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GPON-Based FTTH Network Design in Koto Gunung Village

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ABSTRACT

The rapid development of information and communication technology has increased the demand for fast and reliable internet access, especially in rural areas. However, Koto Gunung Village, Batang Kapas District, Pesisir Selatan Regency, still experiences limited and unstable internet connectivity. Therefore, this research aims to design a Fiber To The Home (FTTH) network based on Gigabit Passive Optical Network (GPON) technology to provide stable and high-quality internet services for the community. The research method used in this study is the Network Development Life Cycle (NDLC), which includes literature study, field survey, network route design using Google Earth Pro and AutoCAD, and network simulation using OptiSystem software. The network performance was analyzed based on attenuation, link power budget, rise time budget, and Bit Error Rate (BER) parameters. The results showed that the total attenuation values for distribution route 1 and route 2 were 23.8216 dB and 23.874 dB, respectively, which are still below the maximum allowable standard of 28 dB. The total rise time values obtained were 0.2636 ns and 0.264 ns, which also meet the maximum standard of 0.29 ns. In addition, the simulation results showed BER values of 1.42×10^{-19} and 2.322×10^{-19}, indicating excellent transmission quality with very low error rates. Based on these results, the designed GPON-based FTTH network is considered feasible for implementation in Koto Gunung Village.

INTRODUCTION

The rapid development of information and communication technology in the modern era has significantly increased the demand for high-speed internet access. High-speed internet provides various benefits, including access to information, education, healthcare services, entertainment, and digital communication. However, many regions in Indonesia, especially rural areas, still experience limited and unstable internet connectivity. This condition creates a digital divide between urban and rural communities, which affects social and economic development. Therefore, the development of reliable telecommunication infrastructure is essential to support internet accessibility in rural areas. One of the most effective solutions for providing high-speed internet access is the implementation of a Fiber To The Home (FTTH) network (Prastowo & Yulianto, 2025).

The use of copper cables as transmission media in communication systems is no longer capable of supporting long-distance data transmission with large capacity and high speed requirements. As a result, optical fiber technology has replaced copper cables due to its superior performance in terms of bandwidth capacity, transmission speed, and resistance to electromagnetic interference. FTTH is an optical fiber-based technology that transmits data directly from the service provider to users' homes, offering higher speed, larger bandwidth, and better stability compared to conventional access technologies (Armenda et al., 2025).

One of the technologies widely implemented in FTTH infrastructure is Gigabit Passive Optical Network (GPON). GPON technology is capable of providing downstream transmission rates of up to 2.488 Gbps and upstream rates of up to 1.244 Gbps. In addition, GPON supports Triple Play Services, which integrate data, voice, and video services into a single network infrastructure (Yustini et al., 2021). Based on the ITU-T G.984.2 standard, GPON is a flexible optical access technology capable of supporting both residential and business bandwidth requirements through an efficient point-to-multipoint network architecture (Sudiarta, 2021). Therefore, GPON is highly suitable for implementation in rural FTTH network planning due to its broad coverage capability and efficient network architecture.

The performance of an FTTH network can be evaluated through several important parameters, such as rise time budget, Bit Error Rate (BER), and Signal-to-Noise Ratio (SNR). According to the applicable standards, the maximum rise time budget value is 0.219 ns, the BER value must not exceed 10^{-9}, and the minimum SNR value must be at least 21.5 dB (Yuhanef et al., 2023). These parameters are essential to ensure the quality and reliability of optical communication systems. Consequently, understanding the principles of FTTH network design, installation, and performance analysis is highly important for researchers, students, and telecommunication practitioners.

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Koto Gunung Village, located in Batang Kapas District, Pesisir Selatan Regency, currently has inadequate internet access. The village mainly relies on cellular internet services provided by Telkomsel, which are considered unstable and insufficient for daily communication and digital activities. Considering the increasing demand for internet connectivity and future bandwidth requirements, it is necessary to design an FTTH network infrastructure capable of providing reliable and high-capacity communication services in the area. The network planning process includes determining the transmission routes, calculating the number of required devices, and analyzing network feasibility.

Previous research conducted by (Timothy Sutjipto et al., 2024) applied the Network Development Life Cycle (NDLC) method in designing network infrastructure systems. The NDLC method consists of several stages, namely analysis, design, simulation, prototyping, implementation, monitoring, and management. In this research, the most relevant stages are analysis and design, followed by simulation-based evaluation to measure network feasibility and performance. Based on these considerations, this research is entitled "GPON-Based FTTH Network Design in Koto Gunung Village." The expected outcome of this research is the development of an FTTH network design from the central office to end users by determining the appropriate transmission routes, device specifications, and network configurations.

LITERATURE REVIEW

Fiber To The Home (FTTH) is an access network technology that uses optical fiber as the transmission medium from the provider's central office to the customer's premises. FTTH technology is capable of providing internet, voice, and video services with large bandwidth capacity and stable transmission quality. The implementation of FTTH generally uses Gigabit Passive Optical Network (GPON) technology because it has efficient network distribution and supports high-speed broadband services. GPON operates based on the ITU-T G.984 standard with downstream speeds up to 2.5 Gbps and upstream speeds up to 1.25 Gbps. The GPON system uses passive splitters to distribute optical signals from the Optical Line Terminal (OLT) to multiple subscribers, making network infrastructure utilization more efficient. The main performance parameters in GPON-based FTTH networks include link power budget, rise time budget, and Bit Error Rate (BER), which are used to determine the quality and feasibility of optical networks.

Research on GPON-based FTTH networks has been widely conducted to evaluate the performance and quality of optical transmission systems. Research conducted by (Mahjud et al., 2022) discussed the design of the FTTH network of PT Telkom Indonesia Witel Makassar in Bontomanai Village, Bulukumba, using OptiSystem simulation. The results showed a total attenuation value of 26.15 dB, a total rise time of 0.262 ns, and a BER value of 8.24×10^{-19}, indicating that the network was feasible according to ITU-T and PT Telkom standards.

Another study conducted by (Yuhanef et al., 2023) discussed the design and performance analysis of FTTH networks using GPON technology with OptiSystem in Bungo Timur Village, Bungo Regency, Jambi Province. This study analyzed rise time budget, Signal-to-Noise Ratio (SNR), and Bit Error Rate (BER) parameters. The results showed that the rise time budget ranged from 0.0050438404 ns to 0.00527393627 ns, which was still below the maximum standard of 0.219 ns. The BER values ranged from 2.71856×10^{-49} to 2.27036×10^{-65}, meeting the BER standard of $\leq 10^{-9}$, while the SNR values ranged from 50.050211 dB to 50.053279 dB, exceeding the minimum standard of 21.5 dB. Based on these results, the GPON-based FTTH network was declared feasible because all performance parameters met optical network quality standards.

Furthermore, research conducted by (Purba & Suharyanto, 2021). discussed the design of an FTTH network using GPON technology in the Tanjung Uma area, Batam City. The study aimed to design an FTTH network and calculate link power budget, rise time budget, received power, and network traffic capacity parameters. The results showed that the network design consisted of 1 OLT, 1 ODC, and 10 ODPs serving 55 customers. The highest attenuation value on the uplink was 26.21 dB and on the downlink was 26.01 dB, which still met the Proxynet attenuation standard of 28 dB. The received power values obtained were -10.53 dBm for uplink and -10.51 dBm for downlink. In addition, the rise time system value of 0.250 ns was still below the maximum limit of 0.583 ns, indicating that the FTTH network was feasible for implementation.

Another study conducted by (Septima et al., 2025) discussed the design of an FTTH network in Rangkiang Luluih Village, Solok Regency, using the Network Development Life Cycle (NDLC) method and GPON technology. This study used OptiSystem simulation to analyze network performance based on BER, Q-Factor, and Link Power Budget parameters. The results showed that in the first proposal all areas met GPON standards with the best BER values of 3.97523×10^{-31} for downlink and 3.88455×10^{-103} for uplink, as well as Q-Factor values of 11.5431 and 21.5315. However, in the second proposal several areas were declared infeasible because the BER values exceeded the 10^{-9} standard and the Q-Factor values were below the minimum standard of 6. This study indicated that the distance between OLT and ONT, the number of splitters, and attenuation values significantly affect the quality of GPON-based FTTH networks.

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Another study conducted by (Sudiarta, 2021) discussed the performance analysis of a Fiber To The Home (FTTH) network using Gigabit Passive Optical Network (GPON) technology based on OptiSystem simulation. This study analyzed the parameters of Power Link Budget, Rise Time Budget, and Bit Error Rate (BER) to determine network feasibility according to the ITU-T G.984 standard. The results showed that the power link budget values ranged from -17 dBm to -18 dBm, which were still below the receiver sensitivity limit of -28 dBm. The Bit Error Rate (BER) values ranged from 10^{-50} to 10^{-22}, which still met the maximum standard of 10^{-9}. In addition, the downstream rise time budget values ranged from 0.27 ns to 0.2808 ns, while the upstream values ranged from 0.25 ns to 0.51 ns, which were still below the maximum system limit. Based on these results, the GPON-based FTTH network was declared feasible and compliant with the ITU-T G.984 standard.

Another study by (Ikhwan et al., 2023) discussed the design of a Fiber To The Home (FTTH) network using Gigabit Passive Optical Network (GPON) technology in Cibeber Village, Tasikmalaya, using Link Power Budget and Rise Time Budget analysis. The results showed that the received power values ranged from -16.631 dBm to -15.631 dBm for uplink and from -16.644 dBm to -15.574 dBm for downlink, which still met the receiver sensitivity standard of -8 dBm to -27 dBm. In addition, the rise time budget values ranged from 0.2044 ns to 0.2039 ns for uplink and from 0.2188 ns to 0.21574 ns for downlink, which were still below the maximum PT Telkom standard limits of 0.56 ns for uplink and 0.292 ns for downlink. Based on these results, the GPON-based FTTH network was declared feasible for implementation.

Based on previous studies, it can be concluded that link power budget, rise time budget, and BER, are the main indicators in determining the quality and feasibility of GPON-based FTTH networks. However, most previous studies focused only on simulation analysis without considering the geographical conditions of residential areas. Therefore, this study aims to design and analyze a GPON-based FTTH network in the selected research area using OptiSystem simulation while considering network performance and geographical conditions.

METHOD

The research site for the FTTH network design is located in Koto Gunung Village. The tools and materials used include a PC/Laptop, Google Earth Pro and AutoCAD software for network design, and OptiSystem for simulating the designed network.

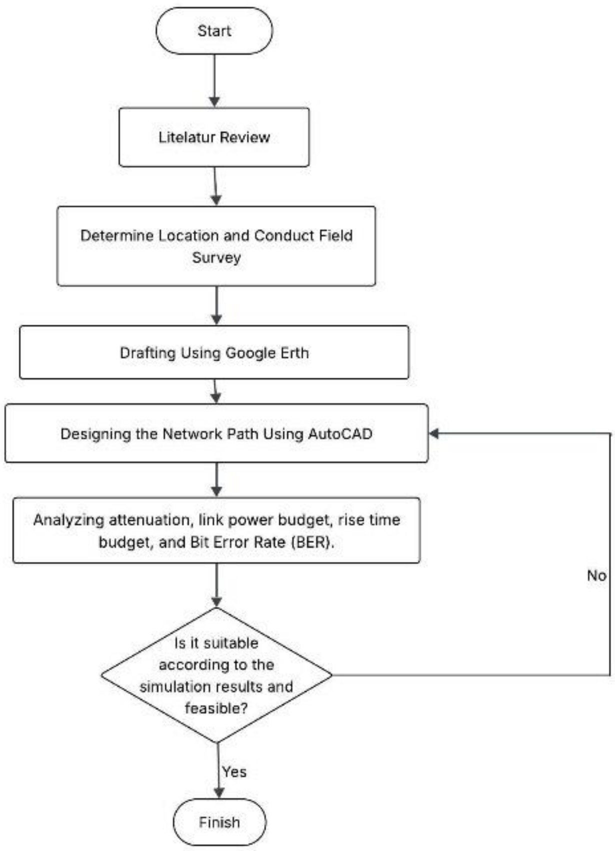

Figure. 1 Design Procedure Flowchart

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After conducting a literature study and field survey to analyze the FTTH network, the network design was then carried out in Koto Gunung Village, Batang Kapas District, Pesisir Selatan Regency. Figure 1 shows the research procedure flow used in the GPON-based FTTH network design process. The research began with a literature study to understand the concepts of FTTH and GPON technology, followed by a field survey to obtain data on the research location. After that, the network was designed using Google Earth and AutoCAD applications, then simulated using OptiSystem software, followed by network performance analysis based on the technical parameters used.

Drafting Using Google Earth

This process was carried out to determine the estimated route path, distance measurement, and network topology planning based on the survey results. By using the Google Earth application to design the network, the result of the design is:

Figure 2. Coverage Area Map of Koto Gunung Village

Figure 2 shows the coverage area of Koto Gunung Village which was used as the research location for FTTH network planning. This coverage map was used to identify the geographical conditions of the area, determine the network service coverage, and assist in planning the fiber optic cable distribution routes.

Figure 3. Fiber Optic Route from the OLT to the ODC

Figure 3 presents the feeder fiber optic cable route from the Optical Line Terminal (OLT) to the Optical Distribution Cabinet (ODC). The feeder cable has a total distance of 8.3 km and includes two cable joints (manholes) installed every 4 km along the route. The route was designed based on field survey results and distance measurements using Google Earth to obtain an efficient distribution path suitable for the geographical conditions of the research area.

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Figure 4. Locations of Devices and Fiber Optic Cable Routes

Figure 4 illustrates the locations of network devices and the planned fiber optic cable routes in the research area. The designed network consists of 1 new Optical Distribution Cabinet (ODC), 19 new Optical Distribution Points (ODP), and 21 new utility poles installed to support the FTTH network infrastructure. In addition, there are 2 distribution cable routes originating from the ODC to distribute the optical network to the customer areas. The placement of network devices and cable routes was designed based on the geographical conditions and service coverage requirements in Koto Gunung Village.

Designing the Network Path Using AutoCAD

After obtaining the draft route, the network path was designed in detail using AutoCAD software. This stage included designing the cable route, network layout, and supporting infrastructure required for the Fiber Optic network implementation.

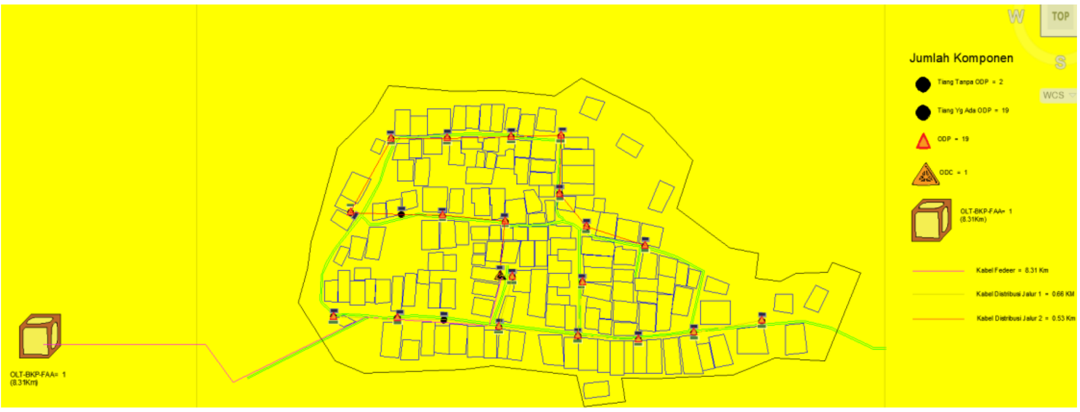

Figure 5. FTTH Network Routing Design

Attenuation, Link Power Budget, Rise Time Budget, and BER Analysis

The performance of the Fiber Optic network was analyzed based on attenuation, link power budget, rise time budget, and Bit Error Rate (BER) parameters to evaluate network feasibility according to transmission standards (Adiati et al., 2022).

Table 1. Data Used in the FTTH Network Design

Parameters	**Value**
Daya *Transmitter* (OLT)	5 dB
Sensitivitas Receiver (ONT)	-27 dBm
Downstream	2.5 Gbps
Rise Time Transmitter (OLT)	0.15 ns
Rise Time Receiver (ONT)	0.2 ns
Spectral Width	1 nm
Dispersi Material (1490)	0.01364 ns/nm.km

E-ISSN: E-ISSN: 3064-0377
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RESULT

Feasibility Parameter Analysis

- **Power Link Budget**

The link power budget calculation is carried out to determine the allowable total attenuation limit between the transmitter output power and the receiver sensitivity. According to (Faathir Haq, 2024), the power link budget value in a GPON network ranges from −17 dBm to −18 dBm and is still below the receiver sensitivity limit of −28 dBm based on the ITU-T G.984 standard, indicating that the network is feasible for use. The equation for total attenuation is:

$$atot = L \cdot aserat + Nc_{APC} \cdot ac_{APC} + Nc_{UPC} \cdot ac_{UPC} + N \cdot as + s_{(1:4)} + sp_{(1:8)}$$

Where:
$atot$ = Total Attenuation (dB)
$aserat$ = Cable Attenuation (dB/km)
L = Cable Length (km)
Nc_{APC} = Number of Connectors (units)
ac_{APC} = Connector Attenuation (dB)
Nc_{UPC} = Number of Connectors (pieces)
ac_{UPC} = Connector Attenuation (dB)
Ns = Number of Splices (pieces)
as = Splice Attenuation (dB)
$s_{(1:4)}$ = Splitter Attenuation 1:4 (dB)
$s_{(1:8)}$ = Splitter Attenuation 1:8 (dB)

At the ONT, there is a device sensitivity parameter that determines whether the network signal is properly received or not. The designed sensitivity calculation is as follows:

$$Pr = Pt - atotal$$

Where:
Pr = Power Received at the Receiver (dBm)
Pt = Optical Source Output Power (dBm)

The following is a link analysis from the Batang Kapas Central Office (Optical Line Terminal) to customers in Koto Gunung Village (Optical Network Terminal), which is divided into two distribution paths from the ODC to the ODP.

Path 1

- Attenuation

$atot = L \cdot a\text{fiber} + Nc_{APC} \cdot ac_{APC} + Nc_{UPC} \cdot ac_{UPC} + N \cdot as + s_{(1:4)} + sp_{(1:8)}$
$atot$ = 8,54143 . 0,28 + 2 . 0,35 + 10 . 0,25 + 6 . 0,1 + 7,25 + 10,38
$atot$ = 2,3916 + 0,7 + 2,5 + 0,6 + 7,25 + 10,38
$atot$ = 23,8216 dB

- Received Power

$Pr = Pt - atotal$
Pr = 5 – 23,8216
Pr = –18,8216 dB

Path 2

- Attenuation

$atot = L \cdot a\text{fiber} + Nc_{APC} \cdot ac_{APC} + Nc_{UPC} \cdot ac_{UPC} + N \cdot as + s_{(1:4)} + sp_{(1:8)}$
$atot$ = 8,729 . 0,28 + 2 . 0,35 + 10 . 0,25 + 6 . 0,1 + 7,25 + 10,38
$atot$ = 2,444 + 0,7 + 2,5 + 0,6 + 7,25 + 10,38
$atot$ = 23,874 dB

- Received Power

$Pr = Pt - atotal$
Pr = 5 – 23,874
Pr = –18,874 dB

- **Rise Time Budget**

According to (Adawiah et al., 2023), "Rise Time Budget is a method used to determine the dispersion limitation of an optical fiber link." In an FTTH network using GPON technology, the downlink transmission speed (*bit rate*) is 2.5

E-ISSN: E-ISSN: 3064-0377
Volume 3, **Number** 1, January 2026
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Gbps. By using the Non Return to Zero (NRZ) format, the maximum value of the *Rise Time Budget* can be calculated using the following equation:

Tr = 0.7 / Br

Where:

Br = bit rate (Gbps)

Tr = Maximum rise time (ns)

So, the maximum value of the Rise Time Budget is:

$$Tr = \frac{0.7}{Br}$$

$$= \frac{0.7}{(2.4 \times 10^{9})}$$

= 0.29 ns

Meanwhile, the calculation of fiber rise time to determine the total rise time is performed using the following equation:

$$tf = \sigma\lambda \cdot L \cdot D$$

Where:

$\sigma\lambda$ = Spectral width (nm)

L = Optical fiber length (km)

D = Material dispersion (ps/nm·km)

After knowing the fiber rise time parameters, the total rise time in this network can be calculated using the following equation:

$$t_{sis} = \sqrt{(t_{tx}^2 + t_{rx}^2 + t_f^2)}$$

Where:

t_{sist} = total *Rise time budget* (ns)

t_{tx} = *rise time transmitter* (ns)

t_{rx} = *rise time receiver (ns)*

t_f = *rise time fiber* (ns)

The following is an analysis of the Rise Time Budget calculation in Koto Gunung Village (ONT), which is divided into two distribution paths from the ODC to the ODP.

Path 1

- Rise Time Fiber

$tf = \sigma\lambda \cdot L \cdot D$

tf = 1 . 8,54143 . 0,01364

tf = 0,116

- Rise Time Total

$$t_{sis} = \sqrt{(t_{tx}^2 + t_{rx}^2 + t_f^2)}$$

$$t_{sis} = \sqrt{(0.15^2 + 0.2^2 + 0.116^2)}$$

$$t_{sis} = 0.2636\ ns$$

Path 2

- Rise Time Fiber

$tf = \sigma\lambda \cdot L \cdot D$

tf = 1 . 8,7209 . 0,01364

tf = 0,11895

- Rise Time Total

$$t_{sis} = \sqrt{(t_{tx}^2 + t_{rx}^2 + t_f^2)}$$

$$t_{sis} = \sqrt{(0.15^2 + 0.2^2 + 0.11895^2)}$$

$$t_{sis} = 0.264\ ns$$

PERFECT JOURNAL OF SMART ALGORITHMS

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Table 2. FTTH network feasibility parameters

Parameters	Path 1	Path 2	Standard	Feasible
Attenuation	23,8216 dB	23,874 dB	< 28 dB	Yes
Sensitivity	–18,8216 dB	–18,874 dB	> -27 dB	Yes
Total Rise Time	0.2636 ns	0.264 ns	< 0.29 ns	Yes

Design Simulation

The designed network is then simulated using OptiSystem from the OLT to the ONT to evaluate the total attenuation and the resulting Bit Error Rate (BER). According to (Utami et al., 2023), The FTTH network simulation using OptiSystem is performed to analyze the performance of the optical communication system based on attenuation, received power, and transmission quality parameters, so that the feasibility of the designed network can be determined.

- Distribution Path 1

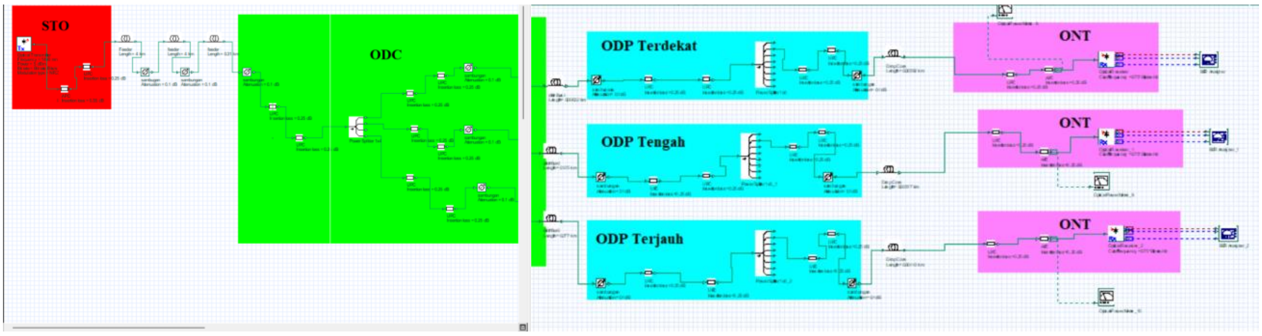

Figure 6. FTTH Network Design in OptiSystem for Path 1

After performing the simulation on the Path 1 design in OptiSystem, the total attenuation at the ONT and the Bit Error Rate (BER) of the network can be determined as follows:

Figure 7. OPM Measurement at ONT for Path 1

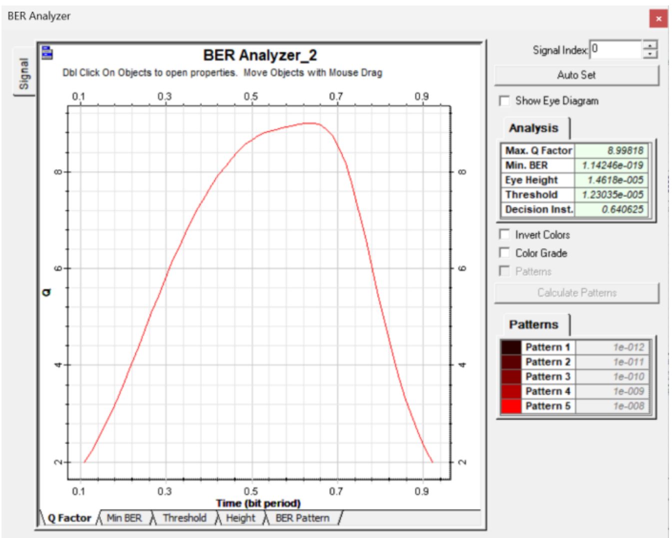

Figure 8. BER Analyzer Results for Path 1

E-ISSN: E-ISSN: 3064-0377
Volume 3, **Number** 1, January 2026
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The total attenuation obtained is 18.908 dB, which is very close to the manual calculation result of 18.8216 dB. The BER obtained from the simulation result is 1.42×10^{-19}, indicating that the bit error rate is extremely low and meets the required standard.

- Distribution Path 2

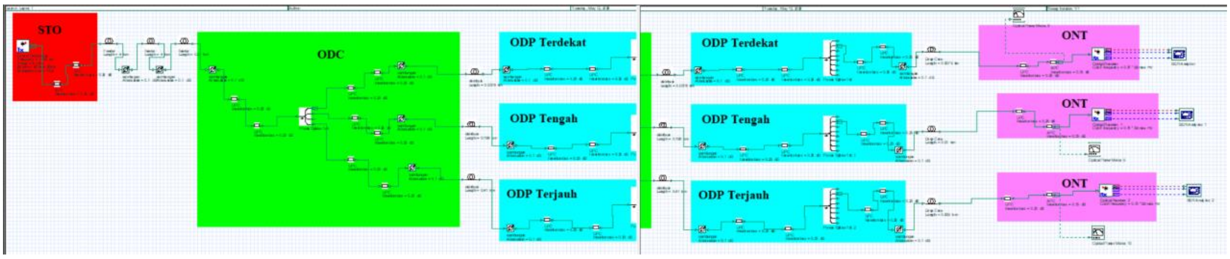

Figure 9. FTTH Network Design in OptiSystem for Path 2

After performing the simulation on the Path 2 design in OptiSystem, the total attenuation at the ONT and the Bit Error Rate (BER) of the network can be determined as follows:

Figure 10. OPM Measurement at ONT for Path 2

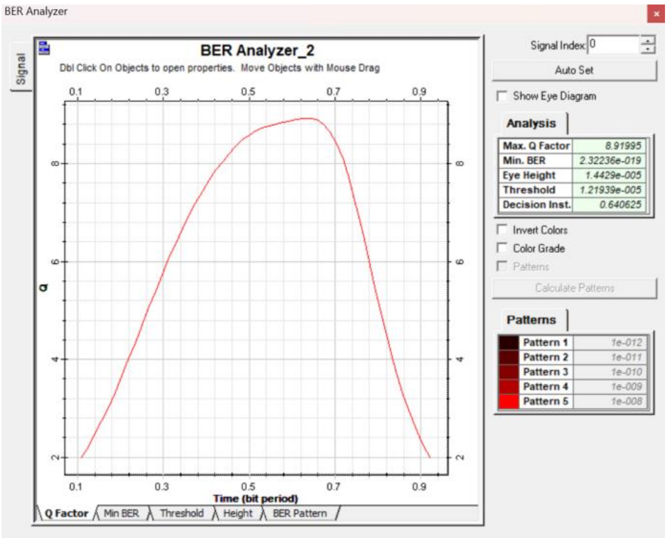

Figure 11. BER Analyzer Results for Path 2

The total attenuation obtained is 18.948 dB, which is very close to the manual calculation result of 18.874 dB. This value is slightly higher than that of Path 1. Meanwhile, the BER obtained from the simulation result is 2.322×10^{-19}, indicating that the bit error rate is extremely low and meets the network feasibility standard. This result is also slightly higher than the BER of Path 1. According to (Putra et al., 2025), A FTTH network is considered to have good communication quality if the Bit Error Rate (BER) does not exceed the maximum limit of 10^{-9} and the Q-factor value is above 6.

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DISCUSSION

Based on the results of the GPON-based Fiber To The Home (FTTH) network design in Koto Gunung Village, the designed network has met the feasibility standards for optical communication systems. The link power budget analysis showed that the attenuation values on distribution route 1 and route 2 were 23.8216 dB and 23.874 dB, respectively, which are still below the ITU-T G.984 standard limit of 28 dB. The slightly higher attenuation value on route 2 was caused by the longer transmission distance compared to route 1. However, the difference between the two routes was relatively small, indicating that the designed network distribution was efficient and balanced.

The received power values obtained from manual calculations were –18.8216 dBm for route 1 and –18.874 dBm for route 2, which still met the receiver sensitivity standard above –27 dBm. The OptiSystem simulation results also showed similar attenuation values, namely 18.908 dB and 18.948 dB. The small difference between manual calculations and simulation results indicates that the network design calculations were accurate and reliable. This result confirms that the designed FTTH network can transmit optical signals properly from the OLT to the ONT.

Furthermore, the rise time budget analysis produced values of 0.2636 ns and 0.264 ns, which are still below the maximum allowable standard of 0.29 ns for GPON systems with a 2.5 Gbps downstream bit rate. These results indicate that the dispersion effect in the optical fiber does not significantly affect the transmission quality. In addition, the BER values obtained from the simulation were 1.42×10^{-19} and 2.322×10^{-19}, which are far below the maximum BER standard of 10^{-9}. This shows that the designed network has excellent transmission quality with a very low error rate.

Compared with previous studies, the results of this research are consistent with other GPON-based FTTH studies that also produced attenuation, rise time, and BER values within standard limits. However, this research specifically considers the geographical conditions and network distribution routes in Koto Gunung Village, making the design more suitable for implementation in rural areas. Therefore, the proposed FTTH network is expected to improve internet accessibility and support digital communication activities for the local community.

CONCLUSION

Based on the results of the design and analysis of the Gigabit Passive Optical Network (GPON)-based Fiber To The Home (FTTH) network in Koto Gunung Village, Batang Kapas District, Pesisir Selatan Regency, it can be concluded that the proposed network design is feasible for implementation. The network planning process using Google Earth Pro and AutoCAD successfully determined the optical fiber routes and supporting infrastructure required for FTTH deployment. The analysis results showed that the total attenuation values on distribution route 1 and route 2 were 23.8216 dB and 23.874 dB, respectively, which are still below the ITU-T G.984 standard limit of 28 dB. The received power values of –18.8216 dBm and –18.874 dBm also met the receiver sensitivity standard above –27 dBm. In addition, the total rise time values of 0.2636 ns and 0.264 ns were still below the maximum allowable standard of 0.29 ns. The OptiSystem simulation results showed BER values of 1.42×10^{-19} and 2.322×10^{-19}, indicating excellent transmission quality with very low error rates. Therefore, the designed GPON-based FTTH network is capable of providing stable and high-quality internet access for the community in Koto Gunung Village. However, this research is limited to simulation-based analysis and has not yet been implemented directly in the field. Further studies are recommended to conduct real network implementation and evaluate additional parameters such as Quality of Service (QoS), network reliability, and long-term performance.

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