Design and Implementation of a Rural Broadband Model in Pagar Dewa Village Bengkulu

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***Abstract*—Reliable and affordable internet connectivity is crucial to support community development, especially in rural areas with limited telecommunications infrastructure. This study presents the design and implementation of a rural broadband model in Pagar Dewa Village, Bengkulu, aimed at providing stable internet services and reducing the digital divide in a cost-effective manner. The design process involved field surveys, network requirement analysis, topology selection, hardware and software deployment, and bandwidth capacity calculations. The system utilizes RouterOS and Mikrotik Hotspot Monitor (MIKHMON) for bandwidth management, supported by additional devices to extend network coverage. The network configuration, consisting of one OS Router and three access point, delivers a total bandwidth of 30 Mbps, serving up to 10 users with 2 Mbps each, covering approximately two to three households. System testing demonstrated sufficient bandwidth performance, low packet loss, minimal delay and jitter, and overall cost-efficiency, making it a viable solution for rural broadband deployment. This model is expected to enhance digital inclusion, improve quality of life, and stimulate economic growth in rural communities.**

***Keywords*—Broadband Village, Digital Divided, MIHKMON, Bandwidth, Internet**

I. Introduction

Communication technology has witnessed significant advancements in recent years. With the continuous evolution of the Internet and computer network technologies, Internet access has become an essential medium for acquiring knowledge and information [1]. As a result, the quality and reliability of Internet services must be consistently enhanced to accommodate the increasing dependence on the Internet for information retrieval [2]. This necessity has become even more pronounced in the aftermath of the COVID-19 pandemic, which has underscored the importance of broadband connectivity as a fundamental element of modern infrastructure. Reliable Internet access is now vital for participation in educational activities, engagement in remote professional work, and the maintenance of social interactions [3].

Access to technology and digital literacy are essential for modern societal participation. The digital divide significantly affects social integration and life satisfaction, as limited digital skills and access negatively impact social relationships and well-being [4]. Rural areas, in particular, face greater challenges in technology availability and adoption [5]. Despite government initiatives, broadband deployment costs in rural regions remain higher than in urban areas [6]. Developing digital economic innovations is therefore crucial to address regional disparities, promote inclusive employment, and drive sustainable growth [7]. In Indonesia, this divide, particularly between urban and rural areas, presents substantial challenges in ensuring equitable access to technology, which consequently impacts key sectors such as education, employment, and economic opportunities [4].

To address this issue, it is recommended that policies prioritize investment in and subsidies for digital infrastructure, with a particular focus on lower-income communities. Such initiatives are expected to narrow the digital divide and promote social equity between urban and rural areas, thereby facilitating more inclusive participation in the digital economy [8]. Many rural areas in Bengkulu Province still lack internet access, causing digital gaps and slow tech development [9]." According to data from the *Badan Pusat Statistik* (BPS) of South Bengkulu Regency, the population of Kota Manna District, which encompasses Pagar Dewa Village, is projected to reach approximately 32,296 people in 2024, within an area covering 1,219.91 km² [10] [11]. This underscores the need for focused digital infrastructure to ensure equitable growth and inclusion.

A Broadband Village can be categorized as a type of Internet Service Provider (ISP) that delivers internet connectivity within a defined local area. When integrated with Fiber to the Home (FTTH) infrastructure, its service coverage can be substantially expanded, as fiber optic technology enables high-speed, interference-free data transmission over distances of up to 100 kilometers [12]. To accommodate increasing user demands and evolving digital needs, the network infrastructure, reflecting a transition from traditional systems to advanced fiber-optic networks. This shift not only improves performance but also ensures long-term scalability and resilience.In its practical implementation, network management is commonly supported by RouterOS, which is integrated with Mikrotik Hotspot Monitor (MIKHMON) to facilitate bandwidth allocation, user access management, and usage monitoring. The utilization of MIKHMON enhances the flexibility, efficiency, and effectiveness of network administration through its comprehensive online management capabilities [13].

This paper aims to evaluate the role of digital infrastructure, specifically FTTH and Mikrotik Hotspot Monitor, in bridging the digital divide and improving internet access in rural areas, offering insights for enhancing digital equity in regions like Bengkulu Province.

II. Related Works

Broadband Village has been widely discussed and studied, both nationally and internationally, particularly in the telecommunications industry, as one of the efforts to address the digital divide, which can have a significant impact on the affected areas. This is in line with the research conducted by Martha Correa, who stated that the digital divide can negatively impact economic, educational, and health conditions [14].

Several initiatives have been proposed to minimize the digital divide, including community-based network models and government-supported broadband expansion projects. Research by Smith et al. Emphasized the importance of localized network infrastructure in rural areas to ensure sustainable internet access [15]. Moreover, a study by Lee and Park, demonstrated that investment in rural broadband connectivity significantly improves local economic development and enhances educational opportunities [16].

At the national level, in Indonesia, numerous studies have proposed solutions to address the digital divide. Several works have discussed the implementation of Broadband Villages, such as the study conducted by Noraga and Suharjo, who designed an FTTH-based Broadband Village system in one of the districts affected by social inequality [17]. Another study by Arifin and Rulida emphasized the importance of internet access in overcoming the digital divide and provided an analysis of the implementation of Broadband Villages in areas impacted by digital disparities [18].

Overall, the literature focuses on reducing the number of areas affected by the digital divide and supports government programs aimed at expanding network access to various regions to enhance digital inclusivity, promote socio-economic development, and ensure equitable access to information and communication technologies across rural and underserved communities.

III. System Models

This study proposes a solution to the issue of limited internet access, a key factor contributing to the digital divide, by introducing a system that is simple, cost-effective, and well-suited for implementation in rural areas. The proposed approach is grounded in the Technology Acceptance Model (TAM), which suggests that the likelihood of a system being adopted increases with its perceived ease of use and usefulness [19]. By prioritizing user-friendliness and practicality, the system is designed to address common challenges associated with technology adoption in under-resourced communities. Furthermore, the system promotes scalability and long-term sustainability, enabling it to accommodate diverse regional needs and varying infrastructure capacities. A robust and well-defined network architecture is essential for the system's implementation, as illustrated in Fig. 1 below.

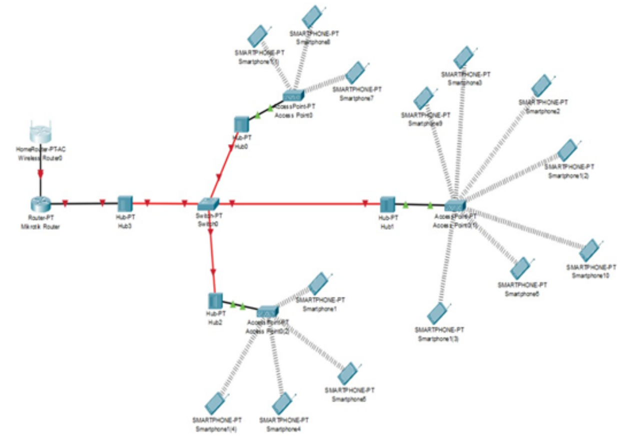

Fig. 1. Architecture design of broadband village.

The implementation of a broadband network, as illustrated in Fig. 1, requires the comprehensive integration of several physical components, including:

1. ISP Router: Used as the main source of the internet network, the ISP provides high-speed access supported by increasingly sophisticated router technology. Modern routers feature support for high-speed internet services, Voice over Internet Protocol (VoIP), and Internet Protocol Television (IPTV).
2. RouterOS: Connected to the ISP router, RouterOS manages bandwidth distribution. In addition to bandwidth management, it also offers network management features such as firewall and VPN services. With the additional MIKHMON feature, administrators can monitor the network and adjust bandwidth allocation according to usage needs.
3. Copper Cable: Connects devices over short distances using Ethernet protocols, more economical than fiber in small setups.
4. Fiber Optic Cable: Ensures fast and stable data transmission, compliant with ITU-T G.652D standards.
5. Media Converter: Converts electrical to optical signals, supporting interoperability between different network technologies.
6. Passive Splitter: Distributes the bandwidth and network speed processed by RouterOS into two or more branch cores.It efficiently distributes connections to multiple point. Passive splitters come in several split ratios with different insertion losses.
7. Access Point: Bridges users to the network, extending connectivity to various locations.

All components must be meticulously integrated, with careful consideration of the geographical characteristics and environmental conditions of the deployment area, to ensure optimal network performance, stability, and reliability. Proper alignment of hardware, software, and connectivity infrastructure is essential to minimize latency, maximize coverage, and reduce potential interference. The broadband network design proposed in this study comprehensively incorporates these critical factors, ensuring it is both technically sound and contextually appropriate for rural implementation. A detailed representation of this design is presented in Fig. 2.

Fig. 2. Actual Design of Rural Broadband Network Architecture.

As illustrated in Fig. 2, the practical design of the broadband system is largely influenced by geographical conditions, including the distance between residential units and the presence of physical obstacles within the area. These environmental factors play a crucial role in determining signal strength, coverage range, and network layout. The network infrastructure originates from the main ISP router, which is strategically placed at the village office, and is subsequently extended to three designated distribution points to ensure efficient and widespread connectivity.

A. Method

The broadband network design proposed to mitigate the digital divide in rural areas utilizes Mikrotik for its implementation, with MIKHMON employed as the bandwidth monitoring method through a hotspot system. Internet access is provided to customers via vouchers that are automatically generated by MIKHMON. Notably, MIKHMON does not require continuous active status, allowing it to be activated only as needed. Furthermore, MIKHMON offers a range of user-friendly tools and features, including options for managing customer bandwidth, assigning data quotas, and regulating user connection limits [13].

To ensure the successful implementation of this solution, a systematic design of the system architecture is essential. This design must take into account factors such as network scalability, security, and ease of maintenance, particularly given the limited technical resources often available in rural areas. Additionally, the system must be adaptable to various geographical conditions, including distance between households and physical obstacles such as trees or buildings that may affect signal propagation.

The operational workflow of the system starting from the distribution of internet from the ISP's main router located at the village office to three different distribution points has been carefully structured to optimize network coverage and service reliability. This workflow is illustrated in the following diagram.

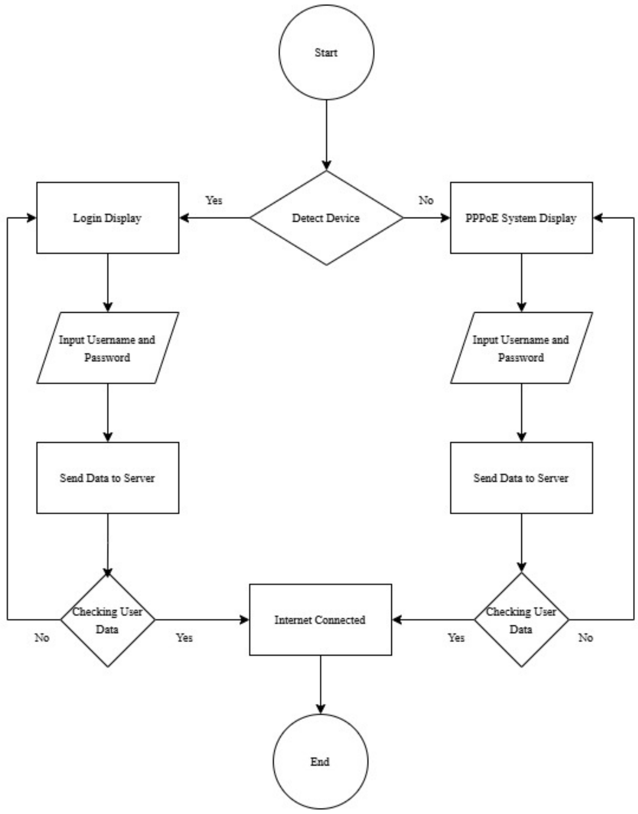

Fig. 3. System Operation Flow.

Based on Fig. 3, the system workflow in implementing the proposed solution is illustrated. The process begins when a user is detected by the system through their device attempting to access the network. Upon detection, the system automatically redirects the user to an authentication page, requiring them to input a username and password that have been pre-registered in the system. If the authentication credentials entered by the user are valid and match the data stored on the server, the system grants access, and the user is connected to the internet and can utilize the available services. Conversely, if the credentials are invalid, the user receives an error notification and is prompted to verify or re-enter the correct authentication information.

This authentication process ensures that only authorized and registered users are allowed network access, thereby maintaining the security and integrity of the system.

B. System Measurement

Accurate system measurements are essential to ensure the reliability and performance of the broadband network. This process involves calculating both the bandwidth and the Quality of Service (QoS) parameters, which are critical indicators in the design, development, and evaluation of the broadband system. The bandwidth can be calculated using the following equation:

$$\text{Bandwidth} = \text{Upstream} + \text{Downstream} \tag{1}$$

For QoS measurement, the throughput can be determined using the following formula:

$$\text{Throughput} = \frac{\text{Total Bytes} \times 8}{\text{Time Span}} \tag{2}$$

To calculate packet loss, the formula is as follows:

$$\text{Packet Loss (\%)} = \left(\frac{\text{Packets Sent} - \text{Packets Received}}{\text{Packets Sent}} \right) \times 100 \tag{3}$$

In addition to throughput and packet loss, it is essential to measure delay and jitter to assess the system's quality. Delay and jitter can be calculated using the following formulas:

$$\text{Average Delay} = \frac{\text{Total Delay}}{\text{Number of Packets Received}} \tag{4}$$

$$\text{Average Jitter} = \frac{\text{Total Jitter}}{\text{Number of Packets Received} - 1} \tag{5}$$

From the analysis of these parameters, the quality of the designed broadband network can be assessed.

C. Implementation Scenarios

The implementation scenarios for the design of the broadband village network comprehensively include:

1. Area determination: analyzing the target area for implementation, including assessments of geographical characteristics and physical obstacles that may impact network deployment.
2. Network architecture development: designing a network topology that is tailored to the specific geographical and physical conditions of the implementation area.
3. Mikrotik configuration: The configuration of RouterOS/MikroTik devices involves setting up WLAN and LAN ports, creating bridge groups for each port, assigning IP addresses to the LAN bridge, and configuring a DHCP client to obtain internet access from the ISP router. It also includes setting up DNS and DHCP servers, configuring firewall NAT rules, enabling hotspot login functionality, setting up an SNTP client for network time synchronization and issue monitoring, and integrating MIKHMON for user authentication and management.
4. MIKHMON configuration: The configuration of MIKHMON includes establishing a connection between MIKHMON and Mikrotik, utilizing the IP address from Mikrotik, setting up user packet and speed configurations, configuring the creation of hotspot vouchers, and determining the pricing for service usage.
5. Analysis of System Implementation Results: This section analyzes the outcomes of the broadband village system implementation. The analysis evaluates the system's performance based on the measured parameters, including bandwidth, throughput, packet loss, delay, and jitter. The purpose of this analysis is to assess the system's ability to meet user needs, ensure service quality, and identify potential areas for future improvement. Additionally, the findings serve as a reference for optimizing network design and usage efficiency in similar rural broadband deployment projects.
6. Cost Usage Analysis: A cost analysis is conducted to evaluate the affordability of the broadband village system, considering that the target users are residents with lower income levels. This analysis is essential to ensure that the system not only provides adequate technical performance but also remains economically accessible to the community.

IV. Performance Evaluation

In this section, the performance of the system will be evaluated under various conditions to assess its effectiveness and efficiency. The performance evaluation will focus on key metrics related to bandwidth, including both upstream and downstream speeds, as well as Quality of Service (QoS) parameters, such as throughput, packet loss, delay, and jitter. Through this analysis, the aim is to identify areas for improvement and provide insights into the system's performance. The specifications of the primary or ISP router at the village office require a minimum speed of 25 Mbps, or approximately 30 Mbps. The results of the speed test are presented in Fig. 4 below.

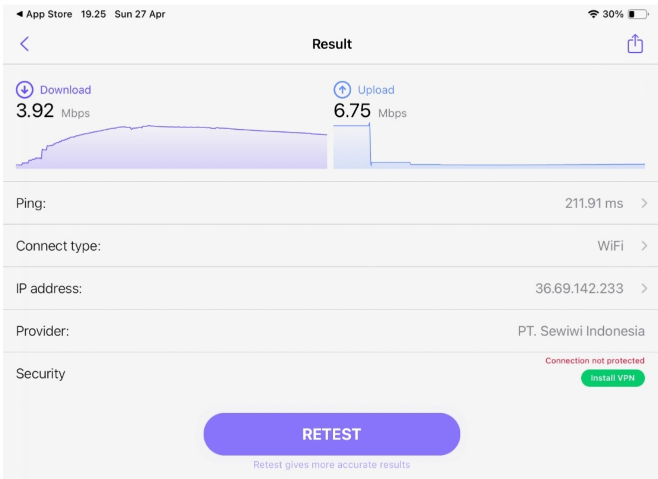

Fig. 4. Speedtest results of the ISP router.

As shown in Fig. 4, the ISP router at the village office has upstream and downstream speeds of 6.75 Mbps and 3.92 Mbps, respectively. This results in a total bandwidth of approximately 10 Mbps, which is calculated by summing the upstream and downstream speeds. After understanding the specifications of the ISP router, an evaluation of the implemented broadband village system design will be conducted.

A. Bandwidth Parameter

In the design of the broadband village system, bandwidth allocation is managed through the MIKHMON application. The allocated bandwidth is then distributed to each access point. The bandwidth configuration within MIKHMON is shown in Fig. 5.

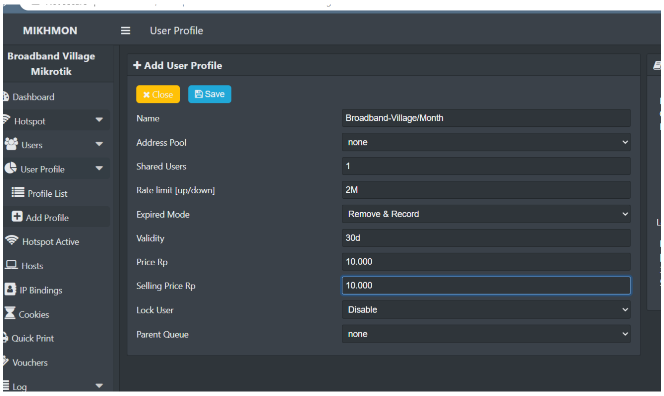

Fig. 5. Bandwidth configuration on MIKHMON.

As illustrated in Fig. 5, the bandwidth allocated for distribution to each access point is set at 2 Mbps. The bandwidth allocation can be adjusted according to specific usage requirements. After the implementation of the broadband village, the bandwidth parameter values obtained align with the settings defined in MIKHMON. The values measured at the access point are illustrated in Fig. 6.

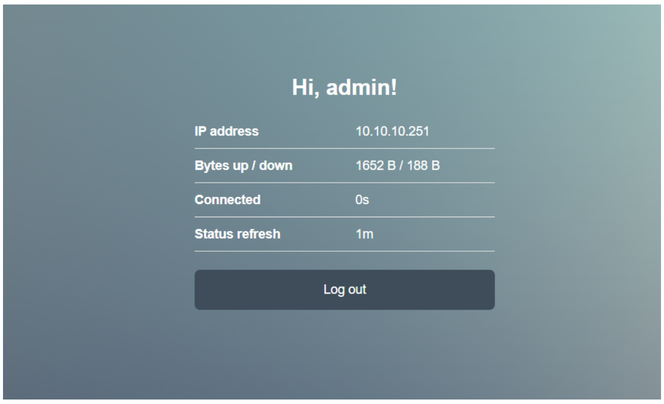

Fig. 6. Bandwidth results obtained from the broadband village.

In the illustration shown in Fig. 6, the obtained values for upstream and downstream are 1652 Bps and 188 Bps, respectively, indicating that the resulting bandwidth is approximately 0.015 Mbps. The bandwidth obtained will not exceed 2 Mbps. This bandwidth allocation is deemed sufficient to support activities such as internet browsing and live streaming in a household with approximately five family members.

B. QoS Parameter

The calculation results of the QoS parameters in this test were performed using the Wireshark application as the measurement tool, as shown in Fig. 7 below.

Statistics

Measurement	Captured	Displayed	Marked
Packets	6062	1267 (20.9%)	—
Time span, s	24.246	24.060	—
Average pps	250.0	52.7	—
Average packet size, B	727	102	—
Bytes	4404601	129135 (2.9%)	0
Average bytes/s	181 k	5367	—
Average bits/s	1453 k	42 k	—

Fig. 7. Throughput results obtained from the broadband village.

As illustrated in Fig. 7, the data obtained from the Wireshark application presents the calculation for one of the QoS parameters, namely throughput, in the broadband village system. The measured throughput during testing was 42 Kbps. This value may fluctuate depending on user activity at the time of measurement; however, it remains within the allocated bandwidth limit of 2 Mbps. The packet loss results recorded during testing are shown in Fig. 8.

Statistics

Measurement	Captured	Displayed	Marked
Packets	6062	2 (0.0%)	—
Time span, s	24.246	2.410	—
Average pps	250.0	0.8	—
Average packet size, B	727	60	—
Bytes	4404601	120 (0.0%)	0
Average bytes/s	181 k	49	—
Average bits/s	1453 k	398	—

Fig. 8. Packet loss results obtained from the broadband village.

As depicted in Fig. 8, a total of 2 lost packets were recorded, indicating a very low packet loss rate. The packet loss observed may also vary depending on the user's network activity during the measurement. After obtaining the results for throughput and packet loss, the evaluation continues with the measurement of delay and jitter in the designed broadband village system. The results obtained through Wireshark are presented in Fig. 9.

23.401871	23.408409	0.006538		0.006537	-1.9E-05	-0.00656
23.408409	23.40841	1E-06		-1.9E-05	1.4E-05	3.3E-05
23.40841	23.40843	2E-05		1.4E-05	6E-06	-8E-06
23.40843	23.408436	6E-06		6E-06	-9E-06	-1.5E-05
23.408436	23.408436	0		-9E-06	-4E-06	5E-06
23.408436	23.408445	9E-06		-4E-06	-0.186398	-0.18639
23.408445	23.408458	1.3E-05		-0.186398	0.155354	0.341752
23.408458	23.594869	0.186411		0.155354	-0.017486	-0.17284
23.594869	23.625926	0.031057		-0.017486	-0.328452	-0.31097
23.625926	23.674469	0.048543		-0.328452	0.368576	0.697028
23.674469	24.051464	0.376995		0.368576	0.008419	-0.36016
24.051464	24.059883	0.008419		0.008419	-24.059883	-24.0683
24.059883	24.059883	0				
	Delay Summary	24.059883	Jitter Summary			-24.0535
	Delay Average	0.003969623	Jitter Average			-0.00397

Fig. 9. Delay and jitter results obtained from the broadband village.

As illustrated in Fig. 9, an average delay of 3.96 ms and an average jitter of 3.97 ms were recorded. The delay value of 3.96 ms indicates excellent network performance, reflecting minimal transmission latency. Furthermore, the jitter value of 3.97 ms, which remains below the 5 ms threshold, demonstrates stable transmission quality, ensuring that the connection is suitable for real-time applications such as video streaming and voice communication.

C. Cost Efficiency

Cost efficiency is a critical factor in the design and implementation of broadband systems, especially when the target population consists of individuals with lower income levels. A detailed analysis of the costs associated with the system, including installation, maintenance, and operational expenses, must be conducted. The goal is to ensure that the system provides an optimal balance between performance and cost, making it accessible and sustainable for the intended users.

In the design of the broadband system, the components and devices used are significantly more affordable compared to the costs of installing other network infrastructures. This is a key advantage of the system, as it does not require extensive repairs; only monitoring the expiration of vouchers used within MIHMON is necessary. Additionally, the cost of network services can be adjusted according to the socio-economic conditions of the community, further enhancing its accessibility.

V. Conclusion

The design and implementation of the rural broadband model in Pagar Dewa Village successfully addressed the digital divide challenges by providing stable and affordable internet access. Through the integration of RouterOS and MIKHMON, the system achieved efficient bandwidth management, ensuring service reliability even with limited resources. Performance evaluations showed satisfactory results in terms of bandwidth allocation, throughput, packet loss, delay, and jitter, supporting common household internet activities. Moreover, the cost analysis demonstrated that the system is economically viable for low-income communities, ensuring sustainability. Future improvements may focus on scaling the network for larger populations and integrating renewable energy sources to enhance system resilience and sustainability.

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