Gigabit Passive Optical Network (Review Paper)

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ABSTRACT

This paper introduces some of the previous research topics related to Fiber-To-The-Home (FTTH) technologies that taking precedence today’s people search for a reliable broadband access owing to the fact that old broadband like DSL and ISDN are struggling to deliver reliable broadband access to users with the presence of new applications that impacts network efficiency, distance reach, scalability energy consumption and competitive data rates per user. The large-scale adoption of Internet of Things (IOT) has ushered the need for reliable broadband connections for swift and easy deployment of IOT devices. These challenges have led many researchers and industries to examine and vigorously study alternative designs based on passive optical network devices to provide scalable, low cost, long distance reach, energy efficient, and high-speed networks. This work proposes a simulation of the Gigabit Passive Optical Network (GPON) standard of the FTTH in order to deliver reliable connection to 64 subscribers, using Optisystem over a distance of 50 km. Optical amplifiers was introduced to extend the reach of GPON beyond the 20km mark in order to achieve a high performance working system.

Keywords - Passive Optical Network, GPON, FTTH, Optical Amplifiers.

I. INTRODUCTION

Fiber-To-The-Home is the installation and the use of optical fiber from a central point (Switching center) directly to individual buildings i.e from the Optical Line Terminal (OLT) to the Optical Network Units (ONU) such as residences and apartment buildings to provide unprecedented high-speed Internet access. FTTH dramatically increases the connection speeds available to users compared with technologies used in most places [1]. FTTH is predicted to replace existing copper infrastructure[2] such as telephone wires and coaxial cable.

FTTH became a popular solution to broadband as a response to several residential access factors, these factors include; the explosive wide adoption of the Internet of Things (IOT) [3]; provision of high data rates compared to old broadband technologies like DSL and ISDN. FTTH has mostly been developed in response to several residential access market drivers [4]. There exist two main architectures used with FTTH; they are Point-To-Point (P2P) and Point-to-Multipoint (P2MP)[5]. P2P architecture uses all active components throughout the link while P2MP architecture uses passive optical splitters at the aggregation layer [6].

The presence of a shared link in FTTH system means all the signals are combined into a single fiber link. Sending traffic upstream i.e. from the ONU’s to the central office requires accurate multiple access techniques in order to multiplex in a collision-free way the traffic streams generated by the ONU’s onto the common feeder fiber [7].

Four major categories of multiple access techniques for fiber access networks have been developed, they are; Time Division Multiple Access (TDMA), Subcarrier Multiple Access (SCMA), Wavelength Division Multiple Access (WDMA), and Optical Code Division Multiple Access (OCDMA).

Optical splitters are used in P2MP architectures to split light in the optical fiber to different destinations. The use of optical splitters is playing an important role in implementing FTTH where one optical link can be split to serve multiple subscribers. The optical split ratio may include 1:2, 1:4, 1:8, 1:16, 1:32, 1:64 and 1:128. Gigabit Passive Optical Network[8] is an enhancement of PON to Gbps domain. The GPON architecture, set in Recommendation G.984.1 [9], is much alike the ATM-PON one, the maximum optical splitting ratio is 128, and the maximum fiber reach from OLT to ONU is 20 km whereas its minimum is zero. The downstream signal operates within 1480nm-1500nm wavelengths with data rates of 2.5Gbps or 1.25Gbps. The upstream signal operates between 1550nm wavelengths with data rates of 1.25Gbps.
within 1260nm-1360nm wavelengths with data rates of 2.5Gbps, 1.25Gbps, 622Mbps, and 155Mbps. GPON supports quality of service, as it enables Service Level Agreement (SLA) negotiations between the OLT and the ONU through the ONU management and configuration interface set in G.984.4 [10]. This paper will further be divided along the lines of review literature, methodology, results of simulation and final section of conclusion.

II. Related Works

A great deal of research has been conducted in the area of Gigabit passive optical network. In particular, extending the destination reach of the network and accommodating more users[11]. A few of the works reviewed are mentioned below. In [12] the work discussed in detail the architecture used by the main Slovenian operators to implement FTTH in the form of Point-to-Point (P2P), or Point-to-multi-point (P2MP). P2MP is used by a few public-private partnership projects and a few cable television operators as discussed in the paper. The work pointed out although the P2P solution can provide a larger bandwidth per customer than the P2MP, it has already been noted that a mixture of P2P and P2MP solutions will be the right future-proof option because it allows multiple operators to be active on a single network. The limitation of this work was the connection of a dedicated single mode fiber for each user directly from the central office in the P2P model. Even though the P2P provides high speeds, the cost of maintaining this link would be expensive and in turn, drive the prices of such FTTH deployment to skyrocket.

In [13], the author discussed the economic and technical aspects of deploying FTTH. In this work designing, planning and deploying of FTTH network based on Gigabit Passive Optical Network (GPON) was evaluated in order to obtain an optimal practical sample when designing and implementing any FTTH network. The network was designed to serve about 6000 subscribers; the plan is to use 6000 ONTs, one ONT per subscriber. Each OLT will connect to the converged Layer 3 switches and then the routers to ITPC (Iraq Telecommunication Post and Company) Passive Distribution Network (PDN). The research found out that the FTTH networks have now established their economic competitiveness by providing significantly reduced operating expenses and enhanced revenue opportunities for carriers. In addition, an FTTH solution based on Wavelength Division Multiplexing (WDM), or a λ-based structure, allows for additional flexibility and adaptability to support future services.

In [14] the paper introduced an explanation to the basic components of a GPON FTTH access network, which includes; OLT, which is the main element of the network, the optical splitter that splits the power of the signal, ONTs that are deployed at customer’s premises. The network architecture adopted by this paper use two level of splitting between the central office and the user premises achieving an overall splitting ratio of 1:64. Two methods were 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 Reflectometer OTDR is used for

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**Figure 1. Block diagram of 64 GPON System**
attenuation monitoring and fault location in the feeder network while laser source/power meter is used for the other tests. This paper adopted an engineering approach to emphasize practical aspects and field experience. The adoption of the procedure presented in this paper has saved a lot of efforts, cost and it has speeded up project commission. The author brilliantly outlined steps required to implement the GPON FTTH deployment. The necessary calculations were done and total losses were calculated which was within the acceptable range.

III. Methodology and Simulation

This work will use a top-down approach to a successful completion. Figure 1 is a block diagram describing the steps carried out in this work. The steps are illustrated in the figure 1 below. The architecture of this GPON implementation covers a total of 64 ONUs using a single bidirectional optical fiber extended with optical amplifiers[15] is shown in figure 2. Optical amplifiers are used both on the downstream and upstream part of the fiber link. Bidirectional single fiber WDM-PON can reduce the use of fiber links, as well as the number of network equipment, and hence reduce energy consumption and the cost [16] [17].

In the downlink, an optical transmitter is used on the 1490nm wavelength with 10dBm out power with data rate of 2.5Gbps; the optical amplifier is placed before the splitter owing to the fact that it was observed a significant amount of power was lost at the splitter.

The ONU is made up of the receiver and the uplink transmitter. In the uplink, an optical transmitter is used on the 1310nm wavelength with 0dBm power with data rate of 1.25Gbps to transmit signal from the ONU to the OLT. The signal passes through the PIN photodiode that detects the optical signal at the receiver side; the signal moves to a low pass filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates the signal with frequency higher than the cutoff frequency. A 3R generator is used to recover the original bit sequence and electrical signal. The first output port is the bit sequence, the second one is modulated NRZ signal and last one is copied on the input signal. These three signals can be directly connected to BER analyzer, avoiding additional connections between the transmitter and receiver stage.

IV. Results and discussions

The system designed is a purely passive implementation meaning it required the need to use a passive optical splitter supporting 64 ONUs. 1550nm wavelength was chosen at the optical fiber for the Downlink and Uplink signal owing to the fact that using this wavelength was advantageous because of its low attenuation of 0.25dB/km [18]. Fig 3 displays the optical spectrum using optical spectrum visualizer that allows the user to calculate and display optical signals in the frequency domain. These spectra are observed and transmitted over the optical fiber; the optical transmitter also inserted some error in the form of noise that you can observe from the image.

Figure 2. Optical Spectrum

The optical time domain spectrum shown in Figure 3 allows the user to calculate and display optical signals in the time domain. It displays the signal intensity, frequency and phase parameters. For this 2.5Gbps system, a best BER value of 0 was obtained that means the system works perfectly at optimum.

Figure 3. Optical Time Domain
The eye diagram shown in figure 4 for reveals the signal of 64 users at a distance of 50km. It can be observed from figure 4 the eye diagram is an eye opening signifying minimal distortion to the signal. This signifies inter-symbol interference and channel noise is so minimal and acceptable[19]. This signal of the eye diagram satisfies the requirements of signal extraction in an optical link [20].

Figure 5 corresponds to Q- Factor of the downlink signal of 64 users with data rate of 2.5Gbps. It was observed that Q-Factor is dependent on the input power, number of subscribers and the distance of the fiber link, Q-factor decreases in respect to the input power and it accommodates more users and if we maintain an appropriate input power. Table 1 shows the performance metrics that were obtained at the downstream.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream Bit Rate</td>
<td>2.5Gbps</td>
</tr>
<tr>
<td>Q factor</td>
<td>246.993</td>
</tr>
<tr>
<td>Min BER</td>
<td>0</td>
</tr>
<tr>
<td>Eye height</td>
<td>0.000306951</td>
</tr>
<tr>
<td>Threshold</td>
<td>3.61752e-05</td>
</tr>
<tr>
<td>Decision Inst.</td>
<td>0.53125</td>
</tr>
</tbody>
</table>

From table 1 the downstream uses a data rate of 2.5Gbps, a Quality factor of 246.993 and a minimum BER of 0, which is a best-case value for this GPON system. Eye height value of 3.06951e-04 here refers to the eye opening in the eye pattern, which shows a high quality of the signal. Threshold represented above is a value based on whose value is the binary signal logical value being decided. If the value of the signal is less than threshold, it is considered a ‘0’ and otherwise, a ‘1’. Decision instant is a value of the decision instant for the maximum Q-factor/minimum BER.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit Rate</td>
<td>1.25Gbps</td>
</tr>
<tr>
<td>Q factor</td>
<td>174.943</td>
</tr>
<tr>
<td>Min BER</td>
<td>0</td>
</tr>
<tr>
<td>Eye height</td>
<td>5.26297e-05</td>
</tr>
<tr>
<td>Threshold</td>
<td>4.57078e-06</td>
</tr>
<tr>
<td>Decision Inst.</td>
<td>0.5</td>
</tr>
</tbody>
</table>

From table 2, the upstream uses a data rate of 1.25Gbps. Quality factor of 174.943 was achieved, minimum BER of Zero was also achieved making this GPON implementation an efficient system. Eye height value of 5.26297e-05 here refers to the eye opening in the eye pattern, which shows a high quality of the signal. The threshold represented above is a value based on whose value is the binary signal logical value being decided. If the value of the signal is less than threshold, it is considered a ‘0’ and otherwise, a ‘1’. Decision instant is a value of the decision instant for the maximum Q-factor/minimum BER.

V. Conclusion
In this paper, the design of a purely passive GPON with bidirectional optical fiber was carried out. Data rates of 2.5Gbps at the
downstream and 1.25Gbps at the upstream were used to achieve an extension of the optical fiber to a distance of 50km by taking advantage of optical amplifiers. A successful simulation was achieved by extending the coverage distance beyond the 20 km mark as originally designed, both downstream and upstream received the optimized result, which was shown. It was observed that with asymmetric data rates, error-free performance can be achieved for this GPON over a bidirectional 50 km feeder using 64 users. These performance metrics evaluated are sufficient to provide subscribers access to efficient and high quality broadband access.

References

11. Al Romathi, K., et al. Automation of fiber to the home network design with different types of network elements. in Information and Communication Technology Research (ICTRC), 2015 International Conference on. 2015. IEEE.