Spreading Factor of IoT-LoRa Effect for Future Smart Agriculture

Puput Dani Prasetyo Adi
Telecommunication Research Center
National Research and Innovation Agency (BRIN-RI)
Bandung, Indonesia
pupu008@brin.go.id, ORCID: 0000-0002-5402-8864

Agoestina Mappadang
Faculty of Economics and Business
Budi Luhur University
Jakarta, Indonesia
agustina.mappadang@budiluhur.ac.id
ORCID: 0000-0002-5813-8438

Abdul Wahid
Informatic and Computer Engineering department
Universitas Negeri Makassar
wahid@unm..ac.id
ORCID: 0000-0002-0439-6140

Seny Luhriyani
English Department
Universitas Negeri Makassar
Makassar, South Sulawesi, Indonesia
senyluhriyanifbs@unm.ac.id

Riny Jefri
English Department
Universitas Negeri Makassar
Makassar, South Sulawesi, Indonesia
riny.jefri@unm.ac.id, ORCID:0000-0002-1016-7870

Nurindah Nurindah
Research Center for Horticulture and Estate Crops
National Research and Innovation Agency (BRIN-RI)
Jakarta, Indonesia
nurindah@brin.go.id, ORCID:0000-0003-4389-0261

***Abstract*—Agricultural Technology continues to grow rapidly, development towards IoT is currently increasingly widespread with the use of WiFi modules such as ESP32, 8266, or Node32, using the Blink GUI that is already available on Google Play, and monitoring systems that are currently being carried out such as tomatoes, chilies, even rice fields such as rice and shallots and garlic are still conventional, especially locations close to settlements will be very vulnerable to water pollution, namely the presence of household waste that can pollute agricultural water; specifically, this paper focuses on the Spreading Factor of LoRa, which is found at several points in agricultural locations, and the impact generated by the server, whether there is attenuation or packet data loss that causes small throughput. Research results found that on the spreading factor 7, the occupied Bandwidth is 130,676 kHz, while in SF 12, the occupied Bandwidth is 123,323 kHz. Research hopes that agricultural yields can be increased more than the conventional method, at least in balance with this method.**

Keywords— lora, modulation, Adaptive Data Rate, lorawan, agriculture, monitoring, Spreading Factor, IoT

I. INTRODUCTION

In smart farming, specifically conventional agriculture, detailed agricultural inputs must be determined before being integrated into the monitoring systems. These include the biotic and abiotic components, such as the crop type, cultivation system, and all agroclimatic information about the location of crop cultivation. When these inputs have been integrated to the system and necessary acts executed accordingly, a successful farming would be obtained. Meanwhile, artificial farming by setting all factors of plant to grow optimally, especially the plant requirement for nutrition and environmental conditions [1]-[5] in the plant growth monitoring system, would make the artificial farming gives similar result as the conventional one.

Nowadays, the agricultural sector faces the availability of land for farming due to the increasing human population that needs to use the agricultural lands for building houses [6]-[10]. As a result of this land-use transformation, there are plenty of agricultural lands that are located close to the community houses. This situation could affect agricultural inputs, such as water, that might be polluted by household wastes. Furthermore, the polluted water might be able to be detected by the monitoring system, and then the input could affect the performance of the system to process the data and give the output.at this time, LoRaWAN continues to show its fangs in the world of competition for Wireless Sensor Network (WSN) devices for Agriculture; the growth of LoRaWAN from time to time until 2023 continues to rise until it reaches 730.69 (million) in that year. And LoRa solves not only agricultural problems but also other problems such as smart-city, healthcare, and other sectors.

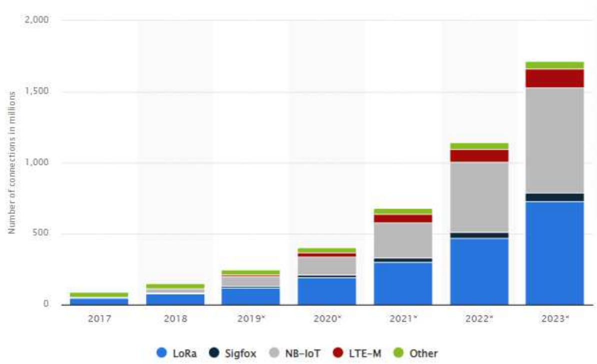


Fig. 1 Comparison of Quantity LoRaWAN and another device of WSN

Long Range Wide-Area Network (LoRaWAN) is now being an influential Wireless Sensor Network (WSN) devices for utilization on smart management in agriculture, city healthcare and many other sectors [11]. The need for Low Power Wide-Area Network (LPWAN) was projected steadily increases from 2017 to 2023 [Fig.1], and the use of LoRaWAN is dominant among the other such networks like Sigfox, NB-IoT and LTE-M [12], Communication system in LoRa can transmit data [13],[14] as far as > 15 km on the Line-of-Sight position. Maximizing the distance upto 15 Km under LOS conditions would be possible by increasing the Tx Power or making a signal amplifier antenna such as a Wbolic placed in a building. Comparing 3G/4G/5G to LoRa transmission power for an RF device, as shown on Table 1, 3G/4G/5G would transmit to a distance of 5 km with a transmission power of 5,000 mW or 5 Watt, while LoRa only required 20 mW [15]-[19]. LoRa type 915 MHz, e.g., Dragino LoRa [Table 3] and Gateway LG01-P. LoRA used an RF96 chip with Effective Bitrate up to 37.5 kbps; the dynamic RSSI at 127 dB; and the modulation type were similar to those of FSK, GFSK, MSK, GMSK, and OOK.

II. Method

A. *LoRa for Agriculture*

The specification of LoRa provides it ability to be used in the agriculture monitoring system.

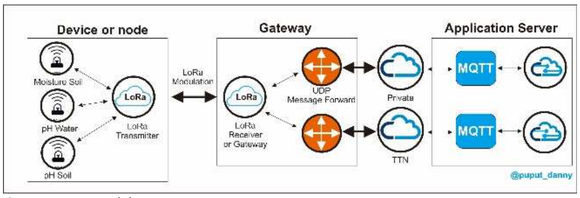


Fig. 2. LoRa Architecture

TABLE I. RF DEVICE COMPARISON

Technology	Parameter			
	Wireless Communication	Range	Tx Power (mW)	Tx Power (dBm)
Bluetooth	Very Short Range	10 m	2.5	4
WiFi	Short Range	50 m	80	19
3G/4G/5G	Long Range	5 km	5000	37
LoRa	Long Range	2-5 m (urban) 5-15 (rural) >15 km (LOS)	20	13
NB-IoT	Short Range (indoor coverage)	10 m	200	23
Cat-M1	Long Range	10 m	100	20

A block diagram of the LoRa Communication system in Fig.1 shows the three essential parts of the system, i.e., End Node, Gateway, and Application Server on the sensor node; several connected sensors for detecting soil moisture, pH, and water content. A gateway is a communication link from LoRa Receiver to the Application server via Private or TTN [Fig.2]. The objective of this study was to evaluate the effect of agricultural location and it's monitoring systems to the communication server to interpret the received data.

TABLE II. RF96 SPECIFICATION

No	Specifications	Value of Spesification
1	Frequency_Range (MHz)	137-1020 MHz
2	Spreading Factor (SF)	6-12
3	Bandwidth (kHz)	7.8-500 kHz
4	Effective Bitrate (bps)	0.18-37.5 kbps
5	Estimation Sensitivity (-dBm)	-111 to -148 dBm

Furthermore, in table 4, SF specifications are compared to the value of Sensitivity and Time on Air. It can be seen in the data that if the SF is small, then the sensitivity is also getting smaller, or in SF 7, the sensitivity value is -123 dBm, but in SF 12, the sensitivity reaches -137 dBm. While the ToA SF 7 is 41 ms, SF 12 is 991 ms, indicating that the location of the SF 7 point shows the closest distance between TX and Rx, while SF 12 is the farthest distance between Tx and Rx.

TABLE III. DRAGINO LORA 915 MHZ SPESIFICATION

No	Specification	Value of Spesification
1	Link Budget	168 dB
2	Constant RF Output	+20 dBm – 100 mW
3	High-efficiency PA	+14 dBm
4	Programmable bit rate	300 kbps
5	High sensitivity down to	-148 dBm
6	Bullet-proof front end: IIP3	-12.5 dBm
7	Low RX current	10.3 mA
8	Fully integrated synthesizer Resolution	61 Hz
9	Modulation type	FSK, GFSK, MSK, GMSK, LoRaTM and OOK
10	Dynamic Range RSSI	127 dB
11	Packet engine with CRC	256 bytes

TABLE IV. SF, DATA RATE, SENSITIVITY, AND TOA COMPARISON

No.	Parameter		
	Data Rate (Spreading Factor)	Sensitivity (-dBm)	ToA (ms)
1	SF7	-123	41
2	SF8	-126	72
3	SF9	-129	144
4	SF10	-132	288
5	SF11	-134.5	577
6	SF12	-137	991

There are three classes in LoRaWAN as shown in Fig. 3, i.e., class A, class B, and class C, where the difference is in the Tx and Rx transmission time or Tx delay (Table III). Furthermore, SF Specifications on Table IV shows that the smaller value of SF results in a smaller sensitivity value. For example, in SF 7, the sensitivity value is -123 dBm, but in SF 12, the sensitivity reaches -137 dBm.

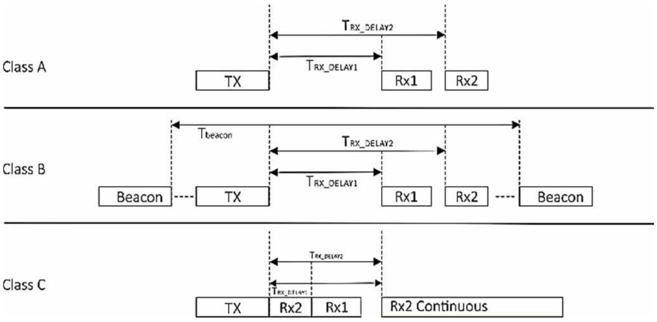


Fig. 3. LoRaWAN class

While in ToA SF 7 is 41 ms, SF 12 is 991 ms, indicating that the location of the SF 7 point shows the closest distance between TX and Rx, while SF 12 is the farthest distance between Tx and Rx. The method used is to increase the battery power at the sensor node utilizing the effectiveness of the Energy or Power [20]-[25] from the Power PTx transmission, which is continuously issued by the Tx or end node during data transmission (bytes). It can be seen that the Bit rate is formulated as equations (1) and (2), where the Bit Rate (Rb) is the product of the Spreading Factor, Bandwidth, and Chip Rate.

$$R_B = SF \times BW/2\text{^}SF*CR \quad (1)$$

$$R_b = SF \times (4/(4+CR))/2\text{^}SF/BW*1000 \quad (2)$$

$$ToA \text{ or } T_{Packet} = T_{Preamble} + T_{Payload} \quad (3)$$

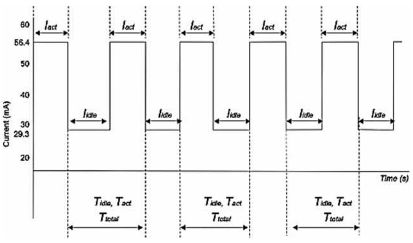


Fig. 4. Normal Transmit data

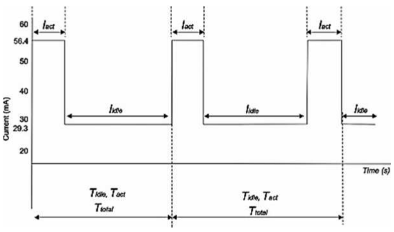


Fig. 5. Modifiy Transmit Data

Fig. 4 illustrates the delay (ms), for example, 1000 ms set in the transmission code (Tx). While Fig.5 is an attempt to add delay to, for example, 3000 ms, so the Current (mA) can be held for a long time at 30 mA if the data transmission condition is 60 mA. Of course, the greater the power consumption, the faster the battery will run out. From this experiment, the Power can last using a Lipo Battery capacity of 700 mAH for up to 16 hours, while 1000 mAH for 23 hours as shown in Fig. 6.

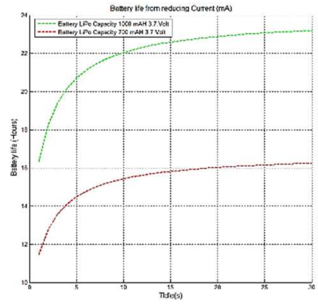


Fig. 6. Battery life (hours) of modification delay

Fig. 7 is the resulting prototype. The relay used is a 6-channel relay that functions to connect to several sensors at once, i.e., Ultrasonic sensors, pH water sensors, and turbidity sensors, this is an attempt to get complex data on the internet or application servers. while the LoRa used is the Dragino 915 MHz type which communicates with the Dragino LG01-P Gateway.

III. Result and Discussion

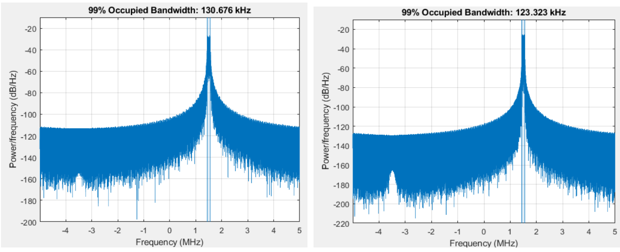
The type of plant planted is Pakcoy [Fig.8], which is given a narrow planting area with the kind of soil, e.g., husk. From the picture, it can be seen that Pakcoy can survive well and is ready to be harvested. This is an example of artificial planting using LoRa testing and several sensors that can automatically provide feedback if conditions are not as expected. For example, the temperature is too hot, the pH is too alkaline or alkaline, or the soil or husk has less than normal humidity.

Fig. 7. The Prototype of IoT devices

Fig. 8. Nozzle for automatic plant watering

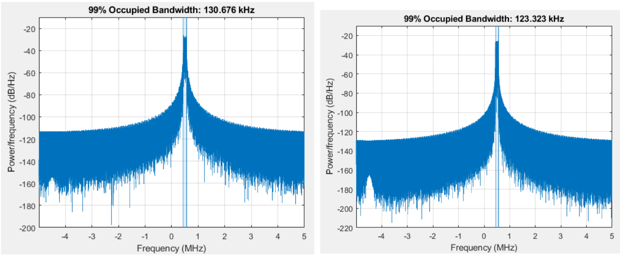
Furthermore, specifically in this study, we will discuss the use of LoRa Bandwidth, not specifically on the plant; this is to provide an appropriate title scope for this theme, i.e., the analysis of spreading factor, Bandwidth, and other parameters that determine the quality of Services of LoRa. Fig. 9 shows the LoRa test frequency of 920 MHz with SF 7

& 12 with a Bandwidth of 125 kHz with PTx 14 dBm on (a) and (b) the occupied Bandwidth 130 kHz on SF 7 and 123.3 kHz on SF 12.



(a) (b)

Fig. 9. LoRa 920 MHz Frequency analyzes SF 7&12, 125 kHz, PTx 14 dBm.



(c) (d)

Fig. 10. LoRa 915 MHz Frequency analyzes SF7&12, 125 kHz, PTx 14 dBm.

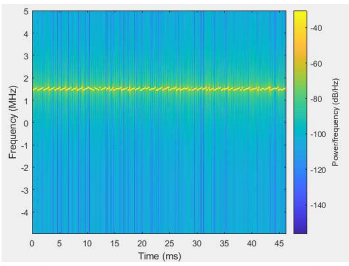


Fig. 11. Chirp signal LoRa 920 MHz Frequency analyzes SF7, 125 kHz, PTx 14 dBm.

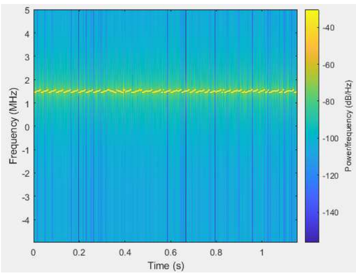


Fig.12 Chirp signal LoRa 920 MHz Frequency analyzes SF12, 125 kHz, PTx 14 dBm

While Fig.10 (c) is SF 7 at 915 MHz LoRa frequency which is 130.47 kHz bandwidth, and (d) is 915 MHz LoRa frequency at SF12 123.3 kHz bandwidth? Moreover, Fig.11 shows SF 7 takes 45 ms in the simulation; if it is changed to SF 12 [Fig.12], then the time required is 1 second. So, in this case, ToA is influenced by the magnitude of SF, as in equation 3. It's the same in Fig.13 and Fig.14, only the difference is in the LoRa frequency of 915 MHz.

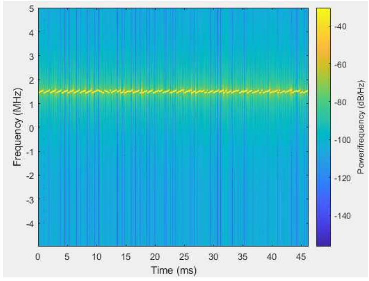


Fig. 13. Chirp signal LoRa 915 MHz Frequency analyzes SF7, 125 kHz, PTx 14 dBm

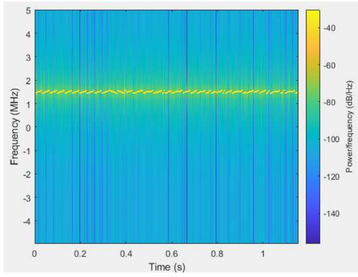


Fig. 14. Chirp signal LoRa 915 MHz Frequency analyzes SF12, 125 kHz, PTx 14 dBm

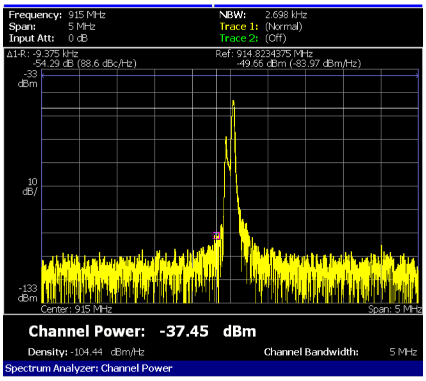


Fig. 15. Signal Power (-dBm) of LoRa 915 MHz realtime use signal analyzer Textronix RSA

The Power of the LoRa signal is shown in Fig. 15; this signal is viewed using a real-time signal analyzer from the transmission data using the LoRa module. The farther the distance from Tx and Rx, the weaker the Channel Power; this test shows a signal power of -37.45 dBm. Moreover, Fig.16 is the entire output displayed on the Internet server. (a) and (b) are water levels on channel_1 and channel 2, (c) and (d) are water level_3, and Turbidity 1, (e) and (f) Turbidity sensor value, and (g) and (h) are Turbidity 4 and pH sensor value. Moreover, Fig.17 shows 99% Occupied Bandwidth (kHz) and SF Comparison on different SF LoRa 7-12. On SF 7, it shows 130 kHz, while on SF 12, it is 123 kHz.

So the decrease in bandwidth value occurs if the SF increases. Furthermore, Table 4 compares SF, Tx, and 99% Occupied Bandwidth (kHz) of LoRa. As shown in Fig.17, the table shows the transmit power value is the same, i.e., 14 dBm. The decrease in occupied Bandwidth occurs when the SF increases.

Fig. 16. All sensors output in the Thingspeak Application Server

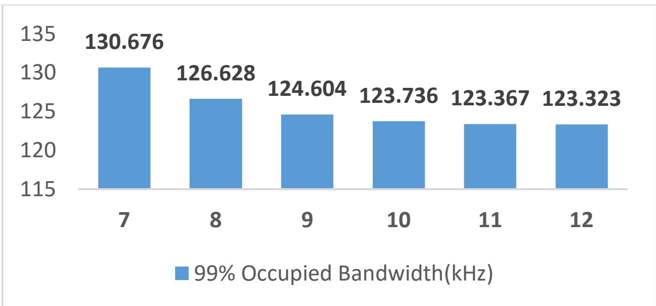


Fig. 17. 99% Occupied Bandwidth (kHz) and SF comparison

Moreover, Table 5 shows the ratio of SF and minimum Power/Frequency (dB/Hz). In this condition, using Power/Freq max (dB/Hz) is stable, namely -30 dB/Hz, but at Power/Freq min, there is a weakening that in SF 7 is -110 dB/Hz; therefore, in SF 12 Power/Freq min is -129 dB/Hz. Finally, in table 6, the comparison of SF 7-12 when compared to Time Chirps (s), with Power/Freq in Chrips (dB/Hz) stable at -75 dB/Hz, but Time Chrips shows an increase if SF increases, for example, SF 7 has a Time Chirps(s) of 0.045 seconds, increasing steadily as SF is increased, until, at SF 12, Time Chrips is 1 second.

TABLE IV. LORA 915 AND 920 MHZ FREQ. DATA RESULT: MESSAGE RECEIVED = PH_WATER='VALUE':BW: SF COMPARISON

SF	Transmit Power (dBm)	99% Occupied Bandwidth (kHz)
7	14	130,676
8	14	126,628
9	14	124,604
10	14	123,736
11	14	123,367
12	14	123,323

TABLE V. LORA 915 AND 920 MHZ FREQ. DATA RESULT: MESSAGE RECEIVED = PH_WATER='VALUE':POWER_DB: SF COMPARISON

SF	Power/Freq max (dB/Hz)	Power/Freq min (dB/Hz)
7	-30	-110
8	-30	-115
9	-30	-119
10	-30	-122
11	-30	-128
12	-30	-129

TABLE VI. LORA 915 AND 920 MHZ FREQ. DATA RESULT: MESSAGE RECEIVED = PH_WATER='VALUE': CHIRP S SIGNAL: SF COMPARISON

SF	Freq in Chirps (MHz)	Power/Freq in Chirps(dB/Hz)	Time Chirps (s)
7	1,5	-75	0,045
8	1,5	-75	0,09
9	1,5	-75	0,16
10	1,5	-75	0,3
11	1,5	-75	0,5
12	1,5	-75	1

IV. CONCLUSIONS

From the results of this study, the automation system in Agriculture using LoRa technology can run well, this research focuses on the analysis of the spreading factor and its impact on occupied Bandwidth, Rb or Bit Rate, and Time of chirps or Time on Air, these are essential parameters that determine the quality LoRa data can be achieved to the maximum. For example, SF 7 has 99% occupied bandwidth reaching 130,676 kHz, while on SF12, it reaches 123,323 kHz. While the Time on Air of Chips on SF 7 is 0.045 seconds and on SF 12 is 1 second. It shows the impact of the Spreading Factor changes. In SF 7, it shows the distance between adjacent Tx-Rx, while in SF 12, the Tx-Rx distance is at the farthest point, so it affects the Bit Rate; the bit rate gets smaller if SF increases.

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