# LoRaWAN Network Planning for ODP Door Monitoring in Banyumas Districts

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Abstract— This study aims to design a LoRaWAN network on the coverage side to find out how many gateways are needed and to design an IoT-based monitoring system at ODC doors to minimize damage due to vandalism or forced opening. The method used is a simulation using Atoll software version 3.40 and several stages of calculations to predict signal strength and quality in the Banyumas Regency area. This study uses a frequency of 920 MHz with a bandwidth of 125 kHz and a Spreading factor of 1 to 12. The results obtained are a comparison of the number of gateways, signal strength and signal quality based on variations in the spreading factor. SF 7 produces 104 gateways with a signal strength of -71.88 dBm and a signal quality of 9.43 dBm. spreading factor. SF 12 produces 48 gateways with a signal strength of -79.8 dBm and a signal quality of 10.78 dBm. The larger the SF used will improve signal quality but reduce signal strength and also fewer gateways.

Keywords— LoRaWAN, Planning Coverage, Spreading Factor, Monitoring

## 1. Introduction

In the current era of technological development, many common problems are found among the people, especially in big cities in Indonesia [1]. One of the common problems that occur today is vandalism [2]. Such as the case of vandalism in the Purwokerto square, Banyumas Regency, Central Java [3]. There are many irresponsible people who carry out vandalism and cause damage due to being forced to open one of the FTTH architectures, namely ODC (Optical Distribution Cabinet) which can damage fiber optic cables in that architecture [4]. This will result in a decrease in the quality of services provided to consumers. To anticipate and minimize the occurrence of these problems, a system for monitoring the ODC door is needed so that it can be monitored in real-time in case of damage.

Now in the era of globalization, the internet will synergize with electronic devices to help human activities. This is called the Internet of Things (IoT) [5]. IoT was developed to support human activities to be more effective and efficient [6]. Lora technology is a development technology from IoT, namely LPWAN (Low Power Wide Area Network) which has the advantage of being able to optimize battery life so that the power is also low, the lowest data rate is 27 kb/s with a spreading factor of 7 and 500 kHz or 50 kb channels. /s with FSK, has a bandwidth of 125 kHz, and has a communication coverage of 2-5 km in urban areas and 15 km in sub-urban areas [7]. LoRaWAN is a communication protocol and system architecture for networks while LoRa's physical layer enables long-distance communication coverage [8].

To maximize its implementation, it is necessary to design a LoRaWAN network on the coverage side to find out how many gateways are needed as a means of communication between sensors and servers in the data transmission process [9]. This design uses Atoll software version 3.4.0 and several calculation steps to predict signal strength and quality in Banyumas Regency based on parameters such as frequency, bandwidth, spreding factor, RSSI and SINR.

## 2. Literature Review

In a study conducted by [10], a system design was built to monitor air quality using lora communication based on a wireless sensor network. This system makes it easier for users to find out if there is an increase in air pollution in a place. From the test results, this system is able to perform sensor readings according to the datasheet and is able to send data to a web application using LoRa communication up to a distance of 300 meters and a packet loss ratio of 0%.

In a study conducted by [11], analyzed how the comparison of packet loss and signal strength with distance with the LOS (Line of Sight) scheme in urban areas. The results obtained are the maximum range received as far as 2 km, from this study, signal strength decreases and packet loss increases with each increase in distance.

In a study conducted by [6], LoRaWAN network design was carried out to find out how many gateways were needed in the city of Bandung as one of the big cities in Indonesia and almost all parts of the city including the urban area. The analysis is carried out by comparing the results of the parameters on each spreading factor to predict the strength and quality of the resulting signal.

In research conducted by [12], it is explained that to maximize the implementation of smart metering in the industrial area of the Karawang area, LoRaWAN network planning is needed to find out how many gateways are needed to cover all areas in the area. This study uses Atoll software to predict signal strength and quality in the area.

Based on previous research, this study designed a LoRaWAN network using Atoll software version 3.4.0 to predict signal strength and quality in the Banyumas district as one of the LPWAN technologies to implement a monitoring system on LoRaWAN network-based ODC.

## 3. Method

The method used in this research is a simulation using Atoll software version 3.4.0 to design coverage in analyzing the comparison of the parameters of Spreading factor, SNR, RSSI, and the number of gateways. Before conducting the simulation, data are needed such as the area of the research area, link budget, and calculations.

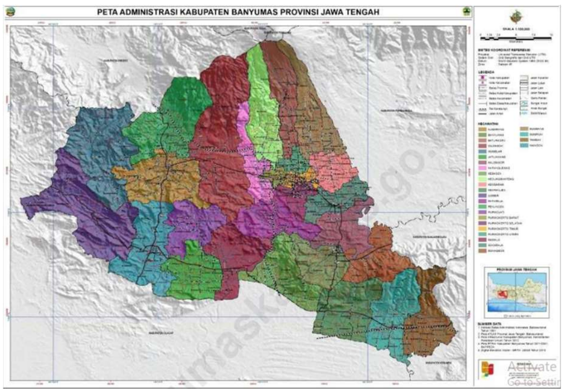


Fig. 1 Banyumas Regency Map [13]

Banyumas Regency is a medium-sized city with an area of about 1,328 km2 with a population of 1,776,918 million in 2020 and has 27 sub-districts based on data from the Central Statistics Agency for Banyumas Regency. [14].

The link budget calculation is required to calculate the signal power loss between the gateway and the end device to get the maximum coverage area per site [6].

### *3.1. Calculating LoRa . Sensitivity Value*

Table 1. Link Budget [12]

| 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) | 920 | |
| *Bandwidth* (kHz) | 125 | |

LoRa sensitivity calculation is based on Spreading Factor and SNR, where the sensitivity calculation is as follows:

Table 2. LoRaWAN sensitivity

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

$$Sensitivitas\ SF = -174 + 10\log(BW) + 6 + (-SNR\ limit)$$

### *3.2. Maximum Allowable Path Loss (MAPL)*

MAPL is required to find out the highest value of attenuation allowed between the LoRa gateway and the end device [15]. The EIRP and MAPL calculation formulas are as follows:

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

$$MAPL\ (UL/DL) = EIRP - Sensitivity$$

Table 3. EIRP Value

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

Table 4. MAPL Value

| *Spreading Factor* | MAPL *Downlink* (dBm) | MAPL *Uplink* (dBm) |
|---|---|---|
| 7 | 151,00 | 139,00 |
| 8 | 153,00 | 141,00 |
| 9 | 156,00 | 144,00 |
| 10 | 158,00 | 146,00 |
| 11 | 161,00 | 149,00 |
| 12 | 163,00 | 151,00 |

### *3.3. Calculating Cell Radius using Propagation Model*

The propagation used in this coverage planning is Okumura Hatta propagation. This model is used to determine pathloss in the frequency range of 150 MHz to 1500 MHz, the cell radius is 1-20 km, the transmitter antenna height is 30-200 m, and the terminal antenna height is 1-10 m.[6]. The equation used to calculate the pathloss is as follows:

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

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

Table 5. Cell Radius

| *Spreading Factor* | a(*hm*) | *Cell Radius* (km) | |
|---|---|---|---|
| | | *Downlink* | *Uplink* |
| 7 | 0,0167 | 4,91148 | 2,241527899 |
| 8 | | 5,5975 | 2,551802035 |
| 9 | | 6,8102 | 3,104660478 |
| 10 | | 7,7603 | 3,542154177 |
| 11 | | 9,4325 | 4,30486301 |
| 12 | | 10,7499 | 4,906111623 |

### *3.4. Calculating Cell Area*

After getting the cell radius (d) value, it is necessary to calculate the cell area at the gateway to get the required number of gateways. The equation used to calculate the cell area is as follows:

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

Table 6. Cell Area

| *Spreading Factor* | *Cell Area* DL (km2) | *Cell Area* UL (km2) |
|---|---|---|
| 7 | 12,76040826 | 5,823660312 |
| 8 | 14,54262009 | 6,629776164 |
| 9 | 17,69333875 | 8,066144531 |
| 10 | 20,16192356 | 9,202786504 |
| 11 | 24,50641348 | 11,18436218 |
| 12 | 27,9291582 | 12,7464519 |

### *3.5. Counting Number of Gateways*

The formula for calculating the number of gateways is as follows:

$$Number\ of\ Gateways = \frac{An\ area}{Cell\ Area}$$

Table 7. Number of Gateway

| *Spreading Factor* | Number of *Gateway* DL | Number of *Gateway* UL |
|---|---|---|
| 7 | 104 | 228 |
| 8 | 91 | 200 |
| 9 | 75 | 165 |
| 10 | 66 | 144 |
| 11 | 54 | 119 |
| 12 | 48 | 104 |

## 4. Result and discussion

Planning this research using Atoll software with SF 7 to SF 12 with a downlink scheme. Based on the calculation results, the number of data transmission gates generated in Banyumas Regency with the highest total gateway using SF 7 is 104 and with the least total gateway using SF 12 is 48.

### *4.1 Gateway placement*

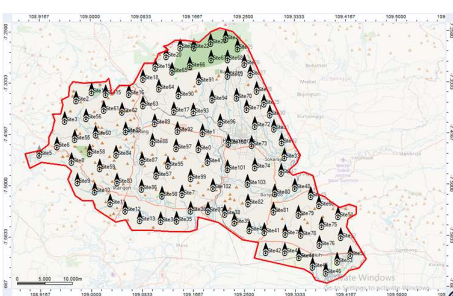

Fig 2. Spreading factor 7

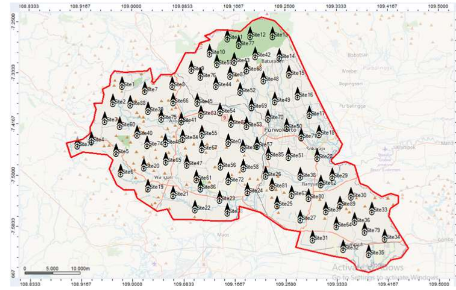

Fig 3. Spreading factor 8

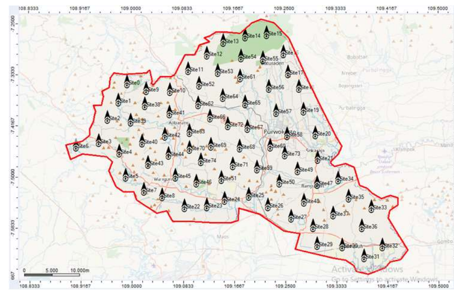

Fig 4. Spreading factor 9

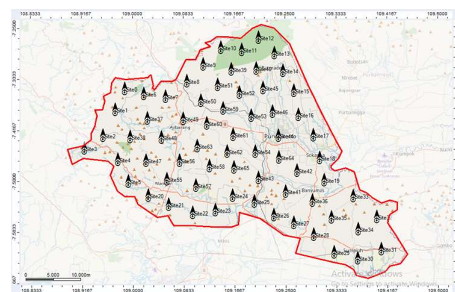

Fig 5. Spreading factor 10

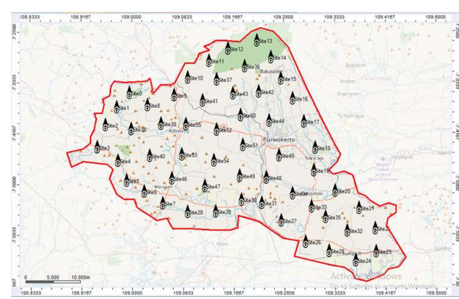

Fig 6. Spreading factor 11

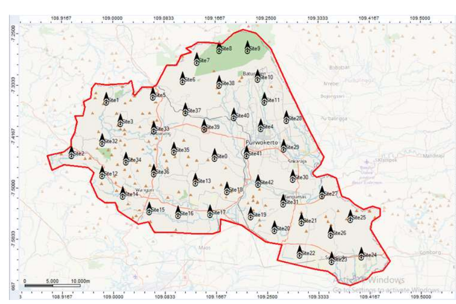

Fig 7. Spreading factor 12

### *4.2 Effective Signal Analysis*

This parameter is used to view or predict the signal strength sent from the Gateway to the End Device. The following is the result of the signal strength based on the spreading factor 7 to the spreading factor 12 after performing the simulation.

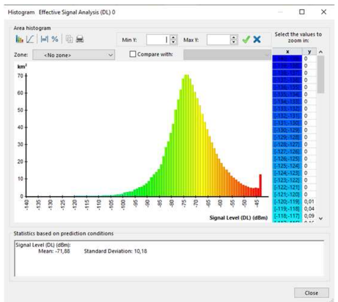

Fig. 8 Histogram Spreading factor 7

The simulation results show the placement with the number of gateways used is 104. In the histogram generated, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -71.88 dBm with a standard deviation of 10.18 dBm, which means it is in the good category.

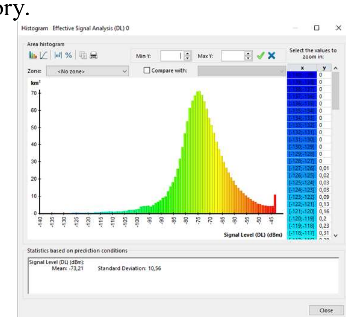

Fig. 9 Histogram Spreading factor 8

The simulation results show the placement with the number of gateways used, namely 91. In the histogram generated, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -73.21 dBm with a standard deviation of 10.56 dBm, which means it is in the good category.

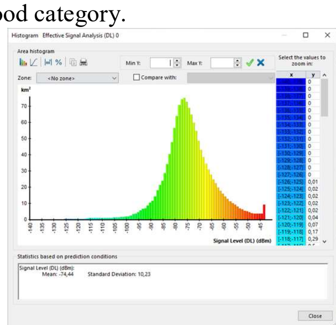

Fig. 10 Histogram Spreading factor 9

The simulation results show the placement with the number of gateways used is 75. In the resulting histogram, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -74.44 dBm with a standard deviation of 10.23 dBm, which means it is included in the good category.

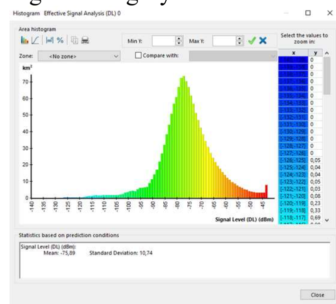

Fig. 11 Histogram Spreading factor 10

The simulation results show the placement with the number of gateways used, namely 66. In the histogram generated, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -75.89 dBm with a standard deviation of 10.74 dBm, which means it is in the good category.

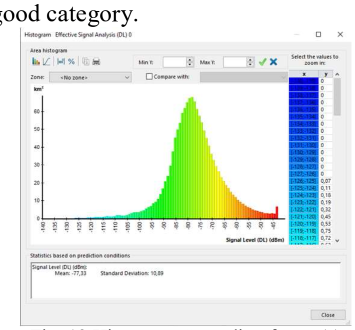

Fig. 12 Histogram Spreading factor 11

The simulation results show the placement with the number of gateways used is 54. In the histogram generated, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -77.33 dBm with a standard deviation of 10.89 dBm, which means it is in the good category.

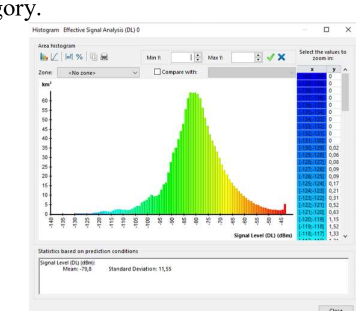

Fig. 13 Histogram Spreading factor 12

The simulation results show the placement with the number of gateways used is 48. In the histogram generated, the values on the x-axis to indicate the signal strength are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is -79.8 dBm with a standard deviation of 11.55 dBm, which means it is in the good category.

*4.3 Signal to Noise Ratio*

This parameter is used to view or predict the quality of the signal sent from the Gateway to the End Device. The following are the results of signal quality based on a spreading factor of 7 to a spreading factor of 12 after performing the simulation.

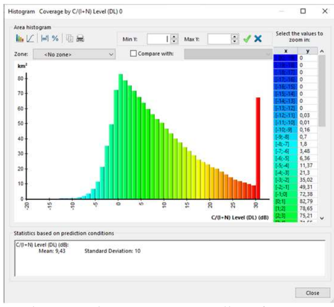

Fig. 14 Histogram Spreading factor 7

The simulation results show the placement with the number of gateways used is 104. In the histogram generated, the values on the x-axis to indicate the quality of the signal are generated and on the y-axis to indicate the distance in square kilometers. The resulting signal strength is 9.43 dBm with a standard deviation of 10 dBm, which means it is in the good category.

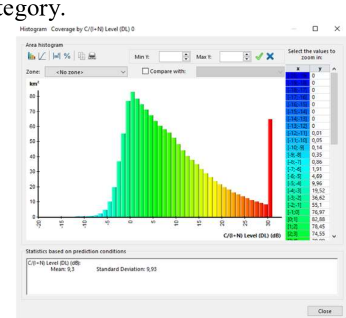

Fig. 15 Histogram Spreading factor 8

The simulation results show the placement with the number of gateways used, namely 91. In the histogram generated, the values on the x-axis to indicate the quality of the signal are generated and on the y-axis to indicate the distance in square kilometers. The resulting signal strength is 9.3 dBm with a standard deviation of 9.93 dBm, which means it is in the good category.

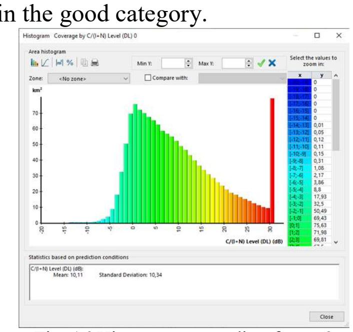

Fig. 16 Histogram Spreading factor 9

The simulation results show the placement with the number of gateways used is 75. In the histogram generated, the values on the x-axis to indicate the quality of the signal are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is 10.11 dBm with a standard deviation of 10.34 dBm, which means it is in the good category.

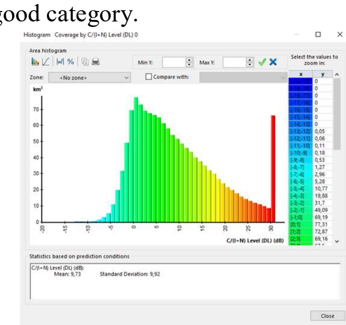

Fig. 17 Histogram Spreading factor 10

The simulation results show the placement with the number of gateways used, namely 66. In the histogram generated, the values on the x-axis to indicate the signal quality are generated and on the y-axis to indicate the distance in square kilometers. The resulting signal strength is 9.73 dBm with a standard deviation of 9.92 dBm, which means it is in the good category.

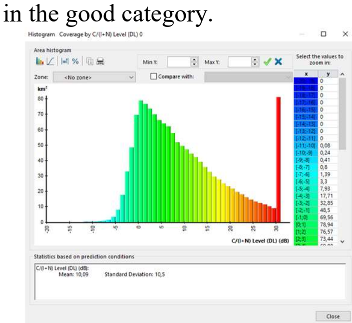

Fig. 18 Histogram Spreading factor 11

The simulation results show the placement with the number of gateways used is 54. In the histogram generated, the values on the x-axis to indicate the quality of the signal are generated and on the y-axis to show the distance in square kilometers. The resulting signal strength is 10.9 dBm with a standard deviation of 10.5 dBm, which means it is in the good category.

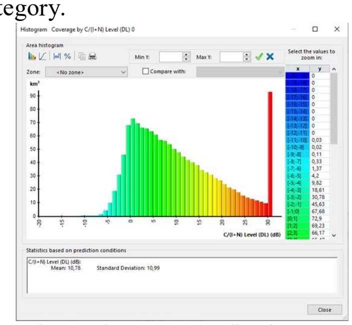

Fig. 19 Histogram Spreading factor 12

The simulation results show that the placement of the number of gateways used is different from the number of gateways on the spreading factor 7, which is 48. In the histogram generated, the values on the x-axis to indicate the signal quality are generated and on the y-axis to indicate the distance in square kilometers. The resulting signal strength is 10.78 dBm with a standard deviation of 10.99 dBm, which means it is in the good category.

Table 8 Downlink Schema Parameter Comparison

| *SF* | Sensitivity | MAPL (dBm) | *Cell Radius* (km) | *Cell Areal* (km) | Number of *Gateway* | Effective Signal (dBm) | Signal to Noise Ratio (dBm) |
|---|---|---|---|---|---|---|---|
| 7 | -125 | 151,00 | 4,91148 | 12,76040826 | 104 | -71,88 | 9,43 |
| 8 | -127 | 153,00 | 5,5975 | 14,54262009 | 91 | -73,21 | 9,93 |
| 9 | -130 | 156,00 | 6,8102 | 17,69333875 | 75 | -74,44 | 10,11 |
| 10 | -132 | 158,00 | 7,7603 | 20,16192356 | 66 | -75,89 | 9,73 |
| 11 | -135 | 161,00 | 9,4325 | 24,50641348 | 54 | -77,33 | 10,9 |
| 12 | -137 | 163,00 | 10,7499 | 27,9291582 | 48 | -79,8 | 10,78 |

## 5. Conclusion

Based on the simulation of the LoRaWan network design at a frequency of 920-923 MHz for monitoring ODC in Banyumas Regency, it is concluded that LoRaWAN planning needs to use 104 gateways for the downlink scheme using a spread factor 7. With an average of -77.94 dBm for signal strength parameters and average 9.43 dBm for the signal quality parameter, this shows that the simulation results can be categorized as good. For a downlink scheme using a spreading factor of 12, it is necessary to use 48 gateways. With an average of -79.8 dBm for the signal strength parameter and an average of 10.78 dBm for the signal quality parameter, this shows that the simulation results can be categorized as good.

The difference when using the SF variation is that the greater the SF used, the signal strength will decrease while the signal quality will increase, the gateway used will be less but will increase the data transmission time and will also save costs because the number of gateways required is less. when compared to using a smaller SF.

Suggestions from this research are for the hope that in the future it can make LoRaWAN network planning in terms of capacity or can be called Capacity Planning to find out the data rate and also the total end devices that can be covered by the gateway.

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