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Utilization of Fiber Optic Network in Support of Voip Infrastructure: Case Study of Implementation at State Polytechnic of Malang

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ABSTRACT

In the modern era, the need for fast and high-performance communication is crucial to support the advancement of information technology. Voice Over Internet Protocol (VoIP) enables voice transmission over IP networks, offering cost savings compared to conventional telephony. The State Polytechnic of Malang (Polinema) transitioned from a conventional Private Automatic Branch Exchange (PABX) system, which is now difficult to maintain, to a custom Internet Protocol Private Branch Exchange (IP PBX) system that is more flexible and integrated with existing data networks. The use of Ethernet Passive Optical Network (EPON) in VoIP infrastructure offers benefits such as high capacity, quality VoIP data transmission, energy efficiency, and reduced operational costs. This combination of optical fiber (EPON) and VoIP allows Polinema to create a more efficient and reliable communication solution, enhancing accessibility and the quality of the learning experience. This research is also expected to inspire other educational institutions to adopt similar innovations.

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1. INTRODUCTION

The State Polytechnic of Malang (POLINEMA) previously relied on the conventional PABX system for its telecommunication infrastructure. The PABX TD500 system used has a capacity of 312 ports, with 144 ports used. The Civil Building uses TDE200 with a capacity of 96 ports and 48 used ports, Graha Polinema uses TDE100 with a capacity of 64 ports and 15 used ports, with a total of 207 ports used. However, this system is no longer in production and according to the data, many slots have already begun to break down, where one port can connect 16 phones. This poses problems in its maintenance and use. In addition, dependence on device manufacturers leads to difficulties in obtaining spare parts and technical support.

To address this issue, an initiative to switch to a fully custom IP PBX system emerged. IP PBX systems provide greater flexibility and allow integration with existing data networks. With a custom IP PBX, Polinema can customize the communication system according to specific needs without depending on a single manufacturer. In addition, the installation of an internet gateway allows communication systems to utilize existing internet networks, eliminating the need for physical cables connecting the back buildings to the head office.

To date, Polinema has installed a total of 30 IP Phones. In addition, there are 22 analog phones using 2-Port Analog VoIP Gateways, 143 analog phones using 24-Port Analog VoIP Gateways, and 5 analog phones using 16-Port Analog VoIP Gateways. Installation of analog phones using ONT is also underway, with a total of 12 phones planned. The AH, AI, and AL buildings are already using full IP PBX, with the Telecommunications study program already using IP PBX.

EPON, also called Ethernet PON, is sometimes known as Gigabit EPON (GEPON) or Ethernet in the First Mile Fiber (EFMF). This technology is based on the IEEE 802.3ah standard. EPON operates on the principle that Ethernet cables can connect users over a distance of up to 20 km from the source. By integrating the economical PON structure with the affordable Ethernet technology, EPON minimizes the need for equipment and reduces the amount of fiber required at the Central Office (CO) [1].

The use of Ethernet Passive Optical Network (EPON) in VoIP infrastructure provides many significant advantages. Ethernet passive optical networks (EPON) are considered the best solution for access networks because of their simplicity, high data rates, and low cost compared to other technologies [1].

The results of this research will be analyzed using quality of service (QoS) parameters that include jitter, delay, and packet loss. Using Wireshark software, you can measure throughput, delay, jitter, and packet loss parameters at a sampled access point in each building [2].

By combining the advantages of fiber optics (EPON) and VoIP technology, Polinema can create more efficient and reliable communication solutions. It is hoped that the adoption of this technology will improve communication accessibility and provide a better learning experience.

2. LITERATURE REVIEW (11 PT)

2.1 *Ethernet Pasif Optical Network*

Ethernet-based PON, known as Ethernet PON (EPON) or Gigabit EPON (GEPON), leverages the 802.3 specification, including full-duplex 802.3 media access control (MAC) [3][4]. The use of Ethernet Passive Optical Network (EPON) also has the advantage of ease of installation and the cost of providing infrastructure that is much more affordable [5]. The working principle of EPON allows the use of Ethernet cables to reach the end user up to a maximum distance of 20 km from the source.

2.2 *Optical Line Terminal*

The OLT (Optical Line Terminal) is a hardware device on the network provider's side in a PON (Passive Optical Network). It controls and manages the PON network and connects it to other networks, such as the Internet [6]. The OLT is a key element in an ODN-based optical access network, providing services to customers via the ODN (downlink) and interfacing with service nodes (uplink). It manages and maintains the ODN, ONU, and ONT, and is responsible for transmitting voice, data, and video services from providers to customers [3].

2.3 *Optical Network Terminal*

The ONT (Optical Network Terminal) connects a fiber optic network to a household or business. Located on the customer's side, it converts optical signals from PON networks into electrical signals for devices like computers, routers, and televisions [6]. The ONT (Optical Network Termination) is an active XGSPON device that interfaces with the customer side and serves as the endpoint of the Optical Distribution Network (ODN) at the customer's location [3].

2.4 *Voice over Internet Protocol*

VoIP is a rapidly growing internet application with two main advantages over traditional telephone networks: improved bandwidth efficiency through voice compression and easier development of integrated services, combining voice with media and data applications like video, whiteboards, and file sharing [7].

3. METHODS

This research explores the implementation of Fiber Optic Network (EPON) to enhance Voice over Internet Protocol (VoIP) infrastructure at Malang State Polytechnic. A quantitative approach is used, following a structured testing framework. The process begins by selecting campus locations that represent different network conditions for EPON installation and VoIP integration. Initial data on EPON configuration is collected, followed by the integration of VoIP with the existing network. Tests are conducted to measure download and upload speeds using specialized tools, and Quality of Service (QoS) is evaluated. The analysis focuses on assessing network performance and determining the effectiveness of EPON in supporting VoIP within an academic setting, aiming to improve the efficiency and effectiveness of VoIP services at State Polytechnic of Malang.

The stages of this research include several important steps to optimize VoIP infrastructure at the Malang State Polytechnic by utilizing fiber optic networks (EPON). First, problem identification is carried out to determine the focus of the research. Then, a literature research was carried out to understand the basic theories and concepts related to EPON and VoIP. Furthermore, field studies are conducted to understand the condition of the existing VoIP infrastructure and identify the problems faced. Based on these results, the researcher designed a solution that includes the type, topology, and configuration of the fiber optic network to be used. After the design, the solution was implemented and followed by an evaluation of the performance of the new VoIP infrastructure, to ensure that the solution provided optimal benefits for the Malang State Polytechnic.

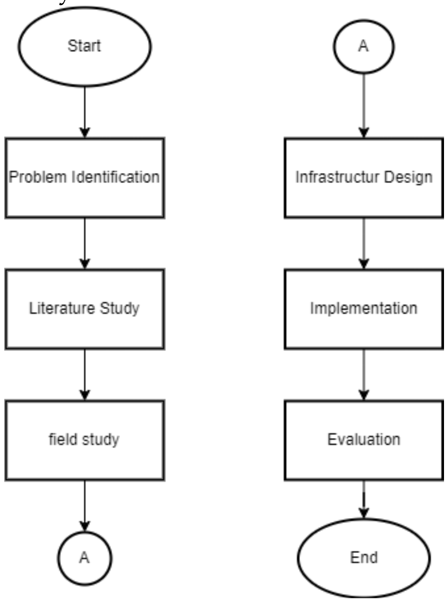

Figure 1. Research Diagram

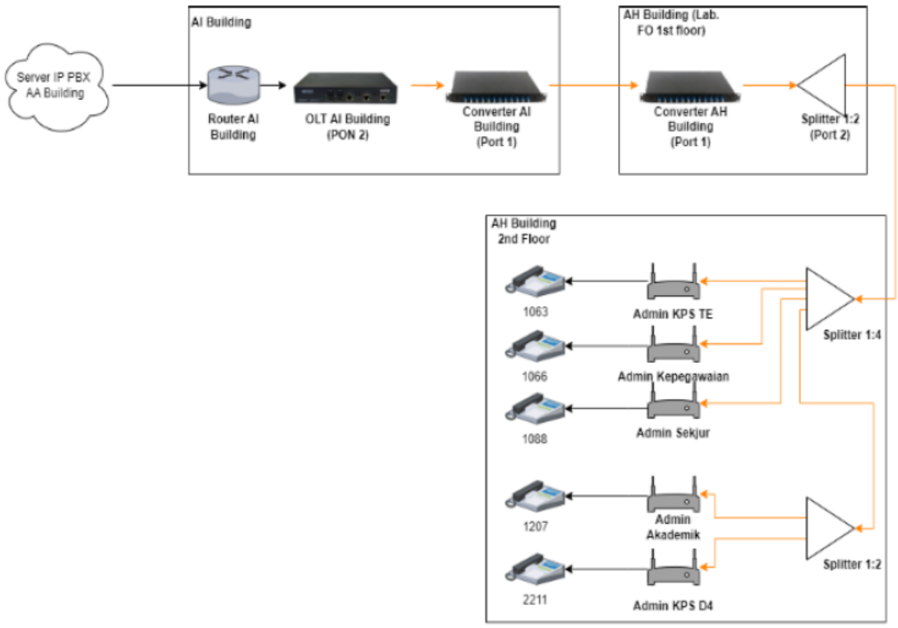

Figure 2. System Diagram

In the network implementation in Building AH, the switch will connect to the existing VoIP server in Building AA. This switch will connect to several devices, namely 4 IP Phones and 2 Linksys which are each connected to 2 analog phones. In the AH Building, 10 analog phones will also be implemented, the first 5 analog phones will be connected to a 1:8 splitter and will be connected to a 1:2 splitter in the Fiber Optic Laboratory which will later be connected to the Optical Line Terminal (OLT) in the AI Building. Likewise with the other 5 analog phones, 3 analog phones will be connected to a 1:4 splitter and 2 analog phones will be connected to a 1:2 splitter. This is done to minimize power loss. Of these 5 analog phones, it will also be connected to a 1:2 splitter at the Fiber Optic Laboratory and connected to the Optical Line Terminal (OLT) in the AI Building.

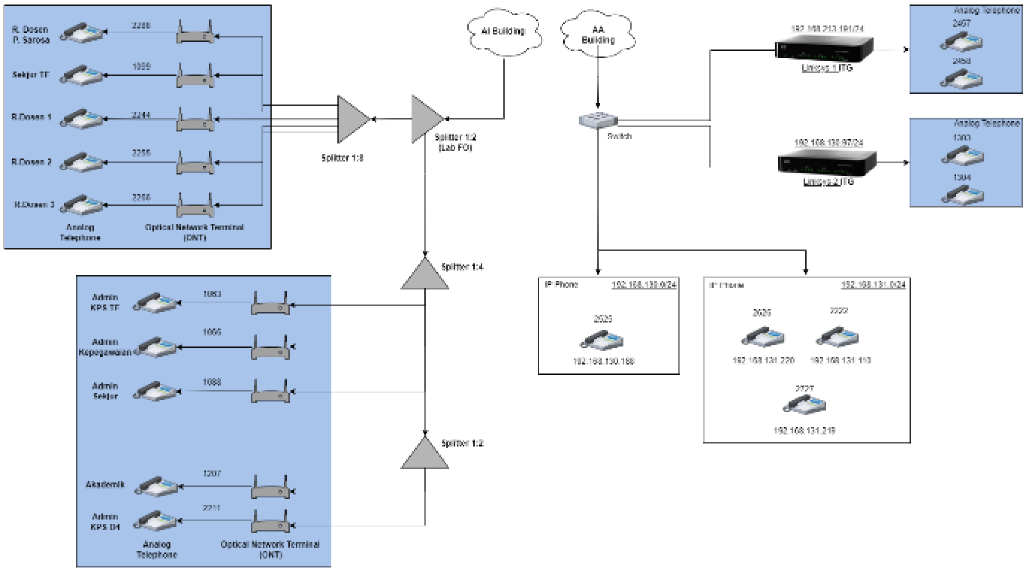

Figure 3. Infrastructure Design

In the network implementation in Building AH, the switch will connect to the existing VoIP server in Building AA. This switch will connect to several devices, namely 4 IP Phones and 2 Linksys which are each connected to 2 analog phones. In the AH Building, 10 analog phones will also be implemented, the first 5 analog phones will be connected to a 1:8 splitter and will be connected to a 1:2 splitter in the Fiber Optic Laboratory which will later be connected to the Optical Line Terminal (OLT) in the AI Building. Likewise with the other 5 analog phones, 3 analog phones will be connected to a 1:4 splitter and 2 analog phones will be connected to a 1:2 splitter. This is done to minimize power loss. Of these 5 analog phones, it will also be connected to a 1:2 splitter at the Fiber Optic Laboratory and connected to the Optical Line Terminal (OLT) in the AI Building.

4. RESULTS AND DISCUSSION

4.1 Network Speed Testing

Network speed testing is one of the important steps to ensure the performance and quality of network services and the test will compare each ONT. In this research, the research used the OpenSpeedTest tool to measure several key parameters of network speed. Download speed and upload speed are two important aspects measured by OpenSpeedTest. Download speed measures how quickly data can be downloaded from the internet to the user's device, while upload speed measures how quickly data can be sent from the user's device to the server. In this test, OpenSpeedTest will evaluate the time it takes to download and upload a specific amount of data, providing a clear picture of the user's internet connection performance.

Network speed measurements were carried out under two different conditions. Each condition is tested based on two time parameters, namely testing during the day and in the morning.

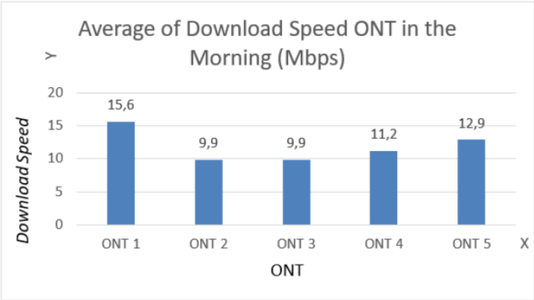

Figure 4. Result of Download Speed

From the data obtained, it can be seen that there is a variation in the average download speed of the five ONTs (Optical Network Terminals) tested. ONT 1 recorded the highest speed with an average of 15.6 Mbps, indicating the most superior performance among all devices. Meanwhile, ONT 2 and ONT 3 showed the lowest performance with an average speed of 9.9 Mbps, which may indicate a problem with their devices or network connections. ONT 4 and ONT 5 have average speeds of 11.2 Mbps and 12.9 Mbps, respectively, which puts them in the middle in terms of performance.

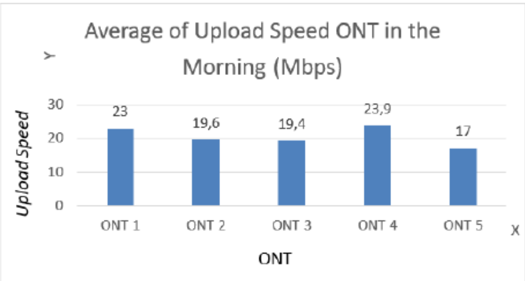

Figure 5. Result of Upload Speed

From the upload speed data presented, it can be seen that there is variation among the five ONTs tested. ONT 4 has the highest upload speed with an average of 23.9 Mbps, followed by ONT 1 with 23 Mbps, demonstrating superior performance in terms of upload speed. ONT 2 and ONT 3 have almost the same average speed, 19.6 Mbps and 19.4 Mbps, respectively. ONT 5 has the lowest upload speed, which is 17 Mbps.

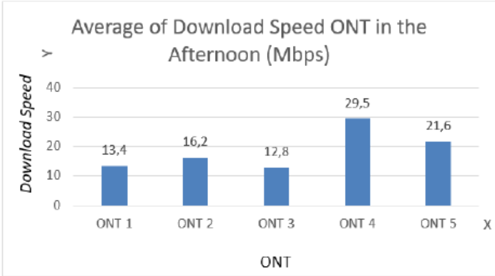

Figure 6. Result of Download Speed (Afternoon)

Based on data obtained from five ONTs (Optical Network Terminals), the average download speed recorded ranged from 12.8 Mbps to 29.5 Mbps. ONT 4 showed the best performance with the highest download speed of 29.5 Mbps, almost double compared to ONT 3 which had the lowest speed of 12.8 Mbps. ONT 5 and ONT 2 also showed good performance with their respective speeds of 21.7 Mbps and 16.2 Mbps. Meanwhile, ONT 1 and ONT 3 have lower download speeds, namely 13.4 Mbps and 12.8 Mbps, showing less than optimal performance compared to other ONTs.

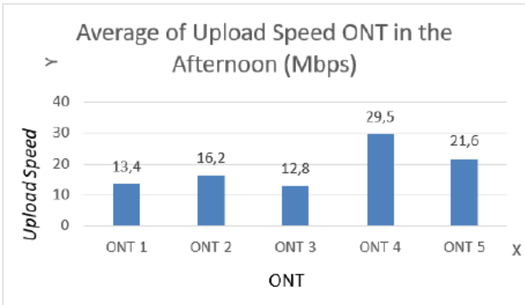

Figure 7. Result of Upload Speed (Afternoon)

Based on the data provided, the average upload speed from the measured ONT (Optical Network Terminal) is around 19.72 Mbps. ONT 4 shows the highest upload speed with 24.6 Mbps, while ONT 2 has the lowest with 15.5 Mbps.

4.2 Quality of Service Testing

Discussing the results of Quality of Service (QoS) tests carried out in active conditions of making phone calls using VoIP networks implemented on fiber optic infrastructure at the Malang State Polytechnic. This test aims to evaluate the network's performance in supporting VoIP services, especially in terms of delay, jitter, and packet loss. In this test, a softphone application is used to make calls between various points in the network. In addition, network analysis software is also used to capture and analyze data packets sent and received during calls. Allows for the collection of more detailed data regarding the movement of packets within the network, aiding in identifying the source of the problem and evaluating network performance more deeply.

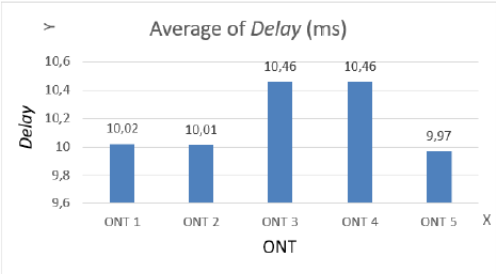

Figure 8. Average of Delay

Based on data obtained from five ONTs (Optical Network Terminals), the analysis shows that the average delay recorded ranges from 9.97 ms to 10.46 ms. ONT 1 has an average delay of 10.02 ms, ONT 2 is 10.01 ms, ONT 3 and ONT 4 are 10.46 ms each, and ONT 5 shows the lowest delay of 9.97 ms. The highest difference between ONT and the highest average delay (ONT 3 and ONT 4): 10.46 ms) and the lowest (ONT 5: 9.97 ms) was 0.49 ms, indicating that the delay between ONTs was fairly stable without significant variation. ONT 5 has the most optimal performance with the lowest delay, while ONT 1 and ONT 2 also show good performance with delays close to optimal average. Consistency is also seen in ONT 3 and ONT 4 which have the same average delay. According to the Tiphon (Telecommunications and Internet Protocol Harmonization Over Networks) standard, which recommends an end-to-end delay of no more than 125 ms for good quality conversations, all tested ONTs are still well below this threshold.

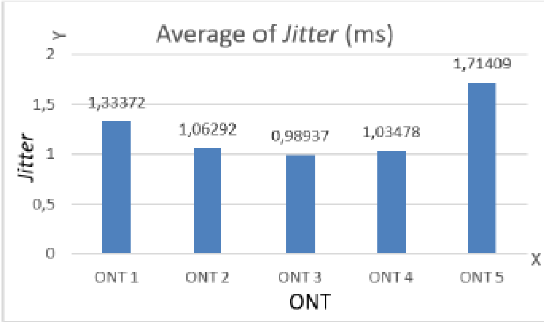

Figure 9. Average of Jitter

Based on data obtained from five ONTs (Optical Network Terminals), the analysis shows that the average jitter recorded ranges from 0.98937 ms to 1.71409 ms. ONT 3 has the lowest average jitter of 0.98937 ms, indicating the best performance, while ONT 5 has the highest jitter of 1.71409 ms, which indicates less than optimal performance compared to other ONTs. ONT 2 and ONT 4 show fairly close jitter values, 1.06292 ms and 1.03478 ms, respectively, indicating consistency in their network performance. Meanwhile, ONT 1 has a slightly higher average jitter, which is 1.33372 ms. According to the Tiphon standard, the ideal jitter for applications such as VoIP should be less than 75 ms to ensure good sound quality. In this context, indicating that the network was performing well in terms of jitter.

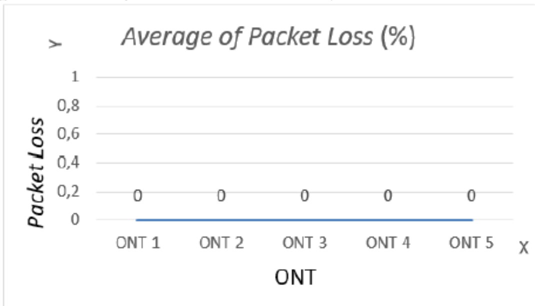

Figure 10. Average of Packet Loss

Based on data from five ONTs (Optical Network Terminals), the average packet loss recorded is 0% across all units, indicating that no packet loss occurred during data transmission. This suggests the network is highly reliable and capable of maintaining data integrity. Packet loss is a crucial metric in network quality assessment, especially for VoIP applications, where the Tiphon standard recommends minimal packet loss for optimal sound quality. The 0% packet loss observed across all ONTs demonstrates that the network is functioning at an optimal level, ensuring high-quality service for users.

4.3 Link Loss Budget Testing

The results of the link loss budget calculation for ONT presented show significant variations in the signal power received by each device. ONT 4 and ONT 5 have the highest link loss budget values. Meanwhile, ONT 1 showed the lowest results and ONT 2 and ONT 3 recorded balanced results

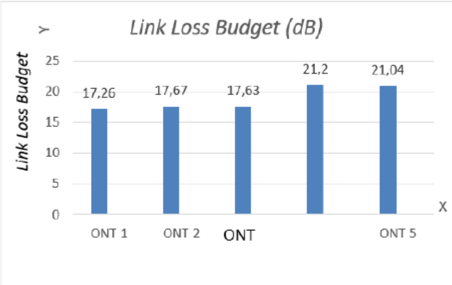

Figure 11. Link Loss Budget

5. CONCLUSION

Based on the results and discussion of research on the use of fiber optic networks in supporting VoIP infrastructure at the Malang State Polytechnic, it can be concluded that the design of the VoIP infrastructure implemented is in accordance with the communication needs of the institution, with the implementation of the EPON network and TA2400 devices that ensure stable voice quality and connection. Proper configuration of ONTs proved to be critical for optimal performance, with all ONTs demonstrating quality of service in accordance with Tiphon standards, especially when it comes to delay, jitter, and packet loss. While there was variation in upload speeds between ONTs, overall network performance remained in the good category. However, there are obstacles in speed testing under certain conditions, possibly due to differences in Wi-Fi networks and the configuration of the Open Speed Test that is not optimal. In addition, the results of the link loss budget calculation show significant variation in the signal power received, with some ONTs indicating sufficient excess power, while others require adjustments to ensure optimal signal quality.

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