand. Also the progress in the electronic equipment and dropping prices of fiber will make FTTV deployment a great choice for the telecom operators that will result in long term returns.

1.1 PASSIVE OPTICAL NETWORK

PON is a point to multipoint (P2M) network. A passive optical network system usually consist of optical splitter, optical line terminal (OLT) and optical network unit (ONU) at every subscriber house, and also the optical fiber lines that joins all these components. Every subscriber is connected via a passive optical splitter into the

network[1,2]. The ability to withstand the demanding and severe outside environment of purely optical passive components are the main advantage of FTTX PON[2].
In PON downstream signals are broadcasted to every subscriber which shares multiple fibers. Upstream signals are combined from every subscriber using multiple access protocols such as TDMA (Time division multiple access).
PON FTTX solutions are driven by two key standards: IEEE and ITU, and solutions can be built with any of the both standard. There are different PON technologies available today.

1.2 PON COMPONENTS AND ARCHITECTURES

PON basically consist of a centrally based office node; know as optical Line Terminal (OLT), one or more than one subscriber node; often known as Optical Network Terminal (ONT) or Optical Network Unit (ONU), Optical Splitters and Fibres, called Optical Distribution Network (ODN).

In passive optical network ONT acts as a transceiver and is the physical connection between the subscriber and central office. The Multiplexer module in the OLT separates all the wavelengths 1550nm, 1490nm and 1310nm [2,3]. ONT accepts data at 1490nm and burst traffic is send back at 1310nm. Protocol such as MAC (Medium access control) controls the upstream traffic in an ordered manner and avoids the collision due to upstream of data from different subscribers. Video receiver converts the 1550nm signals to co-axial signals. ONU has plain old Telephone service (POTS), Ethernet and RF video interface. Figure 2.1 shows the typical PON architecture [3].

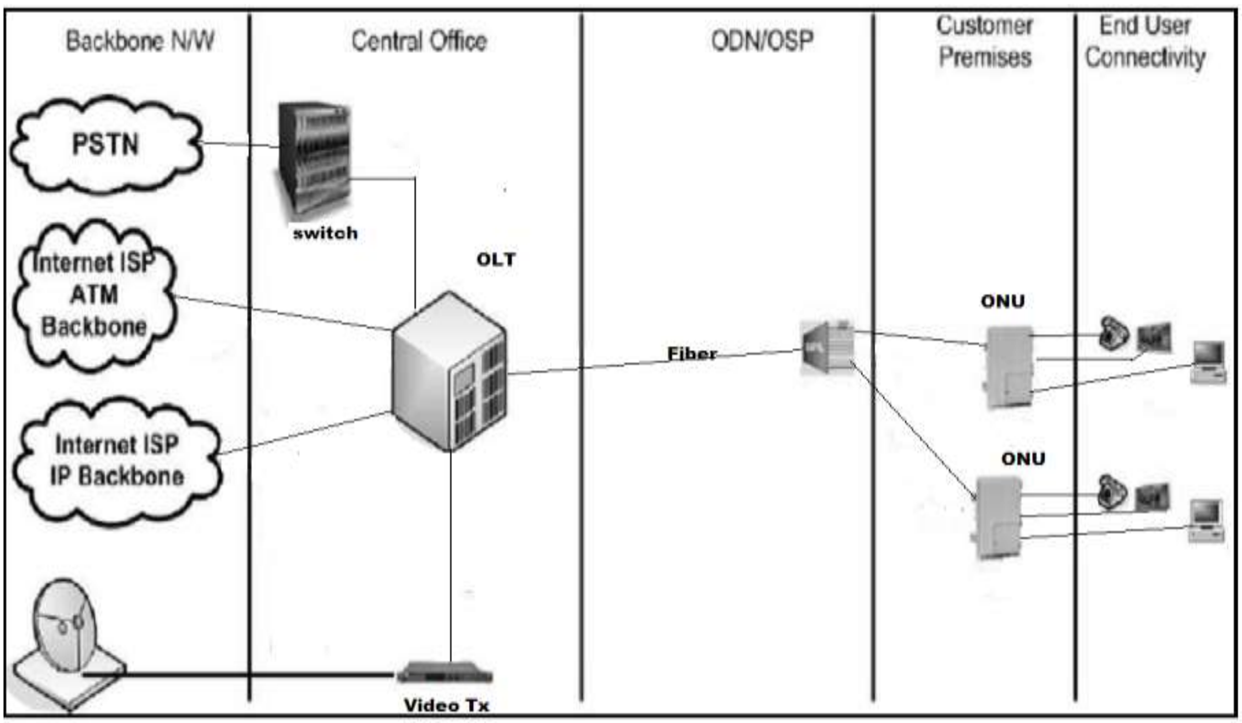

Figure PON Architecture [2]

2. FAULT TOLERANT PASSIVE OPTICAL NETWORK

Property that enables a system to continue operating even when a failure of one or more component occurs is known as Fault tolerance. Passive optical networks are basically made on physical and broadcast topologies such as bus, tree or a star topology. These topologies are easily liable to link damage and failures. In this chapter a reliable, tree structured passive optical network configuration is presented which can resist all single and double link failures in a network architecture [4].

By conducting several experiments it has been seen that the topology which has to be chosen for network is independent of other system consideration. This information gave the direction that tree topology was best suitable topology than star and bus topology on the basis of cost and power respectively. Another important aspect to see after on the grounds of power and cost is the fault tolerance of a topology. By service provider perspective this fault tolerance issue will be playing a critical role when network would be deployed in rural areas. The network that is proposed basically protects from single link failure and double loop topology based.

2.1 REDUNDANT TREE TOPOLOGY

Redundancy is a technical term meaning things which can be left out without the loss of functionality. The redundant tree structure was configured using two separate physical discretely routed trees. The two diverse routed trees were super positioned or overlaid on each other which resulted in redundant tree. In general PON Optical couplers are used at the nodes which behave as filter and switch of the network. The only switch here was in the subscriber premises from where the subscriber was permitted to choose any of the two routed trees. The so called redundancy was maintained by this overlapping of trees. The main challenge was to keep the whole network passive and also flexible and efficient [4].

3. IMPLEMENTATION OF REDUNDANT TREE TOPOLOGY

The implementation of the redundant tree topology is very basic. The construction of this redundant tree topology was done from the two discrete routed trees wherein one was named as Left Tree (LT) and the second one Right Tree (RT) (Fig. 3.1). Basically the functionality of both the trees is identical in the sense that both the trees touch each and every station or subscriber end. Now both the trees are overlaid on each other which make each subscribe end or station (Leaf Node) or ONU available with two different inputs, one from each tree (Fig. 3.2).

Figure Discrete Routed Tree[4]

In the network that is implemented, every station or subscriber has a way to reach the root of the network or OLT with two different links. As every station can reach the root with two different paths so if there is a single link failure than to the station will not be disconnected from the network. The couplers are located in the internal nodes of the network and these internal nodes are kept in the protected areas i.e. physically protected areas. So the danger on damaging of internal nodes is minimized. So in this research the internal nodes are perfectly reliable.

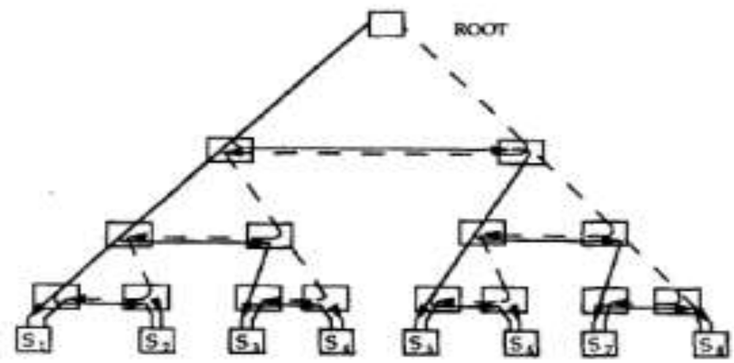

Figure Redundant Tree [4]

3.1 FAULT TOLERANT PROPERTIES

The network as can be seen is now protected from single link failure. In order to rattle the network one can easily state the conditions under which multiple link failure will make a disorder in the network.

3.2 CONDITION FOR MULTIPLE LINK FAILURE

Assuming the two failures have occurred shown in figure 3.3 or the multiple link failure is occurred, consider that at the lowest level of the tree i.e. farthest away of the root node the failure has occurred. Suppose the break down occurs at the left link, then sub tree which is just beneath the failure has a backup path which is on the right link. Hence in order to cause complete disorder of a station the second breakdown should be on the backup path.

Generalizing it can be said that in order to disrupt the network the second failure should have to be on the backup path but network can still be connected after these link failures [4]. From a practical point of view, we can easily state that the number of the failures will increase as we go down in a network because links goes on increasing as we go down the network. Therefore we can conclude that larger the tree the less is the probability that the number of breakdown are path correlated. Hence we can conclude that probability that multiple link failure cause disorder in network goes on decreasing as number of breakdown of links goes on increasing in large trees.

3.3 FAILURE IDENTIFICATION

The tree structure shown here has the ability to detect where in the network the failure took place. The failure identification is shown as follows:

If a station gets affected by any breakdown, it transmits the signal to network control centre that the breakdown has occurred. It also tells the station that which link i.e. the left link or the right link has a failure [4]. Then with the aid of message that is received from the station and the awareness of the position of the station NCC detects the exact location of the network. This is shown in figure 3.4 below:

If we suppose that link BC has a breakdown. Then all the station in left tree which are just beneath the node B communicates that the breakdown in the right tree has occurred. Now the network control centre analyzes that which link i.e. either BC or AB has a breakdown. Now the measurements at local level are used to determine the breakdown [4].

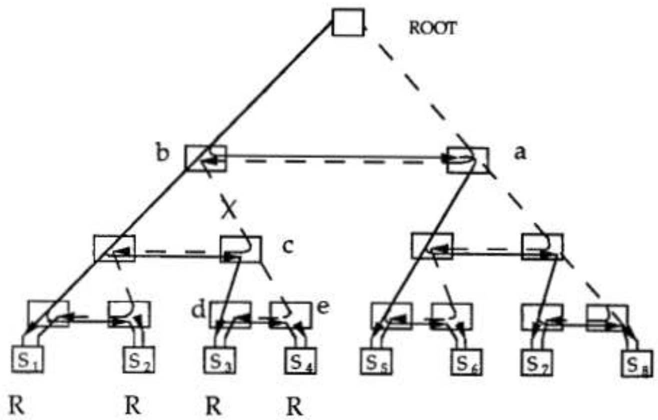

Figure Failure Identification with Redundant Tree [4]

Suppose a station say S_3 does not report a breakdown of the right tree link failure, then network control centre doubts that station S_3 has breakdown or link DE has also failed.

When a subscriber switches itself from one path to another path then recalibration of power may be required as the attenuation of second path may differ from primary path due to difference in path lengths. Such synchronization is provided by the calibration unit installed in the subscriber station [4].

4. DESIGN OF FIBRE TO THE VILLAGE NETWORK

4.1 BASICS OF FIBER TO THE VILLAGE

Basically fiber to the village would be an application of passive optical network. It is basically a passive optical network with some improved devices in the network. The basic idea comes from the fact that there is optical network everywhere and if we bring fiber as close to as subscriber then subscriber could be benefited more and more.

Establishment of fiber to the village technology in semi urban and rural areas is considered as a challenge since it requires many challenges to settle in. Firstly, it is a complete new infrastructure and 70% of the total cost for deployment of a new network is roughly considered as engineering cost. Secondly, the maintainces cost which is the other major challenge in the establishment of a new network.

Key challenges that would be faced in designing the network are:

- Optical Network is considered as expensive and faulty.
- Fiber cabling and optical devices are expensive.

4.2 FAULT TOLERANT FTTV NETWORK PROPOSED

Considering the study of fault tolerant network, a network was proposed which resembled the same properties that were discussed in the chapter 3. Figure 4.1 shows the fault tolerant network. Another network was made as discussed in chapter 3 as shown in Figure 4.2

Network consists of a parent node or root node that would be optical line terminal. The network shown is assumed to be deployed from central office to subscriber where in subscriber is located in the village. The root node that is optical line terminal is assumed to be located in the city and fiber is deployed from the root node to the main node where in the main node is assumed to be located in the village. Fiber is deployed to village via passive optical splitter which is 1:4 optical splitters. From main node of the village fiber is splitted into different subscriber house named station S_1 to S_{16}.

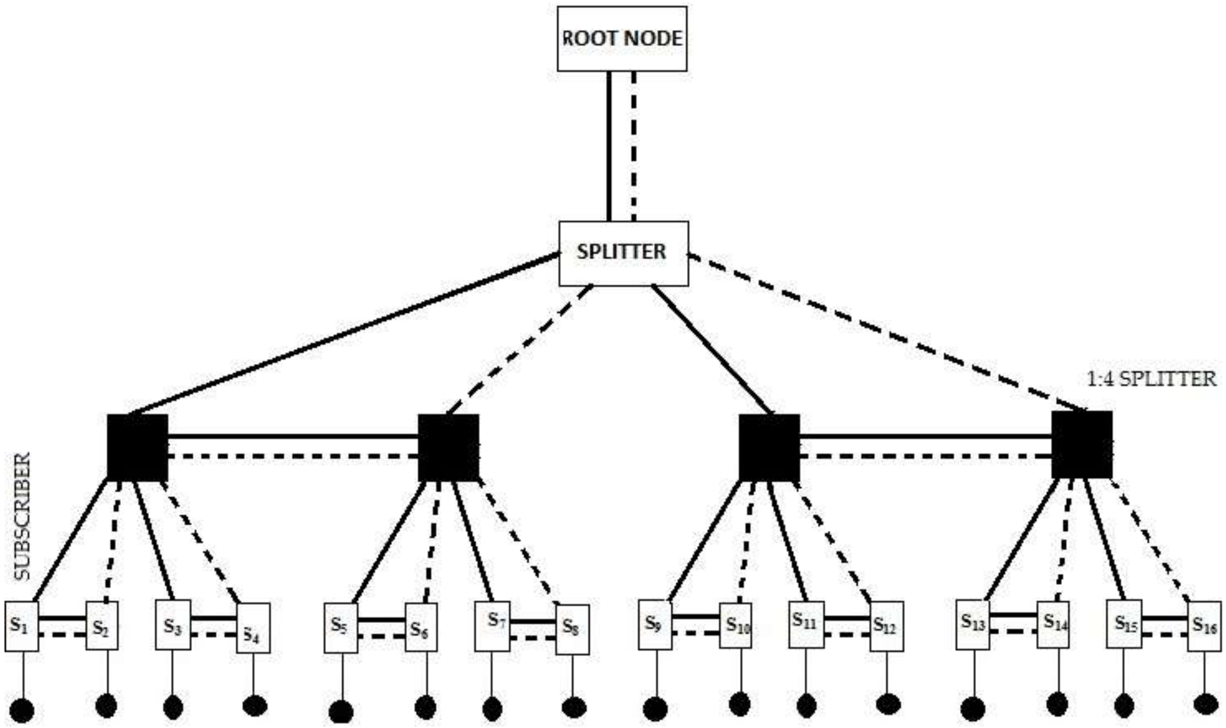

Figure Fault Tolerant Tree Structure with 1:4 Optical Splitters

4.3 DEGREE OF FAULT TOLERANCE OF PROPOSED NETWORK

Degree of fault tolerance of both the networks can be compared by a measure. The measure is that what is the probability that a particular number of a link breakdown can disconnect a station from the network.

Analysis of 1:4 Optical Splitter Based Network

Analysis for 1:4 splitter based network is based on the case of double link breakdown as one link breakdown will not produce disconnections in the network. We do not consider the case of more than four link failures as more than four links failure are very rare in a network. The assumption is taken that the two link breakdown can occur anywhere in the network. Second assumption is that all the links have the same probability to be faulty.

The links are basically categorized in two categories:

- Lined Link
- Intersected or Bisected Link

Lined links belongs to a same tree i.e. both the link which are broken can be of a single tree either the right tree or left tree. Similarly, Intersected or Bisected links are composed of two links one link which is broken should of left tree while the other broken link should be of right tree.

Below are all the possible combinations of four link breakdown which can cause disruption of the network. For each of the below cases we will take out a equation which will show the number of link pairs by which disconnection of station occurs. Let the maximum number of levels for a tree is some arbitrary N. And let there be a intermediate level M. The possible cased are:

Four bisected links at distinct level of tree, where the two links broke down at lower level should be a part of the subtree of the two links broke down at upper level.

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The number of pair of link L_1 for this case can be calculated as follows:
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Firstly we consider all the bisected links at some level *M*
From basic knowledge of graph theory it can be inferred as
Links at a particular level is given by: - $4^{(M-1)}$
Links lower than that particular level, M is given by: - $4(4^{(N-M)} - 1)$

Where N is the maximum numbers of level in a tree and 4 is multiplied because there are 4 bisected trees. Now by multiplying both the links we can get maximum number of links,

$$L_1 = \sum_{M=1}^{N-1} 4^{(M-1)} 4(4^{(N-M)} - 2)$$

Four lined Link at distinct tree i.e. two link of right tree and the other two of the left tree where the two links broke down at lower level should be a part of the subtree of the two links broke down at upper level. In this case there is also a case where disruption occurs if both the lined links are going from same node and are on same level as well.

The number of pair of link L_2 for this case can be calculated as follows:
From basic graph theory it can be inferred as described below
Lined links at same level is given by: – $(4^N – 1)$
Maximum Number of Links belonging to same tree is given by: - $4^{(M-1)}$
Lined link of the other tree which is a subtree of first lined link is given by: - $(4^{(N+1-M)}-4$
The summation is taken so that it takes the entire linked link at different level. 4 is multiplied because there are two trees Right and left tree. Now for every level M the number of lined link which belong to any of the two tree i.e. $4^{(M-1)}$ is multiplied by the lined link of the other tree which is a subtree of first lined link. So,

$$L_2 = 4\sum_{M=1}^{N-1} 4^{(M-1)}(4^{(N+1-M)} - 4) + (4^{L} - 2)$$

Two Lined Link and Two bisected link where the two lined link should be at a upper level than the other two bisected link and the other two should be a part of subtree of lined link.
The number of pair of link L_3 for this case can be calculated as follows:

$$L_3 = 4\sum_{M=1}^{N} 4^{(M-1)}(4^{(N+1-M)} - 4)$$

Two Bisected link and two lined link where the two lined link should be a part of two bisected link. More accurately it can be seen as the two lined link should be a part of left tree if it on left side of the two bisected link and vice versa.
The number of pair of link L_4 for this case can be calculated as follows:

$$L_4 = \sum_{M=1}^{N-1} 4^{(M-1)}(4^{(N-M)} - 2)$$

So easily now the total number of pairs of link which disrupt the network can be given by L_B

$$L_B = L_1 + L_2 + L_3 + L_4$$

Now, Total Number of links in a graph N_T i.e. both the lined links and cross links can be given by

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$$T_N = 3(4^N - 2)$$

And Total Number of pairs in graph is given by

$$N_p = \binom{T_N}{4}$$

So the probability that two link breakdown can cause disconnection in the network can be given by

$$P_D(N) = \frac{L_B}{T_N}$$

On calculating the probabilities, a graph can be made between the levels of tree and the probability of disconnection

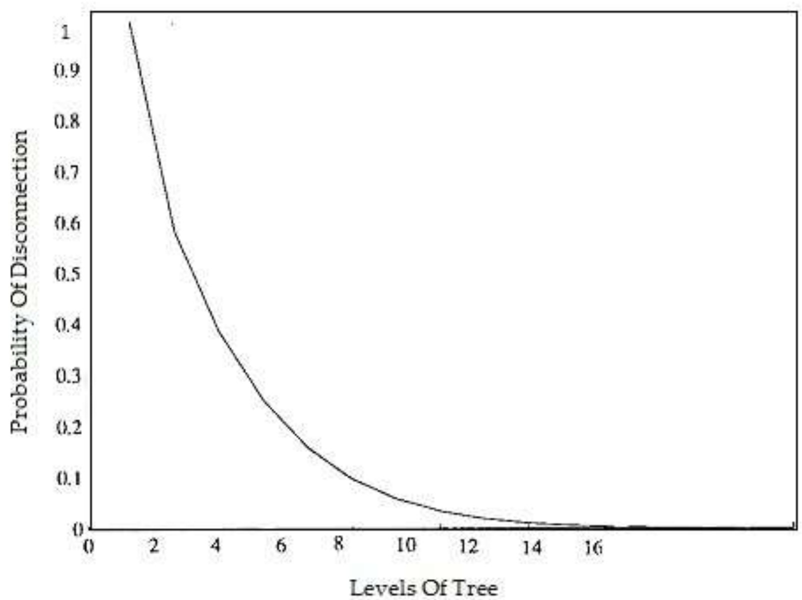

Figure Probability of Disconnection vs. Levels of Tree for 1:2 Splitter based Network

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