

Construction of Fiber Optical Communication System Infrastructure for 3T (*Terdepan, Terluar dan Tertinggal*) Areas Using Fiber to the Area Network System

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Abstract. Distribution of telecommunications in Indonesia, the government is aggressively building telecommunications network facilities, especially for 3T areas (Frontier, Outermost and Disadvantaged). Because there are still many areas that have not received access to telecommunications services, the Fiber to The Area (FTTA) network is the right solution to meet the needs of the community in economic, environmental and technical aspects. This design will provide an expansion of Fixed Broadband services around the Tanjung Lesung Special Economic Zone (SEZ), Pandeglang Regency, Banten. Later this fiber optic access network will use a Fiber To The Area (FTTA) network topology that connects the CO (Central Office) as a Metro Ethernet and DWDM hub with the Mini OLT Shelter as an Optical Line Terminal (OLT) hub supported by NG-PON (Next-Generation) PON (Passive Optical Network) technology with 2 Stage architecture which involves two stages of sending information signals through optical fiber. This design must first be designed on Google Earth to determine the fiber optic cable path and to determine the feasibility of performance on the system the author uses several test components including: Link Power Budget (LPB) testing, Rise Time Budget (RTB), Signal to Noise Ratio (SNR), Bit Error Rate (BER), Quality Factor (Q-Factor) which is simulated on optisystem to be able to provide performance values that match the eligibility standards at PT Telkom Indonesia.

Keywords: 3T (*Terdepan, Terluar dan Tertinggal*), FTTA, Special Economic Zone (SEZ), Google Earth, Optisystem, Link budget.

A. INTRODUCTION

Today, telecommunications provide a necessary foundation for everyone's existence. Alongside the quickening pace of technological growth, the telecoms industry continues to develop (Senkans et al., 2019; Nyarko-Boateng et al., 2020). Communications technology advancements are advancing quickly in keeping with the traits of contemporary society, which demands high mobility, flexible and simple services, happiness, and efficiency in every way (FTTH, 2021; Johnson, 2023). The environmental factor, which pertains to strategically building paths to meet efficient needs while taking into account aesthetic characteristics of the surroundings, is one of the aspects that must be satisfied (Li et al., 2004). The economic side comprises funding the design and income factors for PT. Telkom's company, while the technical aspect is focused with Quality of Service (QOS) in network architecture.

The growth of fiber optic networks must be facilitated by both the national and regional governments, according to the Director-General of Resources and Information Technology Devices (Dirjen SDPPI) at the Ministry of Communication and Information Technology (Delano & Astuti, 2017; Fam et al., 1997). Uchok Sky Khadafi, the executive director of the CBA (Center for Budget Analysis), claims that 12.500 communities still lack access to telecommunications. Rudiantara, the former minister of communication and information technology, had previously asserted that after BAKTI (Telecommunication and Informatics Accessibility Agency) completed the Palapa Ring, all Indonesian communities would be able

to use telecommunication services, including broadband internet. In order to meet the communities' needs for telecommunications networks in the 3T areas, it is necessary to build an infrastructure of optical fiber communication systems (Muliandhi et al., 2020; Lam et al., 2010).

The Tanjung Lesung region in Pandeglang Regency, Banten Province, is the author's choice for a location that fits the 3T category. Tanjung Lesung is not only designated as a 3T, but it is also one of the locations with the highest priority for development for Special Economic Zones (KEK), as defined by the KEK Law (Law Number 39 of 2009 concerning Special Economic Zones) and its amending and implementing regulations. The construction of the FTTA (Fiber to the Area) network entails the transfer of digital data via optical fiber cables from the provider center to consumers, with the goal of enabling customers to access data services with high bandwidth capacity and minimal interference (Muliandhi et al., 2020; Ogbé & Dike, 2017).

The Metro Ethernet (ME) in CO Labuan is used in the proposed design to cover KEK Tanjung Lesung, although the OLT (Optical Line Terminal) is not sourced from CO Labuan. This choice was chosen to prevent having to go a very long way to get the feeder optical fiber from CO Labuan. As a result, the author intends to construct Telkom Shelter Citereup, a Mini OLT Shelter. After path design on Google Earth and performance testing to obtain Link Power Budget (LPB), Rise Time Budget (RTB), Signal to Noise Ratio (SNR), Bit Error Rate (BER), and Quality Factor (Q-Factor) values, which will first be carried out in the optical system simulation, the fiber optic access network design with FTTA technology aims to provide quality telecommunication services to households.

B. LITERATURE REVIEW

1. Optical Fiber

A type of cable consisting of glass or plastic is used in fiber optics, a communication transmission medium, to send light signals from one location to another. The laser or LED is often the light source utilized to send signals (Li et al., 2022). The core, cladding, and coating make up the three main components of a fiber optic, as depicted in Figure 1 (Fiber Optic Installation).



Figure1. The Structure of Optical Fiber

2. FTTA (Fiber to the Area)

Fiber to the Area (FTTA) is an optical signal transmission path that uses optical fiber as the transmission medium to carry signals from the service center (vendor) to the user area. Typically, there is a 20 kilometer limit distance between the service center and the consumers (Samudro et al., 2023).

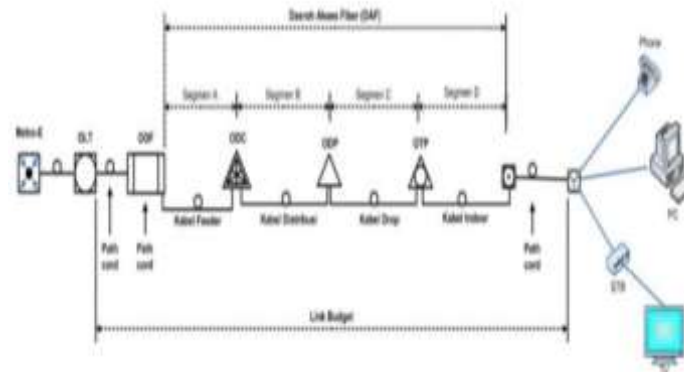


Figure 2. FTTA Topology

- Optical Line Termination (OLT): An active device that serves as a hub point with the provider.
- Optical Distribution Frame (ODF): A switching device that distributes outdoor cables to indoor cables towards the ODC.
- Optical Distribution Cabinet (ODC): A passive device that functions as a connection point for feeder cables.
- Passive Splitter: A device that divides optical signal information.
- Optical Distribution Point (ODP): A location where the optical drop cable terminates towards the customer.
- Optical Network Terminal (ONT): An active device located at the end of the network, situated at the customer's premises.
- Feeder Cable: Connects ODF to ODC.
- Distribution Cable: Connects ODC to ODP.
- Drop Cable: Connects ODP to ONT (Yuwana, 2017).

3. Google Earth Pro

An online globe application is called Google Earth Pro. It maps the Earth using data gathered from satellite mapping, aerial photography, and 3D GIS globes. Users can look for addresses using Google Earth (in some nations). It is employed by the author to plan the fiber optic access network's route (Samudro et al., 2023).

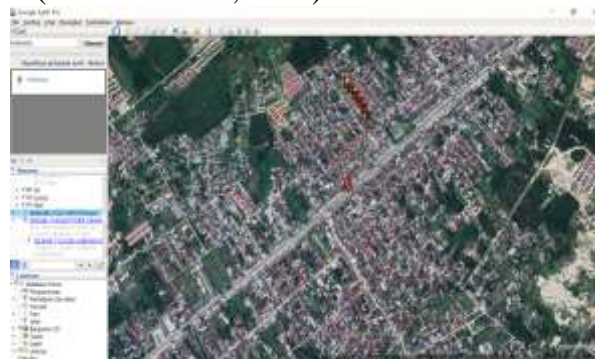


Figure 3. Google Earth View

4. Optisystem

The tool used to model this fiber optic network is called Optisystem. Values like BER, Q-Factor, SNR, LPB, and RTB will be derived from the optisystem simulation results to verify the viability of the network performance.

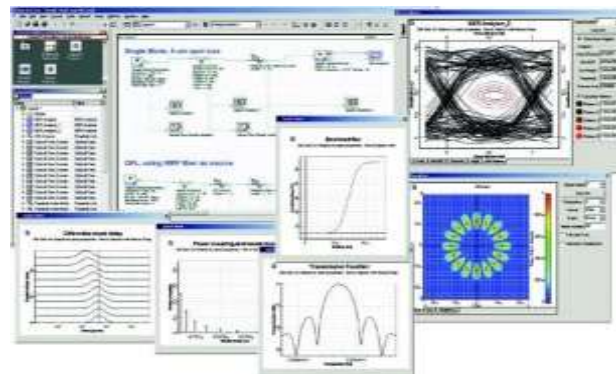


Figure 4. Optisystem View

5. BOQ (Bill of Quantity)

A document called a bill of quantities is closely tied to the work of a quantity surveyor. It makes sure that everything goes off without a hitch and occasionally acts as a guide for next projects. The BoQ aids in cost calculations when construction and design are finished and specifications are finalized.

6. Revenue Stream

The term "revenue stream" is formed from the English terms "revenue" and "stream." As a result, "aliran pendapatan" (income flow) is a common term used to describe revenue stream in Indonesian. A company's operational operations or future enterprises that will be established and managed are considered its income streams in a broader sense.

C. METHOD

The author's fiber optic access network aims to expand fixed broadband services in the area of Tanjung Lesung's Special Economic Zone (SEZ), which is located in Pandeglang Regency, Banten. The proposed fiber optic access network will make use of the Fiber to the Area (FTTA) network topology, which links the Central Office (CO), which serves as the Metro Ethernet and DWDM hub, with the Shelter Mini OLT, which serves as the hub of the Optical Line Terminal (OLT). This topology is supported by Next-Generation PON (Passive Optical Network) technology and has a two-stage architecture that involves two stages of information delivery through optical fiber to the customers.

1. How the System Works



Figure 5. Research Flowchart

The functioning of this fiber optic access network entails creating a Fiber to the Area (FTTA) network, and the Tanjung Lesung Special Economic Zone (SEZ) is included in the proposed design. While the Optical Line Terminal (OLT) is not taken from CO Labuan due to the considerable distance if feeder optical fiber is drawn from there, it involves the use of Metro Ethernet (ME) located at CO Labuan. Since this is the case, the author has created a Shelter Mini OLT that will be called Telkom Shelter Citereup. Between CO Labuan and the Tanjung Lesung SEZ, in the Citereup area, the Shelter Mini OLT will be used to store both active and passive devices.

Using fiber optic patch cords, it will be connected to the Optical Distribution Frame (ODF) from the OLT. Then, utilizing a fiber optic feeder, it will travel from the ODF to the Optical Distribution Cabinet (ODC), which is situated inside Tanjung Lesung's Special Economic Zone. To get to the Optical Distribution Point (ODP), it will employ fiber optic distribution from the ODC. It will then use fiber optic drop cables to connect from the ODP to the Optical Network Terminal (ONT). The optical signal will then be changed by the ONT into an electrical signal so that it may be connected to the client's equipment.

2. FTTA Access Network Path Design

The author uses Google Earth software to create the two primary routes for the FTTA fiber optic access network, which will travel through one Telkom T-Cloud and one Telkom Shelter:

- a. Route covering 26.7 kilometers from Telkom T-Cloud Labuan to Telkom Shelter Citereup;
- b. Route covering 9.95 km (containing ODC-FAB and ODC-FAC) from Telkom Shelter Citereup to ODC-FAA (fiber optic feeder 1);
- c. Route of 15.35 km (containing OC-FAD, ODC-FAE, and ODC-FAF) from Telkom Shelter Citereup to ODC-FAG (fiber optic feeder 1).



Figure 6. Designing the Fiber to the Area (FTTA) Fiber Optic Access Network Path Using Google Earth Software

The author uses a number of parameters during the design and simulation process. The following are a few of the parameters the author used:

1. General Parameters

General parameters are listed in the following table:

Table 1. General Parameters

General Parameters	
Bit rate (Gbps)	10
Bandwidth (Ghz)	9
Modulation Format	NRZ

Margin system	3
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2. Transmitter Parameters

Transmitter parameters are listed in the following table:

Table 2. Transmitter Parameters

Transmitter Parameters	
Type of Optical Source	CW Laser
Frequency(nm)	1310
Rise Time (ps)	30
Spectral Width (nm)	0,07
Transmit Power (dBm)	12

3. Receiver Parameters

Receiver parameters are listed in the following table:

Table 3. Parameter Receiver

Receiver Parameters	
Photodetector Type	PIN
Rise time (ps)	15
Receiver Sensitivity (dBm)	-22

4. Optical Fiber Parameters

Optical Fiber Parameters are listed in the following table:

Table 4. Optical Fiber Parameters

Optical Fiber Parameters	
Type of Fiber Optic	SMF G.652
The Link Length (km)	26.7 ; 9.95 ; 15.35
Attenuation (dB/km)	0,2
Chromatic dispersion (ps/nm.km)	0,07
Splice Damper (dB/splice)	0,1
Connector Damper (dB/connector)	0,3

3. Performance Feasibility Measurement

a. Link Power Budget (LPB)

Link power budget is the total permitted attenuation of the optical link from the source to the reception point, taking into account cable attenuation, connector attenuation, splice attenuation, and system margin. Using the formula, the Link Power Budget is calculated from the overall attenuation:

$$\alpha_{total} = L.\alpha_f + N_c.\alpha_c + N_s.\alpha_s + N_{sp}.\alpha_{sp} + L_{dc}.\alpha_{dc} \quad (1)$$

Information:

- α_{tot} = Total attenuation of the source (dB)
- L = Optical fiber length (Km)
- α_f = Fiber optic attenuation (dB)
- N_c = Number of connectors
- α_c = Connector attenuation (dB/connector)
- N_s = Number of connections
- α_s = Connection attenuation (dB/connection)
- L_{dc} = Drop core Length
- α_{dc} = Drop core Attenuation
- N_{sp} = Number of Splitters = Splitter Attenuation (dB)

The goal of the link power budget calculation is to use the equation to determine the receiver's necessary power budget so that the received power level does not fall below the minimal sensitivity:

$$Pr_x = P_{tx} - \text{Link loss Budget} \quad (2)$$

Information:

- Pr_x = Receiver Sensitivity (dBm)
- P_{tx} = Transmitter Output Power (dBm)
- α_{tot} = Link Loss Budget (dB)

b. Rise Time Budget

The limit or threshold for optical fiber dispersion (pulse broadening) is determined by the rise time budget. The following equation can be used to compute the dispersion coefficient value using the chromatic dispersion value:

$$t_f = D(\lambda) \cdot S \cdot L \quad (3)$$

Information:

- $D(\lambda)$ = Chromatic Dispersion Coefficient (ps/nm.km)
- S = The Spectral Laser Width (nm)
- L = Distance Length (km)

The rise time budget equation is:

$$L = \sqrt{(t_{tx}^2 + t_f^2 + t_{rx}^2)} \quad (4)$$

Information:

- t_{tx} = Rise time Transmitter (ns)
- t_{rx} = Rise time receiver (ns)
- $t_{chromatic}$ = (Rt) chromatic dispersion (ns)
- capital = It has no value or is zero because it uses single-mode optics

c. Signal To Noise Ratio (SNR)

SNR (Signal-to-Noise Ratio) measures the relationship between signal and noise power at a certain location. A system's SNR is better the higher its SNR value. The formula below can be used to calculate the SNR value:

$$SNR = 10 \log \left(\frac{(P_{in}RM)^2}{2qP_{in}RM^2F(M)Be + \frac{4K}{RL}} \right) \quad (5)$$

Information:

- P_{in} = The received power at the receiver (Prx in Watt)
- R = Responsibility (A/W)
- M = Avalance photodiode gain
- q = Elektron Change (1.69×10^{-9} C)
- F(M) = Noise Figure
- Be = Receiver electrical bandwidth (Hz)
- KB = Boltzman constant (1.38×10^{-23} J/K)
- RL = Resistence (Ω)
- T = The temperature of the Avalanche Photodiode (APD) (K)

d. Q- Factor

The Signal to Noise ratio at the Decision circuit, expressed as voltage or current, is known as the Quality Factor (Q-factor). It is a crucial characteristic in optical communication that serves as a benchmark for a fiber optic network's quality. The Q-factor should be set to Q 6 [9]. You can use the following equation (Fiber Optic Installation) to calculate the Q-factor value:

$$Q = \frac{10 \frac{SNR}{20}}{2} \quad (6)$$

Explanation:

- Q = Quality Factor
- SNR = Signal to noise Ratio

e. Bit Error Rate (BER)

Bit Error Rate is the highest value of the ratio of bit mistakes to the total amount of bits transferred. The following formula can be used to determine the BER (Alfarizi, 2015):

$$BER = \frac{1}{Q\sqrt{2\pi}} \exp \frac{-Q^2}{2} \quad (7)$$

Information:

- Q : Q-Faktor
- π : Phi Constant (3.14)

4. Optisystem Design and Design Simulation

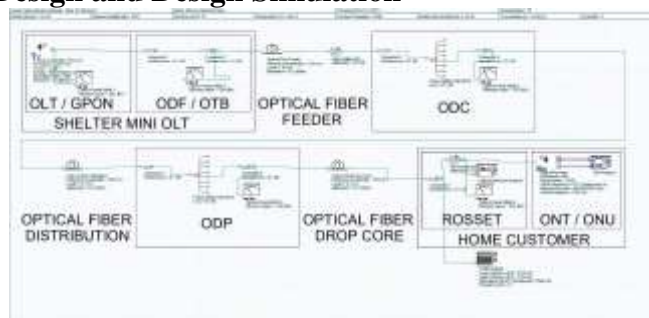


Figure 7. Designing the Link Budget of Fiber to the Area Access Network Using OptiSystem 20.0 Software

Starting with the active devices in the OLT/GPON and moving toward the Home Customer, which is the ONT/ONU, this OptiSystem will design the link budget of the fiber optic access network. To test the performance viability of this fiber optic access network, the findings will offer values for the Link Power Budget (LPB), Rise Time Budget (RTB), Signal to Noise Ratio (SNR), Bit Error Rate (BER), and Quality Factor (Q-Factor). The network design diagram for OptiSystem can be found here.

D. RESULT AND DISCUSSION

1. Optisystem Test Results



Figure 8. The result of the Link Power Budget (LPB) testing for the Fiber To The Area network

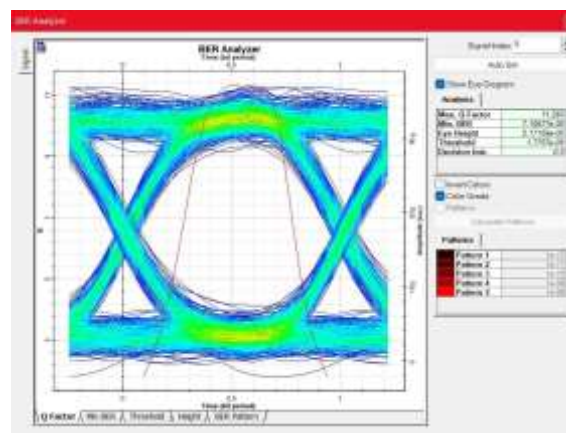


Figure 9. Results of Fiber To The Area Network Q-Factor Testing

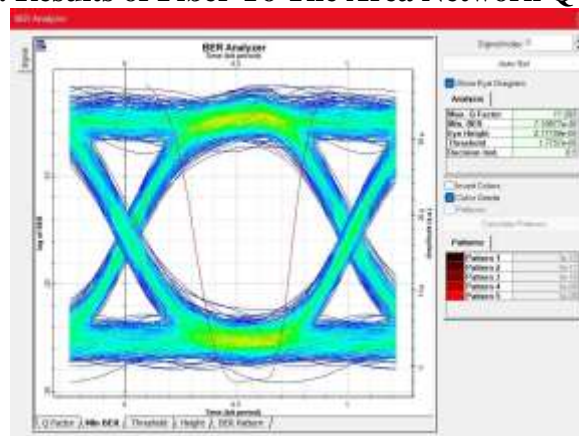


Figure 10. Results of the Fiber to the Area Network BER Test

2. The Results of the Manual Calculation Test

a. Link Power Budget (LPB)

$$\begin{aligned} \alpha_{total} &= L. \alpha_f + N_c. \alpha_c + N_s. \alpha_s + N_{sp}. \alpha_{sp} + L_{dc}. \alpha_{dc} \\ &= (10 \times 0.2) + (8 \times 0.1) + (2 \times 0.1) + (2 \times 10) + (0.1 \times 0.2) \\ &= 23.02 \text{ dB} \end{aligned}$$

Information:

$$\begin{aligned} \alpha_{tot} &= \text{Total attenuation (dBm)} \\ L &= 10 \text{ KM} \\ \alpha_{\square} &= 0.2 \text{ dB} \\ N_c &= 8 \\ \alpha_c &= 0.1 \text{ dB/connector} \\ N_s &= 2 \text{ pcs} \\ \alpha_s &= 0.1 \text{ dB/splice} \\ N_{sp} &= 2 \\ \alpha_{sp} &= 10 \text{ dB/splitter} \\ L_{dc} &= 100 \text{ m} = 0.1 \text{ Km} \\ \alpha_{dc} &= 0.2 \text{ dB} \end{aligned}$$

The Link Power Budget calculation aims to determine the required power budget at the receiver so that the received power level does not fall below the minimum sensitivity using equation (2):

$$\begin{aligned} P_{rx} &= P_{tx} - \text{Link loss Budget} \\ &= 3 - 23.02 \\ &= -20.02 \text{ dBm} \end{aligned}$$

Information:

$$\begin{aligned} P_{tx} &= 3 \text{ dBm} \\ \alpha_{tot} &= 23.02 \text{ dB} \end{aligned}$$

b. Rise Time Budget (RTB)

Based on equation (3), we can calculate the chromatic dispersion value using the following equation:

$$\begin{aligned} t_f &= D(\lambda). S. L \\ t_f &= 3.56 \times 0.8 \times 10 \\ &= 0.02848 \text{ ns} \end{aligned}$$

Explanation:

$$\begin{aligned} \lambda &= 1310 \text{ nm} = D(\lambda) = 3.56 \text{ ps/nm.km} \\ S &= 0.8 \text{ nm} \\ L &= 10 \text{ km} \end{aligned}$$

Thus, the Total Rise Time can be calculated based on equation (4) :

$$\begin{aligned} t_s &= \sqrt{(t_{tx}^2 + t_f^2 + t_{rx}^2)} \\ &= \sqrt{(0.03^2 + 0.02848^2 + 0.02^2)} \\ &= 0.0312 \text{ ns} \end{aligned}$$

Explanation:

$$\begin{aligned} t_{tx} &= 0.03 \text{ ns} \\ t_{rx} &= 102 \text{ ns} \end{aligned}$$

$$\square\square h\square\square\square\square\square\square\square\square = 0.02848 \text{ ns}$$

c. Signal Noise Ratio (SNR)

$$\begin{aligned} \text{SNR} &= 10 \log \left(\frac{(Prx.R.M)^2}{2.q.Prx.R.M^2.F(M)Be + \frac{4KB.TBE}{RL}} \right) \\ &= 10 \log \left(\frac{(3,98.10^{-6} \times 9 \times 3)^2}{2 \times 1,69.10^{-19} \times 3,98.10^{-6} \times 9 \times 3^2 \times 0,2 \times 50.10^9 + \frac{4 \times 1,38.10^{-23} \times 298 \times 50.10^9}{50}} \right) \\ &= 10 \log 658,39 \\ &= 28,18 \text{ dB} \end{aligned}$$

Explanation:

$$Prx: 3,98 \times 10^{-6}$$

$$R : 9 \text{ A/W}$$

$$M : 3$$

$$\Omega q : 1,69 \times 10^{-19} \text{ C}$$

$$F(M): 0,2$$

$$Be : 50 \times 10^9 \text{ Hz}$$

$$Kb : 1,38 \times 10^{-23} \text{ J/K}$$

$$RL: 50 \Omega$$

$$T : 298 \text{ K}$$

d. Q-Factor

$$\begin{aligned} Q &= \frac{10 \frac{\text{SNR}}{20}}{2} \\ &= \frac{10 \frac{28,18}{20}}{2} \end{aligned}$$

$$= 7,04$$

Information:

$$\text{SNR} = 28.18 \text{ dB}$$

e. Bit Error Rate (BER)

$$\begin{aligned} \text{BER} &= \frac{1}{Q\sqrt{2\pi}} \exp^{-\frac{Q^2}{2}} \\ &= \frac{1}{7,04\sqrt{2} \times 3,14} \exp^{-\frac{7,04^2}{2}} \\ &= 1,24 \times 10^{-31} \end{aligned}$$

Information:

$$Q : 7.04$$

$$\pi : 3.14$$

3. Comparison of Optisystem Test Results and Calculations

Comparison of Optisystem Test Results and Calculations can be seen in the following table:

Table 5. Comparison of Fiber To The Area Network Testing Results

No	QOS	Manual Calculation	Optisystem	Eligibility Standards	Explanation
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1	LPB	-20.02 dBm	-21.12 dBm	-20 to -28 dBm	Proper
2	RTB	0.0312 ns	-	-	Proper
3	SNR	28.18 dB	54.43 dB	≥ 24 dB	Proper
4	Q-Factor	7.04	11.2	≥ 6	Proper
5	BER	1.24×10^{-31}	7.10×10^{-30}	$\leq 10^{-9}$	Proper

4. BOQ & Revenue Stream

a. BOQ Telkom Shelter Citeureup - Last Mile Tanjung Lesung

Figure 11. BOQ Fiber To The Area

b. Revenue Low Speed Estimation (Indihome 30 mbps 3 plays)

Figure 12. Revenue Low Speed

c. Estimasi Revenue High Speed (Indihome 100 mbps 3 plays)

Figure 13. Revenue High Speed

d. Overall Total Revenue

Kategori	Total Revenue (Rp)
1	Rp138.204.000.000
2	Rp143.756.345.700
3	Rp149.531.756.888
4	Rp155.539.195.221
5	Rp161.787.982.390
6	Rp168.287.814.582
7	Rp175.048.777.533
8	Rp182.081.362.170
9	Rp189.396.480.895
10	Rp197.005.484.515
1-10	Rp1.660.639.199.895

Figure 14. Total Revenue

E. CONCLUSION

Designing a Fiber to the Area access network in the Tanjung Lesung area of the KEK (Special Economic Zone) will aid in balancing the community's needs for telecommunications and information infrastructure so that people can easily access the internet in the current digital era. 1) Environmental considerations, in that the path design in this FTTA is designed with a path starting from the Citereup Shelter to the ODC-FAA which is in the Tanjung Lesung area to the Tanjung Lesung ONT resort with a total distance of 10 Km, are among the three aspects that are fulfilled in the design of the Fiber To The Area network. The design path satisfies the author's desire for environmental features, including the shortest way to reduce costs as well as strategic paths and environmental aesthetics that are generated from each material, tool, and labor; 2) Calculations and simulation results will be used to determine the technical requirements that have been met, such as QoS (Quality of Service) testing as a parameter for the study of the system feasibility test. When the Fiber to the Area Network is manually calculated, the values for LPB, RTB, SNR, Q-Factor, and BER are as follows: -20.02 dBm, 0.0312 ns, 28.18 dB, 7.04 dB, and 1.24×10^{-31} . However, when the results of an optisystem simulation are used, the values are as follows: -21.12 dBm, 54.43 dB, 11. Because it has been tested from the findings acquired to meet the PT criteria, the QOS obtained in this FTTA architecture is deemed practical. Telkom; and 3) the economic factor, specifically the BOQ (Bill of Quantity) IDR 51.610.058.109 and the entire revenue stream IDR 1.660.639.199.895. The BoQ value is reduced and the Revenue Stream value obtained is high and very profitable based on the total BoQ and total Revenue Stream.

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