Design and Implementation of FTTB Network Transmission in High-Rise Buildings Using GPON

Ahmad Yuhani
Magister of Electrical Engineering, Gunadarma University, Indonesia

Emy Haryatmi
Magister of Electrical Engineering, Gunadarma University, Indonesia

Deni Haryadi
Department of Mechanical Engineering, Gunadarma University, Indonesia

Yunus Bakhtiar Arafat
Automotive Industry Engineering Technology, Politeknik Digital Boash Indonesia, Indonesia

Abstract: The advancement of digital communication technology has significantly increased the demand for reliable network infrastructure, particularly in high-rise buildings such as hotels and resorts. This study aims to design and evaluate a Fiber To The Building (FTTB) network system based on Gigabit Passive Optical Network (GPON) technology at The Anvaya Beach Resort Bali. The system is designed to distribute integrated communication services including data voice, and video, through a zoning approach based on the functional layout of the building. The Waterfall method is employed in the system development, encompassing the stages of requirement analysis, topology design, field implementation, and optical performance testing. The findings indicate that most zones have optical attenuation values within the standard range (15–28 dB), and the received signal power remains within the acceptable threshold (-28 dBm). However, several areas exhibit suboptimal signal performance, particularly those with long distribution paths and a high number of optical splitters. Zone C1.1 demonstrates the best performance, with stable attenuation levels and signal strength within standards, without requiring additional active devices. The study concludes that a GPON-based FTTB system can efficiently and flexibly meet the data communication needs of high-rise buildings and other complex building environments with similar systems.

Keywords: FTTB, GPON, passive optical network, optical attenuation, signal power.

Correspondents Author:
Emy Haryatmi, Magister of Electrical Engineering, Gunadarma University, Indonesia
Email: emy_h@staff.gunadarma.ac.id

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Introduction

The advancement of communication and information technologies has significantly influenced the growing demand for reliable network infrastructure, particularly in high-rise buildings such as hotels, apartments, and office complexes (Gong et al., 2022). The increasing need for fast, stable internet connectivity capable of supporting integrated services including data, voice, and video continues to rise in parallel with the proliferation of IP-based devices and the demands of centralized building management systems. One of the leading solutions that has emerged to address this need is optical fiber-based network architecture, particularly Fiber to the Building (FTTB) (Farooq et al., 2015; Ogutu et al., 2024).

FTTB is a network system that delivers optical fiber connections into a building and distributes connectivity to individual rooms or units via additional transmission media (Davey et al., 2006; Xu et al., 2007). Unlike Fiber to the Home (FTTH), which is tailored for residential environments, FTTB is better suited for large-scale and complex buildings due to its advantages in infrastructure efficiency and flexible integration of IP-based services (Feng & Yun, 2009). FTTB offers high bandwidth capacity, low latency, and superior transmission reliability compared to traditional copper-based networks (Moghaddam et al., 2015).

Among the technologies that support FTTB implementation, the Gigabit Passive Optical Network (GPON) is particularly relevant. GPON is a standard passive optical network technology defined by ITU-T under Recommendation G.984. It supports downstream speeds up to 2.5 Gbps and upstream speeds up to 1.25 Gbps using a point-to-multipoint topology (Gilfedder, 2006; Konstadinidis et al., 2018). A single Optical Line Terminal (OLT) port can serve up to 64 subscribers via passive optical splitters, making GPON highly efficient in both infrastructure and cost. GPON also enables simultaneous delivery of Triple Play services—data, voice (telephony), and video. Its ability to integrate IP-based devices such as CCTV, VoIP, IPTV, and WiFi access points makes it an ideal solution for high-rise buildings with complex, interconnected service requirements (Taheri & Ansari, 2015). With centralized network configurations and passive field components, GPON systems are not only cost-effective but also simple to maintain and scalable for future development (Loayza-Valarezo et al., 2021).

Nevertheless, designing and implementing a GPON-based FTTB system in high-rise environments presents specific challenges. These include precise bandwidth requirement analysis, zoning based on room function, accurate link budget calculations to ensure signal strength remains within acceptable limits, and the selection of both active and passive devices that meet field and technical standards (Kawser & Ahmed, 2020; Saeidi et al., 2022).

Furthermore, variables such as inter-zone distance, building structure, and site topography play a critical role in determining network performance and design efficiency. While several previous studies have explored GPON deployment in small-scale or residential environments, comprehensive research on its application in high-rise buildings with complex layouts and multi-IP device integration remains limited (Rotherham et al., 2024). Yet, such implementations require more rigorous planning and system performance validation (Ali et al., 2021).

This study presents a case study of FTTB network design and implementation using GPON technology at The Anvaya Beach Resort Bali a high-rise luxury hotel occupying a 30,000 m² area with diverse functional zones, including meeting rooms, hotel suites, villas, ballrooms, and public facilities. The complexity of spatial functions and the large volume of interconnected devices necessitate a robust and efficient networking solution.

The primary objective of this study is to design a GPON-based FTTB system capable of meeting the comprehensive data communication needs of the entire hotel environment. To achieve this, the Waterfall methodology was applied, encompassing stages of requirement analysis, system design, network implementation, and performance testing. The requirement analysis phase included the identification of integrated IP devices such as CCTV, IP phones, access points, and IPTV units and bandwidth estimation based on their technical specifications. A distinctive aspect of this implementation is the zoning-based design approach, which tailors the GPON layout to the functional characteristics and spatial complexity of the hotel. This method allows for targeted bandwidth allocation, optimized signal distribution, and manageable passive component placement per zone. Compared to flat or symmetrical fiber topologies, the zoning model allows better attenuation control and service management in environments with irregular building geometry and varying device density. The resulting architecture offers a replicable framework that can be adopted by other hospitality buildings with similar service integration and physical layout challenges. In terms of performance and efficiency, the proposed GPON zoning model offers several advantages when compared to other architectures. While FTTH provides high performance through dedicated fiber lines, its application in multi-floor or high-rise buildings can be cost-intensive due to complex cabling and space constraints. Meanwhile, Hybrid Fiber Coaxial (HFC) networks though commonly used—suffer from lower upstream capacity and higher latency, making them less suitable for IP-based service delivery. The GPON-based zoning approach in this study balances efficiency, scalability, and service reliability, making it a compelling alternative for modern hotel infrastructure design.

The network design phase involved mapping the optical fiber routes, dividing service zones according to building function, placing optical splitters strategically, and selecting appropriate active devices (OLT, ONU, ONT) and passive devices (ODC, ODP, splitters). Implementation was carried out on-site, including outdoor and indoor cable installations, strategic device placement, and system configuration. All stages were conducted in accordance with international standards and evaluated through bandwidth allocation parameters and link power budget calculations. With this approach, the designed GPON system is expected not only to meet current communication service demands but also to offer scalability and flexibility for future service expansion and network upgrades.

Research Method

This study employs the Waterfall system development methodology, which is commonly used in engineering system design, including the development of communication networks. The Waterfall method was chosen due to its systematic, structured, and sequential workflow, which is particularly suited for infrastructure-based projects such as fiber-optic deployment. Although originally developed for software engineering, the phase by phase structure of this method is highly applicable to network infrastructure projects, as it allows for thorough planning, stakeholder coordination, and detailed documentation at each stage. Unlike Agile or Spiral models that support iterative revisions, the physical nature of network implementation such as trenching, cable installation, and splicing requires irreversible steps. In such contexts, Waterfall offers greater control, predictability, and alignment with construction schedules and regulatory compliance, making it a more appropriate choice for high-rise building deployments (Mishra & Alzoubi, 2023; Popa et al., 2021).

The methodology is carried out in a systematic approach, starting from the requirement identification phase, followed by analysis, design, implementation, testing/verification, and finally maintenance. The stages of the Waterfall method implemented in the design and deployment of the GPON-based network system at The Anvaya Bali consist of the following:

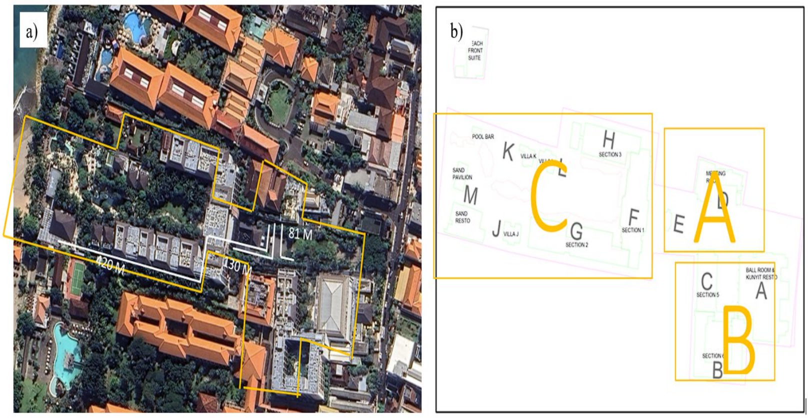

Figure 1 (a) Floor Plan of The Anvaya Beach Resort Bali (b) Block Plan of The Anvaya Beach Resort Bali

Requirement Analysis

This phase began with the examination of the building's layout and the mapping of service zones, which included meeting rooms, hotel rooms, ballrooms, restaurants, and villa areas. The analysis involved identifying all devices to be integrated into the system, such as CCTV cameras, IPTV units, access points, and telephones. Each device was evaluated based on its bandwidth requirements and connection type.

The building was divided into three main zones Zone A, Zone B, and Zone C. Distance measurements between zones were conducted using Google Maps, with an additional 40 meters added as a cable length tolerance to accommodate routing considerations. The analysis revealed a large-scale and complex demand, leading to the selection of GPON technology. GPON was deemed appropriate due to its support for analog telephone integration via POTS ports on the ONT, power efficiency through passive components, and simplified cable management enabled by the use of optical splitters. The selection of GPON was supported by a quantitative analysis of bandwidth demand based on the number and type of IP devices. Bandwidth estimation for each zone accounted for peak load conditions and simultaneous Triple Play services. The results indicated that several zones required over 1 Gbps, validating the need for a high-capacity solution. GPON's capability of delivering 2.5 Gbps downstream and 1.25 Gbps upstream, combined with its passive topology, made it the most efficient choice over EPON and Active Ethernet for a high-rise building with extensive device integration and infrastructure limitations.

Tabel 1 Zone, Room and Devices of The Anvaya Beach Resort Bali

Zone	Building Area Description	Estimated Number of Devices and Services
A	Meeting Room, Utility Room	STB : 21, Telephone : 29, CCTV : 21, Acces Point : 5, DDC : 2

B	Hotel Room, Ball Room, Restaurant Kunyit	STB : 160, Telephone : 265 + 2 IP, CCTV : 65, Acces Point : 22, DDC : 9
C	Premier Area, Hotel Room, Semi Basement (FOH), Villa J, Villa K, Pool Bar, Villa Spa, Villa L, Restaurant Sand	STB : 358, Telephone : 363, CCTV : 109, Acces Point : 35, DDC : 7

System Design

This phase involved the design of the network topology and the planning of device distribution. The system was configured with a centralized control hub located in Zone A. The design included the routing plan for the backbone fiber optic cable both indoor and outdoor segments and the selection of active network devices, such as a Raisecom OLT with 32 PON ports, a 24-port PoE ONU, and the Raisecom HT803G-WS2 ONT, which supports both WiFi connectivity and analog telephony.

Additionally, the placement of passive optical components was planned, including splitters with ratios of 1:2, 1:4, 1:8, 1:16, and 1:32, along with ODC (Optical Distribution Cabinet), ODP (Optical Distribution Point), and OTB (Optical Termination Box) units. The zoning of the distribution system was based on the functional classification of devices—whether for facilities, guest rooms, or office areas—in order to prevent bandwidth overload and to optimize the efficiency of the network bandwidth allocation.

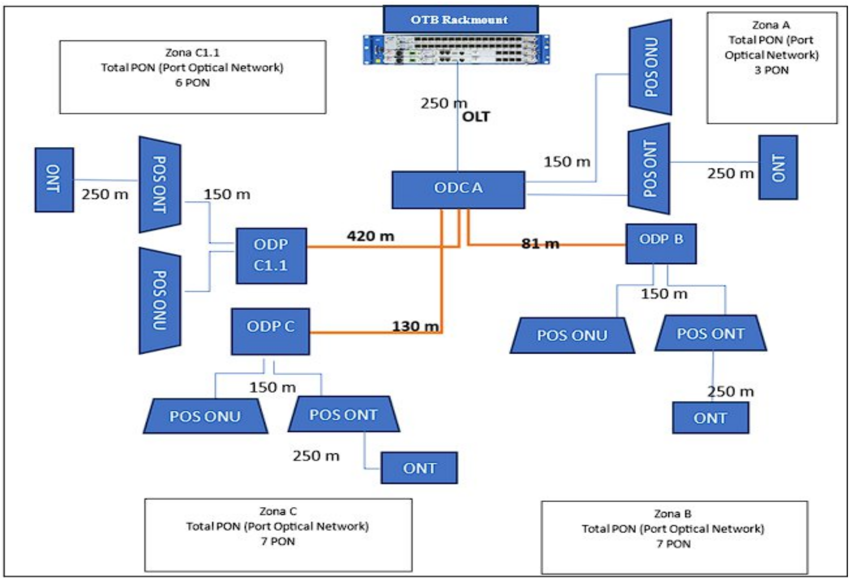

Figure 2 Network Topology with Splicing Points

Implementation

The implementation phase began with the preparation of tools and administrative tasks, including obtaining work permits and material approvals. The installation of fiber optic (FO) cables was carried out using an open trench method at a depth of 60 cm, utilizing 24-core direct-buried fiber cables. The installation of Optical Distribution Cabinets (ODC) began with the construction of manholes and foundations. The use of a 24-core direct-buried fiber cable for both outdoor and indoor segments was intentionally standardized to streamline procurement and installation processes. Although typically different cable types are used based on environmental conditions, all indoor cables in this project were routed through enclosed shafts and protective conduits, which offered similar protection as underground ducts. This approach met safety and technical requirements while also ensuring additional spare cores were available for future network expansion or maintenance flexibility.

Fiber optic cable termination at each ODC was performed using splicing techniques. A 4-core dropwire cable was used to connect the ODC to the splitter, and from the splitter to the ONT using patch cords routed through wall outlets (rosettes). ONUs were installed in designated shaft rooms, while ONTs were installed inside individual hotel rooms. The OLT was configured to handle IP addressing, routing, and the registration of ONU/ONT devices within the system.

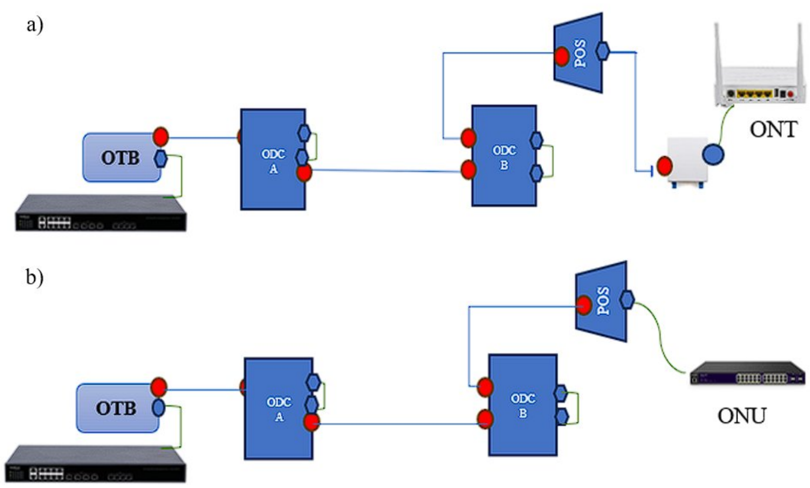

Figure 3 Installation of Splicing Points and ONT & ONU Adaptor Units

Testing

Following the installation, optical signal testing was conducted to ensure that the received power (Pr) was within the acceptable tolerance range as specified by ITU-T standards. In addition, the link power budget was calculated, and functional verification of each device was carried out particularly for the Triple Play services (data, voice, and video), in all designated service zones.

Result and Discussion

Optical Attenuation Analysis by Zone

The attenuation analysis was carried out to evaluate the performance of the FTTB network system based on GPON technology implemented at The Anvaya Beach Resort Bali. Optical attenuation (loss) is a critical factor affecting the quality of the signal received by customer premises equipment (CPE). The attenuation was calculated by considering the contributions from passive components such as fiber optic cables, splicing joints, adapters, and splitters.

The evaluation was conducted across four primary service zones: Zone A, Zone B, Zone C, and Zone C1.1. Each zone was analyzed based on its unique network configuration and device density, allowing for the assessment of signal degradation and the overall transmission quality.

Table 2 Total Attenuation Values Based on Splitting Areas in Zones A, B, and C

Zone	Area	Splitter Ratio	Splitter Loss (dB)	Cable Loss (dB)	Attenuator (dB)	Total (dB)	Total+Tol. (dB)
A	Room/ Meeting Room	1 : 16	14.10	–	–	17.78	18.00
A	Facility	1 : 4	7.25	3.10	10.00	20.58	20.00
A	Office	1 : 2	3.70	3.10	10.00	17.03	18.00
B	Room/ Meeting Room	–	3.80	–	–	25.21	26.00
B	Facility	1 : 4	7.25	3.10	10.00	20.61	21.00
B	Office	1 : 4	7.25	3.10	10.00	20.61	21.00
C	Room/ Meeting Room	1 : 4	7.25	–	–	28.77	29.00
C	Facility	1 : 8	11.00	3.10	10.00	24.37	25.00
C	Office	1 : 4	7.25	3.10	10.00	20.62	21.00

Table 2 presents the total optical attenuation values for each service zone. The calculation results indicate that attenuation levels vary across zones, depending on the network topology and installation characteristics. Zone A shows the highest attenuation occurring in the guest room area, although the values remain within the acceptable standard range of 15–28 dB. Zone B exhibits similar characteristics, where the attenuation in guest rooms is within standard limits, but the office and facility areas show lower-than-expected attenuation, indicating a need for increased attenuation to ensure optimal performance. In contrast, Zone C recorded higher attenuation levels, particularly in the guest room area, where the values exceed the upper threshold of the acceptable range. This condition suggests a potential degradation in signal quality. Meanwhile, Zone C1.1, a subzone of Zone C, demonstrated attenuation values that fall within the acceptable range across all areas. This was achieved through the strategic addition of optical splitters, which helped increase attenuation passively and stabilize signal transmission.

The variation in attenuation values between zones is influenced by several key factors. First, the number of optical splitters: the more splitters used in a network segment, the greater the cumulative attenuation due to signal division. Second, the length of optical cables: Zone C covers a larger geographical area, which results in longer cable runs and consequently higher attenuation levels. Third, the number of splicing points and adapters: each splice and adapter introduce a measurable amount of signal loss. As illustrated in Figure 3, every terminal device has at least one splicing point and one adapter, both of which contribute to the total attenuation.

According to Telkom standards (Zulfikar et al., 2022), acceptable attenuation values should fall within the range of 15–28 dB. The evaluation of each zone's attenuation revealed that Zones A and B generally meet the standard, with the exception of facility and office areas where attenuation values are too low and may require adjustment. Zone C, particularly the guest room segment, exceeds the upper threshold, indicating potential degradation in signal quality. In contrast, Zone C1.1 shows ideal attenuation values throughout, resulting from an optimized splitter configuration.

To maintain attenuation within optimal limits, several technical strategies were applied. The use of attenuators was necessary in areas with abnormally low attenuation values such as office spaces in Zones A and B, where attenuators serve to introduce additional optical resistance, ensuring the signal remains within device operating thresholds. In Zone C1.1, the addition of optical splitters helped raise attenuation passively while also improving topological manageability for maintenance purposes. Furthermore, optimizing the distribution of passive devices, including repositioning Optical Distribution Cabinets (ODCs) and shortening cable lengths where feasible, also contributed to better attenuation control. This was implemented by reanalyzing the spatial layout of each zone and relocating ODCs closer to high-density device clusters such as guest rooms and IPTV areas. Cable routes were revised to eliminate redundant riser paths and minimize fiber looping along utility ducting. These adjustments effectively reduced the total cable length and number of splicing points, resulting in improved attenuation values, particularly in complex zones like Zone C. With this approach, the GPON-based FTTB network is able to maintain attenuation levels in accordance with technical specifications, ensuring reliable data transmission quality across all service zones within the hotel environment.

Signal Power Analysis (in dBm)

Following the calculation of total optical attenuation (loss) in each service zone, the next step involved determining the received signal power (Pr) at the customer end. This value was calculated to assess whether the optical signal delivered through the GPON network remained within the acceptable operational limits at the terminal device level.

$$Pr = Pt - (L_c + L_s + L_f + M) \tag{1}$$

In this context, Pr refers to the received signal power (in dBm), while Pt represents the output power of the Optical Line Terminal (OLT), typically set at +3 dBm. The total losses are composed of Lc, Ls, and Lf, which correspond to the attenuation from connectors, splicing points, and fiber cables, respectively. Additionally, M denotes the design margin, commonly assumed to be around 3 dB to ensure system reliability. According to GPON standards, the minimum acceptable power level that can be received by an Optical Network Terminal (ONT) is -28 dBm. If the received power falls below this threshold, the optical transmission may become unreliable or fail entirely, potentially resulting in service interruptions or degraded performance.

Zone A

Table 3 shows that the received signal power (Pr) values in Zone A range between -21 dBm and -24 dBm. This indicates that the system is performing well, with signal levels well above the minimum threshold of -28 dBm. As such, the optical signal quality in this zone is within acceptable standards, and no additional corrective actions or technical interventions are required.

Table 3 Received Signal Power (Pr) Calculation – Zone A

Zona A	Passive Device	Attenuation Standard
Room/Meeting Room	FO cable	0.23
	Connection + Accessories	3.45
	Splitter 1:16	14.10
	Total	17.78
	Total + Tolerance	**18.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr): Output Power (Pt) + Attenuation Total – Loss Margin	**-21.00**
Facility Area	Splitter 1:4	7.25
	FO Cable	0.23
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	20.58
	Total + Tolerance	**21.00**

	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-24.00**
Office Area	Splitter 1:2	3.70
	FO Cable	0.23
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	17.03
	Total + Tolerance	**18.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr): Output Power (Pt) + Attenuation Total – Loss Margin	**-21.00**

Zone B

Table 4 presents the signal power calculation results for Zone B, revealing two distinct conditions. In the guest room area, the received signal power is measured at -29 dBm, which falls below the minimum acceptable threshold and may lead to potential service disruptions. Meanwhile, the facility and office areas register signal power levels of -24 dBm, which are still within safe and acceptable operating limits.

Table 4 Received Signal Power (Pr) Calculation – Zone B

Zona B	**Passive Device**	**Attenuation Standard**
Room Area /Meeting Room	Splitter 1:2	3.70
	Splitter 1:32	17.45
	FO Cable	0.26
	Connection + Accessories	3.80
	Total	25.21
	Total + Tolerance	**26.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-29.00**
Facility Area	Splitter 1:4	7.25
	FO Cable	0.26
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	20.61
	Total + Tolerance	**21.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr): Output Power (Pt) + Attenuation Total – Loss Margin	**-24.00**
Office Area	Splitter 1:4	7.25
	FO Cable	0.26
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	20.61
	Total + Tolerance	**21.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-24.00**

This condition indicates that the distribution topology and splitter ratio in the guest room area should be re-evaluated. Potential solutions include the installation of higher-output SFP modules or the use of optical signal boosters (amplifiers) to enhance signal strength.

Zone C

Table 5 shows that the received signal power in the guest room area of Zone C is -32 dBm, which is well below the tolerance threshold and indicates a significant degradation in signal quality. This condition is most likely caused by several contributing factors, including excessive cable length, a high number of optical splitters, and suboptimal splicing quality throughout the network segment.

Table 5 Received Signal Power (Pr) Calculation – Zone C

Zona c	**Passive Device**	**Attenuation Standard**
Room Area /Meeting Room	Splitter 1:4	7.25
	Splitter 1:32	17.45
	FO Cable	0.27
	Connection + Accessories	3.80
	Total	28.77
	Total + Tolerance	**29.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-32.00**
Facility Area	Splitter 1:8	11.00
	FO Cable	0.27
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	24.37
	Total + Tolerance	**25.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-28.00**
Office Area	Splitter 1:4	7.25
	FO Cable	0.27
	Connection + Accessories	3.10
	Attenuator	10.00
	Total	20.62
	Total + Tolerance	**21.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-24.00**

Meanwhile, the office and facility areas in Zone C record received signal power levels of -28 dBm and -24 dBm, which remain within acceptable limits. Therefore, improvement strategies such as restructuring the network topology into a cascaded model, the use of repeater amplifiers, or the deployment of ONT devices with higher sensitivity should be considered to enhance performance.

Zone C1.1

Table 6 indicates that all areas within Zone C1.1 maintain signal power levels within the standard threshold (≥ -28 dBm). This outcome demonstrates that the optical distribution configuration in this zone has been effectively designed with optimal attenuation planning. In Zone C1.1, the optimized splitter configuration consisted of cascaded splitters—specifically, two 1:4 splitters (1:4 + 1:4) for guest and facility areas, and a 1:4 followed by a 1:2 (1:4 + 1:2) for the office area. This setup was selected to maintain cumulative attenuation below 19 dB and to distribute the load more evenly. Compared to a flat 1:32 configuration, this arrangement provided lower optical loss and better control over fault localization and service quality stability. The strategic addition of optical splitters, used to manage signal attenuation, has contributed to maintaining signal quality at an ideal and stable level.

Table 6 Received Signal Power (Pr) Calculation – Zone C1.1

Zona c1.1	**Passive Device**	**Attenuation Standard**
Room Area /Villa Villa J, K, L & Sand Restaurant	Splitter 1:4	7.25
	Splitter 1:4	7.25
	FO Cable	0.37
	Connection + Accessories	3.80
	Total	18.67
	Total + Tolerance	**19.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr): Output Power (Pt) + Attenuation Total – Loss Margin	**-22.00**
Facility Area Villa J, K, L & Sand Restaurant	Splitter 1:4	7.25
	Splitter 1:4	7.25
	FO Cable	0.37
	Connection + Accessories	3.80
	Total	18.67
	Total + Tolerance	**19.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr) : Output Power (Pt) + Attenuation Total – Loss Margin	**-22.00**
Office Area Villa J, K, L & Sand Restaurant	Splitter 1:4	7.25
	Splitter 1:2	3.70
	FO Cable	0.37
	Connection + Accessories	3.80
	Total	15.12
	Total + Tolerance	**16.00**
	LOS Margin (Constant)	**6.00**
	Output Power (SFP)	**3.00**
	Received Signal Power (Pr): Output Power (Pt) + Attenuation Total – Loss Margin	**-19.00**

From the overall analysis, it can be concluded that most zones demonstrated strong performance in maintaining the stability of the optical signal throughout the GPON-based FTTB network. However, the guest room areas in Zones B and C experienced significant signal degradation that requires immediate attention. The primary contributing factors include imbalanced network topology, excessive fiber cable length, and the use of non-optimal splitter ratios. To address these issues, the network design should be adjusted through the deployment of active devices such as optical amplifiers, higher-output SFP modules, or, if necessary, a complete redesign of the distribution path to restore the system to compliance with defined technical standards.

Conclusions

This study has successfully designed and evaluated a Fiber To the Building (FTTB) network system based on Gigabit Passive Optical Network (GPON) technology for a high-rise building environment, using The Anvaya Beach Resort Bali as a case study. The system was developed to meet the growing demand for integrated communication services including data, voice, and video through a zone-based design approach tailored to the complex spatial layout of the building, covering meeting rooms, hotel rooms, villas, and public facilities. The results of the analysis and testing confirm that the zonal distribution model implemented in the GPON network design has effectively supported communication requirements in a large-scale building environment. The mapping of IP devices and fiber optic routes was performed with careful consideration of spatial function and technical characteristics in each zone. Most of the measured attenuation values fall within the standard technical range of 15 to 28 dB, in accordance with guidelines from Telkom and ITU-T. However, some areas, particularly the facility and office sections in Zones A and B, recorded attenuation values that were too low, necessitating the installation of attenuators to maintain stable signal levels. Zone C was identified as the most challenging, especially in the guest room segment, where signal levels dropped below the minimum acceptable threshold—reaching -32 dBm. This highlights a technical limitation in the current design, indicating the need for further improvements in network topology, including cable length optimization, splitter ratio adjustment, and potentially the use of signal enhancement devices such as optical amplifiers. Conversely, Zone C1.1 exhibited a well-balanced and stable configuration, with signal levels consistently within the ideal range without requiring any additional active components. This demonstrates that proper splitter planning and fiber path design play a critical role in ensuring overall network quality. Throughout its implementation, the Waterfall methodology proved effective in supporting the systematic development of the network system—covering requirement analysis, system design, field implementation, and optical performance testing. Although no iterative testing or re-simulation was conducted, the structured methodology provided a clear framework for execution and allowed for thorough technical documentation at every stage. In conclusion, the GPON-based FTTB system developed in this study has successfully met the data communication needs of a high-rise building environment and offers scalability for future network expansions. Nevertheless, the limitations observed in certain zones underscore the need for more detailed attenuation modeling and adaptive zoning strategies in future implementations. These findings provide a solid technical foundation for the broader adoption of GPON technology in other large-scale building infrastructures, particularly in hospitality and commercial sectors that demand high efficiency, network stability, and seamless IP service integration.

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