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Simulation of a GPON-Based Fiber-To-The-Home Access Network

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Abstract

As optical fiber communication technology advances, there is a growing demand for increased transmission speeds, extended transmission distances, and wider transmission bandwidths. Telecommunication companies are actively addressing these requirements through continuous monitoring and evaluation of their fiber optic access network systems. Research in this field seeks to explore the design and analysis of these systems. This study introduces a passive optical network architecture designed to fulfill the demands of the widely-used Gigabit Passive Optical Network (GPON) system. Using 'OptiSystem' software, this design is simulated with consideration for real-world system parameters. The simulation assesses the GPON design's compatibility with newer NG-PON1 and NG-PON2 systems and evaluates network performance by minimizing bit errors and enhancing the network quality factor. The model relies on data sourced from published articles about existing networks, with a primary focus on testing GPON network performance using 'Optisystem' optical network software.

1. Introduction

Fiber to the Home (FTTH) is a method of transmitting communications signals through optical fiber that runs from the switching equipment of a telecommunications or internet service provider to a home or business, replacing older copper-based infrastructure like telephone wires and coaxial cable. This technology is relatively new and expanding rapidly, providing significantly higher bandwidth to homes and businesses, enabling advanced video, internet, and telephony services. Directly connecting homes to fiber-optic cable greatly increases the amount of available bandwidth. With current fiber-optic technology, two-way transmission speeds of up to gigabits per second can be achieved, and ongoing advancements in the technology continue to increase available bandwidth without needing to replace the fiber. These networks are considered "future-proof" due to this. GPON is a point-to-multipoint access network, which uses passive splitters in the fiber-optic distribution network, that is its most notable feature. This allows a single fiber to service multiple homes or businesses, provided by an internet service provider. Fiber optics pertains to using cables to transmit light in this technology. GPON is a way of providing internet, voice, and video access to users over fiber-optic cables. This technology uses a point-to-multipoint architecture, which enables faster data transfer and reception through a single fiber, enabling fiber to the home (FTTH) or fiber to the building (FTTB) communication. This method also allows for the provision of triple play services (video, voice, and data) [1] and it was developed as a solution to improve on outdated copper and HFC networks, which at one point in time were no longer able to meet the needs of the users. Nowadays, copper and fiber optics are both suitable options for all kinds of needs.

The main purpose of this research is to study the performance of GPON networks by analyzing, designing and simulating using OptiSystem Simulation Tool; to analyze the results of the simulation in comparison to standard data for the same network devices for a fiber-to-the-home network using OptiSystem and also to explore the implementation of a passive optical attenuator in the GPON upstream of the splitter in order to protect against high-power signal injection attacks

2. Materials and Methods

The materials and methods section, otherwise known as methodology, described all the necessary information that is required to obtain the results of the study.

2.1 Project Description

This project aimed to model the performance and smoothness of passive optical technology by creating a model of a real passive optical network. The model will focus on a Giga passive optical network (GPON) and will compare various designs with downstream and upstream circuits. The results of the model will be used as a guide for further examination of GPON technology. Additionally, this study will also look into how the desire for improved technology to meet customer needs for speed and data capacity has led to the development of newer generations of passive optical networks that utilize the same infrastructure as older ones. This project will simulate the Next Generation Passive Optical Network 1 (NG-PON 1) and Next Generation Passive Optical Network 2 (NG-PON 2) and compare their performance to that of the GPON network. It will also investigate any potential issues that may arise when these networks coexist. In addition, the project will also involve the development and planning of a selected network design using PON technology and conducting a feasibility study for deploying FTTX networks. The project will follow a flowchart that includes a review of existing literature on PON technology, the design of a GPON network using standard ITU-T data and comparing it to data from an existing network, simulating X-GPON (NG-PON1) network coexisting with GPON, and finally simulating NG-PON 2 coexisting with GPON. The workflow of this research is shown in the flowchart at Fig. 1.

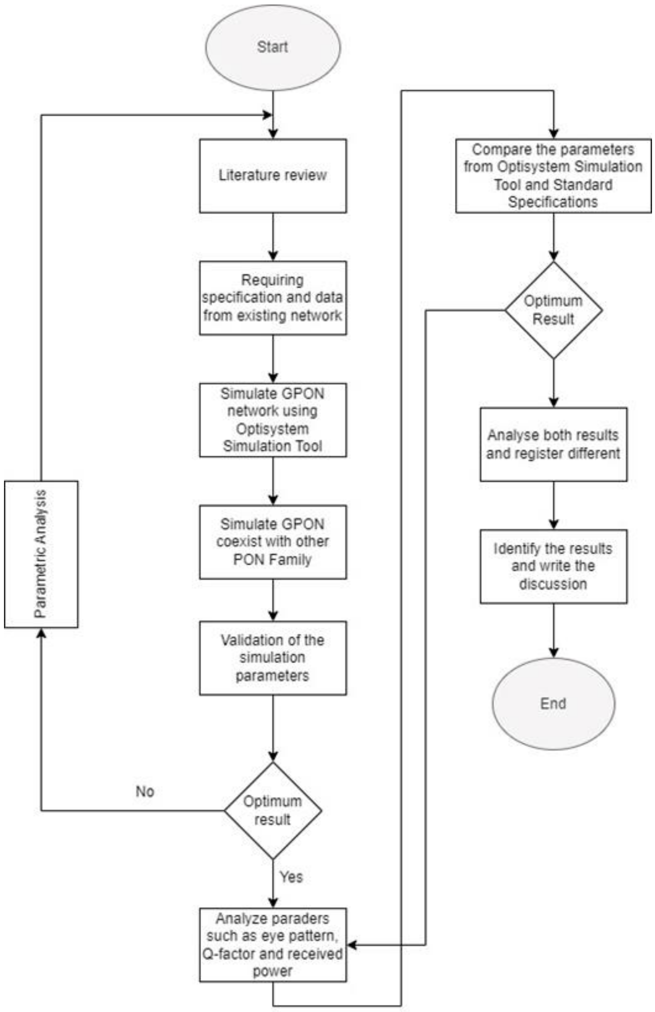

Fig. 1 *Flowchart of the project*

2.2 GPON network design

When building an optical infrastructure, it is important to have a thorough understanding of the deployment environment. This includes identifying key features and factors, as well as understanding the specific needs and requirements of the deployment. With this information, it will be easier to design and implement a suitable infrastructure that can meet the needs of the deployment, whether it be in terms of capacity, speed, coverage, cost, or other factors. This approach is essential to ensure that the optical infrastructure is able to provide the necessary performance and reliability. A GPON (Gigabit-capable Passive Optical Network) is a type of FTTX (Fiber to the x) network, in which a single optical fiber is used to serve multiple customers. GPON networks are typically divided into four parts which is the OLT (Optical Line Terminal) is located at the company site and serves as the central hub of the GPON network. It is responsible for managing the network and controlling the optical signals. The optical splitter, which is connected to the OLT, is used to divide the optical signals into multiple branches. This allows for a single fiber to serve multiple subscribers. The ODC (Optical Distribution Cabinet) is responsible for the distribution of the optical signals to the various districts. The ODP (Optical Distribution Point) is the location where the optical signals are split into individual fibers that run to the subscriber's location.

OptiSystem is a simulation tool for optical communication systems that enables users to design, test, and optimize a wide range of optical link in physical layer of different optical networks. it covers a wide range of systems, from analog video broadcasting to intercontinental backbone systems [2]. OptiSystem is a system-level simulator that uses realistic modeling of fiber-optic communication networks. It offers a robust simulation environment and a fully hierarchical component and system description. The capabilities can be easily expanded by adding user-defined components and seamless interfaces to various commonly used tools [3].

The system parameters are analyzed as below:

- The range of ONU transmitted power between 0 to 5 dBm.
- Upstream wavelength of 1310nm with the data rate of 1.25 Gbps.
- A continuous wave attacker signal will be used.
- Distance covered during simulation is up to 20 km
- Receiver sensitivity of -18 dBm.

3. Results and Discussion

The results and discussion section present data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different experimental configurations, or any logical order as deemed appropriate.

3.1 Downstream configuration

In a simulation of the downstream portion of a G-PON system, the first step is typically to set the simulation parameters. This would typically involve specifying the layout and bit rate of the signal, with a bit rate of 2488 Gbps and a sensitivity of -28 dBm. These parameters can then be used to simulate the performance of the system as the signal travels through the various components and assess the quality of the signal at the receivers using various metrics such as the Bit Error Rate, Eye Diagram, Maximum Q-Factor and Power obtained. The downstream configuration simulation is shown in Fig. 2.

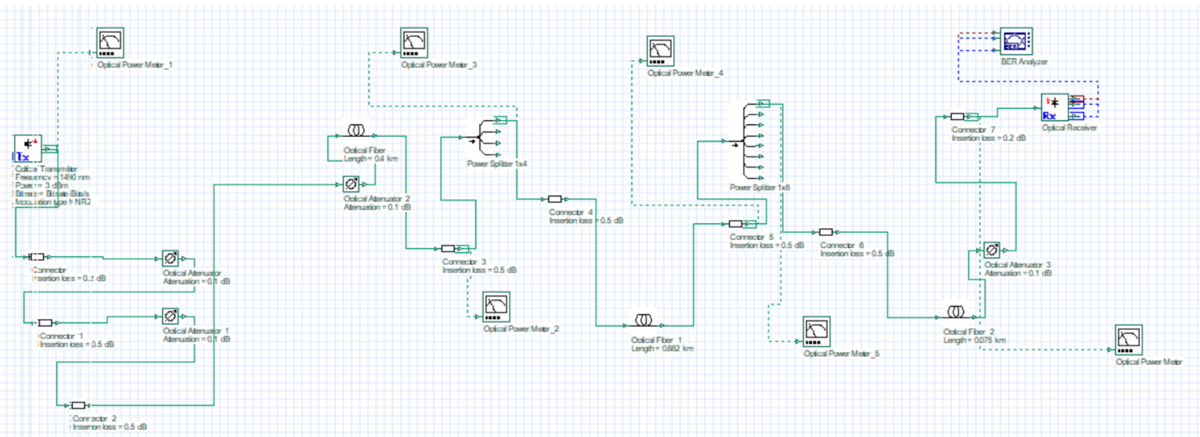

Fig. 2 *Downstream configuration*

Fig. 3 shows the BER Analyzer for the downstream configuration while Fig. 4 is showing the receive power on the downlink configuration.

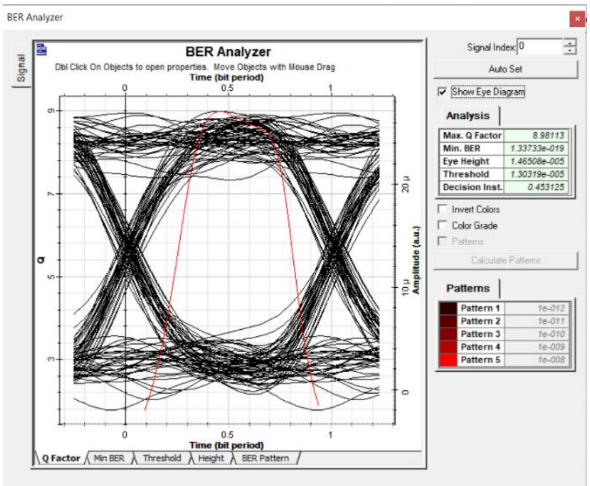

Fig. 3 *BER analyzer for downstream configuration*

Fig. 4 *Receive power on the downlink configuration*

Based on the BER value obtained from the simulation is 1.33733 x 10^{-9}, it is considered to be a good result and smaller than the ideal BER value for fiber-optic transmission, which is usually set at 10^{-9}. A low BER value indicates low error rate and a high signal quality. In addition, a Q-factor value of 8.98113 is considered good as well since is higher than the ideal Q-factor value for fiber-optic transmission which is 6, high Q-factor indicate a high signal quality as well. The measured receive power on the Optical Power Meter (OPM) is -18.719 dBm, this value is also considered good because it is above the sensitivity level of the receiver, -28 dBm, this means the optical receiver is capable of detecting a signal and it is above the noise floor.

3.2 Upstream configuration

In a simulation of the upstream portion of a G-PON system, the first step is typically to set the simulation parameters. This would typically involve specifying the layout and bit rate of the signal, with a nominal bit-rate of 1244 Mbps and a sensitivity of -29 dBm. These parameters can then be used to simulate the performance of the system as the signal travels through the various components and assess the quality of the signal at the receivers using various metrics such as Bit Error Rate, Eye Diagram, Maximum Q-Factor, and Power obtained. The upstream configuration simulation is shown in Fig. 5.

Fig. 6 shows the BER Analyzer for the upstream configuration while Fig. 7 is showing the receive power on the uplink configuration.

Based on the BER value obtained from the simulation is 0, it means that no errors were detected and it is considered a perfect result, this is possible when the signal-to-noise ratio is high. A Q-factor value of 206.953 is also considered good since it is significantly higher than the ideal Q-factor value for fiber-optic transmission which is 6, high Q-factor indicate a high signal quality as well. The received power measured on the Optical Power Meter (OPM) -4.224 dBm is also a good result. This value is well above the sensitivity level of the receiver, -29 dBm, which means that the optical receiver is capable of detecting a signal with high signal to noise ratio and the signal power is well above the noise floor of the system.

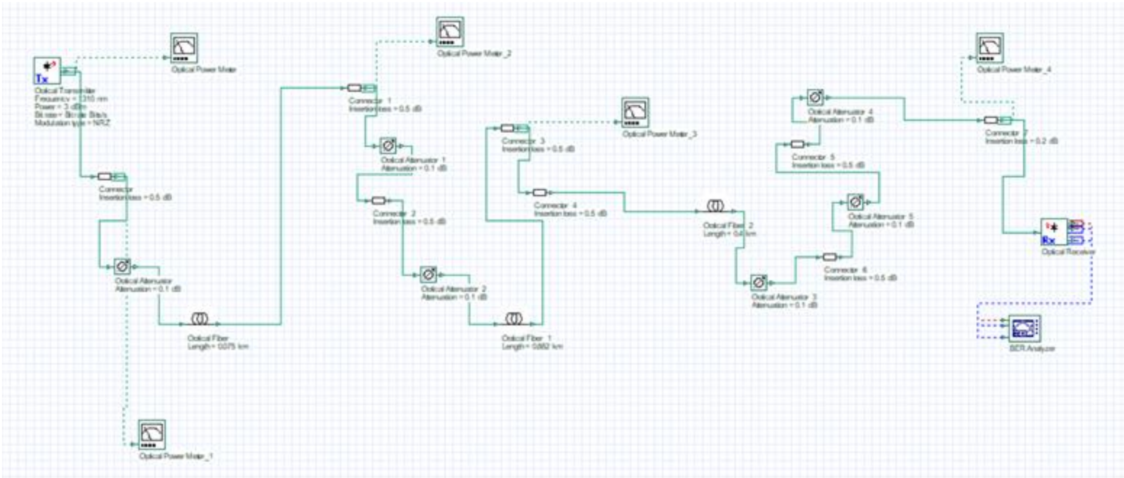

Fig. 5 *Upstream configuration*

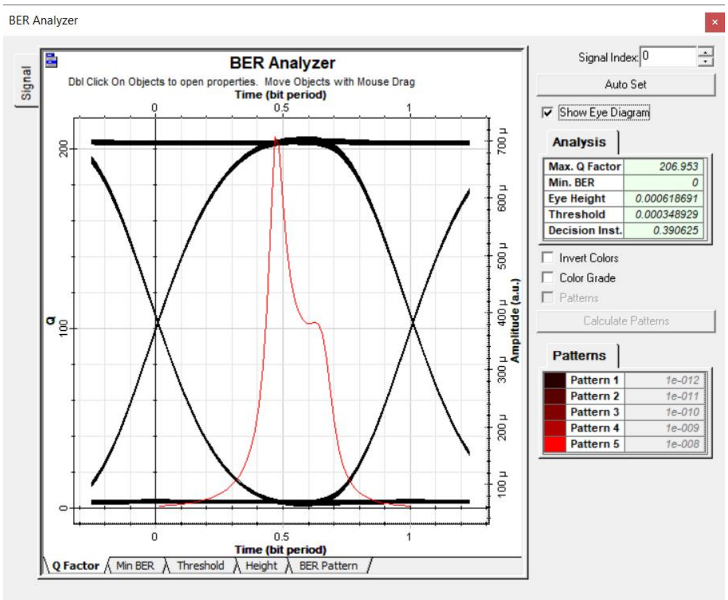

Fig. 6 *BER analyzer for upstream configuration*

Fig. 7 *Receive power on the uplink configuration*

3.3 ONT upstream simulation

In this upstream simulation that shown in Figure 8, the source is the ONT (Optical Network Terminal) and the receiver is the OLT (Optical Line Terminal). Upstream does not use a splitter because the transmitted power does not undergo division, where the position of the OLT and ONT are at the same distance.

The link power budget is used to calculate the attenuation and the final power received at the receiver. In this simulation, the value of the link power budget can be seen on the OPM (Optical Power Meter) that is installed in the circuit. The link power budget value is -2.142 dBm. The Fig. 9 shows the value of OPM Upstream.

Rise time budget is a method used to measure the magnitude of dispersion. The result is obtained from measurements taken on the BER (Bit Error Rate) Pattern at 20% - 80% of the 0 amplitude. In Fig. 10, the rise time budget value is 0.3 x 10^{-9} ps. In this simulation, the bit error rate can be seen using the BER (Bit Error Rate) analyzer device that is installed on the receiver. In this simulation, a value of 0 was obtained, indicating good performance on the circuit as shown in Fig. 11.

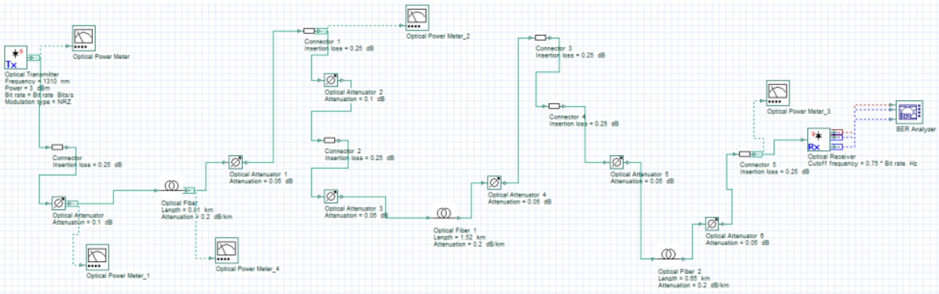

Fig. 8 *ONT upstream configuration*

Fig. 9 *Value of OPM upstream*

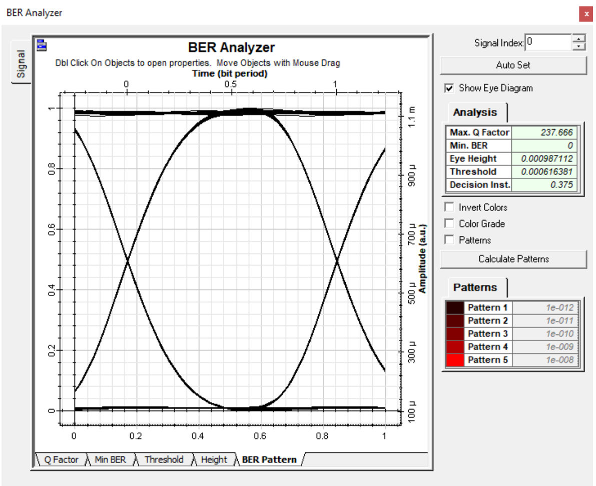

Fig. 10 *BER pattern for ONT upstream*

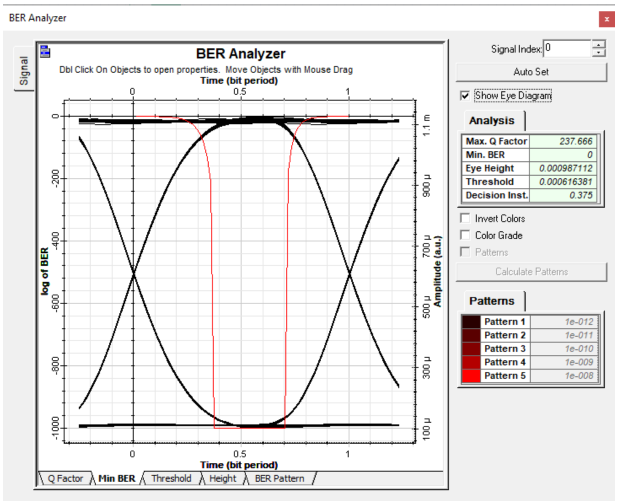

Fig. 11 *BER pattern for ONT upstream*

4. Conclusion

Based on the analysis and calculations performed by the fiber optic access network planning, it can be concluded that the system is considered feasible because it meets the link power budget requirements. As the OptiSystem simulation results show, the power value for downstream is -18.719 dBm and for upstream is -4.224 dBm. Both values are still above the minimum power limit at the receiver set by Telkom Malaysia which is -23 dBm. This means that the signal transmitted by the OLT (Optical Line Termination) at the STO (Service Termination Point) can still be fully received by the ONT (Optical Network Termination) on the customer side. This indicates that the design of the network is able to provide the necessary power level to ensure the signal is received effectively. Based on the simulation of the ONT (Optical Network Terminal) in the network, if the results obtained meet the ITU-T standard for GPON systems, such as a rise time budget value of no more than 17 ps, a BER value of no more than 10^{-9} bps, a link power budget value of no more than 23 dBm, and a SNR (Signal-to-Noise Ratio) value of no less than 21.5 dB, it can be considered that the design is feasible and compliant with the standard. The simulation results indicate that the system is able to meet these standard requirements, and it is likely to provide a reliable and stable communication service.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the completing of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

References

[1] "FTTH Network Based on GPON," Blog, Apr. 28, 2021. https://community.fs.com/blog/components-and-architecture-of-gpon-ftth-access-network.html
[2] Kumar, Naresh. "Improved performance analysis of Gigabit passive optical networks." Optik 125.7 (2014): 1837-1840.
[3] "OptiSystem Overview," Optiwave. https://optiwave.com/optisystem-overview/ (accessed Jun. 16, 2022)