

Optimization of FTTH Network Attenuation Using EPON Based on Splitter Ratio Configuration in the NEM Media RT/RW Net

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Abstract—Fiber-to-the-Home (FTTH) has become a widely adopted broadband access technology due to its high transmission capacity and reliability. However, active fiber-optic distribution networks commonly used in small-scale RT/RW Net deployments experience considerable optical attenuation, increased maintenance complexity, and higher operational costs. This study proposes an Ethernet Passive Optical Network (EPON)-based FTTH architecture employing a cascaded splitter ratio configuration of 5:95 and 8:92 to optimize optical attenuation while maintaining bandwidth and Quality of Service (QoS). The proposed network was implemented on the operational RT/RW Net infrastructure of NEM Media, Indonesia, serving ten subscribers. Optical attenuation was evaluated using an Optical Power Meter (OPM) and Optical Time Domain Reflectometer (OTDR), while bandwidth and QoS performance were assessed using Speedtest and Wireshark. Experimental results show that the average received optical power improved from -26.85 dBm in the existing network to -14.01 dBm, corresponding to an average improvement of 12.83 dB (47.8%). The implemented network maintained bandwidth close to the configured 7 Mbps service profile for all subscribers and achieved 0% packet loss, demonstrating reliable communication performance. The results confirm that the proposed EPON architecture effectively reduces optical attenuation, simplifies network infrastructure by eliminating intermediate active devices, and provides stable broadband service for small-scale RT/RW Net deployments.

Keywords— EPON, Fiber-to-the-Home, FTTH, Optical Attenuation, Passive Optical Network, Splitter Ratio.

I. INTRODUCTION

The Internet has evolved into a fundamental infrastructure supporting a wide range of human activities, including communication, education, electronic commerce, government services, and healthcare. The rapid growth of digital transformation has significantly increased the demand for high-speed, reliable, and widely accessible Internet services. To address these requirements, Fiber-to-the-Home (FTTH) has become one of the most widely adopted broadband access technologies due to its high bandwidth capacity, low latency, and superior transmission reliability compared with conventional copper-based networks [1]. Furthermore, Passive Optical Network (PON)-based FTTH architectures have become an important solution for optical access networks because they provide scalable bandwidth and passive distribution infrastructure for residential and access services [2], [3], [4], [5]. The evolution of PON technologies toward higher capacity further demonstrates the continuing development of optical access networks to accommodate increasing bandwidth requirements [6].

One of the local Internet service providers implementing fiber-optic access is NEM Media, located in Sitirejo Village, Wagir District, Malang Regency, Indonesia. Since 2022, NEM

Media has delivered broadband Internet services through a partnership with ISP JINOM using an active fiber-optic network. Despite its successful deployment, the existing network still experiences significant optical attenuation along the distribution path. Field measurements indicate that the received optical power at customer premises ranges from 0 to -27 dBm, with several links approaching or exceeding the acceptable receiver sensitivity threshold. This condition is mainly caused by transmission distance, splice losses, connector quality, the use of media converters at distribution points, and suboptimal network configuration [7], [8]. Consequently, excessive attenuation reduces service stability and limits network scalability as the number of subscribers increases.

Among various optical access technologies, Ethernet Passive Optical Network (EPON) has been extensively adopted to improve FTTH deployment efficiency. EPON employs passive optical components between the Optical Line Terminal (OLT) and Optical Network Units (ONUs), using a point-to-multipoint fiber architecture in which a passive optical splitter distributes the optical signal to multiple subscriber nodes [9]. This passive architecture can reduce the number of powered devices in the outside plant and simplify network deployment

compared with active optical distribution architectures [3] [9] [10]. Previous studies have demonstrated that EPON-based FTTH deployment using an Optical Distribution Cabinet (ODC) improves service distribution efficiency and network scalability. Nevertheless, ODC-based architectures require additional passive infrastructure, distribution cabinets, and more extensive fiber installation, resulting in higher deployment costs, particularly for small-scale RT/RW Net operators [10].

In addition to network architecture, FTTH performance is strongly influenced by optical splitter configuration. The selected splitter ratio determines the optical power received by each Optical Network Terminal (ONT), directly affecting the overall power budget and transmission quality [5]. Research on optical access networks has also shown that the design and optimization of optical power splitters are important for controlling optical power distribution and insertion loss [11]. An inappropriate splitter ratio increases insertion loss and total optical attenuation, potentially degrading network performance. Previous studies have investigated optical power link budget analysis and attenuation characteristics in FTTH systems, whereas others have primarily focused on evaluating Quality of Service (QoS) metrics such as throughput, delay, jitter, and packet loss. EPON research has specifically addressed jitter and QoS protection through bandwidth allocation and scheduling mechanisms [12] [13] while more recent PON research has considered QoS requirements under bursty traffic conditions [14]. These studies indicate that optical-layer performance and end-to-end QoS are related aspects of access-network performance that should be evaluated together.

Based on the existing literature, several research gaps remain. First, most previous EPON implementations rely on Optical Distribution Cabinets (ODCs), resulting in relatively complex and costly infrastructures that are less suitable for small-scale RT/RW Net deployments. Second, existing studies generally employ conventional splitter configurations without thoroughly investigating the effectiveness of splitter ratio optimization as a strategy for minimizing optical attenuation within the distribution network. Third, network performance evaluations commonly focus on either optical attenuation or QoS metrics separately, providing limited understanding of the relationship between received optical power, bandwidth distribution, and overall service performance.

To address these gaps, this study proposes an attenuation optimization approach for an EPON-based FTTH network using splitter ratio configuration in the NEM Media RT/RW Net. Unlike previous studies, the proposed network architecture eliminates the use of an Optical Distribution Cabinet (ODC), thereby simplifying the distribution infrastructure while reducing deployment costs. Optical attenuation is optimized through an appropriate splitter ratio configuration without compromising service quality. System performance is evaluated using an Optical Power Meter (OPM) and Optical Time Domain Reflectometer (OTDR) for attenuation measurements, Simple Queue bandwidth management on MikroTik routers, and Quality of Service (QoS) analysis, including throughput, delay, jitter, and packet loss.

Such QoS aspects are also relevant in EPON studies because bandwidth allocation and scheduling directly affect delay, jitter, throughput, and packet delivery performance [12] [13] [15]. The proposed approach is expected to provide a simpler, more economical, and standards-compliant FTTH implementation for small-scale RT/RW Net operators.

II. METHOD

The method section provides detail of research conducted.

A. Research Flow

This study was conducted through six sequential stages, namely problem identification, data collection, FTTH-EPON network design, system implementation, performance testing, and result analysis. The overall research workflow is illustrated in Figure 1.

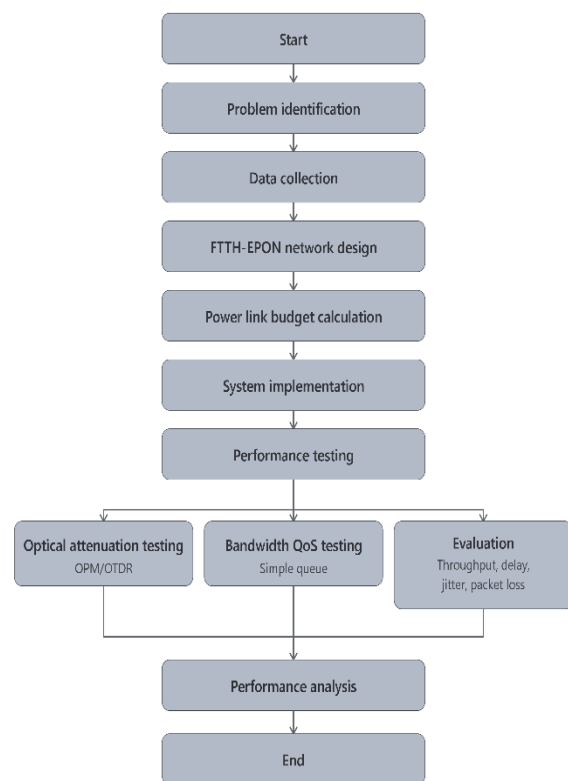


Figure 1. Research Flow of the Proposed Study

As illustrated in Figure 1, the first stage involved identifying the existing network conditions of the NEM Media RT/RW Net located in Sitirejo Village, Wagir District, Malang Regency. The analysis focused on the high optical attenuation observed in the active fiber-optic network. Based on field observations, the received optical power at customer premises ranged from 0 dBm to -27 dBm, with several optical links approaching or exceeding the acceptable receiver sensitivity threshold. In addition, the factors contributing to optical attenuation were identified, including transmission distance, the number of fiber

splices, connector quality, the use of media converters, and the network distribution configuration.

B. Existing Network Architecture

The existing RT/RW Net infrastructure at NEM Media employed an active fiber optic distribution network utilizing media converters, Ethernet switches, and customer routers, as illustrated in Figure 2. Internet access from the Internet Service Provider (ISP) was first connected to a MikroTik router and distributed through a 24-port switch. Optical signal transmission relied on paired media converters to convert electrical signals into optical signals and vice versa before reaching customer access points. Additional switches with 5-port and 8-port capacities were deployed to distribute network connectivity to multiple customers. Although this architecture successfully delivered Internet services, the large number of active devices increased maintenance complexity, electrical power consumption, and optical attenuation caused by repeated signal conversion. Consequently, the existing network required redesign using a passive optical architecture.

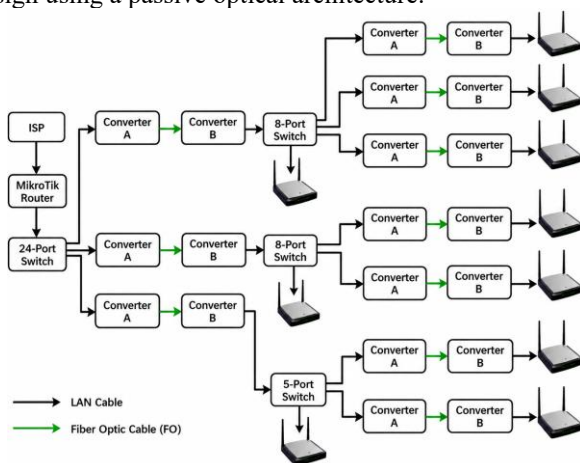


Figure 2. Existing Active Fiber Optic Network Architecture

C. Proposed FTTH-EPON Architecture

Based on the identified limitations of the existing network, a new Fiber-to-the-Home (FTTH) architecture based on Ethernet Passive Optical Network (EPON) was designed, as shown in Figure 3. The proposed architecture replaces the existing active fiber-optic distribution network with a passive optical distribution system. In the existing network, multiple active devices, including media converters and Ethernet switches, are deployed along the transmission path, resulting in additional power requirements, equipment complexity, and cumulative transmission losses. The proposed FTTH-EPON architecture minimizes the use of active devices between the central network and customer premises by utilizing passive optical splitters for signal distribution.

Internet traffic from the Internet Service Provider (ISP) is initially forwarded to the MikroTik RB951 router, which manages and distributes the IP traffic toward the access network. The traffic is then delivered to the HIOSO HA7302CST EPON Optical Line Terminal (OLT). The OLT serves as the main interface between the Ethernet-based network and the optical access network by converting Ethernet

frames into optical signals suitable for transmission through the fiber-optic medium. From the OLT, the optical signal is transmitted through the main fiber-optic link toward the passive distribution network.

The optical signal is subsequently distributed using a cascaded splitter configuration. The first stage uses an asymmetric 5:95 splitter ratio to divide the optical power between two distribution branches. The higher-power branch is connected to the first passive 1:8 splitter box to serve a group of customers, while the lower-power branch is forwarded to the subsequent 8:92 splitter configuration. The second splitter further distributes the available optical power between the downstream branches before the signal is delivered to another passive 1:8 splitter box. This cascaded configuration enables the available optical power to be distributed according to the characteristics of the customer distribution paths while avoiding the deployment of additional active switching equipment in the optical distribution section.

The use of passive 1:8 splitter boxes allows a single optical feeder to serve multiple customer premises through a point-to-multipoint topology. Unlike active Ethernet distribution, the passive optical distribution section does not require electrical power or active switching at the intermediate distribution points. Consequently, the number of active devices installed along the transmission path can be reduced, which simplifies network infrastructure and maintenance requirements. The proposed configuration also provides a more centralized architecture in which network control and traffic processing are primarily performed at the MikroTik router and EPON OLT, while the optical distribution section operates through passive components.

At the customer side, Optical Network Terminal (ONT) devices receive the optical signals from the passive distribution network and convert them back into Ethernet signals. The Ethernet interface of each ONT then provides network connectivity to the customer's end devices. Therefore, the complete transmission path can be represented as ISP → MikroTik RB951 → EPON OLT → cascaded optical splitters → passive 1:8 splitter box → ONT → customer devices. This architecture provides a structured point-to-multipoint FTTH distribution system while reducing the number of active components between the OLT and customer premises.

The proposed architecture is designed to address the limitations identified in the existing network, particularly the accumulation of active devices, electrical power requirements, network complexity, and optical transmission losses. The use of cascaded asymmetric splitter ratios is intended to provide more appropriate optical power distribution among the service branches, while the passive 1:8 splitter boxes provide connectivity to multiple customers. The resulting architecture is therefore expected to improve received optical power, simplify network maintenance, and enhance the reliability of the optical access network. The complete topology and interconnection of the main network components are illustrated in Figure 3.

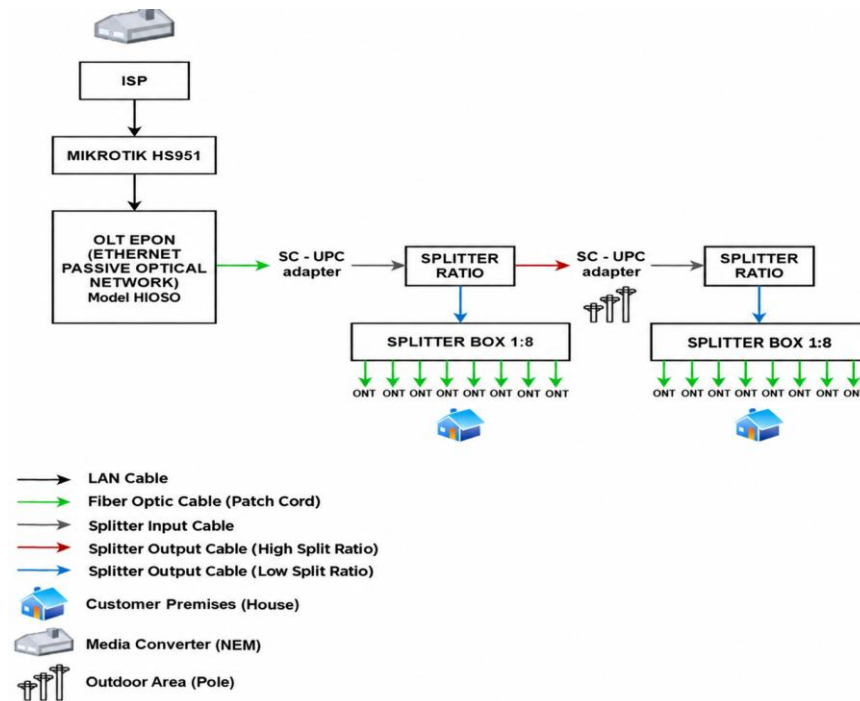


Figure 3. Proposed FTTH-EPON Network Architecture

D. Implemented Network Topology

Figure 4 illustrates the implemented FTTH-EPON network topology deployed at NEM Media based on the proposed architecture presented in Figure 3. The implementation began with the Internet connection received from the Internet Service Provider (ISP), which was forwarded to a MikroTik RB951Ui-2HnD router for routing and bandwidth management. The router was then connected to a HIOSO HA7302CST EPON Optical Line Terminal (OLT), which served as the central optical access device responsible for converting Ethernet traffic into optical signals.

The optical feeder generated by the OLT was connected to a cascaded splitter ratio configuration consisting of 5:95% and 8:92% optical splitters. The first splitter ratio (5:95%) divided the optical signal into two transmission paths. The higher-power optical branch (95%) was directly connected to the first passive splitter box (1:8), while the remaining optical power (5%) was forwarded to the second splitter ratio (8:92%). Subsequently, the second splitter ratio distributed the optical signal to another passive splitter box (1:8), enabling optical signal distribution over a wider service area while maintaining sufficient received optical power at each customer terminal.

Each passive splitter box distributed the optical signal to multiple Optical Network Terminals (ONTs) installed at customer premises. In this implementation, a total of ten ONTs were deployed to provide Internet access for ten subscribers. Each ONT converted the received optical signal into Ethernet data for customer devices and was configured using static IP addresses within the 192.168.10.x subnet to simplify network

management and ensure stable communication between the central office and customer premises.

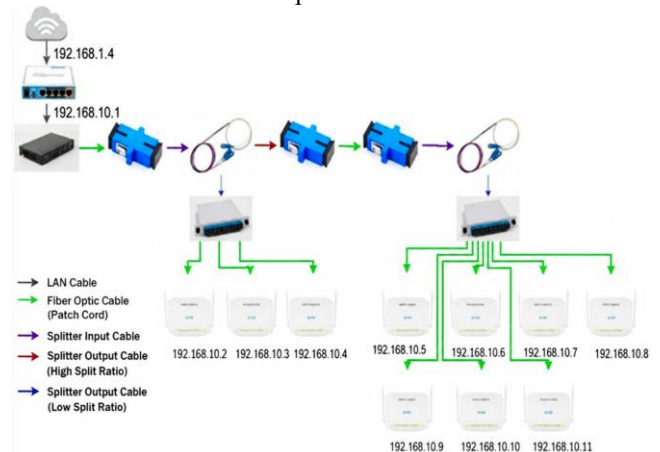


Figure 4. FTTH-EPON Deployment Topology

Bandwidth management was implemented using the Simple Queue feature available on the MikroTik router. Each subscriber received a symmetrical Internet bandwidth allocation of 7 Mbps for both download and upload traffic. This bandwidth configuration ensured fair resource allocation among subscribers and served as the reference configuration during bandwidth and Quality of Service (QoS) evaluations.

The implemented topology represents the practical realization of the proposed EPON-based FTTH architecture, providing a passive optical distribution network with fewer active devices than the previous system. This implementation not only simplifies network maintenance but also serves as the

basis for evaluating optical attenuation, bandwidth performance, and QoS parameters discussed in the subsequent section.

E. Optical Power Link Budget

Before implementing the proposed FTTH-EPON architecture, an Optical Power Link Budget (OPLB) analysis was performed to ensure that the total optical attenuation along the transmission path remained within the allowable operating range of the EPON system. The link budget calculation estimates the total optical loss from the Optical Line Terminal (OLT) to the Optical Network Terminal (ONT) by considering all attenuation sources in the optical distribution network. The total optical attenuation is calculated as follows:

$$L_{total} = L_{fiber} + L_{splice} + L_{connector} + L_{splitter} \quad (1)$$

where:

- L_{total} : total optical attenuation (dB)
- L_{fiber} : attenuation caused by the optical fiber (dB)
- L_{splice} : attenuation caused by fiber splicing (dB)
- $L_{connector}$: attenuation caused by optical connectors (dB)
- $L_{splitter}$: insertion loss introduced by the optical splitters (dB)

Each attenuation component was determined according to the optical network design parameters summarized in Table I.

TABLE I
OPTICAL POWER LINK BUDGET PARAMETERS

Parameter	Value
Fiber attenuation	0.30 dB/km
Fusion splice loss	0.03 dB/splice
Connector loss	0.30 dB/connector
Splitter ratio (5:95)	13.21 dB
Splitter ratio (8:92)	11.17 dB

The fiber attenuation component was calculated based on the total transmission distance between the OLT and each customer terminal. Splice loss was obtained from the number of fusion splice points installed along the optical cable route, while connector loss was calculated according to the total number of optical connectors used in the system. The splitter insertion loss was determined from the specifications of the selected splitter ratio devices. The calculated optical power link budget was then compared with the receiver sensitivity of the deployed ONTs to verify that the received optical power remained within the acceptable operating range. This analysis was used as the primary criterion for validating the feasibility of the proposed FTTH-EPON network before field implementation.

F. Experimental Setup

The proposed FTTH-EPON network was implemented and evaluated on the RT/RW Net infrastructure of NEM Media,

located in Sitirejo Village, Wagir District, Malang Regency, East Java, Indonesia. The experimental deployment was conducted on an operational Internet distribution network serving residential customers. The objective of the experiment was to evaluate the effectiveness of the proposed EPON-based passive optical network in reducing optical attenuation while maintaining stable bandwidth allocation and Quality of Service (QoS). The experimental network consisted of one MikroTik router, one EPON Optical Line Terminal (OLT), two cascaded splitter ratio devices, two passive splitter boxes (1:8), and ten Optical Network Terminals (ONTs) installed at customer premises. The distribution network employed single-mode fiber optic cables interconnected using SC-UPC connectors. Customer bandwidth allocation was configured through the Simple Queue feature on the MikroTik router, providing symmetrical Internet access of 7 Mbps for each subscriber.

Optical attenuation measurements were performed using an Optical Power Meter (OPM) and an Optical Time Domain Reflectometer (OTDR), while bandwidth and QoS evaluations were conducted using Speedtest and Wireshark, respectively. The experimental setup is summarized in Table II.

TABLE II
EXPERIMENTAL SETUP

Component	Specification
Study location	NEM Media, Sitirejo Village, Wagir District, Malang Regency, Indonesia
Network architecture	FTTH based on EPON
Router	MikroTik RB951Ui-2HnD
Optical Line Terminal (OLT)	HIOSO HA7302CST EPON
Splitter Ratio 1	5:95%
Splitter Ratio 2	8:92%
Passive Splitter	PLC Splitter Box 1:8
Optical Network Terminal (ONT)	ZTE F460, ZTE F663NV3A, ZTE F477V2
Fiber optic cable	Single-mode fiber (SC-UPC connector)
Number of customers	10 subscribers
Number of ONTs	10 units
Distribution distance	Approximately 100–500 m
Bandwidth allocation	7 Mbps per subscriber
Optical attenuation measurement	Optical Power Meter (OPM)
Fiber link measurement	Optical Time Domain Reflectometer (OTDR)
Bandwidth evaluation	Speedtest

G. Performance Evaluation

The performance of the proposed FTTH-EPON network was evaluated through four sequential testing stages: optical attenuation measurement, bandwidth evaluation, Quality of Service (QoS) assessment, and comparative performance analysis. These evaluations were conducted to verify that the proposed passive optical network satisfied the design objectives in terms of optical transmission quality and Internet service performance.

1) Optical Attenuation Measurement

The first evaluation focused on measuring the optical attenuation of the implemented FTTH-EPON network. Optical attenuation measurements were performed using an Optical Power Meter (OPM) and an Optical

Time Domain Reflectometer (OTDR). The OPM was used to measure the received optical power at each Optical Network Terminal (ONT), while the OTDR was employed to identify attenuation sources along the optical transmission path, including fiber attenuation, splice loss, and connector loss. The measured optical power was expressed in dBm and compared with the allowable operating range of the EPON system to verify that each optical link satisfied the receiver sensitivity requirements. These measurements were also compared with the calculated Optical Power Link Budget to validate the proposed network design.

2) *Bandwidth Evaluation*

Bandwidth performance was evaluated after the FTTH-EPON network had been successfully implemented. Customer bandwidth allocation was configured using the Simple Queue feature on the MikroTik router, where each subscriber was assigned a symmetrical Internet bandwidth of 7 Mbps. The actual bandwidth received by each customer was measured using the Speedtest application. Two performance indicators were evaluated:

- Download bandwidth (Mbps)
- Upload bandwidth (Mbps)

The measured bandwidth values were compared with the configured bandwidth allocation to determine the effectiveness of the bandwidth management mechanism and to verify that each subscriber received the expected service capacity.

3) *Quality of Service (QoS) Evaluation*

The Quality of Service (QoS) evaluation was conducted to assess the communication performance of the implemented FTTH-EPON network. Network traffic was captured and analyzed using Wireshark, while four QoS parameters were evaluated:

- Throughput, representing the effective data transmission rate achieved during communication.
- Delay, representing the end-to-end transmission time required for packets to travel from the sender to the receiver.
- Jitter, representing the variation in packet delay during data transmission.
- Packet Loss, representing the percentage of packets that failed to reach the destination.

The measured QoS values were subsequently compared with the performance categories defined in the adopted QoS standard to determine whether the implemented network provided acceptable service quality.

4) *Comparative Performance Analysis*

The final evaluation involved a comparative analysis between the existing active fiber optic network and the proposed FTTH-EPON network. This comparison was conducted to determine the effectiveness of

replacing the active optical distribution system with the proposed passive optical architecture.

The comparison considered three main performance aspects:

- **Optical Attenuation.** The received optical power before and after network implementation was compared to evaluate the reduction in optical attenuation achieved by the proposed EPON architecture.
- **Bandwidth Performance.** The effectiveness of the bandwidth allocation mechanism was analyzed by comparing the configured bandwidth with the measured upload and download bandwidth obtained from the Speedtest evaluation.
- **Quality of Service.** QoS parameters, including throughput, delay, jitter, and packet loss, were compared to determine whether the proposed FTTH-EPON network provided better communication performance than the existing active fiber optic network.

The results of this comparative analysis were used to demonstrate the effectiveness of the proposed FTTH-EPON architecture employing a cascaded splitter ratio configuration in improving optical transmission quality and Internet service performance for RT/RW Net deployment.

III. RESULTS AND DISCUSSION

A. *Optical Power Link Budget Validation*

Before implementing the proposed FTTH-EPON network, the designed optical distribution network was validated through an Optical Power Link Budget (OPLB) analysis. This validation was conducted to ensure that the total optical attenuation along the transmission path remained within the allowable operating range of the EPON system before field deployment. The analysis considered all attenuation sources in the optical distribution network, including fiber attenuation, connector loss, patchcord loss, and splitter insertion loss. The validation results are summarized in Table III, which presents the calculated optical power budget together with the measured optical power obtained during implementation. The comparison between the theoretical calculation and the field measurement was performed to evaluate the accuracy of the proposed network design.

TABLE III
OPTICAL POWER LINK BUDGET VALIDATION

Parameter	Value
OLT transmit power	+8.00 dBm
Patchcord loss	0.30 dB
Connector loss	0.30 dB
Splitter ratio (5:95) insertion loss	13.21 dB
PLC splitter (1:8) insertion loss	10.00 dB
Estimated received optical power	-5.81 dBm
Measured optical power (OTDR)	-5.06 dBm
Difference	0.75 dB
Validation status	Valid

Based on Table III, the estimated optical power at the output of the 5:95 splitter was -5.81 dBm, while the optical power measured at the same point was -5.06 dBm, resulting in a deviation of only 0.75 dB. The 1:8 splitter loss was excluded from this validation because the measurement point was located at the output of the 5:95 splitter. The small difference between the calculated and measured values indicates good agreement between the theoretical optical power budget and the field measurement.

The observed deviation is considered acceptable because practical optical installations are influenced by several factors, including connector alignment, splice quality, fiber bending, insertion loss variations, and measurement tolerances of the testing instruments. Consequently, slight differences between theoretical calculations and field measurements are expected and do not significantly affect the validity of the optical power budget.

The measured optical power at the output of the 5:95 splitter also indicates that sufficient optical power remains available for subsequent passive distribution through the downstream splitter stages. Therefore, the Optical Power Link Budget validation confirms that the proposed FTTH-EPON architecture provides an adequate optical power budget for subsequent distribution to the customer ONTs and supports the implementation and performance evaluation stages.

B. Optical Attenuation Performance

Following the successful implementation of the FTTH-EPON network, received optical power was measured at each customer ONT using an Optical Power Meter (OPM). The OTDR was used to identify attenuation sources along the optical transmission paths. The comparison of received optical power before and after implementation is presented in Table IV.

TABLE IV
COMPARISON OF OPTICAL ATTENUATION BEFORE AND AFTER FTTH-EPON IMPLEMENTATION

ONT	Customer	Existing Network (dBm)	Proposed FTTH-EPON (OTDR) (dBm)	Improvement (dB)
AP1	Abdul	-23.67	-15.13	8.54
AP2	Achmad	-25.56	-15.17	10.39
AP3	Adi Prasio	-23.95	-15.46	8.49
AP4	Andik	-27.91	-13.14	14.77
AP5	Anik	-27.76	-13.35	14.41
AP6	Bagus E	-30.13	-13.10	17.03
AP7	Chandra	-26.87	-14.36	12.51
AP8	Dewi	-29.38	-13.24	16.14
AP9	Ari	-23.72	-13.31	10.41
AP10	Anggun	-29.51	-13.87	15.64

As shown in Table IV, the proposed FTTH-EPON architecture significantly improved the received optical power at all customer locations. The average received optical power improved from -26.85 dBm in the existing network to -14.01 dBm after implementing the proposed FTTH-EPON architecture, corresponding to an average improvement of approximately 12.83 dB. Furthermore, the received optical power improved from a range of -30.13 to -23.67 dBm in the

existing network to a range of -15.46 to -13.10 dBm after implementation. These results indicate that the proposed architecture substantially improves the received optical power while maintaining all ONTs within the acceptable operating range.

The largest improvement was observed at AP6, where the received optical power increased from -30.13 dBm to -13.10 dBm, corresponding to an improvement of 17.03 dB. In contrast, AP3 exhibited the smallest improvement of 8.49 dB. Nevertheless, all measured ONTs achieved received optical power values that satisfied the operational requirements of the EPON system, indicating that the proposed network successfully reduced attenuation throughout the optical distribution network.

The observed variations among customers were influenced by the cumulative optical losses along each distribution path. Differences in transmission distance, connector losses, splitter insertion losses, and installation conditions such as cable bending and connector quality contributed to the variation in received optical power. Overall, the results confirm that the proposed FTTH-EPON architecture with cascaded splitter ratio effectively reduces optical attenuation and provides a more reliable optical distribution network than the previous active fiber-optic system.

C. Bandwidth Performance

Following the optical attenuation evaluation, bandwidth performance was measured using the Speedtest application to verify whether the bandwidth allocation configured through the MikroTik Simple Queue mechanism was successfully delivered to each customer. Each ONT was configured with a symmetrical bandwidth limit of 7 Mbps for both download and upload traffic. The measurement results are summarized in Table V.

TABLE V
MEASURED BANDWIDTH PERFORMANCE OF EACH ONT

ONT	Download (Mbps)	Upload (Mbps)
AP1	7.02	6.17
AP2	5.18	6.69
AP3	7.30	6.64
AP4	7.06	7.18
AP5	6.93	6.76
AP6	7.00	6.64
AP7	7.01	7.10
AP8	6.94	6.73
AP9	7.04	6.71
AP10	6.93	6.62

As presented in Table 5, the measured bandwidth closely matched the 7 Mbps configuration applied through the MikroTik Simple Queue mechanism. Download throughput ranged from 5.18 Mbps to 7.30 Mbps, while upload throughput ranged from 6.17 Mbps to 7.18 Mbps. These results indicate that the bandwidth management configuration was successfully implemented, allowing all customers to receive bandwidth close to the configured service profile.

Most ONTs achieved download and upload speeds that differed only slightly from the configured bandwidth limit. The

highest download speed was recorded at AP3 (7.30 Mbps), whereas the lowest download speed was observed at AP2 (5.18 Mbps). Similarly, upload performance remained relatively stable, with values ranging from 6.17 Mbps at AP1 to 7.18 Mbps at AP4. Overall, the measured bandwidth demonstrates consistent service delivery across the deployed FTTH-EPON network.

Small deviations from the configured 7 Mbps bandwidth are expected in practical network deployments. These differences can be attributed to several factors, including protocol overhead, temporary network traffic fluctuations during Speedtest measurements, TCP/IP processing overhead, and measurement uncertainty inherent to Internet-based bandwidth testing. Because the bandwidth allocation is enforced by the Simple Queue mechanism at the router, minor variations do not indicate a configuration failure but rather reflect normal operational characteristics of packet-switched networks.

Furthermore, the cascaded splitter ratio configuration primarily affects the optical power distribution rather than directly limiting the available bandwidth. Since all measured optical power levels remained within the acceptable EPON operating range, the passive optical distribution network did not introduce significant throughput degradation. Consequently, the measured bandwidth remained close to the configured service rate, confirming that the proposed FTTH-EPON architecture successfully maintains stable bandwidth performance while efficiently distributing optical signals to all connected customers.

D. Quality of Service Analysis

To further evaluate the communication performance of the proposed FTTH-EPON architecture, Quality of Service (QoS) measurements were conducted using Wireshark. Four QoS parameters, namely throughput, delay, jitter, and packet loss, were analyzed to assess the capability of the network in delivering reliable Internet services to end users. The measurement results are summarized in Table VI.

TABLE VI
QUALITY OF SERVICE PERFORMANCE OF THE PROPOSED FTTH-EPON NETWORK

QoS Parameter	Measurement Result	Performance Evaluation
Throughput	0.00–4.66 Mbps	Stable packet delivery with varying traffic conditions
Delay	1.54–869.55 ms	Generally low delay, with one outlier at AP1
Jitter	1.54–868.18 ms	Mostly stable, with several high-variation links
Packet Loss	0%	Excellent reliability

As shown in Table 6, the proposed FTTH-EPON network achieved 0% packet loss for all tested ONTs, indicating that every transmitted packet was successfully delivered without loss during the measurement period. This result demonstrates that the optical signal quality obtained after implementing the EPON architecture was sufficient to maintain reliable packet transmission throughout the network. The absence of packet

loss also confirms that the passive optical distribution network operated without significant transmission errors.

The measured throughput varied from 0.00079 Mbps to 4.66078 Mbps, depending on the instantaneous network traffic during the Wireshark capture. Although the throughput values were different among ONTs, this variation reflects the amount of actual transmitted traffic rather than the maximum available bandwidth. Since the bandwidth limitation was configured separately through the MikroTik Simple Queue mechanism, the measured throughput represents real-time user activity instead of the network capacity itself.

The delay measurements showed that nine of the ten ONTs experienced low transmission delays, with values generally below 155 ms, while only AP1 exhibited an exceptionally high delay of 869.55 ms. This isolated value may have resulted from temporary network congestion, background traffic, or measurement conditions during the capture process. Excluding this outlier, the remaining ONTs demonstrated delay values that are suitable for common Internet applications, including web browsing, video streaming, and Voice over IP services.

A similar trend was observed for jitter. Most ONTs recorded jitter values below 10 ms, indicating stable packet arrival intervals. However, AP1 and AP10 experienced considerably higher jitter values, suggesting temporary fluctuations in packet transmission. Because the majority of customers exhibited relatively low jitter, the overall network can be considered sufficiently stable for real-time communication services.

E. Comparative Performance Discussion

To comprehensively evaluate the effectiveness of the proposed FTTH-EPON architecture, the overall network performance was compared with the previously deployed active fiber-optic network. The comparison focuses on optical signal quality, bandwidth distribution, and Quality of Service (QoS) performance to demonstrate the practical benefits achieved after implementing the passive optical network.

TABLE VII
COMPARATIVE PERFORMANCE BETWEEN THE EXISTING NETWORK AND THE PROPOSED FTTH-EPON ARCHITECTURE

Performance Parameter	Existing Network	Proposed FTTH-EPON	Improvement
Average received optical power (dBm)	-26.85	-14.01	Improved by 12.83 dB (47.8%)
Optical power range (dBm)	-30.13 to -23.67	-15.46 to -13.10	Higher and more uniform optical power
Download bandwidth (Mbps)	Not evaluated	5.18–7.30	Stable and close to the configured 7 Mbps
Upload bandwidth (Mbps)	Not evaluated	6.17–7.18	Stable and close to the configured 7 Mbps
Throughput (Mbps)	Not evaluated	0.00079–4.66078	Reliable packet transmission
Delay (ms)	Not evaluated	1.54–869.55*	Acceptable for most ONTs

Jitter (ms)	Not evaluated	1.54–868.18*	Stable for most ONTs
Packet Loss (%)	Not evaluated	0	No packet loss observed

Table 7 summarizes the overall performance of the proposed FTTH-EPON architecture compared with the previous network. The most significant improvement was observed in the optical layer, where the average received optical power increased from -26.85 dBm to -14.01 dBm, corresponding to an improvement of approximately 12.83 dB or 47.8%. In addition, the received optical power became more uniform across all customer locations, indicating that the cascaded 5:95 and 8:92 splitter configuration effectively reduced optical attenuation throughout the passive optical distribution network.

The improvement in optical signal quality positively influenced the upper communication layers. Since all ONTs operated within the recommended EPON optical power range, the network maintained stable optical links without significant signal degradation. As a result, the bandwidth allocated through the MikroTik Simple Queue mechanism was successfully delivered to all customers. Speedtest measurements showed download speeds between 5.18 Mbps and 7.30 Mbps and upload speeds between 6.17 Mbps and 7.18 Mbps, demonstrating that the configured 7 Mbps service profile was consistently maintained despite minor fluctuations caused by Internet traffic and measurement conditions.

Quality of Service evaluation further confirmed the effectiveness of the proposed architecture. The network achieved 0% packet loss during all measurement sessions, indicating reliable packet delivery throughout the optical distribution network. Although several ONTs exhibited higher delay and jitter values during specific measurements, these variations were temporary and are commonly associated with background traffic, protocol overhead, and Internet routing conditions rather than limitations of the passive optical infrastructure itself. Overall, the measured QoS parameters demonstrate that the proposed FTTH-EPON network provides stable communication performance suitable for broadband Internet services.

Compared with the previous active fiber-optic distribution network, the proposed FTTH-EPON architecture offers several practical advantages. The passive optical distribution system eliminates the need for intermediate active devices, thereby reducing optical attenuation, simplifying network maintenance, lowering operational complexity, and minimizing potential points of failure. Furthermore, the cascaded splitter configuration enables efficient optical power distribution while maintaining reliable bandwidth allocation and communication quality for multiple customers connected to the same optical distribution network.

IV. CONCLUSION

This study proposed and implemented an EPON-based FTTH architecture employing a cascaded 5:95 and 8:92 splitter ratio configuration to optimize optical attenuation in the NEM Media RT/RW Net. Optical Power Link Budget validation

confirmed that the designed network satisfied the required optical operating conditions, with only a 0.75 dB difference between the calculated and measured received optical power, indicating good agreement between theoretical analysis and field implementation. Experimental evaluation demonstrated that the proposed architecture significantly improved optical transmission performance. The average received optical power increased from -26.85 dBm in the existing active fiber-optic network to -14.01 dBm, representing an average improvement of 12.83 dB (47.8%). In addition, the bandwidth allocated through the MikroTik Simple Queue mechanism remained close to the configured 7 Mbps service profile for all subscribers. Quality of Service measurements further confirmed reliable network performance, achieving 0% packet loss while maintaining stable throughput, delay, and jitter characteristics for the majority of customer terminals.

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