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Evaluation of Fresnel Zone in Ubiquiti Wireless Simulation and Implementation Using 802.11ac

Ahmad Tantoni[1], Mohammad Taufan Asri Zaen[2*)]
[1]Program Studi Teknik Informatika, STMIK Lombok
[2]Program Studi Sistem Informasi, STMIK Lombok
Email: [1]ahmadtantoni@gmail.com, [2]opanzain@gmail.com

Abstract – The development of wireless communication technology is increasing along with the need for high-speed internet access, both in urban and rural areas. Point-to-Point (PtP) technology based on the IEEE 802.11ac standard is one of the main solutions for providing long-distance connectivity, particularly in backhaul networks, ISPs, and inter-building communication. However, the network implementation process often relies on link simulations using software such as ISP Design Center or AirLink, which do not always accurately represent field conditions. Wave propagation factors, terrain contours, and obstacles in the Fresnel Zone significantly affect signal quality. The Fresnel Zone is a three-dimensional propagation area that must be at least 60% free of obstacles for optimal transmission. Previous research has shown limitations in studies related to evaluating the accuracy of Fresnel Zone simulations on Ubiquiti 802.11ac devices. Therefore, this research evaluates and compares the parameters of RX Signal Strength, throughput, channel width, and Fresnel Zone clearance between simulation results and direct field testing on a PtP connection. The research results are expected to serve as a technical reference for network practitioners in validating simulation results and providing recommendations for more accurate and efficient PtP connection design. This research also emphasizes the importance of Line of Sight (LOS) and Fresnel Zone optimization in maintaining the stability of outdoor wireless networks based on IEEE 802.11ac

Keywords – Wireless, Fresnel Zone, Line of Sight; 802.11ac, Ubiquiti

I. INTRODUCTION

The development of wireless communication technology continues to experience significant improvements, especially in meeting the need for high-speed internet access in both urban and rural areas. (Source: detikInet.com) [1] The number of internet users in Indonesia in 2024 reached 221,563,479 people out of a total population of 278,696,200 Indonesian residents in 2023, meaning the internet penetration rate in Indonesia reached 79.5%, an increase of 1.4% compared to the previous period. One of the technologies widely used to build long-distance connectivity is the Point-to-Point (PtP) system based on the IEEE 802.11ac standard. One example uses Ubiquiti devices that support implementation with the IEEE 802.11ac standard. Using this technology supports high throughput, channel efficiency, and transmission stability, making it widely applied in backhaul networks, internet service providers, RT/RW-Net (community-based internet networks), and communication systems between buildings.

In the process of implementing a wireless network, performing a link simulation using software such as ISP Design Center is often used as a primary reference to determine the height of the tower to be built, how to calculate the link budget, and to estimate the signal quality on the transmission path from the signal transmitter (main1) to the signal receiver (station1). However, the simulation results are often not entirely consistent with the field implementation. This is influenced by many factors such as wave propagation, terrain contours, types of obstacles, and clearance in the Fresnel Zone, which should ideally be completely free of obstructions when wireless technology is used. (Explanation of wireless according to Tanenbaum) [2] Wireless is a computer network communication technology that uses electromagnetic waves as the transmission medium without using cables. This technology allows devices to connect to each other from short to long distances, with high flexibility and mobility of devices/hardware. Therefore, wireless has become one of the main foundations in the development of modern computer networks. According to Cisco, in the world of wireless [3] 802.11ac technology can transmit at a maximum speed of 1300 Mbps, almost three times faster than 802.11n. The 5 GHz spectrum used in 802.11ac achieves higher speeds for data throughput and provides more bandwidth for additional clients, wireless devices, and Internet of Things (IoT) devices to get online. Using beamforming, 802.11ac also results in less interference during transmission.

The Fresnel Zone is a very important factor in LOS (Line of Sight) communication, because interference can lead to increased noise, decreased RX signal strength resulting in loss of throughput and high latency. Previous research shows that at least 60% of the Fresnel Zone area must be free of obstacles to achieve optimal connection. According to Rappaport [4], The Fresnel Zone is an imaginary elliptical region between the transmitting antenna (main1) and the receiving antenna (station1) that forms the main path of radio wave propagation. This zone is not just a straight line called the Line of Sight (LOS), but also a three-dimensional space that must be kept at least 60% free of obstructions. When the Fresnel Zone is obstructed or blocked by trees or buildings, a decrease in signal strength will occur at the receiving (client) antenna.
According to Kumar and Sharma [5], Obstacles in the Fresnel Zone are the main cause of signal quality degradation in wireless communication conducted outdoors. According to Mutmainnah and Hidayat [6] the existence of a clear Line of Sight (LOS) from the

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transmitting antenna to the receiving antenna is the main requirement that must be met in the design of outdoor wireless networks so that signal quality can be maintained optimally. Radio communication systems require a completely unobstructed Line of Sight (LOS) condition. In Line of Sight (LOS) propagation, there is an area that must be free from obstacles; this area is called the Fresnel zone [7]. Research evaluating the accuracy of Fresnel Zone simulations against real-world implementations using Ubiquiti 802.11ac devices is still limited and not widely conducted. There are two types of building-to-building connections. The first type is called point-to-point (PtP), and the second is point-to-multipoint (PtMP). A point-to-point connection is a wireless connection between only two buildings and generally uses semi-directional or highly-directional antennas at each end of the connection [8]. In implementing point-to-point outdoor wireless communication, the objective is to determine how much bandwidth will be transmitted between the signal transmitter and the signal receiver, according to Forouzan [9] Bandwidth is the range of frequencies available for transmitting a signal. In digital communication, bandwidth refers to the amount of data (bits) that can be transmitted per second through a transmission medium, measured in bps (bits per second), Kbps, Mbps, and Gbps. In implementing wireless networks, there are obstacles that hinder signal transmission, known as noise floor. Sklar [10] explains that the noise floor determines the quality of the receiver sensitivity. For successful and effective communication, the received signal must be above the noise floor with an adequate SNR (Signal-to-Noise Ratio) margin. (Source: citraweb.com website) [11] the channel width parameter is directly proportional to data throughput, meaning that the wider the channel width, the greater the throughput that can be transmitted. Channel width is likened to a road, while the data passing through is likened to vehicles; meaning the wider the road, the more vehicles can pass through. (Quoted from Stallings) [12], In outdoor wireless communication, TX (Transmit) is the process of sending data from the source device to the destination device, while RX (Receive) is the process of receiving the signal sent by the transmitter.

Previous research has generally focused on link budget calculations, throughput analysis, or general PtP network design, but there has been no specific research on the gap between AirLink simulation results and field realization based on Fresnel Zone parameters. Therefore, a measurable evaluation is needed to determine the accuracy of AirLink simulations compared to real-world implementation in the field, particularly for the Ubiquiti 802.11ac technology currently used in outdoor wireless implementation scenarios.

This research evaluates the Fresnel Zone in simulations and implementations of Ubiquiti wireless networks using the 802.11ac standard by comparing parameters such as RX Signal Strength, throughput, channel width, and Fresnel Zone clearance values between simulation results and direct field testing. The results of this research are expected to serve as a valid technical reference for network practitioners and provide recommendations for more accurate and efficient point-to-point connection designs in the future.

Research conducted by Han [13] focuses on the Application of the Fresnel Zone Model in the Wireless Sensing Field. Previous research has explored the application of the Fresnel Zone in indoor wireless sensing, gesture recognition, and CSI-based monitoring. However, there is no research that evaluates the accuracy of the Fresnel Zone in simulations and field implementations using Ubiquiti 802.11ac devices in an outdoor Point-to-Point (PtP) network scenario. Therefore, this research focuses on analyzing the differences in technical parameters (RX Signal, throughput, Fresnel clearance, channel width, and noise floor) between AirLink simulation results and real-world implementation, with the aim of producing a more precise and applicable evaluation model and recommendations for wireless link design, thereby bridging the existing gap.

Research conducted by Nnadi, Jacob and Ezeh [14] on Link Budget Analysis for Line of Sight Wireless Communication Link with Knife Edge Diffraction Obstruction aimed to perform a link budget analysis on a Line of Sight (LOS) wireless communication system with a knife-edge diffraction obstruction, and to determine the effect of the Fresnel Zone clearance percentage on diffraction loss, fade margin, link outage, and the feasibility of the communication link based on mathematical calculations. The conclusion of the previous research was that knife-edge diffraction obstruction was proven to increase diffraction loss and directly reduce the maximum distance achievable by the wireless communication system with acceptable quality of service (QoS). The resulting diffraction loss causes a decrease in received power and a reduction in fade margin, thus limiting the maximum communication distance. The larger the obstruction value (Pc%), the lower the maximum distance that can be achieved with acceptable quality of service. Therefore, Fresnel Zone clearance and link budget analysis are crucial in the design of LOS-based wireless networks. The difference between this research and previous studies is that previous research only conducted theoretical link budget analysis considering knife-edge diffraction and percentage changes in LOS clearance in microwave networks, so the analysis results were more mathematical and simulation-based. In contrast, this research will have a more applied approach by conducting a direct evaluation between AirLink simulations and actual field implementation using Ubiquiti 802.11ac devices. The research focuses on comparing RX Signal Strength, throughput, channel width, and Fresnel Zone clearance levels, thus providing validation of simulation performance and technical recommendations for more accurate PtP connection design under actual field conditions.

Research conducted by Hidayat et al [15] on the Analysis of Power Link Budget in Outdoor Wireless Networks Using Internet Service Provider Design Center: A Case Study of Kutanagara Village, Garut, aimed to design an outdoor WiFi network at a frequency of 5725 MHz using the Ubiquiti ISP Design Center application as a representation of internet network implementation in Kutanagara Village. It also analyzed the main network parameters to comply with KOMINFO regulations and TIPHON quality standards. The conclusion of this research is that the calculations and simulations of the Power Link

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Budget parameters met the KOMINFO and TIPHON standards, making the outdoor WiFi network design deemed feasible for implementation in Kutanagara Village. Previous research only focused on calculating and simulating the Power Link Budget using the ISP Design Center application to obtain basic parameters such as EIRP, FSL, FZC, and signal strength as a reference for network design, while this research added an accuracy evaluation stage by comparing the simulation results and direct field implementation based on Fresnel Zone, RX Signal Strength, channel width, and throughput parameters on Ubiquiti 802.11ac devices, resulting in a more comprehensive and applicable gap analysis of real-world conditions.

Research conducted by Ramadhan [16] on the Fresnel Zone Analysis and Link Budget of the WLAN Network from PT. Solo Jala Buana to BTS Karanganyar Using UBNT AIRLINK. The purpose of this research is to analyze Line of Sight (LoS) and Fresnel Zone in the design of a PtP wireless network. It also aims to determine the optimal antenna height and signal performance. The conclusion of this research is that the Radio Mobile simulator shows that with antenna heights of 20 meters (PT. Solo Jala Buana) and 40 meters (Karanganyar BTS), the transmission path has LoS and a Fresnel Zone free from obstacles, resulting in good signal and connection. The difference between this research and previous studies is that this research utilizes the UBNT AirLink and Radio Mobile simulators solely as design tools to determine the feasibility of the Link Budget and antenna height in a Point-to-Point network. This research, however, focuses on evaluating the accuracy of these simulations against real-world implementation conditions. This study specifically tests the validity of the simulation results by comparing parameters such as Throughput, Noise Floor, and RX Signal against the IEEE 802.11ac standard, in order to address the data discrepancies that often occur between the digital planning stage and physical implementation.

The research conducted by Anisa et al [17] on the Analysis of the Implementation of IEEE 802.11ac on the Wireless Backhaul Network of Zettalink Provider, aimed to design a Broadband Wireless Backhaul network based on IEEE 802.11ac, calculate the Power Link Budget for the designed network, including calculating Free Space Loss (FSL) and Received Signal Level (RSL), and analyze the designed network by comparing the theoretical calculation results (Power Link Budget) with actual measurement results using UISP software. The conclusion of this research is that the design, calculation, and analysis of the IEEE 802.11ac wireless backhaul network implementation in rural areas were successful. The theoretical calculation results (FSL = 121.68 dB, RSL = -49.68 dBm) closely matched the actual measurement results (RSL = -49 dBm). The implemented network showed good performance (throughput 480-655.20 Mbps) and was able to meet local internet needs. The difference in this research lies in the validation of the network design by comparing the manual Power Link Budget calculations (such as FSL and RSL) with actual field measurements. Conversely, previous research started from the problem of discrepancies between simulation and real-world implementation, so the focus of the analysis was to measure the accuracy and prediction gap of the AirLink simulation software, with specific parameters on Fresnel Zone clearance, which is often the main cause of signal quality degradation in the field due to obstacles and terrain.

Research conducted by Wirawan et al [18] in "Analysis of Management Network Using Ubiquiti for Local Office at PT Rizki Inti Madani," aimed to optimize the company's network, which was facing challenges such as connectivity disruptions and uneven bandwidth allocation. The study involved a thorough analysis of the existing network conditions and the design of appropriate solutions using Ubiquiti devices. The conclusion of this research was that technicians and IT staff involved in network management should receive advanced training on the use of Ubiquiti and Cisco devices and efficient network troubleshooting techniques. The implementation of the new network should be done gradually to minimize the risk of operational disruptions. The difference between this research and previous studies is that previous research focused on validating manual calculations (theory) against field measurements (practice) to prove the success of a network design and focused on optimizing the architecture and management of local area networks (LAN/WLAN) in terms of efficiency, security, and centralized administration, with a systemic and managerial analysis. In contrast, the current research evaluates the accuracy of AirLink simulation software, not merely proving the design's success but measuring the gap between simulation predictions and real-world implementation, with the Fresnel Zone as the main variable. The current research is more technical and specific at the link level, evaluating the accuracy of predicting radio wave transmission performance for long-distance connections.

II. Research Methodology

The research methodology used is the PPDIOO Method, which is a network lifecycle used by Cisco to design, build, operate, and optimize computer networks to ensure they continue to function according to the organization's business needs. According to Teare [19] The explanation of the PPDIOO stages is as follows:

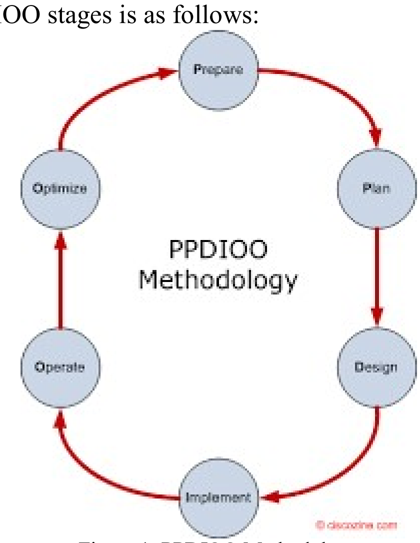

Figure 1. PPDIOO Methodology

A. Prepare

This involves identifying the business needs of an organization that support network development, proposing a reliable conceptual network architecture, and identifying the best technologies that can support the network architecture in the coming years.

B. Plan

The initial network requirements are identified based on technical needs, objectives to be achieved, facilities, user needs, hardware/software requirements, and others. This research involves determining the coordinate locations of the antenna towers to be built, both on the signal transmitting and receiving sides. This planning stage also involves calculating the cost of materials and equipment that will be used in accordance with the infrastructure supporting successful implementation.

C. Design

This involves designing a point-to-point (PtP) network topology simulation using the ispdesign.ui.com application. The main objective of this simulation is to ensure that the planned bandwidth (Mbps) can be successfully transmitted from the signal transmitter to the signal receiver. Determining the appropriate bandwidth (Mbps) requires considering the selection of suitable outdoor wireless hardware to achieve the targeted bandwidth. Various wireless network hardware options offer different throughputs based on the signal transmission distance between the transmitter and receiver. The resulting network design specifications are comprehensive and detailed, meeting both business and technical requirements to support availability, reliability, security, scalability, and performance.

D. Implement

This involves installing antenna towers on both sides, for both the signal transmitter (main1) and the signal receiver (station). It also includes implementing and configuring the outdoor wireless network devices according to the design and hardware used in the previous stage.

E. Operate

The operation phase is the final objective of the conformity in the design and implementation phases that have been carried out. The operation phase involves maintaining the outdoor wireless network through daily activities, including ensuring network availability, monitoring, troubleshooting, maintenance, and reducing costs. This operation phase will evaluate the Fresnel Zone in the simulation and implementation of Ubiquiti wireless using the 802.11ac standard by comparing the RX Signal Strength, throughput, channel width, and Fresnel Zone clearance values between the simulation results and direct field testing.

F. Optimize

The optimization phase involves proactive network management to identify and resolve problems that could affect the business or organization. Detecting and correcting errors (troubleshooting) is necessary when system conditions are unpredictable and can lead to failures. The essence of this optimization phase is to evaluate performance and make improvements if there are problems or new needs.

III. Results And Discussion

A. Design

In this Design phase, simulations are performed using the web-based application ispdesign.ui.com, which runs in a browser, as follows:

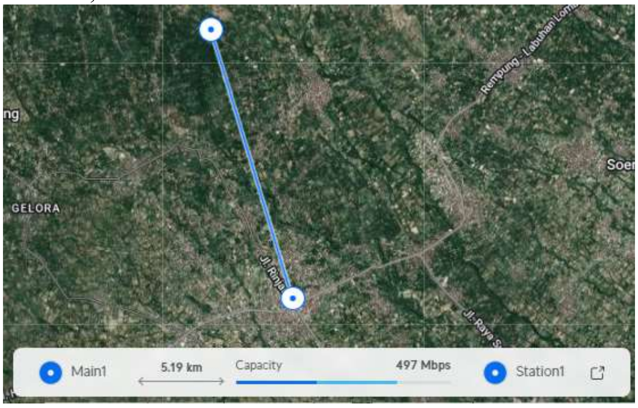

Figure 2. Point-to-Point (PtP) Simulation

Figure 2 shows that the distance between the signal transmitter (main1) and the signal receiver (station1) is 5.19 kilometers, with a simulated bandwidth of 497 Mbps.

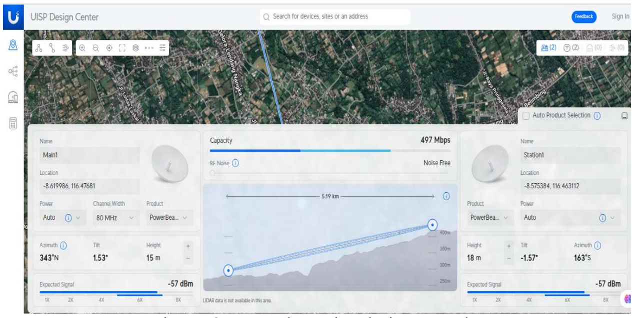

Figure 3. Complete Simulation Results

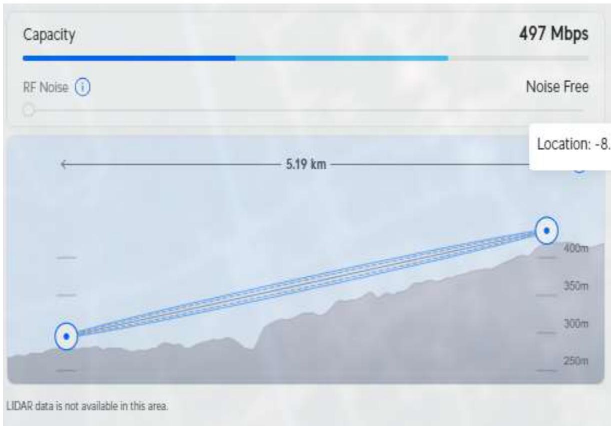

Figure 4. Point-to-Point Results (Side View)

Figure 3 shows the complete simulation results using Ubiquiti Powerbeam 5AC 620 wireless hardware on both sides of the antenna with a distance of 5.19 kilometers. Figure 4 shows the side view, where the signal transmitter (main1) is at an altitude of 300 meters above sea level, while the signal receiver (station1) is at an altitude of 450 meters above sea level.

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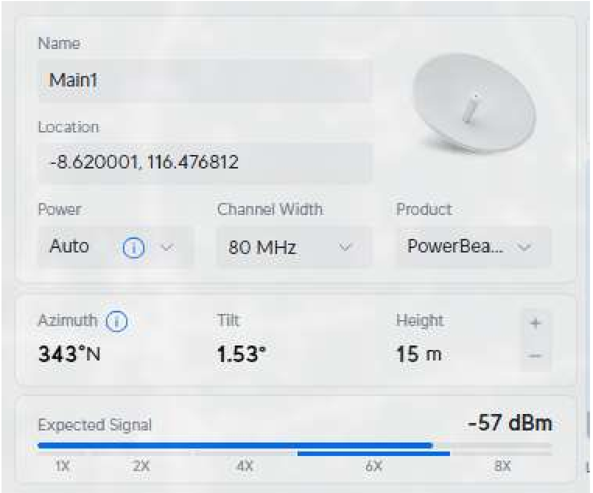

Figure 5. Simulation Results of the Signal Transmitter (main1)

Figure 5 shows the simulation results of the signal transmitter (Main) using Ubiquiti PowerBeam 5AC 620 hardware, with antenna installation coordinates at -8.619986, 116.47681, channel width of 80 MHz, horizontal angle (azimuth) of 343°N, tilt angle of 1.53° (meaning the receiving antenna is directed slightly upwards from the ideal horizontal line (0°)), antenna tower height of 15 meters, expected received signal (RX) of -57 dBm, and expected RX data rate of 6X.

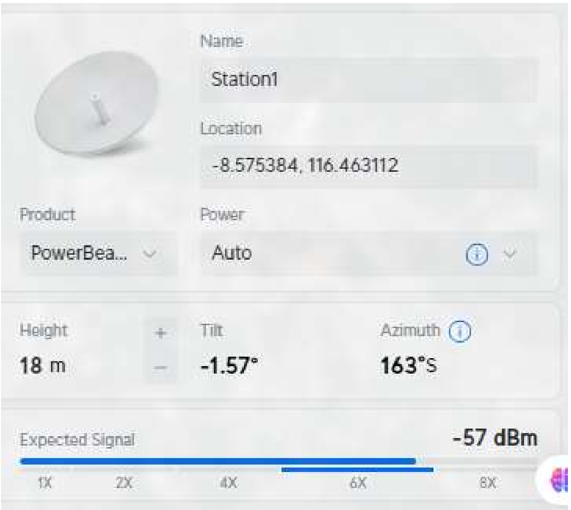

Figure 6. Simulation Results of the Signal Receiver (station1)

Figure 6 shows the simulation results of the signal receiver (Station) with Ubiquiti PowerBeam 5AC 620 hardware, antenna installation coordinates -8.575384, 116.463112, channel width 80 MHz, horizontal angle (azimuth) 163°S, tilt angle -1.57°, which means the receiving antenna is directed slightly downwards from the ideal horizontal line (0°), antenna tower height 18 meters, expected received signal (RX) is -57 dBm and expected RX data rate is 6X.

B. Implement

At the implementation stage, do the following:

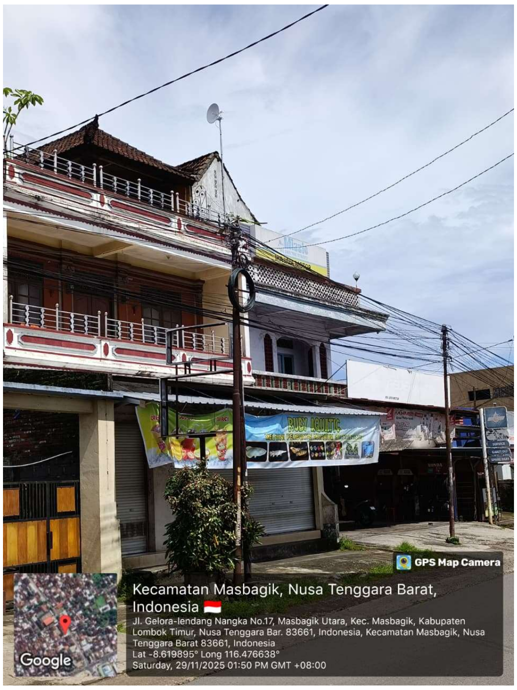

Figure 7. Signal Transmitting Antenna (Main1)

Figure 7 shows the construction of a tower and signal transmitter (Main1) with Ubiquiti PowerBeam 5AC 620 hardware, the antenna's coordinates are Lat -8.619986° and Long 116.47681°, located in Masbagik Utara Village, Masbagik District.

Figure 8. Signal Receiving Antenna (station 1)

Figure 8 shows the construction of the tower and signal receiving antenna (station 1) with Ubiquiti PowerBeam 5AC 620 hardware, the coordinates of the antenna construction point are Lat -8.575384° and Long 116.463112°, located in Pringgasela Village, Pringgasela District.

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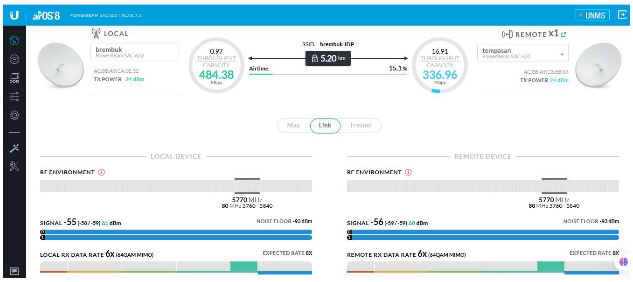

Figure 9. Complete Results of the Actual Implementation

Figure 9 shows the complete real-world implementation results of the Ubiquiti PowerBeam 5AC 620 application over a distance of 5.20 kilometers from the signal transmitter in Masbagik District to the signal receiver in Pringgasela District. At the signal transmitter, a throughput capacity of 484.38 Mbps was achieved, with a TX power of 24 dBm, a Channel Width of 80 MHz at a frequency of 5770 MHz, a received signal strength of -55 dBm, a noise floor of -93 dBm, and a local RX data rate of 6x (64QAM MIMO). Meanwhile, at the signal receiver, a throughput capacity of 336.96 Mbps was achieved, with a TX power of 24 dBm, a Channel Width of 80 MHz at a frequency of 5770 MHz, a received signal strength of -56 dBm, a noise floor of -93 dBm, and a local RX data rate of 6x (64QAM MIMO).

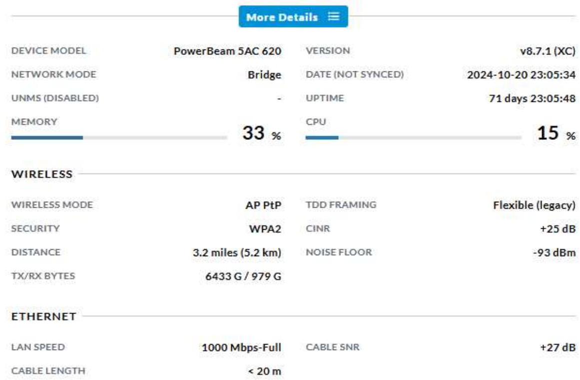

Figure 10. Detailed Information on Signal Transmitters

Figure 10 shows the device model used is PowerBeam 5AC 620, the network mode used is bridge, memory usage is 33%, CPU usage is 15%, the wireless mode used is AP PtP, the wireless security applied is WPA2, the distance is 5.2 kilometers, the noise floor is -93dBm, the LAN speed is 1000 Mbps-full duplex, and the LAN cable length is less than 20 meters.

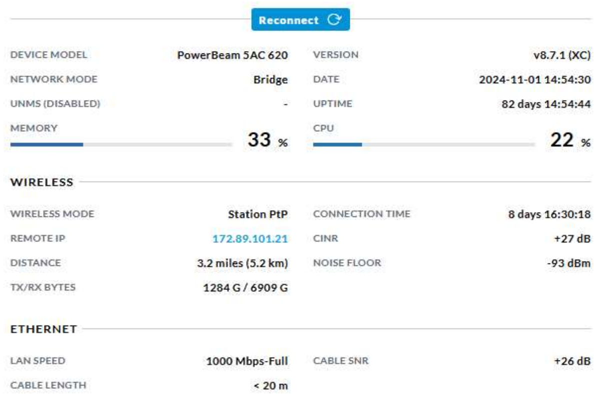

Figure 11. Detailed Information on the Signal Receiver

Figure 11 shows the device model used is PowerBeam 5AC 620, the network mode used is bridge, memory usage is 33%, CPU usage is 22%, the wireless mode used is Station PtP, the wireless security implemented is WPA2, the IP address for remote access is 172.89.101.21, the distance is 5.2 kilometers, the noise floor is -93dBm, the LAN speed is 1000 Mbps-full duplex, and the LAN cable length is less than 20 meters.

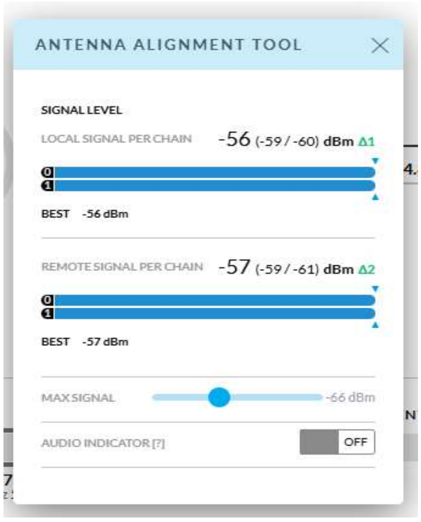

Figure 12. Measuring Signal Alignment Performance

Figure 12 shows the measurement of signal alignment performance from the signal transmitter to the signal receiver or vice versa, where the signal quality at the local signal is -56 dBm (for horizontal -59 dBm and vertical -60 dBm) while the signal quality at the remote signal is -57 dBm (for horizontal -59 dBm and vertical -61 dBm).

C. Operate

During the operation and evaluation phase, testing was conducted by sending duplex data packets (simultaneous download and upload), receive data packets (upload), and transmit data packets (download) for 30 seconds each, as follows:

Figure 13. Duplex Upload and Download Testing

Figure 13 shows the duplex test results over 30 seconds with a ping of 1.06 ms, achieving an average upload speed of 99.96 Mbps and an average download speed of 141.33 Mbps. Furthermore, the highest upload speed achieved was 151.05 Mbps and the highest download speed was 201.57 Mbps.

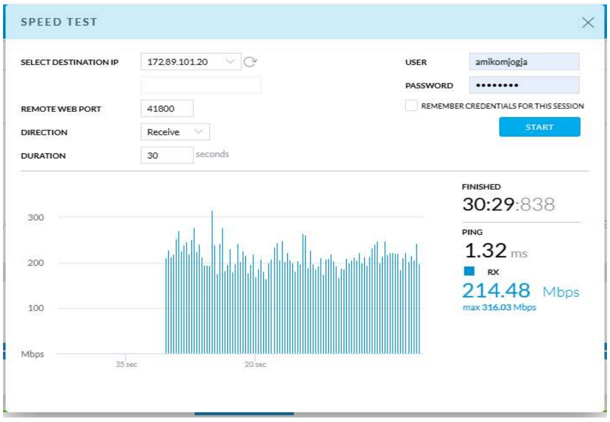

Figure 14. Download Testing

Figure 14 shows a download test lasting 30 seconds with a ping of 1.32 ms, resulting in an average download speed of 214.48 Mbps. Furthermore, the highest download speed achieved was 316.03 Mbps.

Figure 15. Upload Testing

Figure 15 shows the upload test results over 30 seconds with a ping of 1.05 ms, achieving an average download speed of 217.36 Mbps. In addition, the highest download speed reached 293.03 Mbps.

Table 1. Simulation Testing with Real-World Implementation

Testing	Simulation	Real-world Implementation
Total Capacity Download	-	316,03 Mbps
Total Capacity Upload	-	293,03 Mbps
Total Capacity both (Download & Upload)	497 Mbps	201,57 Mbps
Signal Strength at the TX Transmitter	-57 dBm	-56 dBm
Signal Strength at the RX Receiver	-57 dBm	-57 dBm
Clearance Fresnel Zone	Clear	Clear
Noise Floor	Noise Free	-93 dBm
Frequency	5.8 Ghz	5.8 Ghz
Technology	AirMAX AC	AirMAX AC
Channel Width	80 Mhz	80 Mhz

Table 1 shows a comparison of the network simulation results and the actual implementation in the field. The actual implementation shows fairly good results, namely 316.03 Mbps for download and 293.03 Mbps for upload. When combined (download and upload), the simulation obtained a total capacity of 497 Mbps, while the actual implementation only reached 201.57 Mbps, indicating a decrease in performance when applied in real-world conditions, which is likely influenced by environmental factors and interference.

In terms of signal quality, both the simulation and implementation showed relatively consistent results, namely -57 dBm at the transmitter (TX) and receiver (RX) for the simulation. The real-world implementation also showed results close to ideal, namely -56 dBm for TX and -57 dBm for RX. These values can be categorized as good and stable signals for point-to-point (PtP) communication. In both the simulation and real-world implementation, the Fresnel Zone Clearance was declared Clear, meaning the radio transmission path was not obstructed by physical objects and was in optimal LOS (Line of Sight) conditions. For the Noise Floor parameter, the simulation was in a Noise Free condition, while the real-world implementation recorded a value of -93 dBm, which is still considered good because a lower noise floor value (closer to -100 dBm) indicates a cleaner environment with less interference. Technical parameters such as frequency (5.8 GHz), AirMAX AC technology, and 80 MHz Channel Width were identical in both the simulation and real-world implementation, so the differences in results were more influenced by real-world conditions in the field, not network configuration.

IV. CONCLUSION

This research successfully comprehensively evaluated the accuracy of Fresnel Zone simulations using AirLink software against the actual implementation of a Point-to-Point (PtP) wireless network based on the IEEE 802.11ac standard using Ubiquiti PowerBeam 5AC 620 devices. Based on the test results, it was found that the simulation provided performance predictions that were quite close to field conditions, especially in terms of signal strength (RX) and Fresnel Zone clearance, which remained clear, thus ensuring optimal Line of Sight (LOS). However, there was a significant difference in throughput achieved, where the simulation predicted a capacity of 497 Mbps, while the actual field implementation only reached 201.57 Mbps for duplex testing. This proves that environmental factors, terrain contours, noise floor, and external interference still have a significant impact on network performance that cannot be fully represented by the simulation. Therefore, AirLink simulation is very helpful in the implementation of outdoor wireless networks, but it cannot be used as an absolute reference without field validation. The real-world evaluation proves the importance of optimizing technical parameters such as channel width, antenna height, azimuth/tilt angle, and noise floor monitoring to obtain a stable and efficient link quality. The PPDIOO method used in this research proved effective in ensuring that every stage of network design and optimization proceeded systematically and according to implementation needs. The limitations of this research include the scope of the location, which only involved one PtP link and did not test performance under more complex topographical conditions. Further research is recommended to test the influence of variations in distance, weather, and the use of MIMO technology to obtain a more precise predictive model. Overall, this research provides an important technical reference for network practitioners in validating simulation results and designing PtP connections more accurately and practically in real-world field conditions.

REFERENCES

[1] A. T. Haryanto, “APJII: Jumlah Pengguna Internet Indonesia Tembus 221 Juta Orang,” *detikInet*, 2024. https://inet.detik.com/cyberlife/d-7169749/apjii-jumlah-pengguna-internet-indonesia-tembus-221-juta-orang (accessed Nov. 11, 2025).

[2] A. S. Tanenbaum and D. J. Wetherall, *Computer Networks*, 5th editio. Boston: Pearson, 2013.

[3] cisco.com, “What Is 802.11ac?,” *https://www.cisco.com/*. https://www.cisco.com/site/us/en/learn/topics/networking/what-is-802-11ac.html (accessed Nov. 11, 2025).

[4] T. S. Rappaport, *Komunikasi Nirkabel: Prinsip dan Praktik*, Edisi ke-2. Jakarta: Erlangga, 2014.

[5] Kumar, S. and A. Sharma, *Antena dan Propagasi Gelombang Radio*. Yogyakarta: Andi Publisher, 2019.

[6] A. Mutmainnah and R. Hidayat, *Teknologi Jaringan Nirkabel*. Yogyakarta: Andi Publisher, 2020.

[7] Suji, *Transmisi Radio Microwave*. Jakarta Selatan: Nec Pasolink. PT. Alita Praya Mitra, 2013.

[8] A. A. Pangera, *Menjadi Administrator Jaringan Nirkabel*. Yogyakarta: Andi Publisher, 2008.

[9] B. A. Forouzan, *Data Communications and Networking*. New York: McGraw-Hill, 2013.

[10] B. Sklar, *DIGITAL COMMUNICATIONS : Fundamentals and Applications*, 2nd ed. Los Angeles, USA: Prentice Hall, 2001. [Online]. Available: https://www.mangoud.com/EENG373_files/Book-Sklar.pdf

[11] Citraweb.com, “Channel Width dengan Wireless N Mikrotik,” *citraweb.com*, 2025. https://citraweb.com/artikel/144/ (accessed Nov. 11, 2025).

[12] W. Stallings, *Data and Computer Communications*, 10th ed. Pearson, 2014.

[13] J. Han, “Application of Fresnel Zone Model in Wireless Sensing Field,” *Highlights Sci. Eng. Technol. EMIS 2024*, vol. 119, pp. 516–523, 2024.

[14] N. C. Nnadi, H. A. Jacob, and G. N. Ezeh, “LINK BUDGET ANALYSIS FOR LINE OF SIGHT WIRELESS COMMUNICATION LINK WITH KNIFE EDGE DIFFRACTION OBSTRUCTION,” *Sci. Technol. Publ. (SCI TECH)*, vol. 4, no. 6, pp. 369–374, 2020.

[15] M. R. Hidayat, T. I. M. Fauzian, E. Alimudin, and H. Yuliana, “Analisis Power Link Budget Pada Jaringan Wireless Outdoor Menggunakan Internet Service Provider Design Center Studi Kasus Desa Kutanagara Garut,” *TELEKONTRAN*, vol. 10, no. 2, 2022.

[16] A. M. Ramadhan and D. W. Chandra, “Analisis Fresnel Zone dan Link Budget Jaringan WLAN dari PT. Solo Jala Buana ke BTS Karanganyar Menggunakan UBNT AIRLINK,” Universitas Kristen Satya Wacana, 2024.

[17] L. H. Anisa, P. Maria, S. Yusnita, and Y. L. Oktapianus, “Analisis Implementasi IEEE 802.11ac pada Jaringan Wireless Backhaul Distribusi Provider Zettalink Analysis of the Implementation of IEEE 802.11ac on the Wireless Backhaul Network of Zettalink Provider,” *Electron J. Ilm. Tek. Elektro*, vol. 5, no. November, 2024.

[18] S. A. Wirawan, A. N. Tahir, and Sutisna, “Analysis of Management Network Using Ubiquiti for Local Office at PT Rizki Inti Madani,” *Int. J. Eng. Sci. Inf. Technol.*, vol. 5, no. 2, pp. 243–247, 2025.

[19] D. Teare, *Designing for Cisco internetwork solutions (DESGN)*. 2008. [Online]. Available: http://www.loc.gov/catdir/toc/ecip0724/2007032855.html