Comparison LoRaWAN and Wi-Fi HaLow : Study Case for Smart Metering in Urban Area

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***Abstract*—The rapid growth of WiFi technology, predominantly driven by the IEEE 802.11 family of standards, particularly highlights the emergence of the 802.11ah standard tailored for the Internet of Things (IoT) era. This standard endeavors to furnish a cost-effective operational mode capable of servicing numerous devices per cell across expansive coverage areas. This study delves into the IEEE 802.11ah Standard Network Planning for IoT Applications, focusing on enhancing network quality in terms of capacity and coverage to bolster WiFi network efficacy for supporting IoT services. Through simulations conducted for Smart Meters in the Grand Wisata Bekasi Cluster Area, it's discerned that LoRaWAN Coverage Planning necessitates only one site to encompass the Smart Meters, while Wi-Fi HaLow Coverage Planning demands between 7 to 211 sites contingent on the modulation utilized. Examination of various parameters reveals that LoRaWAN maintains a consistent Average Effective Signal Analysis value across spreading factors at -74 dBm, with a stable Average Coverage by Signal Analysis value at -67 dBm. Conversely, WiFi HaLow exhibits a spectrum of Average Effective Signal Analysis values for each modulation, ranging from -69 dBm to -34 dBm, alongside Average Coverage by Signal Analysis values spanning from -60 dBm to -34 dBm.**

Keywords—Wi-Fi, HaLow , Internet of Things, Smart Meter

I. INTRODUCTION

The city of Bekasi, a strategically located and promising city in Indonesia, is currently experiencing rapid population growth. In 2020, the city's population was recorded at 2,543,676 people. To address this issue, the city is looking to implement Smart Meter technology, which is an electronic device used to efficiently monitor and manage energy consumption [1].

The implementation of Wi-Fi HaLow in Bekasi is in line with the worldwide trend toward smart city development. This technology can be utilized in a variety of applications, including environmental monitoring and energy management. By integrating Wi-Fi HaLow into Smart Meters, Bekasi has the potential to enhance energy efficiency and promote sustainable development [2].

The relationship between Long Range (LoRa) and Wi-Fi HaLow has significant implications for coverage [3]. LoRa is a short-range technology that can cover several kilometers, making it ideal for IoT applications in large areas such as parks and sports fields. However, the coverage performance may vary depending on the surrounding environment and other factors [4].

When considering the Smart Meter requirements in Bekasi, the decision between LoRa and Wi-Fi HaLow for coverage should depend on the geographic characteristics and specific needs of the area. These factors may encompass building density, topography, and specific energy consumption monitoring needs in urban areas. By thoroughly understanding Bekasi's particular characteristics, the choice between LoRa and Wi-Fi HaLow can be fine-tuned to achieve effective coverage in the context of Smart Meter implementation [5].

The paper is structured as follows: Section II provides an overview of the planning idea, parameters, and technique. In Section III, the findings derived from simulations for each parameter are presented, along with a discussion of the link budget results. Section IV contains the conclusions, summarizing the results.

II. LITERATURE REVIEW

This research focuses on planning a LoRaWAN Wi-Fi network for Smart Meters in Bekasi, Indonesia. The main goals are to determine the coverage area and the number of sites needed. Additionally, the research emphasizes the importance of implementing an efficient charging strategy for Smart Meters to minimize costs and optimize connection, communication, and charging systems in smart city development [6].

The potential of LoRaWAN and Wi-Fi HaLow networks, based on the IEEE 802.11ah standard, is highlighted [4]. This study evaluates the planning and simulation of various networks to assess the impact of LoRaWAN and Wi-Fi HaLow networks on the performance of smart meters in the area. It emphasizes the importance of comprehensive planning to optimize network performance [7].

This research utilizes Atoll version 3.4.0 for LoRaWAN network planning. The software was used to simulate various scenarios to identify the most effective strategy for network deployment, ensuring robust coverage and high-quality service for smart meters.

In conclusion, this study emphasizes the importance of comprehensive planning and simulation in improving the performance of smart meters in Bekasi. By identifying optimal locations for site deployment, optimizing network capacity, and improving smart meter implementation, this research contributes to the development of an efficient and effective smart meter system in the region [5].

III. RESEARCH METHOD

A. *Research Area*

The study compares LoRaWAN and Wi-Fi HaLow technologies for smart metering in urban areas, specifically in Grand Wisata Bekasi. LoRaWAN offers advantages in battery lifetime, business model, implementation speed, and total costs, while Wi-Fi HaLow excels in range and capacity. Real-world performance experiments evaluate Wi-Fi HaLow's network performance in terms of throughput, latency, and reliability. LPWA-based IoT technology is crucial for smart metering due to its energy usage management capabilities. The experimental field comparison between Wi-Fi HaLow and LoRa provides valuable performance data and insights, aiding informed decision-making in smart metering deployment.

Fig. 1. Map of The Grand Wisata Bekasi [8]

Figure 1 shows a map of the Grand Wisata Bekasi area which provides various facilities that can be a means to develop smart metering. This area offers clusters that carry the concept of smart homes with sophisticated systems and modern designs. In addition, there are facilities such as schools, hospitals, modern markets, culinary areas, Water Park, Celebration Plaza, and Club House. With complete infrastructure and various activities in it, Grand Wisata Bekasi offers great potential for the development of integrated and efficient smart metering solutions [8].

B. *Coverage Planning*

Coverage planning is an important step in network design that aims to determine the optimal location and required coverage parameters. There are two very important site parameters, namely transmission power which refers to the signal strength when sending data and coverage estimation which refers to the signal range. Therefore, network planners can ensure optimal signal coverage, so that network users can access high-quality services at various locations [9].

Figure 2 show a research flowchart, the initial step involves conducting research on the Lora and Wifi HaLow networks. Subsequently, location data is collected with a specific focus on the Grand Wisata Bekasi cluster, which serves as the research area. The case study for this research revolves around the implementation of a smart meter. For the link budget calculation, the Okumura-Hatta propagation model is employed due to its compatibility with the frequencies utilized by the Lora and Wifi HaLow networks.

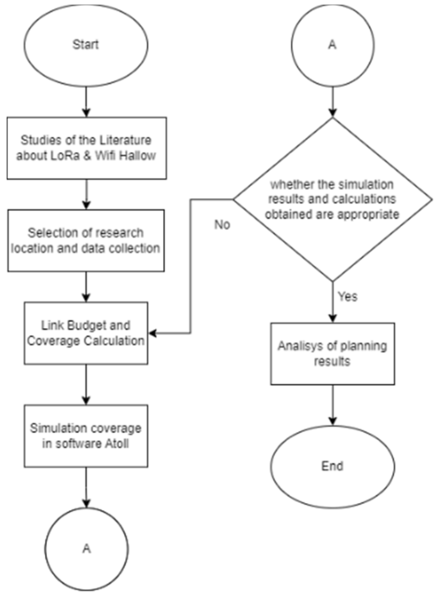

Fig. 2. Flowchart Coverage Planning

1) Link Budget Calculation LoRaWAN

Link Budget calculation is required to calculate the signal power loss between the site and the end device to get the maximum coverage area per site. Table I shows the link budget LoRaWAN used in this study.

TABLE I. Link Budget LoRaWAN [10]

Parameter	UL	DL
Tx Power (dBm)	15	20
Tx Cable Loss (dB)	-1	-3
T x Antenna Gain (dBi)	0	9
Tx Antenna Height (m)	30	
RX Antenna gain diversity (dBi)	10	0
Rx Antenna Height (m)	1,5	
Frequency (MHz)	923	
Bandwidth (kHz)	125	

LoRa has high sensitivity and can be detected even if the signal is weak, allowing for increased communication distance. LoRa sensitivity is used to determine the maximum allowable signal loss (MAPL) value. LoRa sensitivity can be calculated based on the Spreading Factor (SF) according to the Signal-to-Noise Ratio (SNR) value for each Spreading Factor used [11]. The values in Table 2 can be found using the formula equation (1) LoRa Sensitivity

TABLE II. LoRaWAN Sensitivity Value [12]

Sensitivity (dBm)					
SF 7	SF 8	SF 9	SF 10	SF 11	SF 12
-125	-127	-130	-132	-135	-137

6
$$Sensitivity\ SF = -174 + 10\log\ (BW) + + (-SNR\ Limit) \tag{1}$$

Maximum Allowable Path Loss (MAPL) : MAPL is required to determine the highest value of allowable attenuation between the site and the end device [13]. The EIRP and MAPL calculation formulas are as follows:

$$EIRP\ (UL/DL) = Tx\ Power + Gain\ Anntenna\ TX - Loss\ Cable \tag{2}$$

TABLE III. EIRP Value LoRaWAN

Value (dBm)	Device	Value (dBm)
EIRP Downlink	*Site*	26
EIRP Uplink	End Device	14

The formula for the MAPL equation is found in equation (3) and the results of the MAPL calculation in Table IV.

$$MAPL = EIRP - Sensitivity \quad (3)$$

TABLE IV. MAPL LoRaWAN Value

Spreading Factor (SF)	MAPL Downlink (dBm)	MAPL Uplink (dBm)
7	151	139
8	153	141
9	156	144
10	158	146
11	161	149
12	163	151

2) Link Budget Calculation Wi-Fi HaLow

The link budget is used to calculate the overall gain and loss experienced by a signal as it travels from the transmitter to the receiver. The values of the Wi-Fi HaLow link budget parameters can be seen in Table V.

TABLE V. Link Budget Wifi HaLow

Parameter	UL	DL
Tx Power (dBm)	15	24
Tx Cable *Loss* (dB)	-1	-3
T x Antenna Gain (dBi)	0	3
Tx Antenna Height (m)	25	
RX Antenna gain diversity (dBi)	10	0
Rx Antenna Height (m)	1.5	
Frequency (MHz)	923	
Bandwidth (kHz)	2000	

Calculating sensitivity value Wi-fi HaLow : In contrast to LoRaWAN, the RX sensitivity value in Wi-Fi HaLow is dependent on the channel bandwidth being utilized. This information can be found in Table VI, which provides the Receiver Sensitivity for a 2 MHz channel bandwidth.

TABLE VI. Rx Sensitivity at 2 Mhz Channel Bandwidth

Modulation	Rx Sensitivity
256 QAM	-72 dBm
64 QAM	-78.5 dBm
16 QAM	-85 dBm
QPSK	-91 dBm
BPSK	-98 dBm

Maximum Allowable Path Loss Wi-fi HaLow : The calculation of the MAPL and EIRP in Wi-Fi HaLow follows a similar method to the MAPL and EIRP calculation used in LoRaWAN, as described in Equation (2) (3). Tables VII and IX show the EIRP and MAPL values Wi-fi HaLow that were calculated.

TABLE. VII Value EIRP Wi-fi HaLow

Value (dBm)	Device	Value (dBm)
EIRP Downlink	*Site*	24
EIRP Uplink	End Device	14

TABLE IX. Value MAPL Wi-fi HaLow

Modulation	MAPL Downlink (dBm)
256 QAM	96.00
64 QAM	102.50
16 QAM	109.00
QPSK	115.00
BPSK	122.00

3) Coverage Prediction

In coverage planning, the number of sites required to cover an area can be determined. Cell radius calculation is used to calculate the coverage area or Coverage in one site. The propagation model used in LoRaWAN and Wifi HaLow network planning is Okumura Hatta Propagation. The selection of propagation is based on its performance in terms of accuracy and ease of use. To calculate the cell radius distance, the following formula can be used [14]. The results of the cell radius LoRaWAN calculation can be seen in the Table X.

$$PL = 65{,}55 + 26{,}16 \log(f) - 13{,}82 \log(hb)$$

$$- a(hm)\,(44.7 - 6.55 \log(hb) \log10(d) \quad (4)$$

$$a(hm) = (1{,}1 \log(f) - 0.7)\,(hm)\,(1.56 \log10(f) - 0.8) \quad (5)$$

Note:

f : frequency of transmission (MHz)
hb : height of site antenna (m)
hm : height of the device's antenna (m)
d : the distance between the sites and the devices (km)

TABLE X. Value *Cell* Radius LoRaWAN

Spreading Factor	$a(h_{re})$	Cell Radius (km)	
		log (d) (downlink)	d (km) (downlink)
7	0.0167	0.6902	4.8996
8		0.7469	5.5840
9		0.8321	6.7938
10		0.8889	7.7426
11		0.9741	9.4201
12		1.0308	10.7358

Calculation of Cell Area *:* After the cell radius calculation is obtained, the next step is to calculate the cell area that can be covered by one site. The LoRa cell area value can be calculated using Equation (6), while the W-fi HaLow cell area value can be calculated using Equation (7).

$$Lcell = \frac{3\sqrt{3d^2}}{2} \quad (6)$$

$$Lcell = 3.14 \times (d)^2 \quad (7)$$

In the calculation of cell area, it is important to know the value of d which indicates the distance between the transmitter and receiver in kilometers. A cell is an area with limited coverage and is small in size. The calculation results of the LoRaWAN cell area value in Table XI while Wi-fi HaLow in Table XII.

TABLE. XI LoRaWAN Cell Area Value

Spreading Factor	Cell Area (km^2)
7	12.729
8	14.507
9	17.650
10	20.115
11	24.474

12	27.892

TABLE. XII Wi-fi Cell Area Value

Modulation	Cell Area (km^2)
256 QAM	0.05
64 QAM	0.12
16 QAM	0.28
QPSK	0.60
BPSK	1.49

Calculating the Number of Sites: The last calculation in this coverage plan is to calculate the number of sites needed to cover the entire area in the research location. Table XIII contains the results of the calculation of the number of sites LoRaWAN and Wi-fi HaLow.

$$Number\ of\ Sites\ =\ \frac{Area}{Cell\ Area} \tag{8}$$

TABLE. XIII Number of LoRaWAN Sites

Spreading Factor	Site
7	1
8	1
9	1
10	1
11	1
12	1

TABLE. XIV Number of Wi-fi HaLow Sites

Modulation	Site
256 QAM	211
64 QAM	91
16 QAM	40
QPSK	18
BPSK	7

IV. Result and Discussion

In this study, the researchers conducted coverage planning simulations using Atoll software version 3.4.0. The aim was to investigate various parameters related to wireless communication. The study focused on analyzing the required number of sites, signal strength (Effective Signal Analysis), coverage by signal level, and coverage by throughput. To analyze and interpret these parameters, Matlab software was used. The calculations revealed that the number of sites required to cover Smart Meters in an 11.05 km² area can be observed in Tables 12 and 13.

The coverage planning simulation model used in this study may not fully match the real situation. Factors such as the presence of buildings, trees, and other obstructions, as well as sources of electromagnetic interference, can have a significant impact on the propagation characteristics and performance of wireless technologies.

Furthermore, the simulation-based analysis relies on theoretical models and assumptions regarding the behavior of the LoRaWAN and WiFi HaLow protocols. While these models are designed to approximate the real-world performance, they may not accurately reflect the actual performance of the technologies when deployed with real-world smart metering devices and infrastructure.

A. Effective Signal Analysis

This parameter is used to predict the signal strength sent from the Sites to the End Device. Fig.3 illustrates the site placement in the simulation of the Effective Signal Analysis parameters, where a single site is required for all spreading factor scenarios utilized.

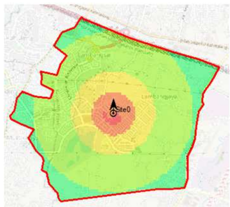

Fig. 3. Effective Signal Analysis Prediction in LoRaWAN

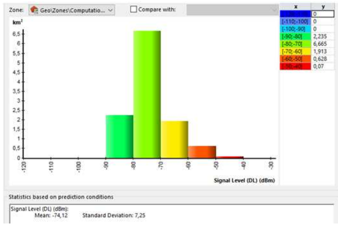

Fig. 4. Histogram Effective Signal Analysis Prediction in LoRaWAN

It can be seen in Fig.4 that the value on the x-axis is the magnitude of the signal obtained while the y-axis represents the distance in kilometers squared. The Effective Signal value obtained is -74.12 dBm with a standard deviation of 7.25 dBm, which means it is included in the good category.

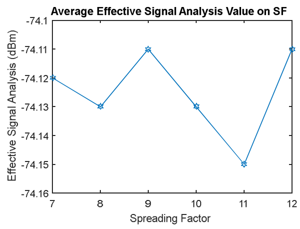

Fig. 5. Average Effective Signal Analysis Prediction on LoRaWAN

When observing Fig.5, it can be observed that the average value of the Effective Signal parameter remains consistently stable at -74 dBm across all spreading factor scenarios utilized in this coverage planning simulation. This indicates that the average results can be categorized as favorable.

Fig. 6. Effective Signal Analysis Prediction in Wifi HaLow

Furthermore, in Fig.6, it is evident that Wi-Fi HaLow exhibits a more diverse range of site quantities for each utilized modulation. This variation in the number of sites can be attributed to several factors, such as the specific modulation scheme employed and the desired coverage objectives.

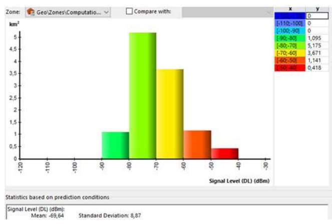

Fig. 7. Histogram Effective Signal Analysis Prediction in Wifi HaLow

In Fig.7 the value on the x-axis is the magnitude of the signal obtained while the y-axis is the distance in kilometers squared. The Effective Signal value obtained by Wifi HaLow is -69.64 dBm with a standard deviation of 8.87 dBm, which is better than the Effective Signal value on LoRaWAN.

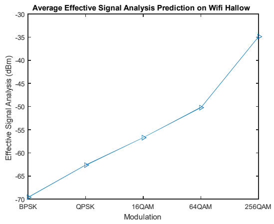

Fig. 8. Average Effective Signal Analysis Prediction on Wifi HaLow

The Average Effective Signal value on Wifi HaLow is more diverse depending on the modulation used, it can be seen in Fig.8, 256 QAM modulation has the best Effective Signal value, the choice of modulation in coverage planning depends on the use and environment.

TABLE. XV Comparison Table of Effective Signal Analysis

Effective Signal Analysis		
Technology	Spreading Factor or Modulation	Effective Signal (dBm)
LoRaWAN	7	-74.12
	8	-74.13
	9	-74.11
	10	-74.13
	11	-74.15
	12	-74.11
Wi-Fi HaLow	BPSK	-69.64
	QPSK	-62.65
	16 QAM	-56.7
	64 QAM	-50.17
	256 QAM	-34.83

Table 14 presents a comparison of the average Effective Signal values between LoRaWAN technology and WiFi HaLow. WiFi HaLow achieves a superior average value compared to LoRaWAN. This can be attributed to the diverse number of sites employed for each modulation scheme utilized in WiFi HaLow technology. Consequently, the signal strength transmitted to the end devices is enhanced due to the increased number of sites within the area.

B. Coverage by Signal

Coverage by Signal refers to the RSSI parameter, which is a parameter used to measure the strength of the signal received by a receiver, it is typically measured in decibels milliwatt (dBm). A higher RSSI value indicates a stronger signal, while a lower value indicates a weaker signal.

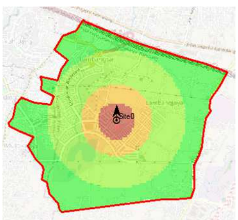

Fig. 9. Coverage by Signal Prediction in LoRaWAN

Fig.9 is the result of simulating the prediction of Coverage by Signal or RSSI which shows that the Grand Wisata cluster area is dominated by green.

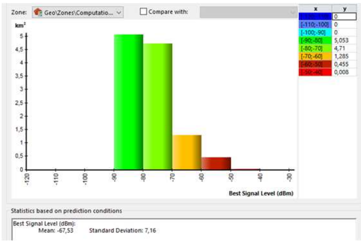

Fig. 10. Histogram Coverage by Signal Prediction in LoRaWAN

Based on the LoRaWAN network planning simulation, the value of Coverage by Signal obtained is -67.53 dBm with a standard deviation of 7.16 dBm so it can be categorized as good for Coverage by Signal.

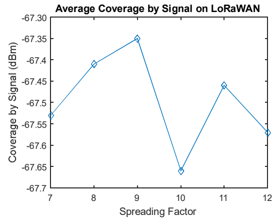

Fig. 11. Average Coverage by Signal Prediction on LoRaWAN

The average value of Coverage by Signal in Fig.11 can be observed to have a consistent value of -67 dBm for all deployment factor scenarios used in the LoRaWAN network planning simulation. The average value can be categorized as good for the Coverage by Signal parameter.

Fig. 12. Coverage by Signal Prediction in Wifi HaLow

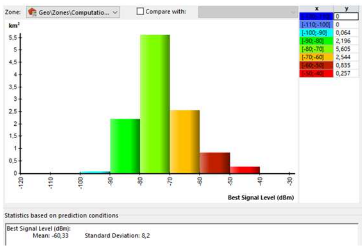

Fig. 13. Histogram Coverage by Signal Prediction in Wifi HaLow

On the histogram of coverage by signal, Wifi HaLow is dominated by light green with an average value of -60.33 dBm (for BPSK modulation) and a standard deviation of 8.2 dBm which can be categorized as good for these parameters.

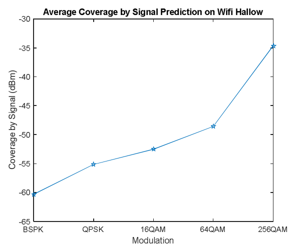

Fig. 14. Average Coverage by Signal Prediction on Wifi HaLow

The Average Coverage by Signal value on Wifi HaLow is more diverse depending on the modulation used, it can be seen in Fig.14, 256 QAM modulation has the best Coverage by Signal value, the choice of modulation in coverage planning depends on the use and environment.

TABLE. XVI Comparison Table of Coverage by Signal

Coverage by Signal		
Technology	Spreading Factor or Modulation	Coverage by Signal (dBm)
LoRaWAN	7	-67.53
	8	-67.41
	9	-67.35
	10	-67.66
	11	-67.46
	12	-67.57
Wi-Fi HaLow	BPSK	-60.33
	QPSK	-55.16
	16 QAM	-52.53
	64 QAM	-48.57
	256 QAM	-34.62

In Table 16, a comparison of signal coverage between LoRaWAN and WiFi HaLow reveals that WiFi HaLow has better signal coverage values compared to LoRaWAN. The coverage by signal value improves as the modulation used increases.

C. Coverage by Throughput

Coverage by Throughput is a parameter that measures the quantity of bandwidth capacity consumed.

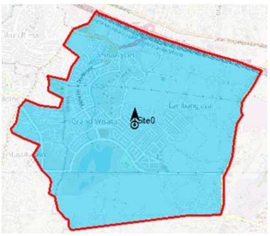

Fig. 15. Coverage by Throughput Prediction in LoRaWAN

Fig. 15 illustrates the throughput prediction for LoRaWAN using the same number of sites (1) across different spreading factors (SF). The contours of the venue terrain and environment, in this case the Grand Wisata Bekasi cluster, have a significant impact on the LoRaWAN throughput performance.

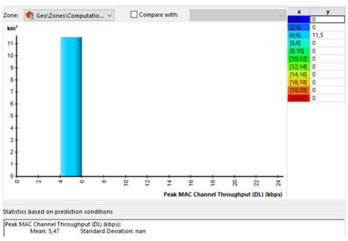

Fig. 16. Histogram Coverage by Throughput Prediction in LoRaWAN

Fig. 16 shows the obtained throughput results, where the histogram indicates a mean throughput of 5.47 kbps within a range of 4-6 kbps. The vertical axis represents the coverage area in square kilometers, which ranges from 0 to over 11 square kilometers.

The following is the relationship between distance and throughput: The lower the received signal strength and the data rate, the lower the achieved throughput. As the distance between the transmitter (Tx) and receiver (Rx) increases, the received signal strength decreases, resulting in lower data rates and, consequently, lower throughput.

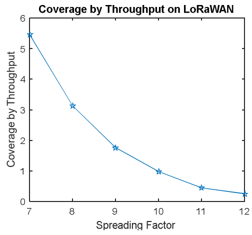

Fig. 17. Average Coverage by Signal Throughput on LoRaWAN

As shown in Fig. 17, the throughput obtained at spreading factor 7 (SF7) is 5.47 kbps, while at spreading factor 12 (SF12) the throughput value is 0.25 kbps. This illustrates an inverse relationship between the spreading factor and the achieved throughput - as the spreading factor increases, the throughput decreases. This is because the higher spreading factors prioritize range over data rate.

Fig. 18. Coverage by Throughput Prediction in Wifi HaLow

Fig.18 illustrates the throughput prediction for WiFi HaLow using a variable number of access points with different modulation. The modulation used affects the achieved throughput. The simulation results show that a minimum throughput of 100 kbps can be maintained in 67.27% of the targeted urban areas.

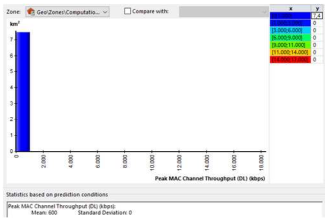

Fig. 19. Histogram Coverage by Throughput Prediction in Wifi HaLow

As shown in Fig. 19, the histogram indicates an average throughput of approximately 600 kbps using BPSK modulation, within the range of 0-1000 kbps. The vertical axis represents the coverage area in square kilometers, spanning from 0 to more than 7 square kilometers.

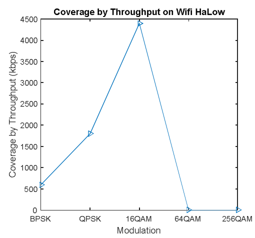

Fig. 20. Average Coverage by Signal Throughput on Wifi HaLow

The Average Coverage by Throughput for WiFi HaLow exhibits diversity depending on the modulation scheme employed, as illustrated in Figure 20. For instance, BPSK modulation achieves a throughput of approximately 600 kbps, while 16-QAM modulation yields a higher throughput of 4400 kbps. This highlights that the selection of modulation for coverage planning must consider the specific usage requirements and environmental factors.

TABLE. XVII Comparison Table of Coverage by Throughput

Coverage by Throughput		
Technology	Spreading Factor or Modulation	Coverage by Throughput (kbps)
LoRaWAN	7	5.47
	8	3.13
	9	1.76
	10	0.98
	11	0.44
	12	0.25
Wi-Fi HaLow	BPSK	600
	QPSK	1800
	16 QAM	4400
	64 QAM	undefined
	256 QAM	undefined

As illustrated in Table 17, the comparison of Coverage and Throughput between LoRaWAN and WiFi HaLow reveals that WiFi HaLow offers higher throughput performance. However, the coverage area with a minimum throughput of 100 kbps is limited to 67.27% for WiFi HaLow. Furthermore, when using higher modulation schemes, the throughput for WiFi HaLow may not even be defined due to the requirement of too many sites to achieve the necessary coverage. In contrast, LoRaWAN is capable of maintaining 100% coverage across all spreading factors.

V. Conclusion

Based on the simulations conducted for LoRaWAN and Wi-Fi HaLow technologies on Smart Meters in the Grand Wisata Bekasi Cluster Area, it can be concluded that LoRaWAN coverage planning requires only one site to cover the Smart Meters in the region. In contrast, Wi-Fi HaLow coverage planning requires between 7 and 211 sites, depending on the modulation used. The prediction test results for each measured parameter indicate that LoRaWAN has a stable Average Effective Signal Analysis value for each spreading factor used, consistently at -74 dBm. Similarly, the Average Coverage by Signal Analysis value for LoRaWAN remains stable at -67 dBm. On the other hand, Wi-Fi HaLow demonstrates a diverse range of Average Effective Signal Analysis values for each modulation, ranging from -69 dBm to -34 dBm. The Average Coverage by Signal Analysis value for Wi-Fi HaLow also varies significantly, ranging from -60 dBm to -34 dBm. Furthermore, the coverage analysis based on throughput shows that the coverage area with a minimum throughput of 100 kbps is limited to only 67.27% for Wi-Fi HaLow. In contrast, LoRaWAN is able to maintain 100% coverage across all spreading factors, ensuring consistent throughput performance. Therefore, this research concludes that Wi-Fi HaLow offers advantages in terms of Effective Signal value and Coverage by Signal compared to LoRaWAN. The greater variability and higher upper range of signal values suggest that Wi-Fi HaLow can potentially provide better signal quality and coverage in certain scenarios, despite the need for more sites to achieve comprehensive coverage. However, LoRaWAN surpasses Wi-Fi HaLow in terms of reliable and consistent coverage based on the critical metric of minimum throughput.

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