

# Fiber-Wireless (FiWi) Access Network: Comparison of Different Topologies

Pranati Sumedha, Akshay Amitabh, Shipra Mishra

**Abstract:** By combining the capacity of optical fiber networks with the wireless networks, FiWi networks form a powerful platform for the support and creation of emerging as well as future unforeseen applications and services. FiWi supports very high speed transmission rate, hence any kind of failure may result in significant data loss. To prevent this, there is a requirement to design a more reliable network. In FiWi networks there are two types of failures: ONU (Optical Network Unit) level failure and OLT (Optical line terminator) level failure. In this paper, we present comparison of backup ONU's connected from each segment in different topologies, to handle segment level failure. Comparison is done on the basis of reduced blocking probability.

**Keywords:** FiWi; ONU; Blocking probability; Ring Topology; Mesh Topology; Star Topology; Tree Topology

## I. INTRODUCTION

The volatile growth of bandwidth concentrated applications is creates the need of lower cost, higher bandwidth and flexible networks. The example of existing access technologies are PON (Passive Optical Network) and WMN (Wireless Mesh Network). Optical fiber provides an unparalleled bandwidth potential that is much greater than any other known transmission medium and also offers considerably longer ranges without requiring any active devices. Optical fiber has some further beneficial properties such as durability and low maintenance costs. WMN provides services in flexible manner but it is constrained by limited bandwidth. Therefore integration of both PON & WMN networks results in a new technology: "Fiber Wireless access network (FiWi)"<sup>1-3</sup>, which contains merits of both PON and WMN. FiWi offers flexibility to users to access broadband services with high data rate at lower cost.

Shipra Mishra, Asst. Professor, Department of ECE, BIT Mesra, 80014 India  
Email: [Shipra@bitmesra.ac.in](mailto:Shipra@bitmesra.ac.in)

In Fig. 1. , the architecture of FiWi network, a tree-mesh topology network, is shown. The network consists of two parts, the front end which includes WMN and back end which includes PON. Front end consist of wireless routers and network users located in different areas, connected to each other in a mesh fashion. Whereas, back end consist of optical cables connected to different ONUs with a wireless gateway, in a tree topology format. These ONUs play very important role in FiWi networks. They establish interface between front end and back end by converting signal in wireless to optical and then again optical to wireless format. FiWi is meant to provide high data rate, hence proper functioning of the network becomes a critical issue. The network needs to provide services even in presence of failure in the network. The failures in the network may occur either on front end or on back end. Because of the mesh structure, chances of failures are less in front end. On the other hand, back end consist of tree topology which results in higher blocking chances due to less number of rerouting paths. So, the failures at back end are starker than wireless front end. We can classify failures at the back end into two categories<sup>4</sup>: ONU level failure and OLT level failure. An optical line termination (OLT) is a device which aids as the service provider endpoint of a passive optical network (PON). Schematics of ONU level failure and OLT level failure are shown in Fig. 2. and Fig. 3. respectively. In ONU level failure, one of the distribution fibers fails whereas in OLT level failure, feeder fiber fails which results in huge data loss in FiWi network as compared to ONU level failure.

The rest of the paper is organized as follows: In Section II we summarize the previous works on FiWi network and related terminologies. In section III, we discuss about the various topologies, their advantages and disadvantages, and in section IV we present a comparison of backup ONU's connected to each segment in different topologies in terms of blocking probability. In Section V we present our conclusions regarding the same.

## II. RELATED WORK

As stated earlier, FiWi is expected to support high data rate, hence survivability and average packet delay are an important concern. Various algorithms were proposed to increase the survivability level of FiWi networks.

---

Pranati Sumedha, student Department of ECE, BIT Mesra, 80014 India Email: [sumedha.pranati@gmail.com](mailto:sumedha.pranati@gmail.com)  
Akshay Amitabh, student Department of ECE, BIT Mesra, 80014 India Email: [aksh.amitabh@gmail.com](mailto:aksh.amitabh@gmail.com)

The author in<sup>6</sup> put forward an algorithm which provides an effectual solution for protecting packet delay in the wireless front end. In this algorithm author envisages wireless link states periodically. After analyzing the links, author allocate weights to each link according to the delay offer by them. It is done in such a way that minimum delay link will assigned by minimum weight. Now from these minimum delay paths author chooses optimal path to transmit the data, which reduces the delay efficiently. To amend DARA<sup>6</sup> (Delay Aware Routing Algorithm) in terms of increased failure awareness, the author proposes RADAR<sup>7</sup> (Risk-And-Delay Aware Routing) algorithm. RADAR reduces successive packet delay among different users and more ever look after front end from different types of failures. The author in<sup>8</sup> propose more cost-effective algorithm than RADAR to shield FiWi against different failures and it is also more cost-effective than RADAR. This algorithm protects the network from different failures with lowest cost by heuristic solutions. The author selects one of the ONUs randomly from each segment as a backup ONU and arranges backup fiber among this backup ONUs. The failed segment will transfer to its neighbour segment via backup fiber connected between them. Each segment will be connected with at least one of the segment in the network. The OBOF<sup>9</sup> (optimizing back-up ONUs selection and backup fibers deployment) algorithm was projected which is better than the preceding algorithm in terms of cost-effective networks. The author concerns on the ideal selection of backup ONUs. Since if we select backup ONUs in random fashion then it will results in increased recovery cost to recover the affected traffic. The author implements the algorithm in two steps. First Backup ONU from each segment is selected by SA (Simulated Annealing) algorithm then to install backup fiber among backup ONUs from each segment EGCE (Enhanced Greedy Cost Efficiency) algorithm is proposed. EGCE algorithm is implemented in two different ways; RBS (Remote Backup Segment) method, BLB (Bound on Length Backup-Optical-Path). Further, author tried to reduce the network cost by using graph theory and termed algorithm as “Auxiliary Graph Based Protection (AGP)” algorithm<sup>4</sup>. In AGP algorithm one backup ONU from each segment randomly selected and then backup fiber is intalled in such a manner that each segment has one backup segment via backup ONU pairs. The algorithm was more efficient than OBOF in terms of optimal path with minimum delay. The algorithm improves the network performance by decreasing the fault chances and solves the problems of Maximum Protection Minimum Hops Number (MPMHN) and Maximum Protection Minimum Backup Fibers Length (MPMFL) more precisely. The author proposed an algorithm WRBR<sup>9</sup> (Wireless rerouting and backup radios) to protect FiWi against single segment failure by retaining wireless routers and configuring backup radios in a cost proficient manner. The author allocates a primary ONU with several backup ONUs via backup radio paths. Backup ONUs and wireless backup routers allocated in the network by mixed

integer linear programming (MILP) and heuristic solution.

Only single segment failure is considered in the above discussed work. In case of multiple failures these algo-

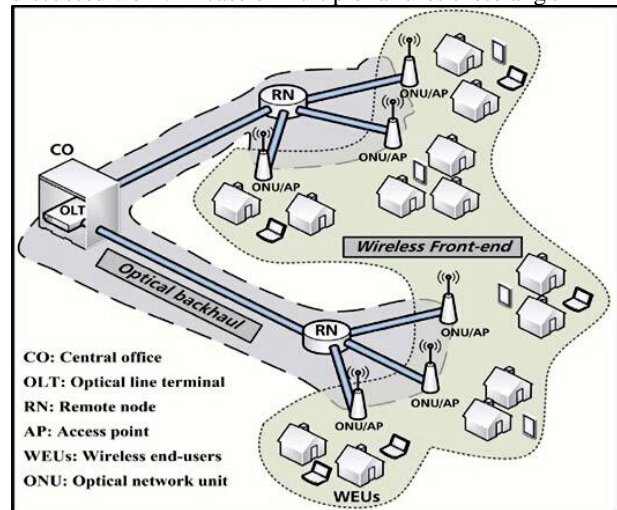


Fig.1. Fi-Wi Architecture

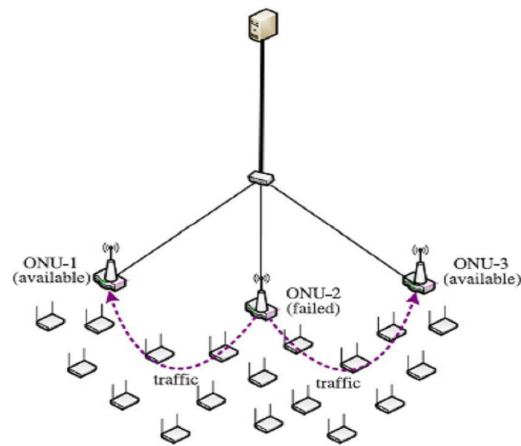


Fig. 2. ONU level failure

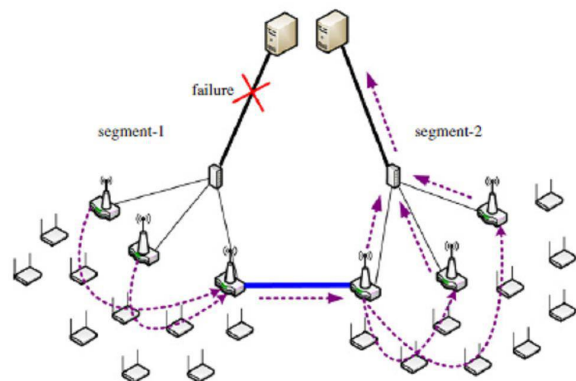


Fig. 3. OLT level failure

-ithms will be unsuccessful to serve. Therefore to guard the network against multiple failures, author put forwards

Ring based Protection considering Multiple Failures (RPMF)<sup>11</sup> algorithm. The backup ONUs from each segment will link to one another in a ring fashion via backup fibers. The system performance will improve, as it offers two optical paths for each segment to reroute the affected traffic. Author in<sup>12</sup> proposes SBR (Sharing Backup Radios) algorithm which protects FiWi from different level of failures in the network, where each ONU will connect to its partner ONU through a backup radio path. On the other hand SPR (Shortest Protection Ring) algorithm is proposed to protect network from OLT level failure.

**III. PHYSICAL TOPOLOGY**

It refers to the way in which a network is laid out physically, how links and linking devices are connected to each other. Following topologies are discussed below:

*A. Mesh Topology*

It is also known as point to point link. The link connecting the two device carries the traffic only between the two devices it connects.  $n(n-1)/2$  duplex physical links are needed for a mesh network with  $n$  nodes. Each connection carries its own data, hence traffic problem is eliminated. It is robust and if one link fails it does not undermine the entire system. Security of data is more as it prevents other users from gaining access to messages. Bulk amount of cabling is required and installation and reconnection is difficult.

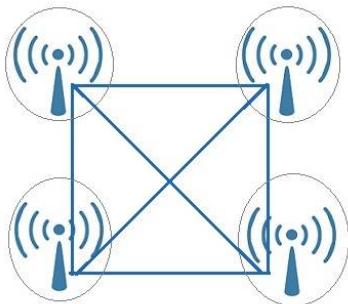


Fig. 4. Mesh Topology

*B. Star Topology*

It has point to point link only to central hub. The devices are not directly linked to one another and therefore there is no direct traffic between devices. The controller acts as an exchange and if one device has to send data to another device, sender sends data to controller which then forwards the data to the intended device. It needs only one I/O port to connect and therefore is easy to install and reconfigure. If one link fails only that link will be affected and others will remain active. As long as hub works it monitors the system.

*C. Ring Topology*

It has point to point connection with only two adjacent devices. All the nodes are connected in a loop. Signal passes through each node, which has a repeater, until it reaches its destination. When the device receives a signal intended for any other device, the repeater regenerates the bits and passes it along. It is relatively easy to install and configure but the unidirectional traffic can be disadvantage. A simple break in the ring affects the whole network.

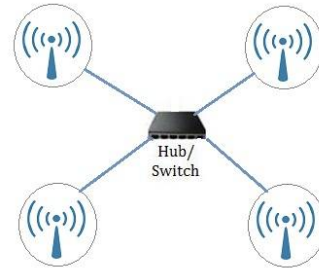


Fig. 5. Star Topology

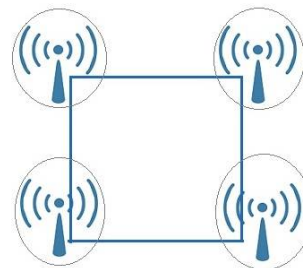


Fig. 6. Ring Topology

*D. Bus Topology*

It has multipoint connection. One cable acts as backbone and devices are connected to it by drop lines and taps. Though there is ease of installation but reconnection and fault isolation is onerous.

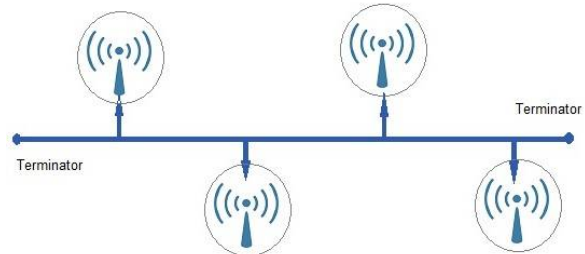


Fig. 7. Bus Topology

*E. Tree Topology*

Tree Topology integrates the characteristics of Star and Bus Topology. In Tree Topology, more than one Star

networks are connected using Bus. The main cable is like a main stem of a tree, and other star networks as the branches. Since, we divide the whole network into segments, it can be easily managed and maintained. Because of its basic structure, tree topology, relies heavily on the main bus cable, if it breaks the whole network breaks.

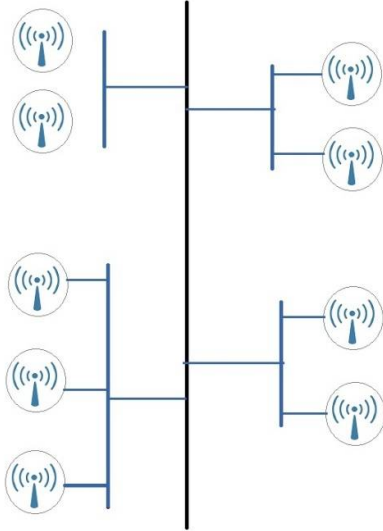


Fig. 8. Tree Topology

**IV. COMPARISON**

To evaluate the performance, we consider blocking probability. Blocking probability is defined as the ratio of number of packets fails to reach the destination to the total number of packets injected in the network. The difference in blocking probabilities among random, Ring, star, tree topology is depicted. By observing the performance evaluation parameter such as blocking probability ratio we compare which topology performs best on

Blocking Probability:

$$\text{Blocking probability} = \frac{\text{number of packets failed}}{\text{total number of packets}}$$

Where, number of packets failed = total packets-successful packets

$$\text{Number of calls} = 100$$

| S.NO | PARAMETERS               | OPTICAL LINKS |      |      |
|------|--------------------------|---------------|------|------|
|      |                          | STAR          | RING | TREE |
| 1.   | TOPOLOGY                 |               |      |      |
| 2.   | Call Blocking Ratio(CBR) | 0.07          | 0.47 | 0.5  |

Table 1. Comparison result based on Call Blocking Ratio<sup>13</sup>

**V. CONCLUSION**

Any component failure in FiWi may result in huge data loss, since it supports high data rate over the network. Hence, there is a need of a network which is more survivable and avoids such data loss. By comparing the values of different topologies on the basis of Call Blocking Ratio, Star topology CBR comes out as 7 percent, Ring topology comes out as 47 percent and CBR of Tree topology is presented as 50 percent. It is observed that the star topology performs best on the basis of blocking Probability. In a high traffic demand situation, that algorithm should be implemented which exhibits less blocking probability.

**REFERENCES**

- [1] Shaddad RQ et al. Survey on access technologies for broadband optical and wireless networks. *Journal of Network and Computer Applications* 2014; vol. 41: pp. 459-472.
- [2] Ghazisaidi N, Maier M. Fiber-wireless (FiWi) access networks: a survey. *IEEE Communication Mag* 2007; vol. 47: pp. 160– 167.
- [3] Ghazisaidi N, Maier M. Fiber-wireless (FiWi) access networks: challenges and opportunities. *IEEE Network* 2011; vol. 25: pp. 36–42.
- [4] Bhatt UR, Sarsodia T, Upadhyay R. Survivability of an Integrated Fiber-Wireless (FiWi) Access Networks. *In Proceedings ICICT 2014;pp.243-248*
- [5] Liu Y, Guo L et al. Auxiliary graph based protection for survivable Fiber-Wireless (FiWi) access network considering different levels of failures. *Optical Fiber Technology* 2012; vol. 18: pp. 430-439.
- [6] Sarkar S. A Novel Delay Aware Routing Algorithm (DARA) for a Hybrid Wireless Optical Broadband Access Network. *IEEE Network* 2008; pp. 20-28.
- [7] Sarkar S, Yen H, Dixit S et al. RADAR: risk-and-delay aware routing algorithm in a hybrid wireless-optical broadband access network (WOBAN). *In Proceedings OFC 2007*; pp.1–3.
- [8] Feng T, Ruan L. Design of a Survivable hybrid Wireless Optical Broadband Access Network. *Journal of Communication Network* 2011;vol. 3(5) ;pp. 4588-464
- [9] Liu Y et al. Optimizing Backup Optical Network-Units Selection and Back fiber deployment in Survivable Hybrid wireless Optical Broad Band Access Network. *Journal of Lightwave Technolu* 2012;vol. 3-(10);pp. 1509-1523.
- [10] Liu Y et al. Deployment of survivable fiber-wireless access for converged optical and data center networks. *Optical Switching and Networking*. 2014; vol. 14(3);pp. 226-232.
- [11] Liu Y et al. Ring-based Protection Scheme for Survivable Fiber-Wireless (FiWi) Access Network Considering Multiple Failures. *In Proceedings ONS 2012*; pp. 333-338.
- [12] Liu Y et al. Protection based on backup radios and backup fibers for survivable Fiber-Wireless (FiWi) access network. *Journal of Network and Computer Applications* 2013; vol. 36 :pp. 1057–1069.
- [13] Chunyong Yang, Shaoping Chen et al. Performance analysis of topologies for optical wavelength convertible networks. *Optik - International Journal for Light and Electron Optics*. 2012 vol. 123(11): pp. 1001–1005.
- [14] B.A. Forouzan. *Data Communication and Networking 5E*. McGraw Hill Education (India) Pvt. Ltd. 2013.