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Signal quality comparison of customer base and branching methods in fiber to the home network design

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Abstract
One communication medium that is well-known for its outstanding and reliable performance is fiber optic. A social example of its application is the Fiber to the Home (FTTH) network. The goal of this study is to evaluate the signal quality of the customer base method and the branching method, two FTTH-building techniques based on the PT.PLN Icon Plus standards, in order to identify the most practical approach for use in the Air Hitam 2 cluster. Two scenarios were used in this study at the Fiber Access Terminal (FAT) with 1:16 and 1:8 splitters. The fiber optic cable path design findings demonstrate that the branching approach is a wise decision, utilizing optical fiber cables for a total of 9 Km, with the greatest cable distance being 2.5 Km from the Optical Line Terminal (OLT) to the end FAT. According to theory, in the 1:16 splitter situation and the 1:8 splitter scenario, the optical power received by the Optical Network Terminal (ONT) is -19.13 dBm and -16.03 dBm, respectively, with an OLT transmit power of 3 dBm. For these cases, the simulation results are -17.98 dBm and -20.27 dBm. Additionally, the budget value for the rising time reaches 0.253 ns. The bit error rate values in the 1:16 and 1:8 splitter scenarios are 3.157×10^{-10}, and 1.63507×10^{-28}, respectively, while the Q factor values are 6.18233 and 11.014, respectively. Based on theory and simulation, these findings suggest that the branching strategy can deliver good performance.

Keywords:
Branching;
Customer Base;
Fiber to the Home;
GPON;
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INTRODUCTION

The global industrial transformation has resulted in numerous enhancements in people's everyday lives, particularly in communication technology [1]. The social, political, and economic domains are only a few of the areas in which the Internet is vital in today's digital era. For example, the Internet can assist farmers in various ways, such as exchanging information, enhancing product sales potential, and improving production through the use of IoT (Internet of Things) [2]. With the number of internet users continuously increasing every year, having access to the internet has now become a basic requirement for people all over the world [3].

New technologies emerged and were implemented by utilizing fiber, which made it possible to multiply threads while optimizing resources. Designing and deploying cost-effective fiber networks is critical to delivering benefits to companies and communities [4]. One application of fiber optics in society is the Fiber to the Home (FTTH) network, It is an architectural concept of a data transmission network from the source (transmitter) to the client (receiver) [5][6]. The FTTH networks have developed to discover affordable fixes [7]. One major advancement is the ability to use fiber optic for both downlink and uplink paths. These networks are point-to-multipoint, and their name, Passive Optical Network (PON), comes from the connection of fiber optic to passive optical splitters [8][9].

Kampar Regency is located in Riau Province, Indonesia. This research will focus on the Air Hitam 2 cluster which is located in Karya Indah Village, Tapung District, Kampar Regency which has an area of 57.57665 Km² and is home to around 12,657 residents.

Air Hitam Cluster 2 is a continuation project of the Air Hitam 1 cluster, which is located on Garuda Sakti Street Km 4 to Km 7. There are around 8 housing complexes that will be equipped with an FTTH network. Currently, part of the Air Hitam 2 Cluster area is connected to the FTTH network through other service providers, but there are still areas that are not yet connected. The main objective in designing this FTTH network is to serve new customers from the people of Karya Indah Village.

According to [10], designing FTTH is an important step in ensuring the optical link's best performance. This research focuses on developing and analyzing an FTTH-GPON network's performance utilizing optical link power and rise time budgets. A minimum of eight feeder cable cores, as well as the related Optical Distribution Cabinet (ODC) and Optical Determination Point (ODP), are required for the 254 user households. The design follows the power link budget, with the narrowest power margins of 2.826 dB and 2.469 dB downlink and uplink at the greatest distance. The system's highest rising time is 0.2236 ns.

During the FTTH GPON network design [11], the measurements yielded the downlink Power Link Budget of -21.125 dBm at the furthest location. Similarly, the Rise Time Budget was assessed at this distant point, with a value <70%, measuring the Downlink as 0.0312 ns, 7.04 dB is the value of Q-factor and BER value is1.24 $\times 10^{-31}$.

This research [12] designs an expansion of the FTTH network with a distance of 0.86 Km between the existing ODC and the Fiber Access Terminal (FAT) plan. However, between the existing ODC and the FAT plan, there is FAT-Existing which is 0.44 Km away. Applying the Branching Technique to the FAT can reduce work completion time and optimize material use. Branching on existing FAT uses idle cores on distribution cables. Simulations using OptiSystem using a transmit power on the Optical Line Terminal (OLT) of 7 dB, show that the value obtained by the optical power meter (OPM) on the new FAT produces an optical power of -19.48 dBm. The theoretical calculation of the Power Link Budget produces an optical power value of -20.40 dBm. It was found that the longer the cable used between the ODC and the FAT, the greater the loss value.

This research has a target to cover the entire area of the Air Hitam 2 Cluster which contains around 8 housing complexes with a population density of around 0.454 people/Km² with a total cable usage of not exceeding 22 Km for the Customer Base Method and 16 Km for the Branching Method where both methods are design methods fiber to the home network owned by PT. PLN Icon Plus. Branching in the customer base method occurs at the joint box, while in the branching method, it occurs at the FAT. Both methods branch by splicing the core between the input distribution cable to the joint box, or FAT, and the output distribution cable from the joint box, or FAT. For medium to large clusters, it is suitable to use the customer base method, and for clusters small to medium, it is suitable to use the branching method. Using an OLT transmit power of 3 dBm, ensures that the power link budget value on the Optical Network Terminal (ONT) is > -26 dBm, rise time budget < 0.26 ns, Q Factor > 6, bit error rate $< 10^{-9}$.

This paper will carry out a signal quality comparison between two methods, the Customer Base Method and the Branching Method using a comparison of the total use of fiber optic cables and feasibility parameters consisting of power link budget, rise time budget, Q Factor, and bit error rate by theory and simulation.

METHOD

Figure 1 shows the flow of work during the carrying out of research starting from Literature Study and Guidance, Data Collection, Needs Analysis, Determining the Cluster Location, determining the GPON components that will be used, designing the Cluster, calculating feasibility parameters, finalizing the design to the Development Team and Making a report.

The survey was conducted at PT. PLN Icon Plus Riau Regional Office, which is the basis of this research. Researchers have identified needs that must be met in FTTH design. In designing the FTTH Cluster Air Hitam 2, researchers aimed to connect internet services to 512 customer homes, in accordance with GPON standards and requirements set by PT. PLN Icon Plus. However, an important note in the research is that this design must also be scalable so that it can handle an increase in the number of customers in the future which may exceed 512 homes with optimal network performance.

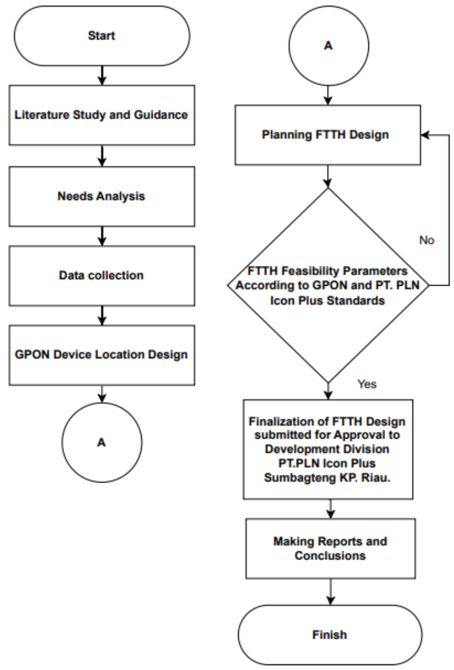

Figure 1. Flowchart

Customer Base Method

The Customer Base method is a method for designing the FTTH network at PT. PLN Icon Plus, where this method is ideal for covering a wide FTTH design area. In this method, the maximum limit for the total use of fiber optic cables permitted is 22 Km with a maximum cable length from OLT to FAT of 7 Km to ensure that FTTH development costs remain controlled within the predetermined budget.

Information:
1. OLT
2. Cable House (CH)
3. Joint Box (JB)
4. FAT

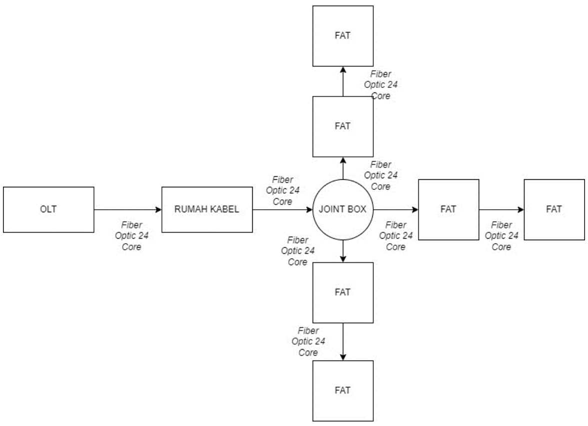

Figure 2. Block Diagram of The Customer Base Method

Figure 2 shows a block diagram of the Customer Base method. To ensure long-distance coverage when designing the Customer Base method, it is effective to utilize JB as a branching point prior to connecting the fiber optic cable to the FAT. JB is a box where fiber optic connections are placed. For example, if a fiber optic cable is disconnected or damaged, the cable will be reconnected through a splicing process, and the splicing results are placed in the JB. JB has various capacities, ranging from 6 cores to 256 cores [12]. In FTTH network design, a JB serves as a branching distribution cable, allowing for the efficient use of fiber optic cables. The box contains multiple holes, with one hole designated for the input of the distribution cable and the other hole used for splicing the output cable branches, which then continue to the FAT. JB which has 6 holes, where 5 holes are used as cable output to FAT, allows efficient cable management and distribution. With JB, the FTTH network can be expanded effectively and meet customer needs in all regions while adhering to predetermined cable length limitations. The fiber optic cable that connects JB to FAT is called a distribution cable [13].

Branching Method

The Branching method is employed in the architecture of the FTTH Network at PT. PLN Icon Plus is well-suited for coverage areas that are relatively narrow and exhibit superior optical power values compared to the Customer Base method. In this method, the total cable length used is not allowed to exceed 16 Km, with a maximum cable length from OLT to FAT of 7 Km.

Information:
1. OLT
2. Fiber Determination Terminal (FDT)
3. FAT

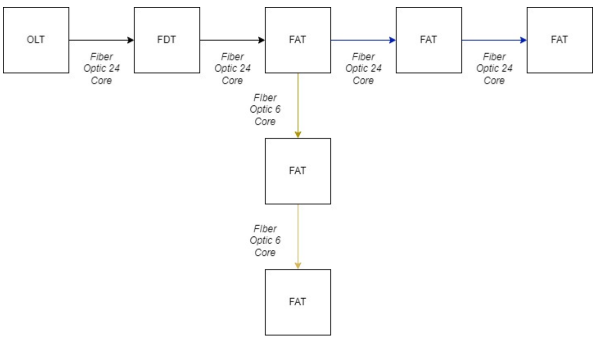

Figure 3. Block Diagram of The Branching Method

Figure 3 is a block diagram of the branching method. The branching method uses FDT as a replacement for CH. The use of FDT can affect the total cable usage and total attenuation. FAT which consists of an optical pigtail, connectors, and a splitter room. This type of device is an optical network termination placed at several locations that use a splitter to connect the distribution cable and drop cable [14]. On FAT, there is a 1:8 splitter, and if all the ports on the splitter are used, it can be upgraded to a 1:16 splitter. Fiber Optic cable branching in this method is centered on the FAT which has three holes, where one hole is used as the distribution cable input, while the other two holes function as the distribution cable output. In the two FAT output holes, the use of Fiber Optic cables can be adjusted to the needs of the cores that will be used after the FAT which functions as a branch point, using either 6-core or 24-core cables.

The distinction between the two approaches to constructing an FTTH network is evident in the design of the FTTH itself. The utilization of fiber optic cables and the distance between the OLT and the FAT play a crucial role in determining performance, as attenuation in the fiber optic cables can have an impact. In addition, the branching approach does not include the usage of a joint box prior to the cable reaching the FAT. If the FAT is not a result of branching, there will be no additional attenuation caused by splicing.

Geographical Conditions

Geographically, the Air Hitam 2 Cluster is in Karya Indah Village, Tapung District, Kampar Village, Riau. Housing for the Air Hitam 2 Cluster is illustrated in Figure 4. Surya Langgeng Housing, Bumi Surya Damai Housing, Zamar Mandiri Regency 2 Housing, Garuda Mas Regency, Permata Housing, 56 Regency Housing, Sumber Daya Prima Housing, and Griya Housing are the eight housing complexes consisting of the area. Nusantara No. 1. In the Air Hitam 2 cluster, housing is represented by the yellow house-shaped insignia, while the area of each housing complex is denoted by the blue and red polygons. A total of 1146 residential units are anticipated to have been sold in the Air Hitam 2 Cluster by 2023.

Figure 4. Housing In Air Hitam 2 Cluster

Existing Infrastructure

Existing infrastructure refers to the pre-existing physical structures and systems in the designated area where the FTTH architecture will be implemented. The current infrastructure consists of a low-voltage network pole and a medium-voltage network owned by PT. PLN, with PT. PLN Icon Plus is a subsidiary of PT. PLN.

Figure 5 depicts an infrastructure pole, which is indicated by a green pin. Additionally, a red pin is used to symbolize the transformer located on the pole. When using the current infrastructure, there are certain limitations in place to ensure safety. For instance, it is prohibited to install GPON devices on poles that already have electrical equipment. The objective is to mitigate potential hazards during the process of installing and maintaining new customers. The identification of safe poles for crossing fiber optic cables has been accomplished by employing a tagging procedure utilizing Google Earth software. For instance, a red pin designates a transformer pole where installation of GPON equipment is prohibited. The outcomes of this tagging procedure enable the meticulous selection of poles that satisfy the safety criteria for fiber optic cable lines.

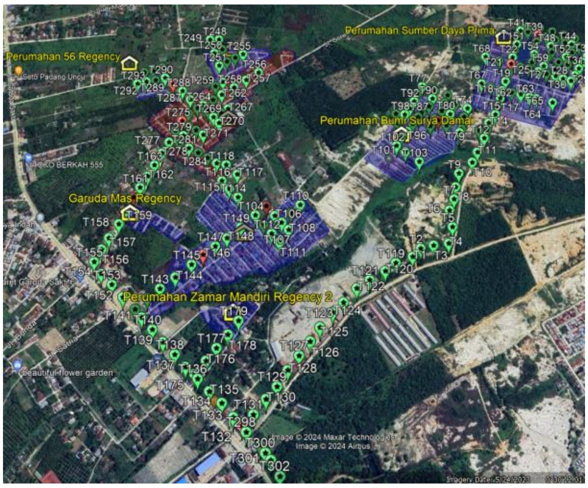

Figure 5. The Existing Pole Belongs To PT. PLN

Feasibility Parameters Calculation

The feasibility parameters will be analyzed by considering the downstream direction, which refers to the transmission of data from the transmitter to all end-points (receivers) using fiber optic media) [15][10]. The examination of feasibility parameters in the downstream direction is utilized for the computation in FTTH design planning [16][17]. In order to assess the calculation of the power link budget, rise time budget, Q Factor, and Bit error rate using both techniques, we will focus on the longest route from the OLT to the FAT. When constructing this FTTH network, we will examine two scenarios: one involving a 1:8 splitter and another involving a 1:16 splitter. The purpose is to ensure that if the 1:8 splitter is replaced with a 1:16 splitter, the optical power remains within the PT.PLN Icon Plus standard.

Power Link Budget

Power Link Budget is a method used to evaluate and compute the power allocation in a communication system. The power budget is crucial for maintaining a received power level at the receiver that is above the minimum sensitivity threshold. This threshold is set to ensure optimal performance in communications and to provide adequate signal power at the client location, in line with the specified performance criteria [18][19].

The GPON standard is used in this computation, which also considers the restrictions imposed by PT. PLN Icon Plus, which provides for a transmission distance of less than 7 Km and a total loss of no more than -26 dB. In the G.984 standard series, the GPON standard established by ITU-T is referred to as the PT.PLN Icon Plus standard [20].

The quantity of power remaining from the transmit power subsequent to transmission-related losses is denoted as the power margin. These losses decrease the safety margin and receiver sensitivity [12]. M > 0 is the usual Power Margin value. The following formula [8][18] can be used to calculate power link budgets:

Power Link Budget

$$Prx = Ptx - Total\ Loss \qquad (1)$$

Where:

$P_{rx} =$ Receiver sensitivity (dBm)

$P_{tx} =$ Transmitter power (dBm)

$\alpha total =$ Total loss (dB)

Total loss

$$\alpha total = L.\alpha f + Nc.\alpha c + Ns.\alpha + Nsp.\alpha sp \qquad (2)$$

Where:

$L =$ Fiber optic cable length (Km)

$\alpha f =$ Loss fiber optic (db/Km)

$Nc =$ Number of Connectors

$\alpha c =$ loss Connector (dB)

$Ns =$ Number of Splicing

$\alpha s =$ loss Splicing (dB)

$Nsp =$ Number of Splitters

$\alpha sp =$ loss Splitter (dB)

Power Margin

$$M = (P_{tx} - P_{rx}) - \alpha total - M_s \qquad (3)$$

Where:

$M =$ Power Margin (dB)

$M_s =$ System Margin (4 – 8 dB)

Rise Time Budget

The Rise Time Budget calculation serves to estimate the dispersion limits within a fiber optic network. It is particularly effective in evaluating digital transmission networks. The objective of this calculation is to assess the overall network performance while ensuring that it does not exceed the channel capacity. The total rise time must remain below 70% of one NRZ bit period, then the total rise time must be below the maximum rise time $(t_{sys} < T_r)$ [3]-[22]. Rise time budget calculations can use the equation [23][11]:

Total Rise Time

$$t_{sys} = \sqrt{{t_{tx}}^2 + {t_{chromatic}}^2 + {t_{modal}}^2 + {t_{rx}}^2} \qquad (4)$$

Where:

$t_{sys} =$ Total rise time (ns)

$t_{tx} =$ Rise time transmitter (ns)

$t_{rx} =$ Rise time receiver (ns)

$t_{chromatic} =$ Chromatic dispersion (ns)

$t_{modal} =$ value 0 for single mode

Chromatic Dispersion

$$Dt = D(\lambda).S.L \quad (5)$$

Where:

$\mathrm{Dt} = \text{Total chromatic dispersion (ns)}$

$D(\lambda) = \text{CD Coefficient (ps/nm.Km)}$

$S = \text{Spectral width (nm)}$

$L = \text{Fiber Optic Length } (Km)$

Maximum Rise Time

$$T_r = \frac{0.7}{B_r} \quad (6)$$

Where:

$T_r = \text{Maximum Rise Time (ns)}$

$B_r = \text{Bit rate (Gbps)}$

Q-Factor

Q-factor, an optical signal quality measure, should be between 4 and 6, with an exceptional value beyond 6. SNR is related to this Q-factor. Quality Factor (Q-factor) is the decision circuit SNR as voltage or current [11].

Bit Error Rate

When sending a digital signal, the Bit Error Rate measures the amount of incorrect bits. A digital system's BER is the percentage of bit errors for all bits transferred. In optic communication systems, the standard bit error rate is < 10^{-9} [24].

GPON devices specifications

It is important to accurately understand the numerous characteristic values before calculating the feasibility parameters for the design of a fiber optic system. The value of each component in the simulation adheres to the characteristic values specified in Table 1. These parameters include factors such as the distance of transmission, types of fiber optic cables used, attenuation characteristics, dispersion effects, and the specific requirements of the intended applications. Such information forms the foundation for accurate and efficient analysis, ensuring the optimal performance and reliability of the fiber optic network [23].

The GPON devices that will be used for this research include the following:

Table 1. The Component's Value

Characteristics	Value
Transmitter Power	3 dBm
Max Rx Sensitivity	-26 dBm
Wavelength	1490 nm
Bit Rate Downstream	2.488 Gbps
Rise time transmitter	200 ps
Rise time receiver	150 ps
Connector Loss	0.15 dB
Splitter 1:4	7 dB
Splitter 1:8	10.2 dB
Splitter 1:16	13.5 dB
Splicing	0.05 dB
Feeder and distribution cables attenuation @1490 nm	0.21 dB/Km
Drop cable attenuation @1490 nm	0.30 dB/Km

Opti system simulation

Table 2 is the component quantity used for the Customer Base method in calculating feasibility parameters both theoretically and in simulation.

Figure 6 is a circuit of the customer base method in simulations. Figure 6 depicts a set of customer base method simulations for the situation when a 1:8 splitter is employed on FAT. In the 1:16 splitter scenario, the 1:8 splitter component on FAT 47 is replaced. The customer base technique utilizes the joint box as a repository for spliced cores between distribution cables. The joint box can be symbolized by a splicing attenuation component due to its exclusive presence of splicing attenuation.

OPM and BER analyzers are visualizer devices for analyzing attenuation, bit error rate, and Q-factor [8]-[25].

Table 2. Components Quantity The Customer Base Method

Component	Qty	Unit
OLT	1	Unit
Feeder cable	0.463	Km
Distribution cable	2.599	Km
Drop cable	0.35	Km
Connector	6	pcs
Splicing	6	pcs
Splitter 1:4	1	pcs
Splitter 1:8	1	pcs
Splitter 1:16	1	pcs

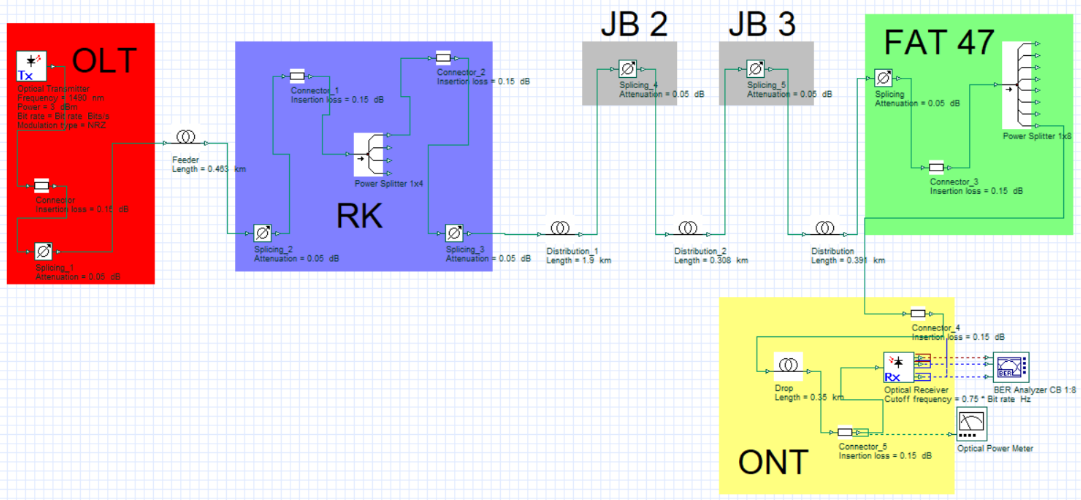

Figure 6. Customer Base Simulation Circuit

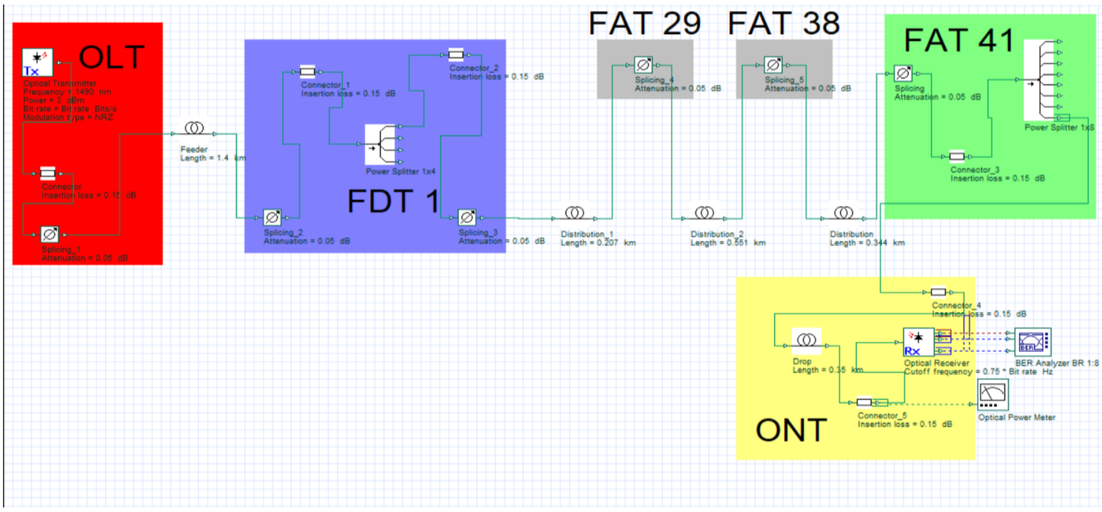

Figure 7. Branching Simulation Circuit

Figure 7 depicts a sequence of simulations using the Branching method. The feasibility parameters of a sample Branching method, which will be calculated, are applied to the FAT Branching. The FAT Branching serves as a connection point for distribution cables, similar to a joint box. However, it also functions as a connection point for the internet to customers and can serve as a branching location. The FAT Branching can be represented by a splicing attenuation component, with a value of 0.05 dB, as it only experiences splicing attenuation.

Table 3 shows the Branching method component quantity for theoretical and simulation calculations.

Table 3. Component Quantity the Branching Method

Component	Qty	Unit
OLT	1	Unit
Feeder cable	1.4	Km
Distribution cable	1.1	Km
Drop cable	0.35	Km
Connector	6	pcs
Splicing	6	pcs
Splitter 1:4	1	pcs
Splitter 1:8	1	pcs
Splitter 1:16	1	pcs

RESULTS AND DISCUSSION

The Fiber Optic cable routing process is carried out using Map Source Software. Existing pole coordinates and FAT coordinates were obtained via Google Earth. Next, the coordinate data from Google Earth is converted into a Map Source file to ensure precision in determining the location and routing of Fiber Optic cables. The routing of fiber optic cables on Map Source is very precise and very easy to review the route.

To analyze the calculation of the power link budget, rise time budget, Q Factor, and Bit error rate from both methods, the sample that will be taken is the longest route from the OLT to the FAT. In the Customer base method, the OLT path to FAT 47 will be analyzed and in the Branching method, the OLT path will be analyzed to FAT 41.

In calculating the feasibility parameters, each method will obtain an additional cable length from FAT to ONT of 0.35 Km, this cable length is the standard set by PT. PLN Icon Plus regarding the maximum installation cable length from FAT to the customer (ONT).

Feasibility parameters will be determined through theoretical analysis and simulation. Specifically, the power link budget will be calculated using both methods, while the rise time budget will be assessed theoretically. The bit error rate and Q factor, on the other hand, will be computed solely through simulation.

Two scenarios will be calculated, the 1:8 FAT splitter scenario and the 1:16 FAT splitter scenario. These two scenarios are calculated to ensure that if the FAT upgrades the splitter to a 1:16 splitter, the feasibility parameter value is still categorized as feasible.

GPON Components

The two methods of building a fiber to the home network have differences in the use of GPON components. These component differences can affect performance, component prices, and the complexity of the FTTH architecture. In the customer base method, 1 unit of OLT component is used, 1 unit of cable housing, more than 4 units of joint boxes, and 64 FATs are usually used. Meanwhile, the branching method uses 1 unit of OLT, 2 units of FDTs, and 64 FATs branching components. Therefore, the branching method uses fewer GPON components, which has an impact on the total price of FTTH development.

These components can also influence the design of the FTTH network, which will have an impact on the total use of fiber optic cables, and this will also affect the total price of FTTH construction. The architectural complexity of the branching method is also better because the splicing on fiber optic cables is not as numerous as the customer base method.

Fiber Optic Cable Routing

In designing fiber optic cable routes using the Customer Base method, the total cable used reaches 11.8 Km, with the longest distance between OLT and FAT being around 3 Km. In this method, 7 JBs will be used to connect a total of 64 FAT units. The cable house (CH) is the termination point for feeder cables and distribution cables. The distribution cable on CH has 4 output cables which will then be distributed to JB before going to FAT.

In Figure 8, the OLT is symbolized by a red square icon, the Cable House is symbolized by a blue cube icon, the Joint Box is symbolized by a blue square icon, the FAT is symbolized by a green square and the black dot is an existing pole.

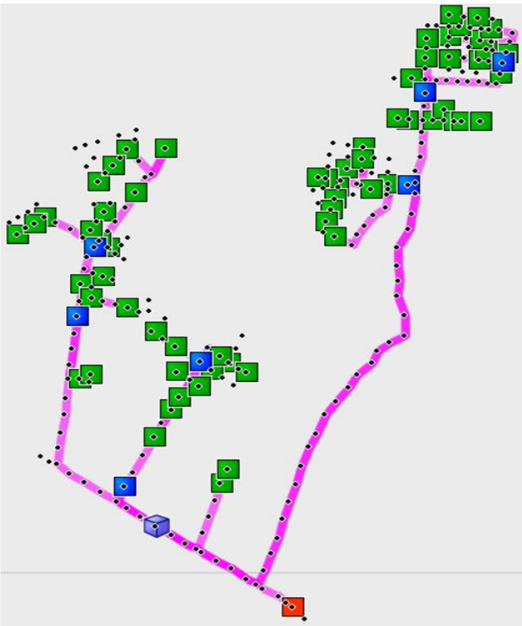

Figure 8. Cable Route Customer Base Method

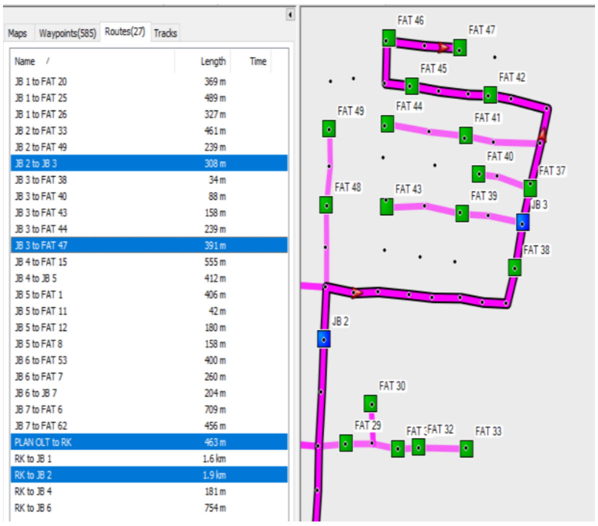

Figure 9. Longest Path Route Customer Base Method

[Figure 9](#) is the fiber optic cable route to FAT 47, where FAT 47 is the furthest in the Customer Base Method. This route starts from OLT to CH with a cable length of 0.46 Km, then the fiber optic cable from CH is distributed to JB 2 with a cable length of 1.9 Km. For efficient use of cables, there is an additional 1 JB unit located 0.308 Km from JB 2 to distribute 11 FAT fiber optic cables. With the length of the JB 3 cable to FAT 47 being 0.391 Km, then FAT 47 is the final FAT with the total cable length from OLT to FAT 47 being 3 Km.

In designing fiber optic cable routes using the Branching method, the total cable length used reaches 9 Km, with the farthest distance between the OLT and FAT being around 2.5 Km. In this method, the termination point for the feeder cable and distribution cable occurs at the FDT. The FDT used in this method is 2 units, where FDT 1 connects 33 FAT and FDT 2 connects 31 FAT. Of the 64 FATs designed, 24 FATs are used as branching points.

In Figure 10, OLT is symbolized by a red square icon, FDT is symbolized by a blue cube icon, FAT is symbolized by a green square, FAT branching is symbolized by a blue square and the black dot is an existing pole. The branching method uses 2 types of fiber optic cables, 6-core and 24-core fiber optic cables where the 6-core are marked in yellow and the 24-core are marked in blue. The choice of using 6-core and 24-core fiber optic cables is influenced by the need for cores to be connected to the FAT where 1 core can only connect 1 FAT.

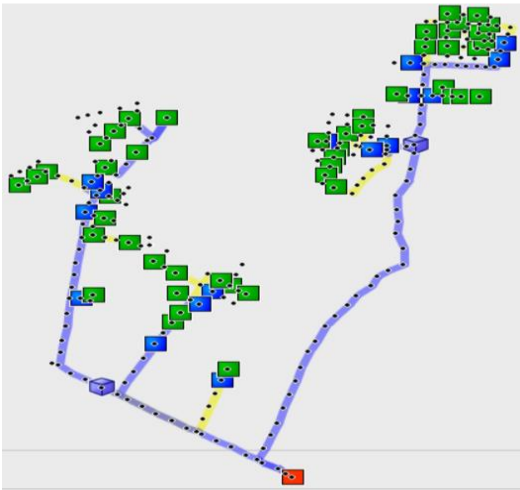
Figure 10. Branching Method Cable Route

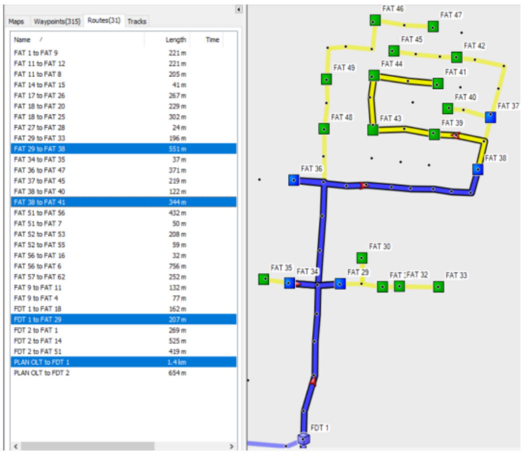

Figure 11. Longest Path Route Branching Method

In Figure 11, this is the fiber optic cable route to FAT 41, where FAT 41 is the farthest in the Branching Method.

This route starts from OLT and is connected to FDT 1 using a 1.4 Km long fiber optic cable. Then the fiber optic cable is distributed from FDT 1 to FAT 29 for 0.207 Km, at FAT 29 a branch occurs, FAT 29 to FAT 38, and FAT 29 to FAT 33. After branching to FAT 38, the fiber optic cable is connected again from FAT 38 towards FAT 41 along 0.344 Km. therefore FAT 41 is the furthest FAT from OLT to FAT 41 which is 2.5 Km.

Power Link Budget Analysis

Power link budget calculations are carried out theoretically (1), (2), and (3) and simulations using an Opti system with the following results:

Table 4. Optical Power Values from Both Design Methods

Design Method			Optical Power On ONT
Customer Base	Theory	Splitter 1:8	-16.15 dBm
		Splitter 1:16	-19.25 dBm
	Simulation	Splitter 1:8	-18.09 dBm
		Splitter 1:16	-20.41 dBm
Branching	Theory	Splitter 1:8	-16.03 dBm
		Splitter 1:16	-19.13 dBm
	Simulation	Splitter 1:8	-17.98 dBm
		Splitter 1:16	-20.27 dBm

Based on data from Table 4, both methods have met the power link budget feasibility standards in the scenario of using a 1:8 splitter and a 1:16 splitter, not exceeding -26 dBm. The optimal optical power from both methods is the branching method both in theoretical calculations and in simulation with a theoretical value of -16.13 dBm on a 1:8 splitter and -19.23 dBm on a 1:16 splitter. The simulated value obtained is -17.9 dBm on a 1:8 splitter and -20.27 dBm on a 1:16 splitter. The difference in the power link budget value of the two methods is caused by the longest distance from the OLT to the FAT, while the branching method has a shorter distance from the OLT to the FAT compared to the customer base method.

The power margin calculations that have been carried out theoretically from both methods, can be summarized as follows:

Table 5. The Power Margin of Both Design Methods

Design Method		Power margin
Customer Base	Splitter 1:8	5.85 dB
	Splitter 1:16	2.75 dB
Branching	Splitter 1:8	5.97 dB
	Splitter 1:16	2.87 dB

Based on data in Table 5, both methods have met the power margin feasibility standards (4 – 8 dB) [8][18], M > 0 in the scenario of using a 1:8 splitter and a 1:16 splitter. The optimal power margin from both methods is the branching method with a value of 5.97 dB on a 1:8 splitter and 2.87 dB on a 1:16 splitter. As long as the margin value is greater than 0, there is still a safety margin to be prepared for unexpected losses during implementation.

Rise Time Budget Analysis

To analyze the rise time budget, calculations are required using (4), (5) and (6). After collecting the entire rise time value, it will be compared to the maximum rise time to determine the standard rise time budget, $(T_{sys} > T_r)$. The calculation of this equation is carried out theoretically.

Table 6 shows the values that will be used to find the total rise time, chromatic dispersion, and maximum rise time values. The difference in the values of the two methods in calculating the rise time budget is only in the cable length of each link. This will have an impact on the chromatic dispersion value which will affect the total rise time value. The rise time budget value is influenced by the characteristics of the signal transmitted through the communication system. Influencing factors include the frequency response of hardware and electronic circuitry, changes in the signal waveform, jitter, and dispersion effects in transmission media such as optical fiber. Increasing the rise time can speed up the data transmission process, but it can also increase the risk of signal distortion. Therefore, careful planning is required to ensure that rise time remains within acceptable limits for the desired system performance.

Table 6. Values For Rise Time Budget

Component	Value	Unit
Ttx	200	ps
Trx	150	ps
$D(\lambda)$	12.9041	ps/nm.Km
S	1	nm
L Customer Base	3.35	Km
L Branching	2.85	Km
Br	2.488	Gbps

Table 7. The Rise Time Budget for Both Design Methods

Design Method	Total rise time
Customer Base	0.254 ns
Branching	0.253 ns

Based on data from Table 7, the customer base method and branching method have met the rise time budget standard where the total rise time value for both methods does not exceed the maximum rise time value, 0.281 ns. The optimal total rise time value of the two methods is the branching method with a value of 0.253 ns.

Q-Factor and Bit error rate

The Bit Error Rate (BER) analyzer serves as a quantitative tool for assessing digital communication performance [26]. An eye diagram is a tool utilized to assess signal quality in the time domain. It involves overlaying numerous sequences in real-time using a fast oscilloscope synchronized with the clock signal of the data. By examining the eye diagram, signal quality can be readily identified. An open eye indicates distinct levels between symbols "1" and symbols "0" [27].

The Q factor and bit error rate values are affected by various factors, including noise, distortion, signal quality, modulation used, transmission distance, and characteristics of the transmission medium (such as optical fiber or wireless channel). These factors can affect the overall performance of a communications system and impact the system's ability to transmit and receive data with high accuracy and efficiency.

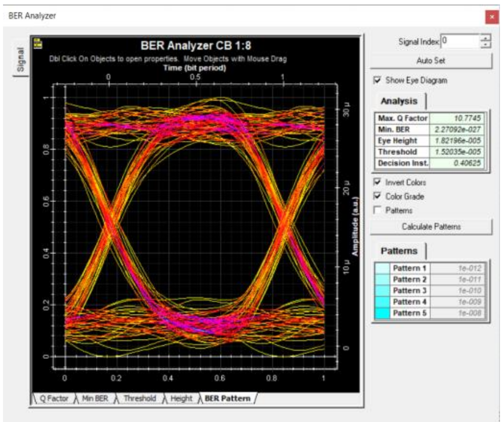

Figure 12. BER Analyzer Customer Base Method Splitter Scenario 1:8

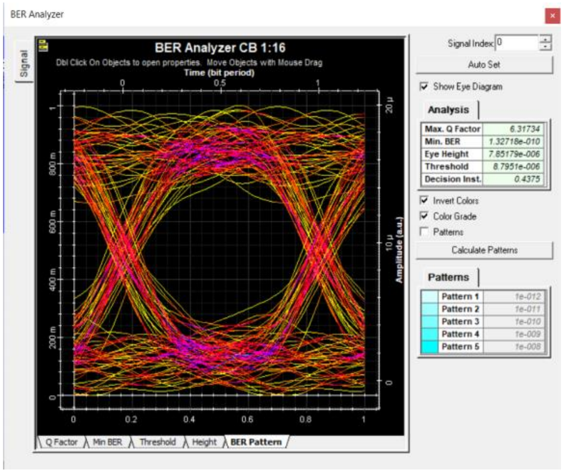

Figure 13. BER Analyzer Customer Base Method Splitter Scenario 1:16

Figure 12 and Figure 13 illustrate the eye diagram in the customer base method splitter scenario 1:8, which has a Q factor of 10.7745, and scenario 1:16, which has a Q factor of 6.41734. Both scenarios meet the minimum value of 6. If the OLT sends 10^{27} bits, the first BER analyzer indicates a bit error rate of 2.27092 $\times 10^{-27}$; 2.27092 bits are erroneous. The 2nd BER analyzer indicates a bit error rate of 1.32718 $\times$ 10^{-10}; the OLT sending 10^{10} bits results in 1.32718 erroneous bits.

Figure 14 and Figure 15 illustrate the eye diagram in the branching method splitter scenario 1:8, which has a Q factor of 11.014, and scenario 1:16, which has a Q factor of 6.18233. Both scenarios meet the minimum value of 6. If the OLT sends 10^{28} bits, the first BER analyzer indicates a bit error rate of 1.63507 $\times 10^{-28}$; 1.63507 bits are erroneous. The 2nd BER analyzer indicates a bit error rate of 3.157 $\times$ 10^{-10}; the OLT sending 10^{10} bits results in 3.157 erroneous bits.

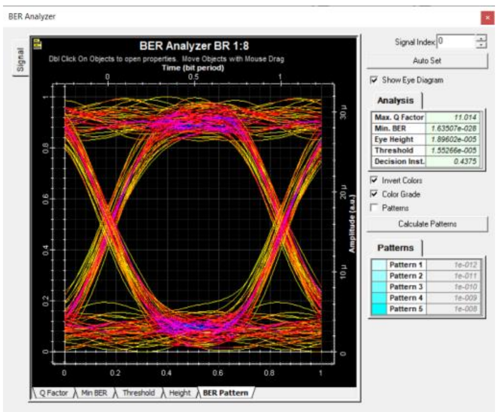

Figure 14. BER Analyzer Branching Method Splitter Scenario 1:8

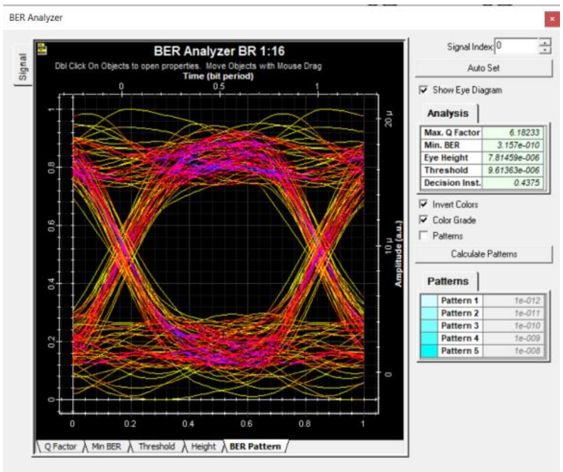

Figure 15. BER Analyzer Branching Method Splitter Scenario 1:16

Comparison with existing works

Table 8 compares our work with existing research. The purpose is to identify the similarities and differences among existing research, assess the quality of methodologies and findings, build a stronger theoretical framework, provide recommendations for future research, support evidence-based decision-making for practitioners, and enhance understanding of the issues being studied. It shows that both methods used in this work provide a high Q factor and BER with comparable results.

Table 8. Comparison with Existing Works

Ref.	Transmit Power (dBm)	Distance OLT To ONT (km)	Optical Power (dBm)	Rise Time (ns)	Q-Factor	BER
[10]	3	6.95	-25.11	0.22	N.A	N.A
[11]	3	10.1	-20.02	0.03	7.04	1.24×10^{-31}
[12]	-7.25	0.018	-28.60	N.A	N.A	N.A
This work						
Branching based	3	2.5	-17.98	0.253	11.014	1.64×10^{-28}
Customer based		3	-18.09	0.254	10.774	2.27×10^{-27}

CONCLUSION

In summary, the research concludes that the FTTH network design in the Air Hitam 2 cluster is more effective using the branching method. This method utilizes 9 km of fiber optic cable, with the furthest OLT to FAT distance being 2.5 km. Comparatively, the branching method proves to be more cost-effective and less complex than the customer base method. Regarding performance metrics, the power link budget meets standard requirements, with values not exceeding -26 dBm. The rise time budget of 0.253 ns falls within the feasible category, and the Q factor values (>6) and bit error rate values (10^{-9}) obtained from simulations also align with appropriate standards. Specifically, in the 1:8 splitter scenario, the Q factor is 11.014, the bit error rate is 1.63507×10^{-28}, while in the 1:16 splitter scenario, the Q factor is 6.12833, and the bit error rate is 3.157×10^{-10}.

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