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LoRA Gateway Coverage and Capacity Analysis for Supporting Monitoring Passive Infrastructure Fiber Optic in Urban Area

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ABSTRACT

In the era of digital transformation, telecommunications infrastructure has become the backbone of global connectivity. Optical Distribution Cabinet (ODC) is a crucial part of an optical network that distributes signals to various points in the network. Maintenance and monitoring of ODCs have become essential to ensure optimal availability and performance. However, conventional approaches are often expensive and difficult to implement. The objective of this study is to develop a LoRaWAN network with the purpose of determining the required number of gateways. Additionally, the research aims to devise an IoT-based ODC device monitoring system within the FTTH network, utilizing data from PT. Telkom Witel Bandung. The approach involves employing simulation techniques through the Atoll apps v 3.40. Multiple calculation stages are applied to expect RSSI and SINR parameters within an area spanning 188.96 km². The study employs a frequency of 920 MHz, a bandwidth of 125 kHz, and a spreading factor of 10. The data analysis includes RSSI and SINR signals. As a result of calculations and planning simulations, this study recommended the use of nine gateways and achieved an RSSI parameter of -70. 35 dBm and a SINR parameter of 17. 33 dBm.

Keywords*:* LoRaWAN, Gateway, Planning, ODC

INTRODUCTION

In the contemporary age of technological advancement, numerous shared challenges persist among the populace, particularly in major urban centers across Indonesia. [1]. In this digital era, telecommunications infrastructure plays a crucial role in supporting connectivity and data communications. ODC (Optical Distribution Cabinet) is an integral part of the telecommunications infrastructure and is responsible for distributing optical signals to various points on the network[2][3].

ODC maintenance and monitoring are critical to ensure optimal availability and performance. Traditional monitoring systems often require complex and expensive cable infrastructure and are difficult to implement in hard-to-reach areas[4].

The Internet is set to interact with electronic devices in the globalization period, facilitating human activities through a phenomenon called the Internet of Things (IoT) [5]. IoT is a technology where all the activities of the actors interact with each other via the Internet. Applications to IoT can assist in the identification, discovery, tracking, object monitoring, and automatic and real-time event triggers [6].

LoRaWAN is a LoRa-modulated Low Power Wide Area Network (LPWAN) technology that includes a communication protocol and system architecture for LoRa physical layer temporary networks, allowing for remote communication coverage [7]. This innovation enables a multitude of devices to engage in wireless communication across extensive distances, typically ranging from 5 to 15 kilometers, contingent upon the prevailing propagation conditions, and it operates at low data rates [8].

LoRa has a unique modulation format acquired by Semtech with Chirp Spread Spectrum (CSS) modulation with the option to add different Spreading Factors and bandwidths to optimize the modulation to meet the range and data requirements so that it can cover a wide area [9].

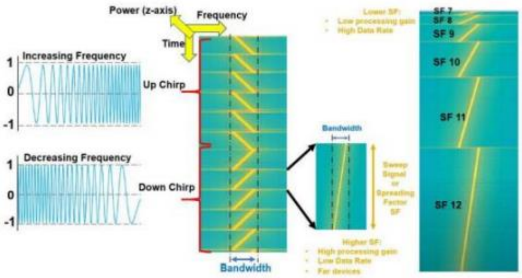

Figure 1. LoRa Chirp Spread Spectrum Illustration [10]

LoRa Chip chirps are classified into two types: up-chirps, which have an increased frequency from low to high, and down-chirps, which have a lowered frequency from high to low. This technology offers a substantial advantage by ensuring temporal and frequency synchronization between the transmitter and receiver, resulting in a significant simplification of the receiver architecture. The frequency bandwidth of this chip closely matches the spectral bandwidth of the signal. Higher data rates are used to extract information-carrying data signals from the end device to the Gateway, which are then modulated onto the chirp carrier signal. Furthermore, the LoRa modulation includes a variable error correction method, which improves the signal's durability. For every four bits of transmitted information, an extra fifth bit containing parity information is appended [10].

LoRaWAN certainly has an architecture to support its design system. There are four parts to the LoRaWAN architecture, namely End Device, Gateway, Network Server, and Application Server.

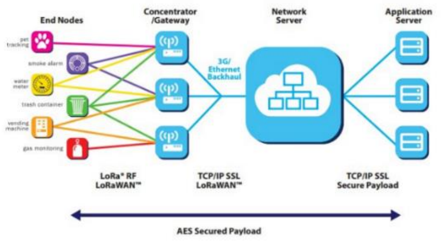

Figure 2. LoRaWAN Architecture [11]

The LoRaWAN network is constructed with a star-to-star topology, enabling devices to operate on battery power for an extended duration compared to the mesh network topology [11]. As depicted in Figure 1, the LoRaWAN architecture comprises a Device, Gateway, Network Server, and Application Server. The Gateway's role is to transmit data from the device to the network server.

It is important to distinguish between LoRa and LoRaWAN. LoRa refers to the physical layer (PHY), which is the wireless modulation utilized in long-distance communications. LoRaWAN, on the other hand, provides mobile, standardized localization and secure two-way communication over an open network protocol. The LoRa Alliance is in charge of managing LoRaWAN [12].

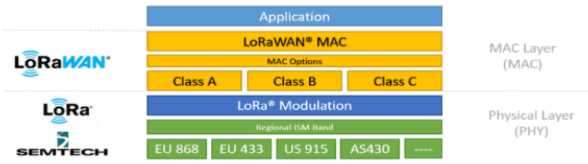

Figure 3. LoRaWAN Layers [13]

Figure 3 illustrates how LoRa operates at the physical layer, which is where factors like frequency and modulation are used because LoRaWAN operates at the MAC Layer. There are three classes, each with benefits and drawbacks.

Table 1 shows the LoRa received signal strength index (RSSI) standard, where practically the range of -90 to -110 dBm is acceptable.

Table 1. RSSI Signal Level [14]

RSSI (dBm)	Information
-30 to -60	**Very strong**: The transmitter and receiver distance is very close
-60 to -90.	**Very good**: Close coverage
-90 to -105	**Good**: Some data are not accepted.
-105 to -115	**Bad**: Can accept but often drop out
-115 -120	**Very bad**: Weak signal data is often lost.

The objective of this research is to oversee the ODC devices within PT. Telkom WITEL

Bandung, to optimize its application, the design of a LoRaWAN network is imperative to determine the required number of gateways essential for comprehensive coverage of all ODCs within the research area. This network serves as a communication infrastructure connecting sensors and servers, facilitating the seamless transmission of data [15]. In this design, the Atoll application v 3.4.0 is employed, along with multiple calculation stages, to anticipate RSSI and SINR by considering parameters such as bandwidth, frequency, and spreading factor.

METHODS

In this work, simulation with Atoll software 3.4.0 was used to build a coverage design and examine parameters such as the number of gateways, Spreading Factor, SNIR, and RSSI. Before the simulation can begin, important information such as the size of the study region, the link budget, and the required computations must be gathered.

A. Flowchart and Research Areas

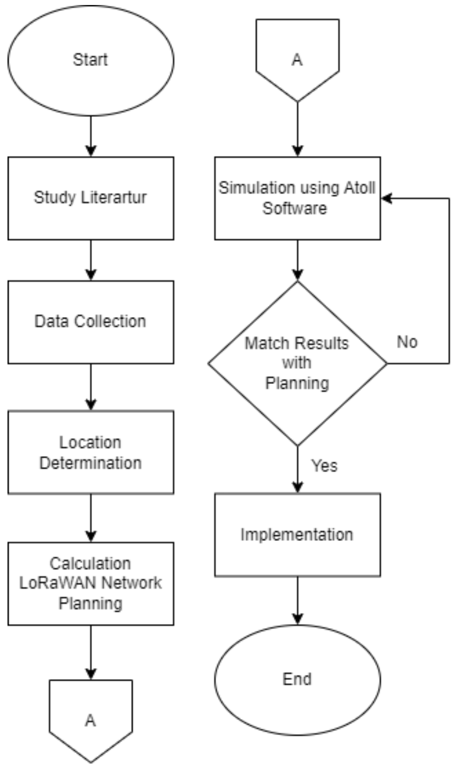

Figure 4. Flowchart LoRaWAN Network Planning

The flowchart is to provide an overview of the workflow or process. The process is illustrated through a chart or symbol so that the information presented is easier to understand. This flowchart illustrates how the system process is offered.

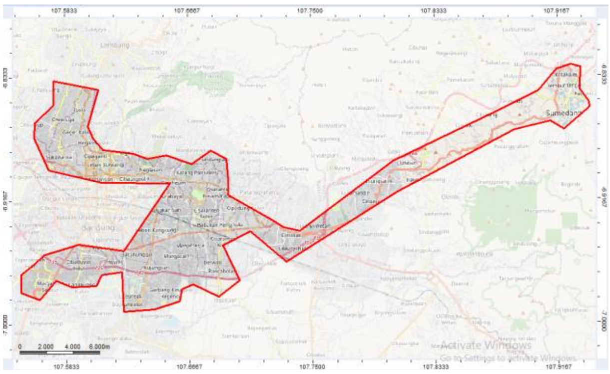

Figure 5. Research Areas

Figure 5 is a research area to cover all ODC at Witel Bandung. The total area of this research area is 188.96 km^2.

B. LoRaWAN Network Planning

A link budget and calculations are necessary to estimate that 188,96 km2 of gateways are required to cover all planning areas in order to plan the LoRaWAN network.

Table 2. Link Budget [16]

Parameter	UL	DL
Tx-Power (dBm)	15	20
Tx-Cable loss (dB)	-1	-3
T x-Antenna Gain (dB)	0	9
Tx-Antenna Height (m)	30	
RX-Antenna gain diversity (dBi)	10	0
Rx-Antenna Height (m)	1,5	
Frequency (MHz)	920	
Bandwidth (kHz)	125	

The link budget computation is required to determine the signal power loss between the Gateway and the end device in order to maximize the coverage area at the site [17].

The calculation of LoRa sensitivity relies on the Spreading Factor and Signal-to-Noise

Ratio (SNR), with the sensitivity calculation outlined as follows:

Table 3. LoRaWAN sensitivity

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

$$\text{Sensitivity} = -174 + 10\,log(BW) + NF + (-\,SNR\ limit)$$

The Noise Figure utilized in LoRaWAN technology is 6 dB[18].

The maximum permitted attenuation between the LoRa gateway and the end device must be determined using MAPL [19]. The following are the formulas used to determine MAPL and EIRP:

$$EIRP = Tx\ Power + Gain\ Antenna\ Tx - Loss\ Cable$$

$$MAPL = EIRP - Sensitivity$$

Table 4. EIRP Value

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

Table 5. MAPL Value

Spreading Factor	MAPL Downlink (dBm)
7	151,00
8	153,00
9	156,00
10	158,00
11	161,00
12	163,00

The cell radius is used to calculate the coverage area or coverage at a single location. The Okkumura Hatta model was used in the design of the LoRaWAN network with a frequency spectrum of 920 MHz. The LoRaWAN network radius cell value can be calculated using the MAPL value [20]. The following equation is used to determine the path loss:

$$PL = 69.55 + 26.16\,log(f) - 13.82\,log\,hb - a(hm) + (44.9 - 6.55 loghb)\,log10\,d$$

$$a\,(hm) = (1.1\,log10(f) - 0.7)hm - (1.56\,log10(f) - 0.8)$$

Table 6. Cell Radius

Spreading Factor	a(hm)	Cell Radius (km)
7	0,0167	4,91148
8		5,5975
9		6,8102
10		7,7603
11		9,4325
12		10,7499

Once the calculation for cell radius is acquired, the subsequent phase involves determining the area that a single LoRa gateway site can cover. This involves figuring out how many gateways there are [21]. The following equation is used to determine the cell area:

$$LCell = \frac{3\sqrt{3d^2}}{2}$$

Table 7. Cell Area

Spreading Factor	Cell Area (km^2)
7	12,76040826
8	14,54262009
9	17,69333875
10	20,16192356
11	24,50641348
12	27,9291582

The following formula can be used to determine the number of gateways:

$$Number\ of\ Gateways = \frac{Research\ Area}{Cell\ Area}$$

Table 8. Number of Gateway

Spreading Factor	Number of Gateway
7	15
8	13
9	11
10	9
11	8
12	7

RESULT AND DISCUSSION

This research will make use of the Atoll 3.4.0 software, SF 10, and a downlink method. According to the calculated outcomes, to provide coverage for all Optical Distribution Cabinets (ODCs) in Witel Bandung, consisting of 44 ODCs, a total of 9 LoRa Gateways are needed.

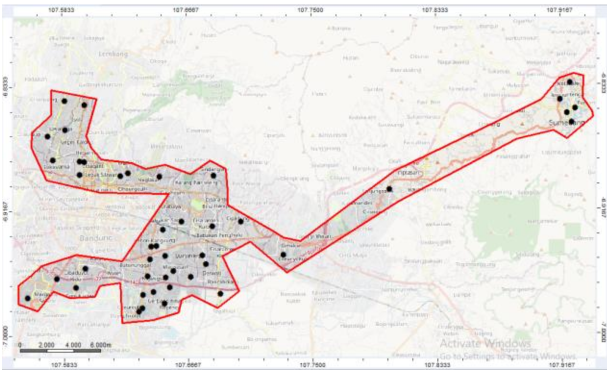

Figure 6. ODC location

This research analysis focuses on two key parameters: RSSI and SINR. RSSI serves as a metric for gauging the strength of the received signal. At the same time, SINR represents the ratio between the signal strength emitted by the primary signal and the interference relative to the background noise.

A. Received Signal Strength Indicator

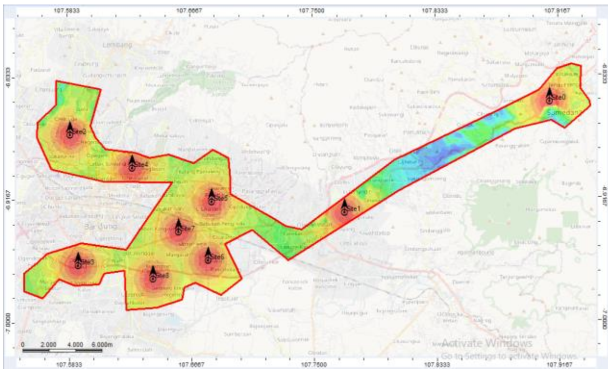

Figure 7. RSSI Prediction Result

The Gateway's location and the results of the simulations performed with respect to the RSSI parameters are shown in Figure 7. The signal level prediction, based on SF 10, indicates the requirement for nine gateways. This prediction allows the observation of the RSSI histogram value.

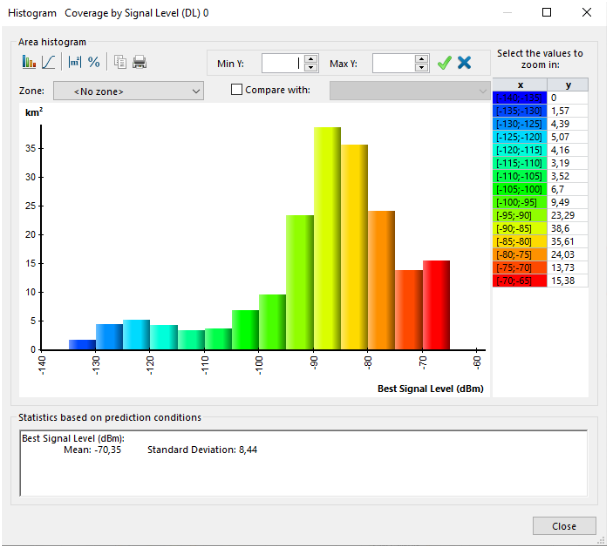

Figure 8. Histogram of RSSI

Figure 8 displays the histogram of RSSI values, showcasing the resultant data. The obtained RSSI is -70.35 dBm, and the standard deviation is 8.44 dBm, indicating its classification within the "good" category.

B. Signal-to-Interference Noise Ratio

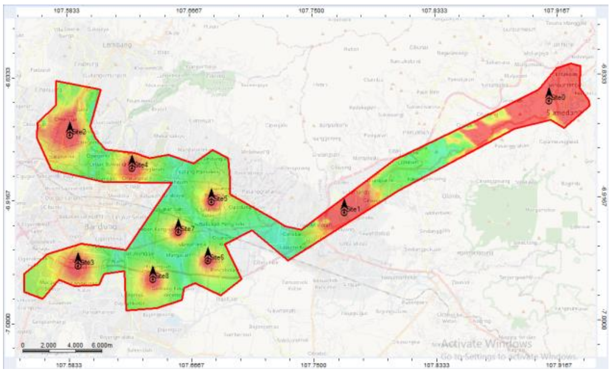

Figure 9. SINR Prediction Result

Figure 9 illustrates the positioning of the Gateway and the simulations conducted concerning the SINR parameters. Based on the signal level prediction, nine gateways are required with SF 10. This prediction allows observation of the SINR histogram value.

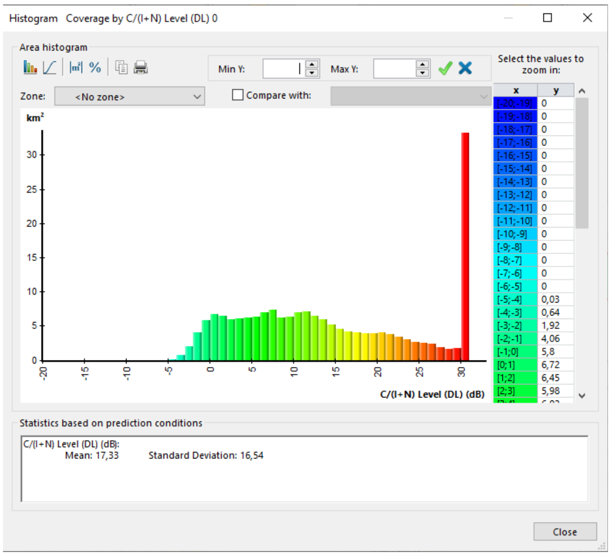

Figure 10. Histogram of SINR

Figure 10 presents the SINR histogram, displaying the resultant values. The achieved SINR is 17.33 dBm, and the standard deviation is 16.54 dBm, indicating its classification within the "good" category.

CONCLUSION

The simulation results for the LoRaWan network design were performed at a frequency range of 920-923 MHz for 44 ODCs at PT. Telkom Witel Bandung, within a planning area of 188.96 km2, indicates that the downlink scheme for the LoRaWAN planning necessitates the deployment of 9 LoRa gateways with an SF of 10. Based on the average values of -70.35 dBm for the RSSI parameter and 17.33 dBm for the SINR parameter, the simulation results are adequate. The limited number of gateways influences the choice of SF 10, which helps with cost-effective planning and produces results that are considered favorable.

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