Planning, Design and Simulation of a Network Access Based on FTTH-EPON for Hadhramout University

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Abstract. In our country copper infrastructure from Central Office (CO) to the end user is responsible for delivering poor Broadband services with loss reach 86% of the overall capacity speed. Not to mention the high prices and the impact of this inferior service to the education and economy of the country. Therefore, This paper presents a procedural proposal solution for planning, design and simulation of Ethernet Passive Optical Network (EPON) performance through Fiber-to-the-Home (FTTH) technology applied on College Of Engineering and Petroleum campus at Hadhramout University as it the best way to overcome all the problems related with copper. Since the fiber terminates at the campus, we termed the network, Fiber To The Campus (FTTCampus). FTTCampus planning the location network was developed through Google Earth and AUTOCAD software which was implemented to map out the college location areas. The proposed optical network system design has been simulated based on EPON IEEE 802.3ah standards through Optisystem software program. Simulation network components such as optical transmitters, Optical network terminals (ONTs), and optical splitters among others were allocated at different coverage areas and various network links were connected among these coverage areas. A downstream network of EPON has been simulated using Continuous Wave Laser (CW Laser) and Directed-modulated Laser (DM Laser) as different optical. Validation was performed with consistent output performance indicators like quality factor, optical source power (dBm) and bit error rate (BER). This paper has a main objective in designing an affordable and feasible network and it is accomplished by utilizing EPON that merges the low-cost Ethernet technology and low-cost PON structure with the DM Laser as an optical source. This unique work revealed that, FTTCampus could be a reliable technology in an educational academic institution, if implemented.

1. Introduction

Broadband penetration is a core driver of the economic development of any nation [1]. In fact, broadband services are the essential part for the growth of any country. Because telecommunication infrastructure with a robust broadband services can not only power the economies, but also enable competitiveness of a country, promote welfare of the people and upgrade the quality of the education [2]. Education is increasingly depending on the technology and on the fast transmission of data [3]. Unfortunately, in our country, both education and telecommunication are considered as inferior services. “The problem with telecommunication in our country is copper infrastructure that make broadband services very bad “said by the head of the Central Office (CO) at Yemen Telecom. In our country, copper infrastructure from telecommunications operator central office to the end user is the major broadband access technology used for voice and internet services. It uses technology like Asynchronous Digital Subscriber Line (ADSL) for delivering poor-speed internet access with maximum download capacity of 8 mbps for a 3 km which considered as short distance. However, the main issue is in the loss that reach 86%, speed instability, interruptions and the higher cost comparing to this weak service witch make it even worse.

On the other hand, in the developed world, the advanced services such as videogames, videogames, IPTV, distances learning, etc., are continuously increasing demands that have made service providers in inconvenient situation concerned about the fulfillment of user’s requirements [4]. They also have come with realization of that the copper media are limited in distance, speed and capacity and digital subscriber line (DSL) systems are bounded to only several Mbps for their data transmission capability [4]. Copper wire limitations pushed the service providers to move towards other technologies to
provide better broadband services in order to satisfy user's requirements [4]. One of the most appropriate technologies is definitely fiber optic technology [4]. Fiber optic technology in compare to copper wires technology, it uses light impulses instead of electrical signals for data transmission and that make it faster and greater in bandwidth [4]. In order to provide the best possible services to users, developed countries and their service providers take the fiber to the end users using technology known by fiber to the x[4]. FTTX is fast growing and promising technology that supports broadband services such as fixed telephone, data and interactive TV which known as the triple play services [5]. In FTTX implementation, passive optical networks (PONs) have been considered as the most cost-effective technology in fiber broadband FTTX access network deployments. The PON presents massive benefits upon deployment in FTTX architecture [6]. PON has many standards and one of them is Ethernet Passive Optical Network (EPON). Ethernet PON, it is a technology that is simple, inexpensive, scalable, and having the advantage of presenting the convergence of low-cost Ethernet with cost-effective PON infrastructures [7].

However, this paper proposes a solution for a new telecommunication infrastructure in Hadhramout-Almukklla city based in EPON-FTTX technology as it is the best way to overcome the problems associated with the exiting infrastructure and the best choice for the future evolution. The network will be on the College Of Engineering and Petroleum campus at Hadhramout University as a way of combining education with communication. Then we will extend to the whole society in order to bring economic benefits to our country. Also the mean objectives of this paper are, in designing a downlink network that is affordable, feasible and upgradeable and in making a comparison in results between CW Laser with DM Laser. Section two presents FTTX, PONs, and EPON. Planning and simulation the network for Hadhramout University is introduced in section three. The results are defined in section four. Finally, section five provides the conclusion of this paper.

2. Optical Access Network

2.1. Fiber To The X
FTTX is the all-purpose term for the fiber access networks that reach the end-user [6]. The variable "X" represents the differences in applications [8]. For Different “X” terms are: Fiber to the Home (FTTH), Fiber to the Building (FTTB), Fiber to the Curb (FTTC), Fiber to the Cabinet (FTTCab) and Fiber to the Node (FTTN), etc. Network operators have several standardized technologies that are available for them, with difference in advantages, disadvantages, capabilities and requirements [9]. For this reason, we termed the work of this paper as Fiber to the Campus (FTTCampus) where the fiber terminates at the university.

2.2. Passive Optical Network
Broadband Passive Optical Networks (PONs) are considered as one of the most used technologies for delivering fiber based FTTX access networks as shown in figure 1 [10].

![Figure 1. PON Architecture over FTTX Access Networks](Image)
For the term PON, it means that there are no active elements from the Central Office to the user's devices. In other words, there is no need for any electrical power or active management for the optical fiber cable and optical passive elements as splitters, hence the name passive [11]. PON is characterized by being cost-effective, energy saver, more secure, and also by its service transparency over FTTX access networks [12]. From figure 1, PON consists of three basic elements that comprise the general architecture of the network. These are, Optical Line Terminal (OLT) at the CO, Optical Network Units (ONUs) at the user premises and Optical Distribution network (ODN) which are passive coupler or splitter used to connect ONUs to the OLT [13]. The standardization of PON architectures was developed by International Telecommunication Union Telecommunication Standardization Sector (ITU-T) and Institute of Electrical and Electronic Engineers (IEEE) as listed in Table 1 [6], [14].

|                | BBON                              | GPON                              | EPON                              |
|----------------|-----------------------------------|-----------------------------------|-----------------------------------|
| Standard       | ITU-T G.983.x (2000)              | ITU-T G.984 (2003)                | IEEE 802.3ah(2004)                |
| Data rate (DS/US) | 622/155 Mbps                      | 2.5/1.25 Gbps                    | 1.25/1.25 Gbps                    |
| Operating Wavelength | DS: 1480-1500 nm                  | DS: 1480-1500 nm                 | DS :1480-1500 nm                 |
|                | US: 1260-1360 nm                  | US: 1290-1330 nm                 | US :1290-1330 nm                 |
| Splitting ratio | Up to 1:32                        | Up to 1:64                       | Up to 1:64                       |
| Coding         | NRZ (+scrambling)                 | NRZ (+scrambling)                | 8b/10b                           |

2.3. Ethernet Passive Optical Network (EPON)
This Ethernet-based PON is known as Ethernet PON (EPON) but is sometime also referred to as Gigabit EPON (GEAPON) or as Ethernet in first mile fiber (EFMF) [15]. EPON is a technology based on the 802.3ah specification of the IEEE [16].The principle of EPON is based on that Ethernet cable can be introduced to end users up to a maximum of 20 km form the source [17]. EPON structure reduces equipment and amount of fiber at CO because it combines low-cost PON structure with the low-cost Ethernet technology. These features made him highest representative of the future-oriented FTTX access networks [18], [19].

3. Hadhramout University FTTCampus
The previous section introduced FTTX and PON systems with an enough details that clarify how these systems are attractive methods for providing the most cost-effective architectures for the whole network plants. However, this is one the reasons behind this work that should be more affordable, feasible, and upgradeable. All these features led us to choose the Ethernet Passive Optical Network (EPON). Figure 2 illustrates how this work can be achieved. However, the hardware part is out of the scope of this work which may be achieved later if a complete project assessment with enough funds of approved from the government authorities. The other part consists of two sections which are planning the location of FTTCampus network and designing and simulation of the network will be explained in details here.
3.1. planning of FTTCampus

The deployment cost per Home Passed can amount to lot of money for a FTTX network. Therefore, it is not uncommon for FTTX projects to run into tons of millions of dollars just for initiating the passive infrastructure. Such large funds require careful planning to minimize financial risk and form the foundation of a flexible network with cost efficient that can be effectively managed and realized during design phases through to conveying subscriber traffic or wholesale services. In this manner, during the planning and stage designing detailed geographical data with respect to the targeted regions and areas needs to be presented.

Figure 3 shows connection nature of HU. The nature of connection of any site is categorized by being a Greenfield or a Brownfield. When the area is a and Brownfield means buildings are already existed, but the existing infrastructure is of a low standard and Greenfield means that new build where the network will be installed at the same time as the buildings [21].
So far, Hadhramout University faculties are located in Fluk, Fowa and Galeelah within Mukallah city. However, this project is intending the future plan for Hadhramout University which is totally located in Fluk which is the future master plan. It consists of 23 areas that will eventually contain 100 buildings located over 2.5 Km², see Table 2. From figure 3, it is clear that the current areas which are Engineering Area, Medicine Area, Student Accommodation and Gust Area are considered as Brownfield and the rest of unconstructed areas are Greenfield.

| NO  | Area Name                          | Area No. | No. of Buildings |
|-----|------------------------------------|----------|------------------|
| 1   | College Of Science                 | 1        | 10               |
| 2   | College Of Engineering             | 2        | 6                |
| 3   | College Of Petroleum               | 3        | 7                |
| 4   | College Of Nursing                 | 4        | 4                |
| 5   | College Of Dentistry               | 5        | 4                |
| 6   | College Of Medicine                | 6        | 4                |
| 7   | College Of Pharmacy                | 7        | 6                |
| 8   | College Of Arts                   | 8        | 5                |
| 9   | College Of Administrate Science    | 9        | 5                |
| 10  | College Of Educational Science     | 10       | 5                |
| 11  | College Of Theology & Law          | 11       | 4                |
| 12  | College Of Agriculture             | 12       | 10               |
| 13  | Univ. Presidency Comp.             | 13       | 8                |
| 14  | Islamic Cultural Center            | 14       | 3                |
| 15  | Museum                             | 15       | 1                |
| 16  | Central Library                    | 16       | 1                |
| 17  | Conference Hall                    | 17       | 1                |
| 18  | Health Center                      | 18       | 1                |
| 19  | Student Center                     | 19       | 1                |
| 20  | Central Storage                    | 22       | 1                |
| 21  | Workshop                           | 23       | 1                |
| 22  | Athletics                          | 24       | 6                |
| 23  | Student Accommodation And Guest    | 29       | 6                |
|     | SUM                                |          | 100              |

In order to simplify the project, we choose Engineering College as case study to demonstrate the possibility of designing Fiber To The Campus Using Ethernet Passive Optical Network. But this study can be applied to Faculty of Medicine and for Accommodations too. Engineering College has six buildings or blocks which are dean block, conference hall and four blocks termed A, B, C, and D as shown in Figure 4.

Figure 4. The Overview Of The Engineering College
Figure 5 shows the geographical model of the network that will be implemented. All elements of PON network are there from the OLT, feeder fiber, splitters, distributed fibers and ONUs. The figure also shows the distance between splitters, route information which is the fiber paths and demand points which is at the end point at each building.

Figure 5. Geographical model of FTTCampus-EPON

3.2. EPON for College of Engineering Campus

From the Geographical model of the EPON showed in figure 5, the OLT is located on a pre-defined location based on two important factors. The first one is how this location can distribute the data in straight line because this will help reducing the overall cost of the fiber network. The second factor the network flexibility to serve more college locations around in the future. The fiber comes out of the OLT called feeder fiber (FF) which feeds to 1x3 optical splitter. The 1x3 optical splitter is assigned for student’s accommodation, college of medicine and college of engineering. Since we choose college of engineering, a fiber called Distributed Fiber (DF) comes out of the 1x3 splitter to distribute to 1x5 optical splitter. The 1x5 splitter is assigned for the four blocks A, B, C, D, and the dean block and conference hall. Then the blocks are fed with 1x32 optical splitter whereas the dean block and conference hall are fed with 1x16 optical splitter.

The proposed EPON access network logical diagram is shown in Figure 6 where the flow of the network related with the Ethernet devices and services is also being illustrated. This model shows how this network can be implemented from the inside where ONUs that can provide internet and telephone could be used for the offices. Also ONUs can be used to provide control for the monitoring system. Others can provide internet with Wi-Fi, these can be used for the classes, library, laboratories, campus and anywhere else.
Figure 6. Logical model of the proposed FTTCampus-EPON

3.3. FTTCampus-EPON Simulation

Since optical fiber communication devices and systems are very costly, network designers cannot test network design with real optical fiber communication device as they can change the design many times to enhance and optimize the network. Computer aided design programs are common to be used in designing such a network.

One of the widely software program used for modeling a real optical fiber communication systems into simulating optical fiber communication systems is OptiSystem. OptiSystem has various types of function such as designing, testing and optimizing. Optisystem has Graphical User Interface (GUI) which comprises of component list, project layout and component model and graphical display. Optisystem contains Library that consists of passive and active components with wavelength parameters [5].

Figure 7 shows the simulation set up which is used to analyze the performance of the signal in downstream traffic. Most the components such as the optical line terminal single optical fiber, splitters and optical network unit have been utilized to form the structure of EPON. A list of almost the entire parametric values adjusted in the optical simulation which based on the standards of EPON network values are shown in Table1. The simulation set up, stimulates the Geographical model in figure 5.

In simulation set up, the OLT block is designed with two different optical sources which are, Continuous Wave Laser and Directly Modulated Laser as shown in figure 8. On the other hand, the receiving blocks A, B, C and D represent the same block in figure 5. These blocks have 1:32 optical splitters inside them. The dean office and the conference hall are represented by the fifth block in the simulation set up with 1:16 optical splitter. The current design network is implemented only for the downstream traffic.
Figure 7. FTTCampus-EPON Downstream Simulation Schematic In Optisystem

| Side Component | parameter Value |
|----------------|-----------------|
| **Global parameters** | | |
| Bit Rate | 1.25Gps |
| Sequence length | 128Bits |
| Samples per bit | 64 |
| No. of samples = sequence length x sample per bit | 8192 |
| PRBS generator | EPON transmission code |
| Amplitude | 1 a.u |
| Rise time | 0.05 bit |
| Full time | 0.05 bit |
| **Transmitter** | | |
| CW Laser | | |
| Power | -5 - 5 dBm |
| Line width | 10 M Hz |
| DM Laser | | |
| Frequency | 1490 - 1500nm |
| Slope Efficiency | 0.1 - 0.9W/A |
| Mach-Zehnder Modulator | Extinction ratio |
| Length | 1.2Km |
| **Channel** | | |
| Single Optical Fiber | | |
| Attenuation | 0.2db/Km |
| Dispersion | 16.75 ps/nm/km |
| Optical Splitter | No. of users |
| 3 , 5 , 16 , 32 |
| **Receiver** | | |
| Photo detector APD | Responsivity |
| Dark current | 10n/A |
| Bassel Filter | Cut off frequency | 0.75Bit rate Hz |
In simulation set up, the OLT block is designed with two different optical sources which are, Continuous Wave Laser and Directly Modulated Laser as shown in figure 8. On the other hand, the receiving blocks A, B, C and D represent the same blocks in figure 5. These blocks have 1:32 optical splitters inside them. The dean office and the conference hall are represented by the fifth block in the simulation set up with 1:16 optical splitter.

Figure 8(a) CW Laser

Figure 8(b) DM Laser

4. Simulation Results

The predominant optical source that is used in optical communication system is the Continuous Wave Laser (CW Laser). Commercially, it is known that CW Laser is the most expensive optical source. It may not be required to use CW Laser for the proposed design since the data rate used is 1.25 Gbps with distance is less than 6 Km for the whole intended university campus. However, there is another optical source called Directly Modulated Laser (DM Laser). This type of optical source is suitable for the data rates of less than approximately 10 Gbps (typically 2.5 Gbps) which support short distances [21]. Therefore, DM Laser matches our design parameters from data rates and distances. Besides that, DM Lasers are also supports our requirements to minimize the network cost to make it more affordable since it has less prices than CW Laser [22]. Therefore, in order to compare the utilization possibility for the two optical sources, real parameters have been considered.

In this simulation, the results have been prepared based on three important factors: the type of optical source, the transmitted power, and the number of users (optical splitter type). Continuous Wave Laser and Directly Modulated Laser are two optical sources that have been used. The transmitted power has been selected to sweep from -5 dBm to 5 dBm. The number of users has been chosen according to the standard optical splitter for the EPON architecture, which is 32 users or less. Therefore, 16 and 32 optical splitters have been used for Engineering College campus.

Figure 9 depicts the variation of BER for both sources represent by Y axis with respect to the optical transmitted power in (dBm) represent by X axis. Where N 16 CW, N 32 CW, N16 DML and N 32 DML represent the network when using CW Laser with 1:16 optical splitter, CW Laser with 1:32 optical splitter, DM Laser with 1:16 optical splitter and DM Laser with 1:32 optical splitter respectively. It is clear, when the transmitted power (dBm) increases, the obtained BER values decreases. The proposed network works properly with transmitted source power between -4 dBm and 0 dBm depending on type of the splitter used where BER of less than 10^-10 has been achieved. The more optical splitters are connected the more the losses. Therefore more optical source power is needed to compensate those extra losses.
Figure 9. Simulation Results For Different Splitter Types

Figure 10 shows the minimum BER (eye diagram) obtained from BER analyzer with transmitted powers of –5 dBm when using both sources with a 32 optical splitter. Also, when using 0 dBm is shown in figure 11. It is clear how the two sources have similar results. DM Laser is a suitable source to be used with EPON since the typical requirements for optical receivers in this simulation are optimized to be BER less than $10^{-10}$ (less than one error in $10^{10}$ bits). According to the simulation results, the affordable network using EPON that merges the low-cost Ethernet technology and low-cost PON structure is accomplished with the DM Laser as an optical source.

Figure 10. Eye diagrams at -5 dBm: (a) CWL and (b) DML
Figure 11. Eye diagram at 0 dBm

5. Conclusion
Ethernet Passive Optical Network (EPON) performance through FTTH technology based on Hadhramout University campus is presented. The Engineering College has been chosen as projected location to demonstrate the possibility of planning and designing FTTCampus. The geographical model of the proposed location is translated to a logical EPON access network. A downstream EPON access network using CW Laser and DM Laser as different optical sources has been simulated where almost the entire parametric values adjusted in the optical simulation based on the standards of EPON network values.

The affordable network using EPON that merges the low-cost Ethernet technology and low-cost PON structure is accomplished with the DM Laser as an optical source. The current proposed network design is applied only for downstream traffic, so up stream traffic channel should be designed too to provide a bi-directional EPON access network.

The network is considered as an economic system based on the theoretical information and accomplished when we have used the DM Laser with it. However, estimation for overall cost of the network from EPON solution cost, equipment of the network such as optical cables and splitters, labor work cost, installation, test and measurement service costs, should be done.
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