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Design and Performance Analysis of GPON-Based FTTH Network in Sikucur Barat Padang Pariaman Regency

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ABSTRACT

The increasing demand for internet services requires broadband infrastructure capable of providing high-capacity and reliable connectivity, including in rural areas. NagariSikucur Barat, Padang Pariaman Regency, requires an optical access network to support the growing communication needs of the community. This study aims to design and evaluate the performance of a Fiber To The Home (FTTH) network based on Gigabit Passive Optical Network (GPON) technology. The research applies the Prepare, Plan, Design, Implement, Operate, and Optimize (PPDIOO) methodology through geographical analysis, network planning using Google Earth Pro and AutoCAD, OptiSystem simulation, and performance evaluation based on Link Power Budget, Rise Time Budget, Q-Factor, and Bit Error Rate (BER). The proposed network serves 88 homepasses using 3 PON ports, 13 Optical Distribution Points (ODPs), 4 PLC 1:4 splitters, and 13 distribution splitters. The calculated attenuation ranges from 27.0523 dB to 27.2632 dB, with received power values between −20.0523 dBm and −20.2632 dBm and power margins ranging from 7.7368 dB to 7.9477 dB. Simulation results produce Q-Factor values of 12.1746 to 13.7883 and BER values of 1.49433×10^{-43} to 6.58298×10^{-35}, indicating compliance with GPON transmission quality requirements. The Rise Time Budget ranges from 0.3637 ns to 0.3712 ns, exceeding the theoretical limit of 0.29 ns. The results indicate that the proposed network is feasible for deployment because it satisfies the received power, power margin, Q-Factor, and BER requirements, while further optimization is needed to improve rise time performance.

INTRODUCTION

The increasing demand for high-speed and reliable internet access has accelerated the deployment of fiber-optic communication networks. Among various broadband access technologies, Fiber to the Home (FTTH) based on Gigabit Passive Optical Network (GPON) has emerged as a promising solution due to its high bandwidth capacity, low attenuation, and efficient network architecture(Saiyyed et al., 2025). However, broadband infrastructure deployment in rural areas remains challenging because of uneven settlement distribution and geographical constraints, resulting in limited service quality and network accessibility(Hambly & Rajabiun, 2021)(Dixit et al., 2022).

NagariSikucur Barat, Padang Pariaman Regency, is one of the rural areas requiring a reliable broadband infrastructure to support growing communication needs. Therefore, an appropriate FTTH network design is necessary to ensure service availability and transmission performance while optimizing infrastructure requirements.

NagariSikucur Barat covers an area of approximately 8.1 km² and is characterized by agricultural land, plantations, and dispersed residential settlements. The area consists of several hamlets with uneven population distribution, resulting in varying distances between potential subscribers and optical network components(Pariaman, 2024). According to local demographic data, the village has a population of approximately 2,581 residents distributed across rural settlements(Stiyanto et al., 2025). These geographical characteristics directly affect FTTH network planning, particularly in determining feeder and distribution routes, optical device placement, and service coverage. Therefore, a network design that considers geographical conditions is required to ensure efficient infrastructure deployment and acceptable transmission performance.

Previous studies have investigated GPON-based FTTH networks using performance parameters such as Link Power Budget (LPB), Rise Time Budget (RTB), Bit Error Rate (BER), and Q-Factor(Kavitha et al., 2021). Nevertheless, most studies focus primarily on performance evaluation and do not comprehensively integrate network design, transmission performance analysis, and network infrastructure planning based on geographical conditions(Kompiyang Karmana Putra et al., 2022).

This study proposes the design and performance analysis of a GPON-based FTTH network in NagariSikucur Barat, Padang Pariaman Regency. The proposed network is evaluated using Link Power Budget (LPB), Rise Time Budget (RTB), BER, and Q-Factor parameters through OptiSystem simulation.

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LITERATURE REVIEW

Several studies have investigated the design and performance of Fiber To The Home (FTTH) networks based on Gigabit Passive Optical Network (GPON) technology. UzmaSeptima et al. (2025) evaluated FTTH-GPON performance using BER, Q-Factor, and Link Power Budget parameters. The results met the ITU-T G.984 standard. However, the study did not analyze Rise Time Budget or estimate network infrastructure requirements through BOQ calculations(Septima et al., 2025).

Muhammad Alfarezi et al. (2025) developed an FTTH-GPON network using Google Earth Pro, QGIS, and SeticsSttar Planner. The receive power values met optical network requirements, but BER and Rise Time Budget analyses were not conducted(Alfarezi et al., 2025). Silvia Fitri et al. (2021) analyzed FTTH-GPON performance using OptiSystem and obtained a BER value of 8.11464×10^{-33} and a Rise Time Budget of 0.029 ns. Nevertheless, the study did not consider geographical planning aspects(Fitri et al., 2021).

Rima FitriaAdiati et al. (2022) evaluated FTTH-GPON performance using Link Power Budget and Rise Time Budget parameters and confirmed compliance with GPON standards. However, BER analysis and infrastructure requirement estimation were not discussed(Adiati et al., 2022). Similarly, ZouhairaAbdellaoui et al. (2021) demonstrated stable GPON performance for broadband services but did not analyze Link Power BudgetandRise Time Budget(Abdellaoui et al., 2021).

Previous studies have shown that GPON technology is suitable for FTTH deployment. However, most studies focus only on network design or performance evaluation separately. Research that integrates geographical-based planning, Link Power Budget, Rise Time Budget, and BER analysis in a single framework remains limited.

Therefore, this study proposes a GPON-based FTTH network in NagariSikucur Barat, Padang Pariaman Regency, by integrating network planning based on geographical conditions, optical performance evaluation using Link Power Budget, Rise Time Budget, and BER parameters. This approach provides a more comprehensive basis for FTTH deployment planning in rural areas.

METHOD

This study employed the Prepare, Plan, Design, Implement, Operate, and Optimize (PPDIOO) methodology to design and evaluate the proposed GPON-based FTTH network in Nagari Sikucur Barat, Padang Pariaman Regency (Saputra et al., 2025). The methodology consists of six sequential stages.

The Prepare stage involved reviewing relevant literature and the ITU-T G.984 standard as the basis for network planning. The Plan stage included collecting geographical data and conducting field surveys to identify settlement distribution and service requirements. During the Design stage, the FTTH topology was developed using Google Earth Pro and AutoCAD, followed by Link Power Budget and Rise Time Budget calculations. The Implement stage consisted of modeling and simulating the network using OptiSystem. The Operate stage evaluated the received power, BER, and Q-Factor obtained from the simulation, while the Optimize stage analyzed the overall results to verify that the proposed network satisfied GPON performance requirements.

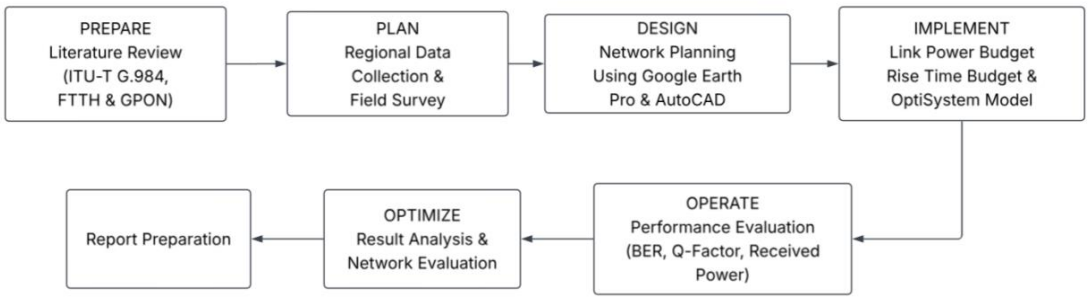


Figure 1. Research workflow based on the PPDIOO methodology.

RESULT

A GPON-based FTTH network was designed for NagariSikucur Barat, Padang Pariaman Regency, based on geographical conditions and settlement distribution. The proposed network serves 88 homepasses distributed across the service area. Network planning was conducted using Google Earth Pro and AutoCAD to determine the locations of optical network components, feeder routes, distribution routes, and drop cable routes. The final design consists of one Optical Distribution Cabinet (ODC), 13 Optical Distribution Points (ODPs), 3 PON ports, and a splitter configuration of 1:4 at the ODC and 1:8 at each ODP.

Figure 2 shows the geographical layout of the proposed FTTH network. The network topology was designed to follow existing road access and settlement distribution in order to improve coverage and simplify network deployment.

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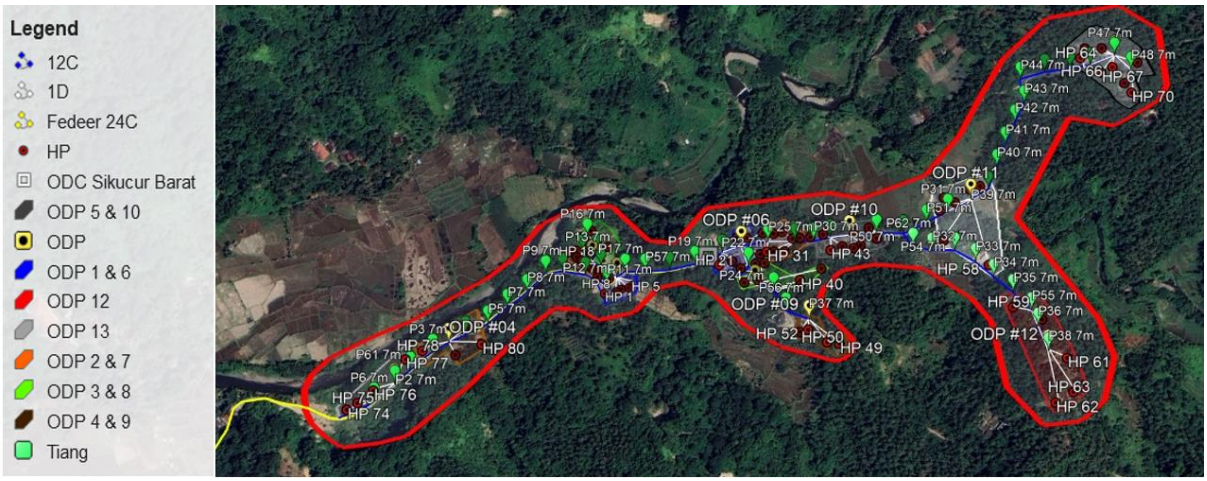


Figure 1. FTTH Network Planning Using Google Earth Pro

The network design was then redrawn using AutoCAD to provide a detailed representation of optical component placement and distribution routes. Figure 3 illustrates the final FTTH network layout used for implementation and performance analysis.

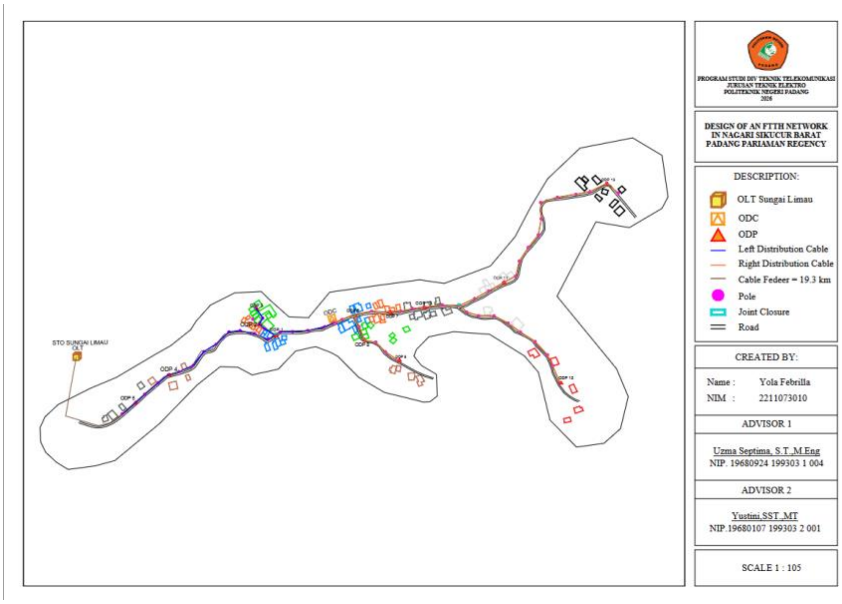


Figure 2. FTTH Network Design Using AutoCAD

The proposed GPON-based FTTH network serves 88 homepasses using 3 PON ports, 1 ODC, and 13 ODPs. Signal distribution employs four PLC 1:4 splitters and thirteen PLC 1:8 splitters. The network uses a 24-core feeder cable, a 12-core distribution cable, and G.657A1 drop cables to connect end users.

The selected distribution routes represent the nearest, middle, and farthest transmission scenarios on both the left and right sides of the proposed FTTH network. The ODC–ODP distance varies from 52.17 m to 754.24 m, while the ODP–ONT distance ranges from 10.2 m to 76.5 m, indicating different transmission path lengths. Longer transmission distances generally increase optical attenuation because the signal travels through a greater length of optical fiber. Therefore, these representative routes were selected to evaluate the influence of transmission distance on the Link Power Budget, Rise Time Budget, and overall optical network performance.

Table 1. Distribution Route Distances

Distribution Route	ODC–ODP (m)	ODP–ONT (m)
Nearest Left	141.59	10.2
Middle Left	428.68	42.3
Farthest Left	526.38	76.5
Nearest Right	52.17	13.2
Middle Right	403.71	22.6
Farthest Right	754.24	64.5

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The parameters used in the Link Power Budget calculation represent the optical characteristics of the proposed GPON network. The calculation includes fiber attenuation, splitter loss, connector loss, splice loss, and transmission distance, together with the transmitter power and receiver sensitivity. These parameters determine the total attenuation experienced by the optical signal before reaching the ONT. Using standardized design parameters ensures that the calculated received power accurately reflects the expected performance of the proposed FTTH network.

Table 2. Link Power Budget Parameters for the Nearest Left Distribution Route.

Nearest Left Distribution Route		
Parameter	**Symbol**	**Value**
Transmit Power (Tx)	PTx	7 dBm
Receiver Sensitivity (Rx)	PRx	-28 dBm
Fiber Attenuation	αfiber	0.28 dB/km
1:4 Splitter Loss	Losssplitter1	7.25 dB
1:8 Splitter Loss	Losssplitter2	10.38 dB
APC Connector Loss	Lossconn	0.35 dB
UPC Connector Loss	Lossconn	0.25 dB
Splice Loss	Losssplice	0.1 dB
OLT–ODC Distance	L1	19.3 km
ODC–ODP Distance	L2	0.14159 km
ODP–ONT Distance	L3	0.0102 km
Number of APC Connectors	Nconn	2
Number of UPC Connectors	Nconn	10
Number of Splices	Nsplice	8

The analytical calculation shows that the proposed transmission link has a total attenuation of 27.0765 dB, resulting in a received power of −20.0765 dBm. This value provides a power margin of 7.9235 dB above the receiver sensitivity limit of −28 dBm, indicating that sufficient optical power is available at the receiver. The largest contribution to the total attenuation comes from the passive optical splitters, followed by fiber attenuation and connector losses. These results indicate that the nearest left distribution route satisfies the Link Power Budget requirement and is suitable for GPON-based FTTH deployment.

The total attenuation and received power were calculated using the Link Power Budget method(Keiser, 2021):

$$\alpha total = (Ltotal \times \alpha fiber) + (Nconn \times Lossconn) + (Nsplice \times Losssplice) + Lsplitter \quad (1)$$

$$Pr = Pt - \alpha total \quad (2)$$

where αtotal is the total attenuation, Pr is the received power, Pt is the transmit power, and Lsplitter is the splitter loss.

Table 3. Link Power Budget Calculation for the Nearest Left Distribution Route

Description	**Calculation**	**Result**
Total Link Distance (Ltotal)	L1 + L2 + L3 = 19.3 + 0.14159 + 0.0102	19.45179 km
Fiber Attenuation	19.45179 × 0.28	5.4465 dB
APC Connector Loss	2 × 0.35	0.7000 dB
UPC Connector Loss	10 × 0.25	2.5000 dB
Splice Loss	8 × 0.1	0.8000 dB
Splitter Loss (1:4 + 1:8)	7.25 + 10.38	17.6300 dB
Total Attenuation (αtotal)	Sum of all losses	27.0765 dB
Received Power (Pr)	7 − αtotal	−20.0765 dBm
Power Margin	Pr − (−28)	7.9235 dB

Table 4. Link Power Budget Calculation Results

Distribution Route	**Total Link Distance (km)**	**Total Attenuation (dB)**	**Received Power (dBm)**	**Power Margin (dB)**
Nearest Left	19.45179	27.0765	-20.0765	7.9235
Middle Left	19.77098	27.1659	-20.1659	7.8341
Farthest Left	19.90288	27.2028	-20.2028	7.7972
Nearest Right	19.36537	27.0523	-20.0523	7.9477
Middle Right	19.72631	27.1534	-20.1534	7.8466
Farthest Right	20.11874	27.2632	-20.2632	7.7368

The Link Power Budget results indicate that the total attenuation ranges from 27.0523 dB to 27.2632 dB. The received power values vary between −20.0523 dBm and −20.2632 dBm, while the power margin ranges from 7.7368 dB to 7.9477 dB. All evaluated routes satisfy the GPON receiver sensitivity requirement of −28 dBm and provide

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sufficient power margin for reliable transmission.

Table 5 presents the parameters used in the Rise Time Budget calculation for the nearest left distribution route.

Table 5. Rise Time Budget Parameters for the Nearest Left Distribution Route

Parameter	Symbol	Value
Transmitter Rise Time	ttx	0.15 ns
Receiver Rise Time	trx	0.20 ns
Spectral Width	σλ	1 nm
Chromatic Dispersion	D	0.01364 ns/(nm·km)
Link Distance	L	19.45179 km

The fiber dispersion and system rise time are calculated using(Ridho et al., 2020):

$$tf = D \times \sigma\lambda \times L \quad (3)$$

$$tsys = \sqrt{(ttx^2 + trx^2 + tf^2)} \quad (4)$$

Example calculation for the nearest left distribution route:

$$tf = 0.01364 \times 1 \times 19.45179$$
$$= 0.2653 \text{ ns}$$
$$tsys = \sqrt{(0.15^2 + 0.20^2 + 0.2653^2)}$$
$$= 0.3645 \text{ ns}$$

The complete Rise Time Budget results are presented in Table 6.

Table 6. Rise Time Budget Results

Distribution Route	Distance (km)	tf (ns)	tsys (ns)
Nearest Left	19.45179	0.2653	0.3645
Middle Left	19.77098	0.2697	0.3677
Farthest Left	19.90288	0.2715	0.3691
Nearest Right	19.36537	0.2641	0.3637
Middle Right	19.72631	0.2691	0.3673
Farthest Right	20.11874	0.2744	0.3712

The Rise Time Budget values ranged from 0.3637 ns to 0.3712 ns. The nearest right distribution route produced the lowest rise time value, while the farthest right distribution route produced the highest rise time value.

Figure 4 shows the GPON-based FTTH network simulation model developed in OptiSystem. The simulation consists of the Optical Line Terminal (OLT), feeder fiber, Optical Distribution Cabinet (ODC), Optical Distribution Point (ODP), optical splitters, and Optical Network Terminal (ONT). The model represents the nearest, middle, and farthest distribution routes used to evaluate network performance.

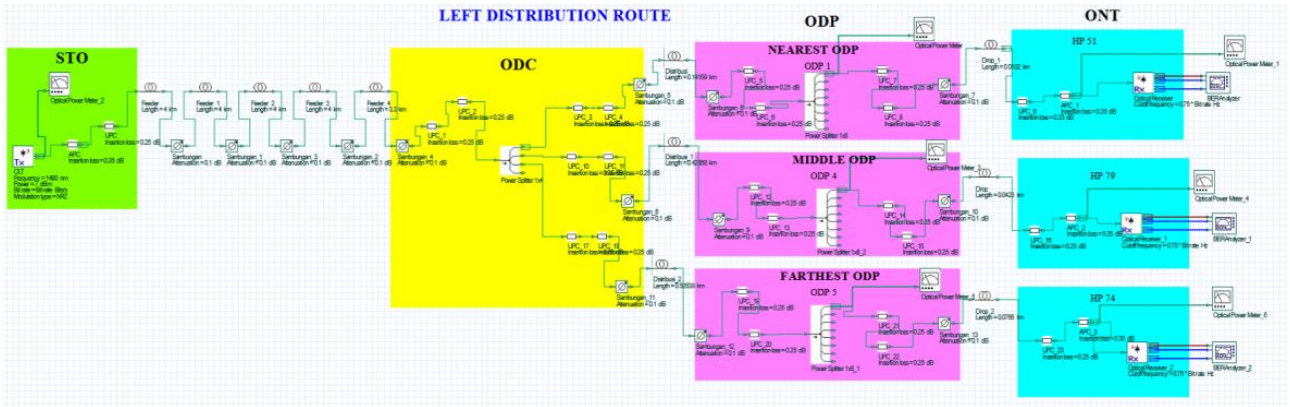


Figure 3. OptiSystem Simulation Model

Figure 5 presents the simulation output obtained from the BER Analyzer and Optical Power Meter for the nearest left distribution route. The eye diagram shows a clear eye opening, indicating good signal quality at the receiver side. The simulation produced a Q-Factor of 13.7883 and a BER of 1.49433×10^{-43}. In addition, the received optical power measured by the Optical Power Meter was −20.094 dBm. These results indicate excellent transmission quality and confirm that the proposed GPON-based FTTH network satisfies the required performance criteria.

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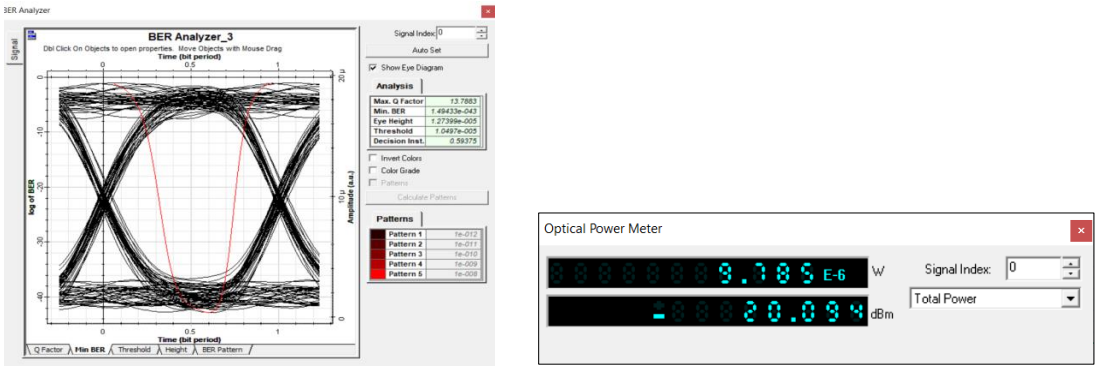


Figure 4. BER Analyzer and Optical Power Meter Results

The simulation results show that all distribution routes satisfy the GPON performance requirements. The Q-Factor values range from 12.1746 to 13.7883, while the BER values range from 1.49433×10^{-43} to 6.58298×10^{-35}. The received power values vary between -20.094 dBm and -20.337 dBm. The nearest left distribution route achieved the highest Q-Factor and the lowest BER, indicating the best transmission performance. Despite the decrease in signal quality on longer transmission routes, all simulated links remained within the acceptable GPON operating range and were therefore considered feasible for deployment.

Table 7. OptiSystem Simulation Results

Distribution Route	Q-Factor	BER	Received Power (dBm)
Nearest Left	13.7883	1.49433×10^{-43}	-20.094
Middle Left	12.1746	2.12303×10^{-34}	-20.184
Farthest Left	12.4246	9.59913×10^{-36}	-20.221
Nearest Right	12.3555	2.27565×10^{-35}	-20.126
Middle Right	12.2697	6.58298×10^{-35}	-20.227
Farthest Right	12.3358	2.89615×10^{-35}	-20.337

DISCUSSION

The Link Power Budget results show that the received power decreases as the transmission distance increases. This trend occurs because longer optical links experience greater attenuation from fiber cables, connectors, splices, and splitters. The nearest right route achieved the highest received power of −20.0523 dBm, while the farthest right route produced the lowest received power of −20.2632 dBm. Despite these variations, all routes remained above the GPON receiver sensitivity threshold of −28 dBm. In addition, the power margin values ranged from 7.7368 dB to 7.9477 dB, indicating sufficient optical power reserves to maintain stable network operation. These results confirm that the proposed FTTH network design can support reliable signal transmission throughout the coverage area.

The Rise Time Budget values range from 0.3637 ns to 0.3712 ns and increase with transmission distance due to chromatic dispersion in the optical fiber. Based on the GPON downstream limit of 0.29 ns at 2.4 Gbps, the maximum allowable link distance is approximately 10.78 km. However, the proposed network has link distances ranging from 19.36537 km to 20.11874 km, causing the calculated rise time values to exceed the theoretical limit. Despite this condition, the simulation results show acceptable transmission quality, with all routes satisfying the GPON Q-Factor and BER requirements.

Table 8. Comparison of Calculated and Simulated Optical Performance Parameters

Distribution Route	Calculated Received Power(dBm)	Margin (dB)	SimulatedQ-Factor	Simulated BER	Simulated Received Power(dBm)
Nearest Left	-20.0765	7.9235	13.7883	1.49433×10^{-43}	-20.094
Middle Left	-20.1659	7.8341	12.1746	2.12303×10^{-34}	-20.184
Farthest Left	-20.2028	7.7972	12.4246	9.59913×10^{-36}	-20.221
Nearest Right	-20.0523	7.9477	12.3555	2.27565×10^{-35}	-20.126
Middle Right	-20.1534	7.8466	12.2697	6.58298×10^{-35}	-20.227
Farthest Right	-20.2632	7.7368	12.3358	2.89615×10^{-35}	-20.337

Table 8 shows a comparison between the analytical calculations and OptiSystem simulation results. The simulated received power values are close to the calculated received power values, with differences of less than 0.1 dB for all distribution routes. This result indicates that the proposed network design accurately represents the optical transmission characteristics of the FTTH network. In addition, all routes achieve Q-Factor values above 12 and BER values below 10^{-9}, confirming good signal quality and a low probability of transmission errors. These results demonstrate that the proposed GPON-based FTTH network can provide reliable broadband services across the entire

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coverage area.

This study evaluated the proposed FTTH network through analytical calculations and OptiSystem simulations. Factors such as installation quality, environmental conditions, component aging, and additional losses that may occur during actual deployment were not considered in the analysis. Therefore, the obtained results represent the expected network performance under ideal operating conditions. Future studies should validate the proposed design through field implementation and direct performance measurements to provide a more comprehensive evaluation of network performance.

The obtained results are consistent with previous FTTH-GPON studies, which reported that GPON networks can satisfy optical power and transmission quality requirements. The received power, Q-Factor, and BER values obtained in this study indicate comparable performance and confirm the suitability of GPON technology for broadband deployment in rural areas.

CONCLUSION

This study designed and evaluated a GPON-based FTTH network for NagariSikucur Barat, Padang Pariaman Regency, based on geographical conditions and settlement distribution. The proposed network serves 88 homepasses using 3 PON ports, 1 ODC, and 13 ODPs. The Link Power Budget analysis produced received power values ranging from −20.0523 dBm to −20.2632 dBm with power margins between 7.7368 dB and 7.9477 dB, indicating compliance with GPON power requirements. OptiSystem simulation results generated Q-Factor values of 12.1746–13.7883 and BER values of 1.49433×10^{-43}–6.58298×10^{-35}, confirming good transmission quality for all evaluated routes. Although the Rise Time Budget values exceeded the theoretical GPON limit, the network maintained acceptable performance based on BER and Q-Factor results. Therefore, the proposed GPON-based FTTH network is feasible for broadband deployment in the study area. Future work should focus on field implementation and performance validation under actual operating conditions.

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