Asian Journal of Applied Science and Technology (AJAST)
Volume 1, Issue 7, Pages 80-84, August 2017



# Design and Implementation of a Fiber to the Home Access Network based on GPON

M.Pradeep[1], S.Kayathri[2], R.Kalaivani[3] and S.Keerthana[4]

[1]*ECE Department, Sasurie Academy of Engineering, Coimbatore, India. Email: saepradeep@gmail.com*
[2]*ECE Department, Sasurie Academy of Engineering, Coimbatore, India. Email: kayusep29@gmail.com*
[3]*ECE Department, Sasurie Academy of Engineering, Coimbatore, India. Email: raniramesh7134 @gmail.com*
[4]*ECE Department, Sasurie Academy of Engineering, Coimbatore, India. Email: keerthikrishna130697@gmail.com*

*Article Received: 24 July 2017* *Article Accepted: 08 August 2017* *Article Published: 10 August 2017*

ABSTRACT

This paper presents a step by step design and field implementation of a protected GPON FTTH access network serving 1000 users. The basic components of the network are presented and the contribution of each component to the architecture of the FTTH network is addressed. The design incorporates Class B protection, to provide redundancy in the feeder and GPON port, the practical implementation of a protected FTTH network is highly emphasized.

Keywords**:** GPON, FTTH, Broadband and Fiber Optics communications.

## 1. INTRODUCTION

Growing demand for high speed internet is the primary driver for the new access technologies which enable experiencing true broadband. It leads telecommunication operators to seriously consider the high volume roll-out of optical-fiber based access networks. They have to renew their access networks that are clearly becoming the bottleneck in terms of bandwidth. Fiber to the Home FTTH appears the most suitable choice for a long term objective: if the clients are wholly served by optical fibers, it will be easier to increase the bandwidth in the future. FTTH is future proof solution for providing broadband services such as Video on demand, Online Gaming, HD TV and VoIP. Passive optical network (PON) based FTTH access network is a point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32–128.Fiber to the Home networks exploit the low attenuation (0.2–0.6 dB/km) and high bandwidth (>30,000 GHz) of single mode optical fibers [12] to provide many times more bandwidth than currently available with existing broadband technologies. In addition, these networks have the ability to provide all communication services viz. voice, data and video from one network platform. Several Time Division Multiplexing TDM PON technologies are standardized for FTTH deployments, Table 1 summarizes these standards with their important parameters. The main disadvantage of TDM PON is that it not possible for different operators to physically share the same fiber. A multi-fiber deployment is necessary to physically share the access network. Wavelength Division Multiplexing Passive Optical Networks WDM PONs is the next generation in the development of access networks. Two flavors of WDM-PON are being studied by Study Group 15 (SG15) of the International Telecommunication Union Telecom Standardization Sector (ITU–T) [15]. The first one is time and wavelength division multiplexing PON (TWDM PON) which transmits 4-16 wavelengths on the same fiber to support higher number of users per fiber at higher transmission rates or more importantly to allow more than one operator sharing the same fiber, i.e. Operators can work with different wavelengths. The second one is arrayed waveguide grating (AWG)-based WDM-PON which aimed to provide each user with a dedicated wavelength, similar to P2P, supporting 1.25 Gbps downstream and upstream transmission capacity. GPON FTTH architecture offers converged data and voice services at up to 2.5 Gbps. GPON enables transport of multiple services in their native format, specifically TDM and data. In order to enable easy transition from BPON to GPON, many functions of BPON are reused for GPON. The GPON standards are known as ITU-T Recommendations G.984.1 through G.984.5The GPON's uses Generic Framing Procedure (GFP) protocol to provide support for both voice and data oriented services. A big advantage of GPON over other schemes is that interfaces to all the main services are provided and in GFP enabled networks packets belonging to different protocols can be transmitted in their native formats. The voice component can be represented as VOIP service (voice over IP, packet-switched protocol) and can be combined with data component in physical layer simulations. Finally, the video component can be represented as a RF video signal (traditional CATV) or as IPTV signal that also can be combined with data. This shortage in access network field experience motivates the publication of this paper. Moreover, this paper provides a hands-on experience on GPON FTTH access networks design, validation and implementation.

Olden days gasoline engine technology vehicles have now become one of the major contributors of greenhouse gases. Plug-in Electric Vehicles (PEVs) have been proposed to achieve environmental friendly transportation. Even though the PEV usage is currently increasing, a technology breakthrough would be required to overcome battery related drawbacks. Although battery technology is evolving, drawbacks inherited with batteries such as; cost, size, weight, slower charging characteristic and low energy density would still be dominating constrains for development of EVs. Furthermore, PEVs have not been accepted as preferred choice by many consumers due to charging related issues. To address battery related limitations, the concept of dynamic Wireless Power Transfer (WPT)[3] enabled EVs have been proposed in which EV is being charged while it is in motion. WPT enabled infrastructure has to be employed to achieve dynamic EV charging concept. The weight of the battery pack can be reduced as the required energy storage is lower if the vehicle can be powered wirelessly [4] while driving. Stationary WPT charging where EV is charged wirelessly. When it is stopped it is simpler than dynamic WPT in terms of design complexity. However, stationary WPT does not increase vehicle range compared to wired-PEVs. WPT is the transmission of electrical power from the power source to an electrical load without the use of physical connectors.

## 2. COMPONENTS OF GPON FTTH ACCESS NETWORK

A passive optical network (PON) is a point-to-multipoint, shared optical fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 64–128. passive optical networks are typically passive, in the sense that they employ a simple passive optical splitter and combiner for data transport. A PON takes advantage of wavelength division multiplexing (WDM), using one wavelength for downstream traffic and another for upstream traffic on a single Non-zero dispersion-shifted fiber (ITU-T G.652).

### *Optical Line Terminal OLT*

The Optical Line Terminal (OLT) is the main element of the network and it is usually placed in the Local Exchange and it's the engine that drives FTTH system [29]. The most important functions that OLT perform are traffic scheduling, buffer control and bandwidth allocation [28]. OLTs typically operate using redundant DC power (-48VDC) and have at least 1 Line card for incoming internet, 1 System Card for on-board configuration, and 1 to many GPON cards. Each GPON card consists of a number of GPON ports.

### *Optical Splitters*

The optical splitter splits the power of the signal. that is each link (fiber) entering the splitter may be split into a given number of fibers leaving the splitter and there is usually three or more levels of fibers corresponding to two or more levels of splitters. This enables sharing of each fiber by many users. Due to power splitting the signal gets attenuated but its structure and properties remain the same. The passive optical splitter need to have the following characteristics.

- Broad operating wavelength range
- Low insertion loss and uniformity in any conditions
- Minimal dimensions.

### *Optical Network Terminal ONT*

Optical Network Terminals (ONTs) are deployed at customer's premises. ONTs are connected to the OLT by means of optical fiber and no active elements are present in the link. In GPON the transceiver in the ONT is the physical connection between the customer premises and the central office OLT. WDM triplexer module separates the three wavelengths 1310nm, 1490nm and 1550nm (for CATV service). ONT receives data at 1490nm and sends burst traffic at 1310nm. Analogue video at 1550nm is received. Media Access Controller (MAC) controls the upstream burst mode traffic in an orderly manner and ensures that no collision occurs due to upstream data transmission from different homes.

GPON uses Dynamic Bandwidth Allocation that is it dynamically allocates the bandwidth depending on the number of packets available in the T-CONT. Once the OLT reads the number of packets waiting in T-CONT it assigns the bandwidth. If there are no packets waiting in the T-CONT, then OLT assigns the bandwidth to other T-CONT which has packets waiting in T-CONT. If an ONT has a long queue OLT can assign multiple T-CONTS to that ONT.

## 3. GPON FTTH ACCESS NETWORK ARCHITECTURE

The fiber cable running between level-1 splitter and level-2 splitter is called level-2 fiber.

### *3.1 FTTH Core Network*

The core network includes the internet service provider ISP equipments (typically BRAS and AAA server), PSTN (packet switched or the legacy circuit switched) and cable TV provider equipment.

### *3.2 Central Office*

The main function of the central office is to host the OLT and ODF and provide the necessary powering. Sometimes it might even include some (or all) of the components of the core network.

### *3.3 FTTH Feeder Network*

The feeder area extends from optical distribution frames (ODF) in the central office CO to the distribution points. These points, usually street cabinets, called Fiber Disruption Frames FDT where level-1 splitters usually reside. The feeder cable is usually connected as ring topology starting from a GPON port and terminated into another GPON port as shown in Fig.1 to provide type B protection. Level-1 splitters with a spilt ratio of 2:4 have been employed by our design. This type of splitters enables the feeder to be connected to 2 GPON ports from one side (for type B protection) and feeds a total of 4 distribution cables from the other side. The fiber cable running between the CO and level-1 splitter is called Level-1 fiber.

### *3.4 FTTH Distribution Network*

Distribution cable connects level-1 splitter (inside the FDT) with level-2 splitter. Level-2 splitter is usually hosted in a pole mounted box called Fiber Access Terminal FAT usually placed at the entrance of the neighborhood. In the design adopted by this paper level-2 splitter is 1:16, which means each FAT serves 16 homes.

### *3.5 User Area*

In the user area, drop cables, or level-3 fibers [2], are used to connect the level-2 splitter inside the FAT to the subscriber premises. Drop cables have less fiber count and length ranges up to 100 meters. Drop cables are designed with attributes such as flexibility, less weight, smaller diameter, ease of fiber access and termination. For ease of maintenance, usually an aerial drop cable is terminated at the entrance of the subscriber home with a Terminal Box TB, then an indoor drop cable connects the TB to an Access Terminal Box ATB reside inside the home. Finally a patch cord connects the ONT to the ATB. It is most important that the optical fibers are distributed in such a way that efficient design, construction, maintenance and operation for FTTH is achieved. Therefore, in order to determine the network architecture, design, construction, maintenance, and operation approach for the optical access network, and to select optical components for FTTH, telecommunication companies should mainly consider the followings.

- Scalability
- Survivability
- Functionality
- Construction and maintenance costs
- Network upgradeability
- Operability and suitability over designed network lifetime.

## 4. TRAFFIC FLOW IN GPON FTTH ACCESS NETWORKS

The data is transmitted from OLT to ONT in downstream as a broadcast manner and as a Time Division Multiplexing (TDM) in upstream. The wavelength of the downstream data is 1490 nm, voice and data services from core network transported over the optical network reaches the OLT and are distributed to the ONTs through the FTTH network by means of power splitting. Each Home receives the packets intended to it through its ONT. The upstream represents the data transmission from the ONT to OLT. The wavelength is 1310 nm. If the signals from the different ONTs arrive at the splitter input at the same time and at the same wavelength 1310nm, it results in superposition of different ONT signals when it reaches OLT. Hence TDMA [1] is adopted to avoid the interference of signals from ONTs. In TDMA time slots will be provided to each user on demand for transmission of their packets. At the optical splitter packets arrive in order and they are combined and transmitted to OLT.

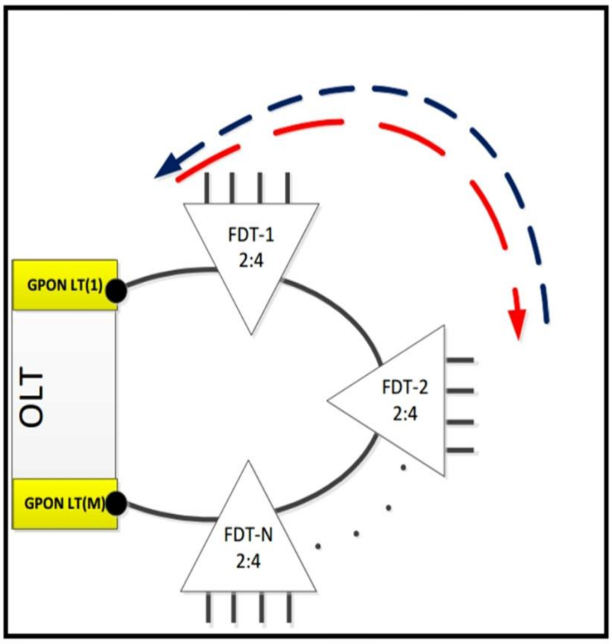


**Fig. 2 Normal direction of traffic flow**

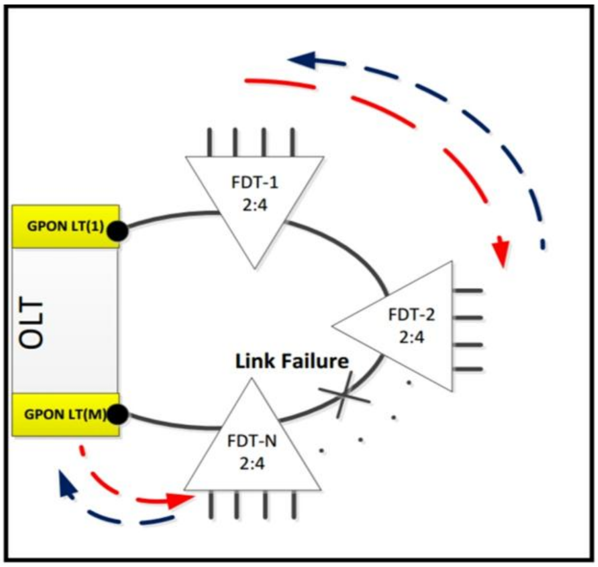


**Fig. 3 Type B protection in GPON FTTH access network, the OLT send and receive traffic through the standby GPON ports to overcome link failure**

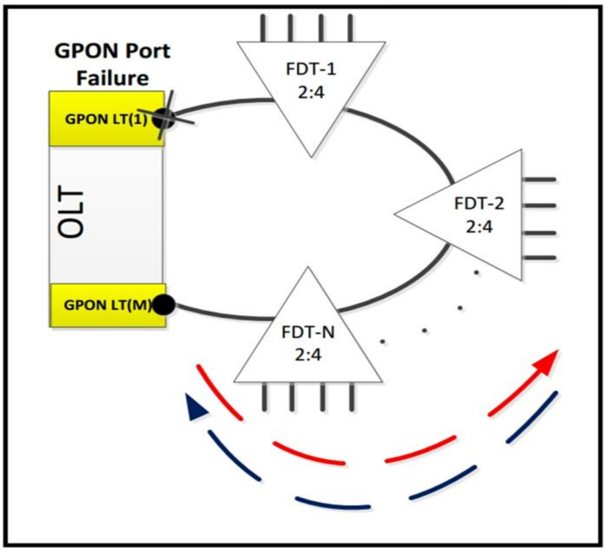


**Fig. 4 Type B protection in GPON FTTH access network, the OLT sends and receives traffic through the standby GPON ports to overcome GPON-port failure**

## 5. DESIGN OF THE GPON FTTH ACCESS NETWORK

The Design of an FTTH access network is challenging one; it needs to compromise different factors including size, cost, and scalability. There is no standard FTTH access network model as the viability of access networks strongly depends on the subscriber density (subscribers per km2) and on settlement structures, thus the modeling has to rely upon a concrete settlement structure, a given country, and the results derived depend on that country .To design the Outside Plant OSP, Desk top planning does not work, each root is surveyed physically and then planned accordingly using knowledge and experience. International standards cannot be applied as each country has its own unique underground factors. Ground thermal line or freeze line should be considered to identify the point in the underground where the temperature of the surrounding soil remains constant (not freezing nor overheating) thus allowing for a constant temperature for the FO cable to lay in. Another important factor that should be addressed is to decide the depth and the type of the backfill material necessary to reduce the ground vibration effects.

Nearby locations are served by a common FAT while each of the diverse locations are served a by a dedicated FAT. Huawei MA5600T OLT located at the CO is used as the access platform. This OLT supports 16 slots of 8-port GPON cards. Two level of splitting is used to provide a total splitting ratio of 64. Level-1 splitters are 2-4 while level-2 splitters are 1:16. This means that each GPON port can serve a total of 64 users. A bottom-top approach is used to determine the required number of GPON ports. By simple math, we can see that 16 GPON ports with 64 split ratio are quite enough to serve 1000 users. This statement is true for FTTH networks where the locations are geographically located close to each other and the number of users distributed evenly among locations, which is not our case. Due to the constraints of our network, the number of required ports will be calculated depending on the number of FATs. According to the 64 splitting ratio, each GPON port can serve a total of 4 FATs as each FAT contain 1:16 splitter, then 48 GPON ports are required to serve the 185 FATs. Another bunch of redundant 48 GPON ports is used to provide type-B protection.

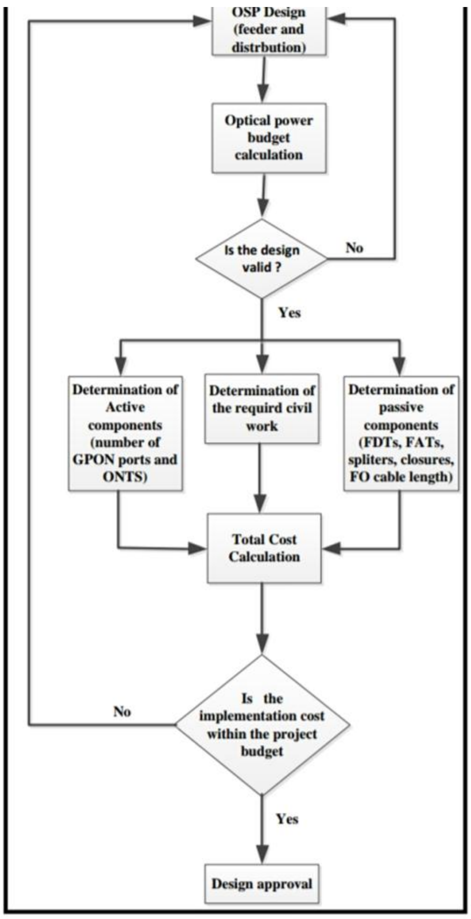


**Fig. 5 GPON FTTH access network design steps**

## 6. THE FEEDER PART OF GPON FTTH ACCESS NETWORK

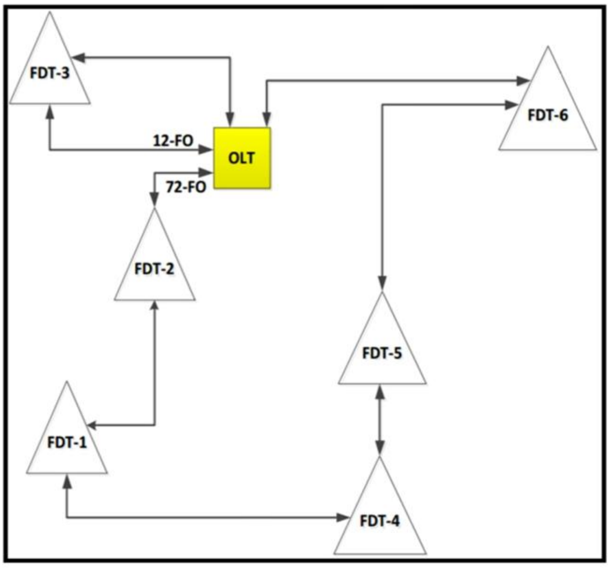


**Fig. 6 The feeder part of the GPON FTTH access network**

***Design validation***

In order to assess the feasibility of the proposed design of the FTTH network and that each user in the network can receive adequate power, the total optical power loss between the GPON port of the OLT and that of the ONT should be considered. This loss can be summarized by the following equation: $loss = lcable + lsplitter + lsplice + lconnector$ (1) Table (2) presents the definition and value of each parameter in equation 1. The power received by the ONT at the receiver premises is: Power received = Power transmitted- loss (2) Where the power transmitted stands for the power emitted by the GPON interface in the OLT card which is 3 dB in this system. Table 2 shows the different values of losses, and the corresponding power received by individual ONTs. These losses are calculated according to the parameters presented in table (2). The locations considered in table (2) are chosen because they are the most remote in network; therefore represent the worst case power loss of the designed network. The calculations presented in this table show that the worst case received power is well above the -26 dB ONT sensitivity.

***Implementation***

An engineering project should be implemented according to a pre-defined sequence of steps. This is especially crucial to projects which involve a mixer of engineering activities, where an error in a certain stage might lead to a propagation of error in the subsequent stages. FTTH projects are amongst such projects where they involve a mixer of civil and technical works. Project implementation planning saves time, efforts and cost. Therefore, a careful consideration is given to this issue. Figure 8 shows the major steps implemented in this project with their sequence. Special consideration is given to FO testing at the end of each step. Two methods are adopted in this project to determine the exact location of broken optical fiber in an installed optical fiber cable when the cable jacket is not visibly damaged. These are OTDR testing and laser source/power meter set. Optical Time Domain

Volume 1, Issue 7, Pages 80-84, August 2017

Reflectometer OTDR is used for attenuation monitoring and fault location in the feeder network while laser source/power meter is used for the other tests.

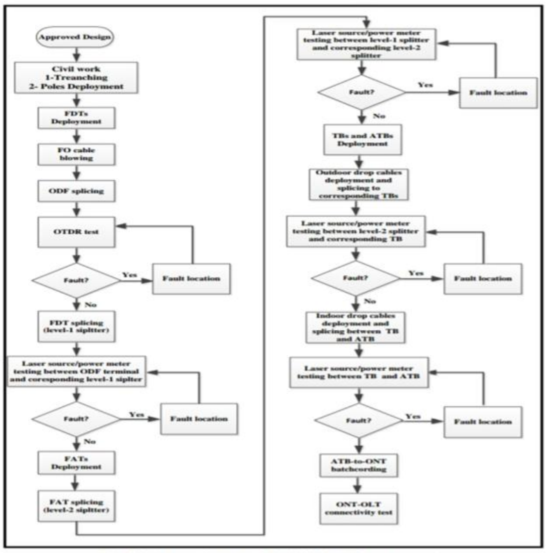


Fig. 9 Implementation steps of the GPON FTTH access network

## 7. CONCLUSIONS

This paper presented a detailed design and implementation of a type B protected GPON based FTTH access network serving 1000 users, it adopted engineering approach to emphasize practical aspects and field experience. The design procedure followed a bottom top approach, in which the size of the network and its components is defined after analyzing the requirements, the number of locations, the geographical separation and the available infrastructure. OSP design should be based on the physical survey of each root, desk top design causes wasting of a lot of time and cost when some roots needs to be redesigned to fit with the physical environments or to avoid certain obstacle. In order to assess the validity of the design, the optical power budgets is calculated for remote locations, and the results showed that the highest power loss was -23.196 dB which is well below the upper limit. The implementation steps and testing procedures are discussed, these steps are summarized in an implementation chart. The adoption of the procedure presented in this paper has saved a lot of efforts, cost and it has speeded up project commission.

## REFERENCES

[1] Salah Al-Chalabi, "Optically Powered Telephone System over Optical Fiber with High Service Availability and Low Risk of Investment in FTTH Infrastructure," *IEEE Communications Magazine,* August 2012.

[2] Christoph Lange and Andreas Gladisch, "On the Energy Consumption of FTTH Access Networks," *IEEE.*

[3] Andreas Gladisch , Christoph Lange and Ralph Leppla, "Power efficiency of optical versus electronic access networks," *in proc. ECOC 2008,* 21-25 September 2008, Brussels, Belgium, pp. 1-4.

[4] Zijad Havic and Branko Mikac, "Software tool for assessment of FTTH access networks," *in proc. 12th International Conference on Telecommunications - ConTEL* 2013, pp. 47-52, June 2013.

[5] Stephan Smith, "Business class services over a GPON network," in proc. IEEE Optical Fiber Communication Conference, *2006 and the 2006 National Fiber Optic Engineers Conference. OFC 2006*.

[6] M. Chardy et al., "Optimizing splitter and fiber location in multilevel optical FTTH network," *European Journal of Operational Research: Elsevier B.V,* pp. 430-440, May 2012.

[7] Deeksha Kocher et al., "Simulation of fiber to the home triple play services at 2 Gbit/s using GE-PON architecture for 56 ONUs," *Optik: Elsevier B.V,* pp. 5007-5010, 2013.

[8] Deepak Malik et al., "Quality of service in two-stages epon for fiber-to- the-home," *International Journal of Soft Computing and Engineering (IJSCE),* vol. 2, No. 2, pp.387-390, May 2012.

[9] Mohd Syuhaimi Ab-Rahman et. al, "New optical splitter design for application in fibre-to-the home passive optical network using virtual lab platform," *Journal of Computer Science: Science Publications,* pp. 846-871, 2012.

[10] James O. "High speed data to the home - an update," in proc. *2011 IEEE International Conference on Consumer Electronics (ICCE),* pp. 663-664, 2011.