Analysis of IoT-LoRa to Improve LoRa Performance for Vaname Shrimp Farming Monitoring System

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ABSTRACT

Shrimp farming requires a touch that must be right on the side of water quality; water is a fundamental factor that must be met to achieve maximum yields. Many factors affect the quality of the water, but some things cause changes in water quality caused by external and internal factors causing death in shrimp. Disease conditions in shrimp can attack at any time, coupled with external factors such as extreme climate change, and cause changes in water components such as water pH, CaMg or hardness, and other factors that cause death in shrimp. Water turbidity oxygen demand (DO) in water determines the life of shrimp. It is coupled with microorganisms that must be maintained to maintain water quality for the growth of a Vaname shrimp. This research raises the Aquaculture System, specifically in the process of intelligent monitoring of water quality in shrimp nurseries to the shrimp harvest process, especially vaname shrimp from the results of observations use three sensors connected to LoRaWAN is able to provide real-time data from pond water and transmit it to LoRa Server or Internet Server, and the realtime data can be read through a Smartphone. This research analyzes in detail the ability of LoRaWAN to send multi-sensor data and Quality of Service LoRaWAN communication at different distances. This research also discusses how the LoRa antenna design can be developed to improve the performance of LoRa as transmitting devices or Radio Frequency 920-923 MHz for sending sensor data for Aquaculture. The contribution of this research is shown in the real-time monitoring system of the water environment, namely water pH, ammonia, turbidity, DO, salinity, water temperature, and nitrate in vaname shrimp ponds. The following contribution is the development of LoRaWAN with Tago IO servers capable of being used in Smart Aquaculture for contributions to The Things Network community or LoRaWAN Community.

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1. INTRODUCTION

Currently, fisheries are one of the hopes for Indonesia; export products through fisheries have been growing, although many obstacles occur, one of which is the decline in the quality of fishery products, especially fish and shrimp farming. One of the shrimp that is a favorite for consumption by the Indonesian people is vaname shrimp. Conventional monitoring factors remain one of the problems that cause a decrease in the quality of vaname shrimp production in Indonesia. Therefore, to overcome these things, a monitoring tool is needed or at least an early warning that is able to provide information quickly to avoid unwanted things in the shrimp breeding process. This research seeks to highlight the nursery-to-harvest cultivation side of Vaname Shrimp. In addition to looking at the water quality factors used, it also looks at the development of analysis on shrimp disease. So, the analysis will expand in 2 years of this research. The first thing that was built in the research was a prototype. Prototypes are essential to ensure that transmitting LoRaWAN data with water quality data can be met with a level of accuracy and that Quality of Service from LoRaWAN can be created optimally.

The contribution of this research is shown in the real-time monitoring system of the water environment, namely water pH, ammonia, turbidity, DO, salinity, water temperature, and nitrate in vaname shrimp ponds. The following contribution is the development of LoRaWAN with Tago IO servers capable of being used in Smart Aquaculture for contributions to The Things Network community or LoRaWAN Community. LoRaWAN has a large community called The Things Network and LoRaWAN industry, a forum that oversees LoRa researchers around the world, with the research in the field of Smart Aquaculture Development will further enrich the repertoire of science in the field of Aquaculture [1]-[4] and specifically on the vaname shrimp development monitoring system that can improve the economy of the community, even the nation and state of Indonesia.

2. THEORY

2.1. Cultivation and treatment of Vaname Shrimp

In this system, vaname shrimp is the object that will be monitored. Vannamei shrimp (Litopenaeus *vannamei*), also known as Pacific white shrimp or King shrimp, is a species of shrimp from the eastern Pacific Ocean commonly caught or farmed for food. Before further discussing the automation system that will be built using LoRaWAN [5]-[9], first understand what objects will be monitored in real-time. It is a member of the family Penaeidae, which also includes the black tiger shrimp and giant tiger shrimp. Vannamei shrimp are usually white or light pink in color, with a translucent body. It has a long, slender body and large claws. They can grow up to 12 inches long, but most farmed *vannamei* shrimp are harvested when they are about 6 inches long. Vannamei shrimp are a good source of protein, omega-3 fatty acids, and vitamins. It is also a low-calorie food, making it a healthy choice for those who are watching their weight. Vannamei shrimp are cultivated in many countries around the world, including Thailand, Vietnam, Indonesia, and China. It is a popular food in many countries and is also exported to other countries. In the breeding of Vaname Shrimp in Indonesia, there are several ways, among others, using a waterwheel for oxygen supply in an open round tub pond or using a closed pond using a roof and blower as an oxygen supply for shrimp, both of which can be applied based on geographical conditions or environmental conditions where vaname shrimp are artificially developed. Some of the conditions obtained in the field are how shrimp experience mass death; this can occur due to conditions that decrease the pH of water that drops significantly and is not known quickly by shrimp farmers. The system that will be built is how to quickly find out changes in water pH and several other parameters such as CaMg, turbidity, DO, or water temperature that can cause mass death in shrimp. In specific research in the following year is to find other irregularities, namely diseases that occur in vaname shrimp such as spots on shrimp that cause death in shrimp.

2.2. LoRaWAN Equations

The fundamental factor that needs to be known in LoRa or LoRaWAN-based communication systems is the availability of Bandwidth, Spreading Factor (SF), Time on Air (ToA), and other LoRa parameters [10]-[14] that will produce bitrates, another factor that is no less important is the method or mechanism of transmitting LoRa data. This Spreading Factor talks about how to produce the highest bitrate, so the best specification of SF is 7 with a Bandwidth of 500 kHz. But Bandwidth is a premium factor, meaning something very valuable and important. Where the greater the Bandwidth, the greater the Bit rate produced. Moreover, LoRa has a maximum bit rate of 5.5 kbps – 21.9 kbps, depending on the LoRa Specification used. LoRaWAN is a Protocol or Media Access Control (MAC) that uses the LoRa Module to communicate at the end-node level, with frequencies in accordance with the regulations of a region; Indonesia uses frequencies of 920-923 MHz. The advantage of LoRa is low power consumption with the large coverage; millions of devices can be connected at a certain time. The communication system that is built with the server is Uplink and Downlink. Uplink and Downlink. Uplink and downlink processes in Europe are determined for the EU is limited to a duty cycle of 0.1% to 10%. While the US is not limited or has No Limit in Europe (EU), Uplink is limited to 30 seconds of airtime per node per day, while Downlink is limited to 10 messages per node per day.

Moreover, Table 1 and Table 2 talk about how to generate throughput (%) from the bitrate capacity of LoRa; logically, the greater the Bandwidth or data interval used to transmit sensor data, the greater the throughput (%) or data entering the Receiver. So Bandwidth, in this case, is an expensive parameter. Then, this

Spreading Factor determines how sensitivity (-dBm) in the process of transmitting data using LoRa can be seen from the Spreading Factor (SF) formula. The greater the value of the Spreading Factor, the weaker the signal sensitivity or the greater the Attenuation that may be generated; it will also cause the datarate produced to be smaller.

Therefore, if depicted with a block diagram, this spreading factor shows how the signal can experience distortion from the signal spreading process; attenuation or signal distortion can occur due to reflection, diffraction, and scattering signals in the signal spreading process, shown in Fig. 1.

SF determines the bitrate or data rate (bps). Equation (1) summarizes this, where bitrate is determined by SF, BW, and CR (1 to 4). And in the process of transmitting data, with Line of Sight (LOS) or Non-Line of Sight (N-LOS) conditions must use a parameter, namely the Free Space Path Loss (FSPL) equation, where this condition will determine the quality of data transmission with obstacles or without using obstacles as stated in (2) and (3). Equation (3) is the conversion of FSPL to a logarithmic (Log) equation.

$$R_b = SF \frac{\frac{4}{4+CR}}{\frac{2^{SF}}{BW}} 1000 \tag{1}$$

$$FSPL = \frac{P_t}{P_r} = \left(\frac{4\pi R}{\lambda}\right)^2 \tag{2}$$

$$FSPL(dB) = 20log10(d) + 20log10(f) - 147.55 \tag{3}$$

Table 1. Spreading Factor, Bandwidth Usage, and Resulting Data Rate

No	LoRa Parameters		
	Spreading Factor	***Bandwidth***	***Data Rate***
1	7	125 kHz	5.5 kbits/s
2	7	250 kHz	10.9 kbits/s
3	7	500 kHz	21.9 kbits/s

Table 2. Spreading Factor and Receiver Sensitivity Impact with 125 kHz Bandwidth

Spreading Factor (SF)	Receiver Sensitivity
7	-123 dBm
8	-126 dBm
9	-129 dBm
10	-132 dBm
11	-134.5 dBm
12	-137 dBm

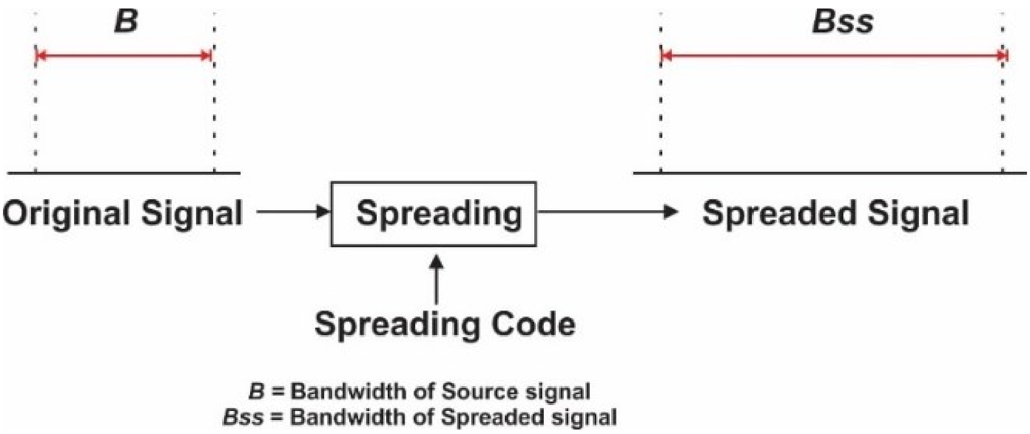


Fig. 1. Spreading signal process

2.3. LoRaWAN Hardware used

Hardware is essential; several sensors are used, as shown in Table 3, which is the device and sensor specification for the monitoring object, the Smart Shirmp Farm Monitoring System.

Table 3. Device and Sensor Specifications for Smart Shrimp Farm Monitoring System

No	Devices or Sensor	Specification
1	pH Water Sensor	Working Current 5-10 mA, pH read 0-14, detection range 0-80, response time 5s, settling Time 60s Humidity 95% RH (nominal humidity 65% RH)
2	Arduino	Microcontroller ATMega 2560, Operating Voltage 5 Volt DC, Input Voltage (Limit) 6-20 Volt, Digital I/O Pins 54 (of which 15 provide PWM output).
3	OLED	I2C dan SPI 0,96 inci layar OLED 128×64
4	Connecting Wires	5 Volt DC connection cable from LoRa and Arduino components
5	Breadboard or Hole PCB	A breadboard is a type of prototyping that requires no soldering connections
6	LoRa Module RF96	Features of RF Transceiver LoRa Module RFM96W, LoRaTM Modem 168 dB maximum link budget. +20 dBm - 100 mW
7	ESP32	ESP32 is a series of low-cost, low-power systems on a-chip microcontrollers with integrated WiFi and dual-mode Bluetooth
8	Water Temperature sensor	The water temperature sensor enables the control unit to identify engine overheating or an unusual rise in temperature.
9	Turbidity Sensor	Turbidity sensors measure the amount of light that is scattered by the suspended solids in water.
10	LoRa Gateway LG01-P Indoor	Receive LoRa End Node data and send it to the LoRaWAN Server

2.4. LoRaWAN Hardware used

Hardware configuration system is needed, as shown in Fig. 2. And the specific sensor data can be seen in Table 4. In Fig. 2, the Hardware Configuration will determine the amount of sensor data sent via LoRa Wireless Communication and LoRaWAN Server [15]-[19]. More sensor data will provide specific data, but new problems arise, which will cause packet loss, data collisions, and other problems. So, it is necessary to regulate transmission data, for example, the use of the Adaptive Data Rate (ADR) algorithm method.

Table 5 shows the type of sensor used in this research, sensor type, detection range or ability, output range, range, and the power supply (VDC) required to run the input or sensor. Input components, as in Table 2, are used as inputs or sensors that will provide data and send it to the internet server via LoRa Wireless Communication with a certain Radio Frequency and LoRaWAN server.

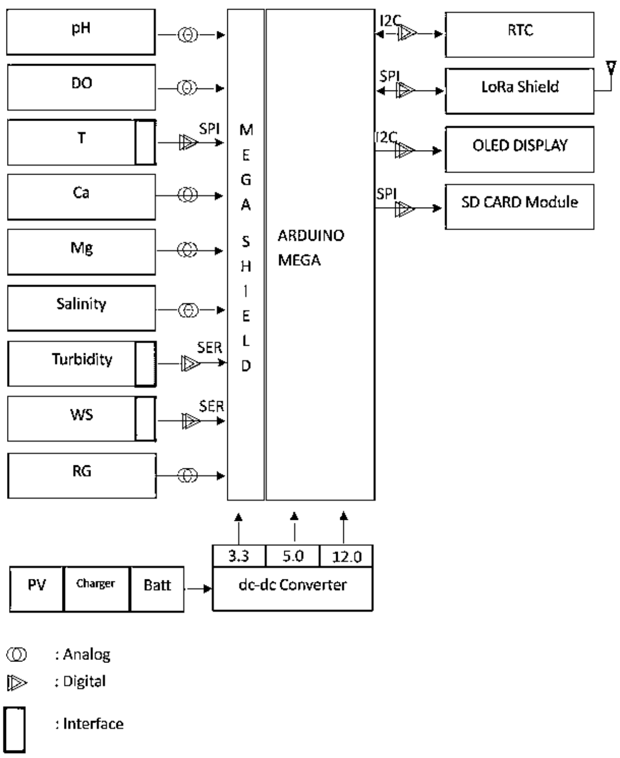


Fig. 2. Hardware Configuration

Table 4. Device and Sensor Specifications for Smart Shrimp Farm Monitoring System

No	Sensor	Type	Detection Range	Output Sensor	Range	Power Supply (VDC)
1	pH	Gravity: Analog Industrial pH Sensor / Meter Pro Kit V2	0-14	DC Voltage	0-3.0 V	3.3-5.5
2	DO	Gravity: Analog Dissolved Oxygen	0~20 mg/L	DC Voltage	0~3.0 v	3.3-5.5
3	T	PT100+MAX31865		SPI		3.0-3.6
4	Ca	NTSensor Magnesium Ion-Selective Electrode+Probe	0,4 a 4000 mg/L	DC Voltage	tbd	tbd
5	Mg	NTSensor Magne*sium* Ion-Selective Electrode	2,4 a 2400 mg/L	DC Voltage	tbd	tbd
6	Salinity	Vernier SAL-BA	0 to 50 ppt (0 to 50,000 ppm)	DC Voltage	16,3 ppt/V	
7	Turbidity	SmartQ	0-4000NTU	RS 485	-	12v
8	WS	CN	0-60m/s	RS 485	-	12v
9	RG	Raindao	-	Analog Pulse	0,2 mm/pulse	12v

Table 5. Input devices on LoRa End-Node

Input	ADC	SPI	I2C	Serial	Interrupt
pH	x				
DO	x				
T		x			
Ca	x				
Mg	x				
Salinity	x				
Turbidity				x	
WS				x	
RG					x
RTC			x		
LoRa Shield		x			
OLED			x		
SD Card		x			
Battery Status	x				
Command					
Total	**6**	**3**	**2**	**3**	**1**

2.5. Chirp Spread Spectrum of LoRa Analysis

Furthermore, In the field of Telecommunications, Radio Frequency is essential to be discussed because of its role as an Internet of Things (IoT) device that can have a good impact on the development of RF-based IoT. One of them is LoRaWAN. LoRaWAN provides a different perspective on IoT. LoRaWAN is one of the most potent LPWAN technologies [20]-[24] regarding range (km). So, it must continue to be considered in developing future IoT technologies other than 5G or WiFi. Besides LoRa, there are also Sigfox and NB-IoT, which also have High Performance in terms of range but still look at other excellent specifications such as Power Consumption and data rate. This article explicitly discusses LoRa and Chirp or Chirp Spread Spectrum as a modulation signal system generated when transmitting data. Deep Learning will study These chirps more profoundly by examining the difference in images when communicating with Normal, transferring with Attenuation, or not sharing data.

Furthermore, The development of Artificial Intelligence (AI), Machine Learning, and Deep Learning is growing significantly, and its applications are also diverse with various sides of topics such as health, daily life, smart city, economy, agriculture, fisheries, and marine, and other specific factors. One of the things discussed in this research is how LoRa can be paired with AI or DL with several parameters that can be taken. For example, LoRa Transmission images focus on the signal's modulation [25]-[27], and Spesific in Fig. 2. A deeper thought is how the Deep Learning solving pattern is used to solve the shape or pattern of CSS from different sensors, devices, distances, and other parameters that can be tested. CSS in Deep Learning The structure can be seen in Fig. 2. The theoretical basis of the Chirp Spread Spectrum is based on the CSSM or Chirp Spread Spectrum Modulation system, which can be solved by coding techniques such as Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK), and M-ary phase shift keying (M-PSK).

Moreover, Chirp Spread Spectrum (CSS) is a spread spectrum technique that encodes information using wideband frequency linear modulated Chirp pulses. A chirp is a sinusoidal signal whose frequency increases or decreases over time (often a polynomial expression relating time and frequency). In this research, CSS, which shows information is sent from the Transmitter to the Receiver, which is the LoRa End-Nodes, which sends information in the form of sensor data. Suppose the behavior of the heart rate sensor has a Chirp pattern consisting of Preamble, Up-Chirp, Down-Chirp, and data or modulate the signal. In that case, it will have the same data pattern; for example, BPM and DHT11, consisting of Temperature and Humidity, also have data in different Chirp shapes. It may be expressed in bytes per second (bps) or Modulate signal Chirp LoRa. In expressing the code, Chirp can also be drawn with Up-Chirp or Down-Chirp depending on the increase in frequency or signal density and can be described using a pattern that then identifies a specific type of data [28]-[30] and in Fig. 1 and Fig. 3. For example, the types of sensors SPO2, Pulse Sensor, or Heart-Rate used for runners and other activities. Several techniques can be used to represent Chirp, namely by using CNN—convolutional Neural Network (CNN). CNN is used to recognize patterns in images. CNNs are used to acknowledge Chirp Patterns in CSS Signals. Apart from using CNN, representing CSS can be done using RNN (Recurrent Neural Network). RNN is tasked with recognizing chirp patterns in CSS Signal, which continuously change based on time.

Chirp Spread Spectrum in Fig. 4, or Chirp, is a LoRa and LoRaWAN modulation system that is indicated by a sinusoidal wave at a specific frequency [31]-[35]. The wave density is based on detecting the object or, in this case, the Receiver. A comparison of different Chirp and SF is shown in Fig. 5 and Fig. 6.

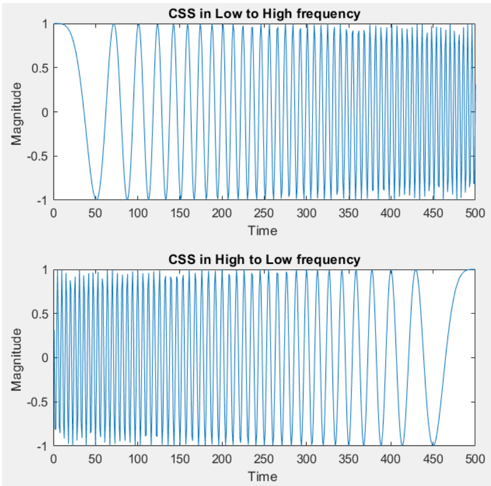


Fig. 3. CSS in Low to High frequency and vice versa

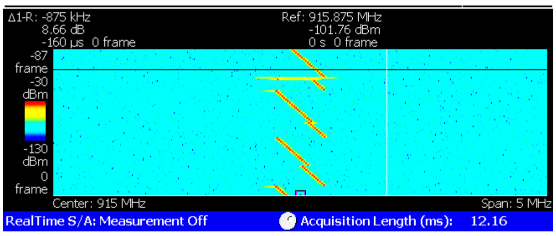


Fig. 4. Chirp Spread Spectrum LoRa Realtime (Puput Dani Doc.)

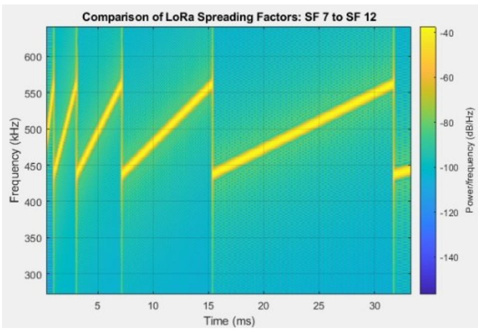


Fig. 5. Comparison of Spreading Factor SF7 to SF 12

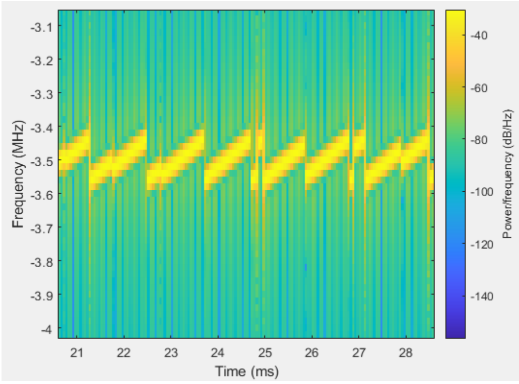


Fig. 6. CSS SF 7 BW 125 kHz, and 915 MHz Freq.LoRa

2.6. Chirp Equations

The chirp signal works with a frequency sweep of the f_1 Hz to f_2 Hz as time goes from t=0 sec to $t = T_2$ sec. In general, the formula is shown in (1) [17]-[20].

$$x(t) = A\,cos(\alpha t^2 + \beta t + \emptyset) = A \cos(\psi(t)) \tag{4}$$

where $\psi(t)= \alpha t^2 + \beta t + \emptyset$, The derivative of $\psi(t)$ is the instantaneous frequency, which is also the frequency heard if the frequencies are in the audible range.

$$f_1(t) = \frac{\frac{d}{dt}\psi(t)}{2\pi} Hz \tag{5}$$

For the chirp defined in (2), determine the formulas for the beginning frequency (f_1), and the ending of frequency (f_2) in terms of α, β, and T_2. And for the Chirp signal as (3).

$$x(t) = \cos(40t^2 + 27t + 13) \tag{6}$$

Derive a formula for the instantaneous frequency vs. time and plot between frequency vs. time over the range $0 \leq t \leq 1$s.

2.7. LoRa Dechirping

The opposite of LoRa Chirps modulation is Dechirping. Dechirping is the process of reversing the chirping operation used for LoRa signal modulation. Chirps is a technique that transmits data over long distances by spreading the signal's Bandwidth from low to high frequency during the symbol period. Dechirping is done by multiplying the received signal with a down chirp, a chirp with a slope opposite to the chirp. This multiplication negates the chirp effect, leaving a Single-tone signal with a continuous phase. Moreover, the Dechirp signal is then passed through a Fourier transform to convert to the frequency domain. This allows the signal energy to be concentrated on a single frequency bin, making it easy to detect and decipher data. Dechirping is done by converting the signal to baseband; the signal is downconverted to baseband by a digital downconverter (DDC), then multiplying the signal by downchirp and performing a Fourier transform on the signal and detecting the signal energy. The Demodulation Signal Diagram is shown in Fig.7.

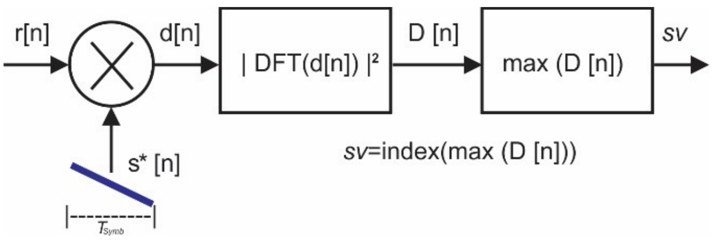


Fig. 7. Demodulation Signal LoRa Chirp Spread Spectrum

3. METHODS

The devices developed are the LoRa End-Node and LoRa Gateway; on the LoRa End-Node side, several sensors are used, i.e., the water pH sensor, Turbidity sensor, and temperature sensor. A minimum of three sensors are used to be transmitted to the LoRa Server. Some other items starting from the End Node are the LoRa Antenna, LoRa Stand, LoRa Box (i.e., Microcontroller, LoRa Module, LCD, sensors, etc.), and LoRa Gateway, which consists of LoRa Stand, LoRa Gateway, Solar Cell, Solar Cell Panel, etc. Moreover, from the aquaculture monitoring system [36]-[40] in the vaname shrimp monitoring system is how the system built is able to be managed very well, starting from the integration of sensors, sensor capabilities, or calibration systems that are close to 100% accurate, renewable energy systems, radio propagation, artificial intelligence, LoRaWAN analysis, multi-point LoRa analysis, server configuration, actuators, and so on. So, the analysis that is built can be applied completely. If depicted on the flowchart, the LoRaWAN system can describe the work system in all parts of the system. Fig. 8, Fig. 9, and Fig. 10 are the Flowchart and Block Diagram of the system to be built, and how the process of transmitting data using LoRaWAN.

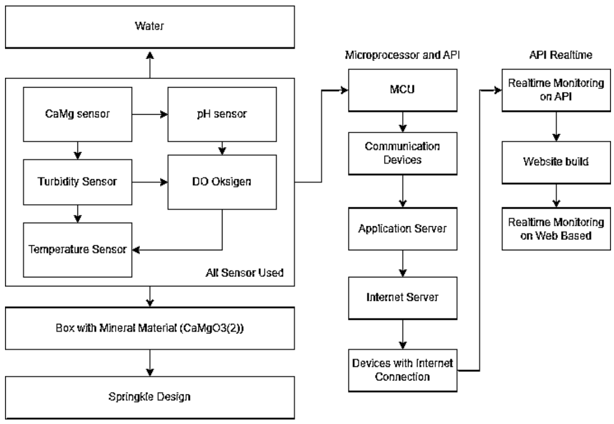


Fig. 8. Flowchart of the entire LoRaWAN aquaculture system

This research method is how smart aquaculture sensors consisting of pH, ammonia, salinity, turbidity, DO, Temperature, and nitrate sensors can send their data in real-time through the LoRaWAN module. Communication occurs between LoRa Nodes; in this case, TX-RX LoRa communication on the LoRa RF network is continued by LoRaWAN on the server. The flow diagram is shown in Fig. 9.

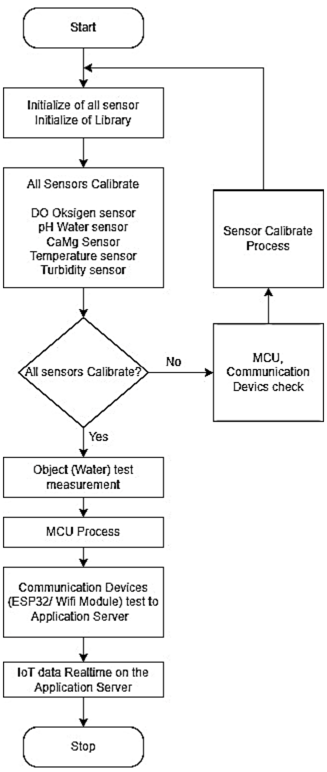


Fig. 9. Flowchart of the Aquaculture system

While Fig. 11 and Fig. 12 are the design of the LoRaWAN measurement system in the field of Aquaculture to help the growth of vaname shrimp. Fig. 13 and Fig. 14 are the data communication systems that will be built using LoRaWAN. In this case, the monitoring object is the Multi-Sensor used for monitoring Vaname shrimp, their productivity and growth, as well as weather conditions that can have an adverse effect on growth before harvest. While Fig.15 is the LoRa Dechirping process which shows the process after CSS Modulation and on the Receiver side there is Dechirping which is the opposite of the modulation process, namely Demodulation of Signal LoRa. To represent Dechirping LoRa can use Python Programming with all the necessary libraries.

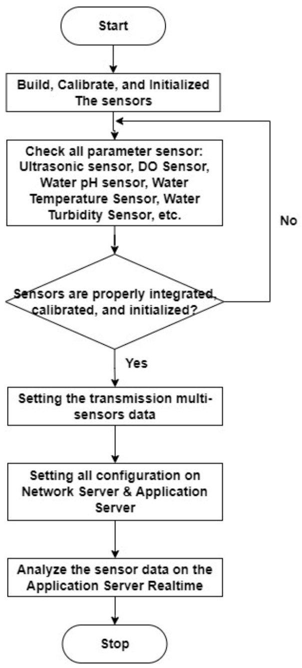


Fig. 10. Transmitting sensor data to Smart Aquaculture LoRaWAN

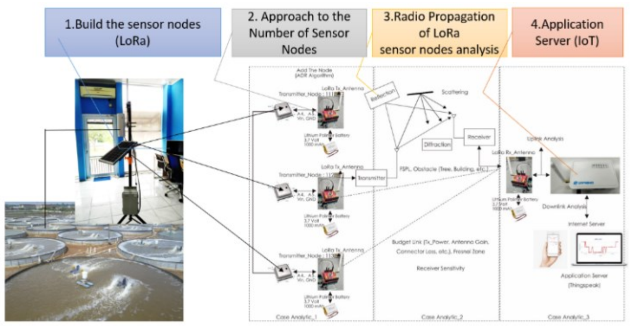


Fig. 11. Outline of Aquaculture Research LoRaWAN analysis [Personal Data]

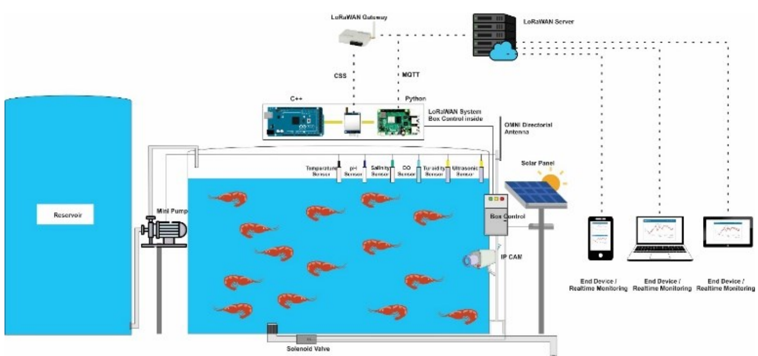


Fig. 12. Vaname shrimp farming system [Personal Data]

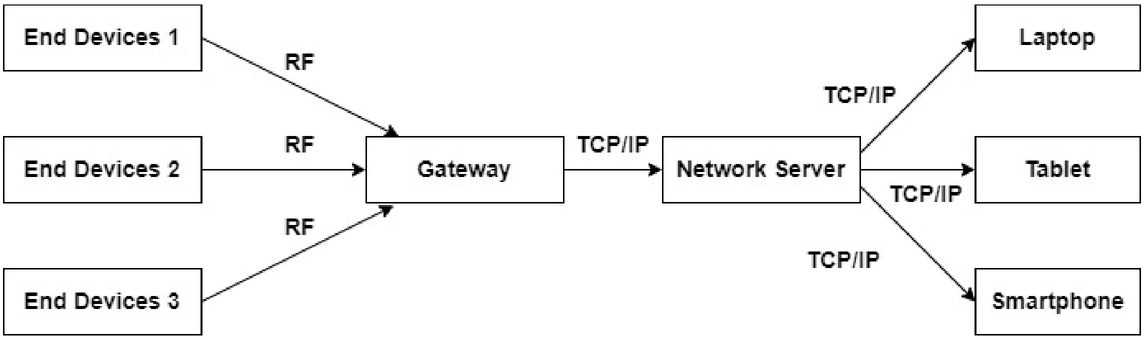


Fig. 13. LoRaWAN data transmitting system

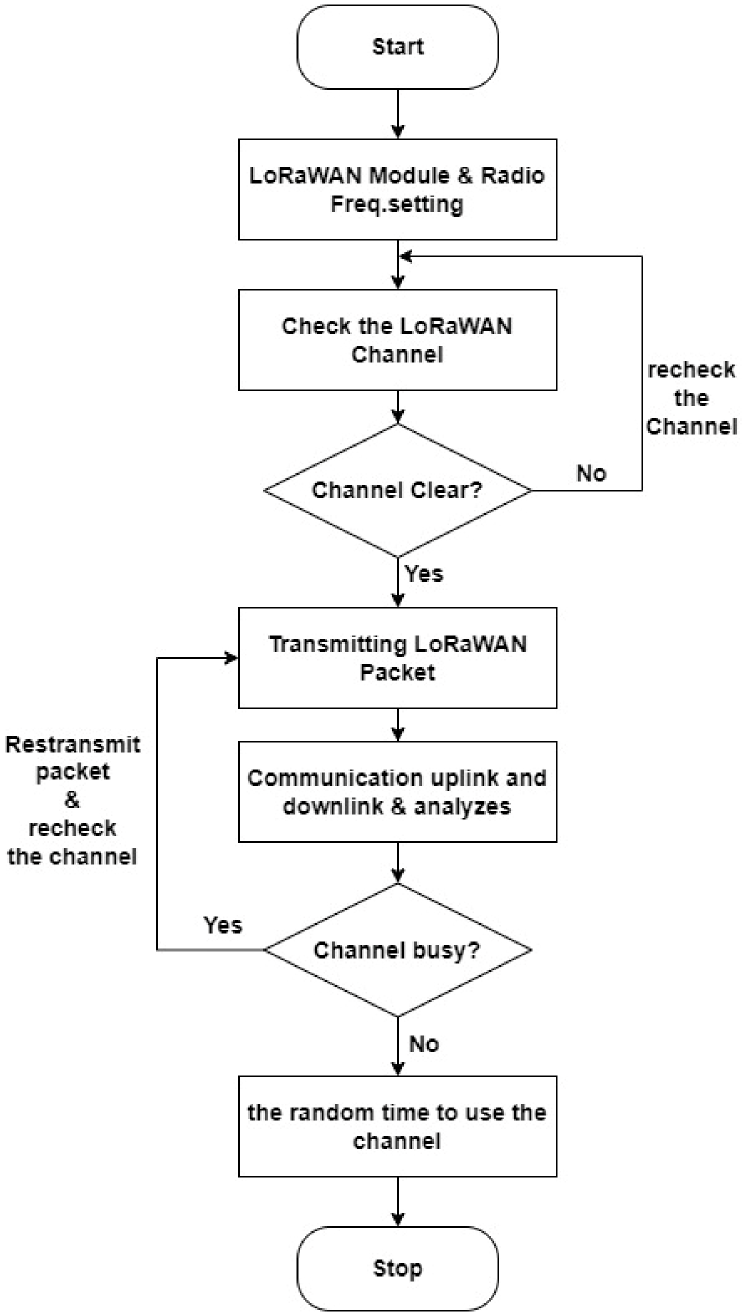


Fig. 14. LoRaWAN data transmitting system with Channel

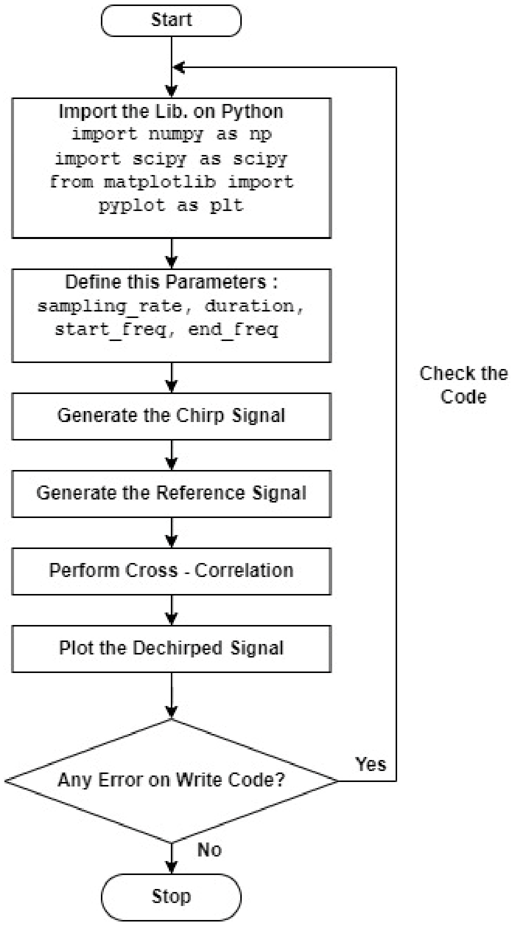


Fig. 15. Flowchart of the Dechirped Signal LoRa

Moreover, field testing is required, Fig. 16 and Fig. 17 show the LoRa test in the position as transmitter and receiver. Several test steps were carried out to determine the extent of LoRa's performance in obtaining data as far as possible, not only looking at the datasheet side of the performance, especially RSSI (-dBm) and SNR (dB) but also to get the real value of the actual situation. Finally, the application to the field will be able to provide specific data on how LoRa works with multi-sensor transmission capabilities and specific distances from the pond location to the server or monitoring room. In its application, the field or land shown in Fig.18 is required, this is the land used by farmers for vaname shrimp farming as well as testing the tools placed there.

Fig. 16. Testing LoRa Transmitter before application [Personal Data]

Fig. 17. Testing LoRa Receiver before application [Personal Data]

Fig. 18. Media or Location of Aquaculture IoT-LoRa multi-sensor Test [Personal Data]

4. RESULTS AND DISCUSSION

4.1. Comparison of LoRaWAN Research Results from Various Researchers

Table 6 compares LoRaWAN and IoT for smart aquaculture from several previous researchers, from previous researchers who used LoRa-MQTT, LoRa TTGO, and Photovoltaic cells for IoT applications.

Table 6. Comparison of Aquaculture LoRaWAN Research Results

Research Theme	Resulting analysis	Research Year	Authors
LoRa-MQTT Gateway Device for Supporting Sensor-to-Cloud Data Transmission in Smart Aquaculture IoT Application	This research proposes the design of a LoRa-MQTT gateway device for supporting sensor-to-cloud data transmission in smart aquaculture IoT applications. In its main functionality, the gateway device receives the collected sensor from the sensor device using the LoRa communication module, builds a message, and transmits it to the cloud-based data storage server using the MQTT protocol. From the functional and performance testing, the gateway can perform as a communication connector between sensor nodes and cloud-based entities using both LoRa and MQTT protocols with reasonable performance.	2019	A. Bhawiyuga, K. Amron, R. Primanandha, D. P. Kartikasari, H. Arijudin and D. A. Prabandari,
Automated Water Quality Monitoring System for Aquaponic Pond using LoRa TTGO SX1276 and Cayenne Platform	This system is accessed through the Cayenne website. The microcontroller used is LoRa TTGO SX1276, and the mechanical feed ejection system uses a 12 Volt DC motor. The test results showed that using an aquaponic system with 40 netpots of pakcoy vegetables significantly reduced ammonia in aquaponic plants by 4.94 ppm in one day. From the results of testing the entire system, it can be concluded that this automatic system can help optimize the process of freshwater aquaculture.	2022	A. O. Silalahi, A. Sinambela, J. T. N. Pardosi and H. M. Panggabean
Design of aquaculture grid system based on Solar energy and the Internet of Things	Solar Panel for IoT development, the photovoltaic panel laying method is designed, and the hybrid power supply mode combining mains power and solar power generation is used to supply power	2023	T. Zhang, T. Hai, J. Lu, X. Zhao, Y. Shangguan and Z. Deng

4.2. Chirp and Dechirping Analysis

Chapter 4 focuses on the development of LoRa signal Dechirping analysis. To find out the output of LoRa Dechirping for all possible LoRa applications such as IoT [1], LoRa for Long-Range communication [2], LoRa for indoor communication [3], and Satellite Communication [4]. Examples of these 4 LoRa Project examples are shown in the various LoRa signal output Dechirping in Chapter 4. For example, the four LoRa parameters used in dechirped LoRa signals are Sampling Rate, Duration, Start Frequency, and End Frequency; sample graphs are shown in Fig. 8 and Fig. 9. The sampling rate is the number of samples taken every second; the higher the sampling rate value, the more accurate the data will be, but it also requires complex processing. Duration relates to the time it takes to capture more data in seconds or milliseconds. Then, the Start Frequency represents the frequency (Hz) used in LoRa in a certain range allowed by a country's regulations, for example, Indonesia between 920 MHz-923 MHz. 920 MHz Frequency is the Start Frequency, and 923 MHz is the End Frequency; the graphical results can be seen in Fig. 19, Fig. 20, Fig. 21, and Fig. 22.

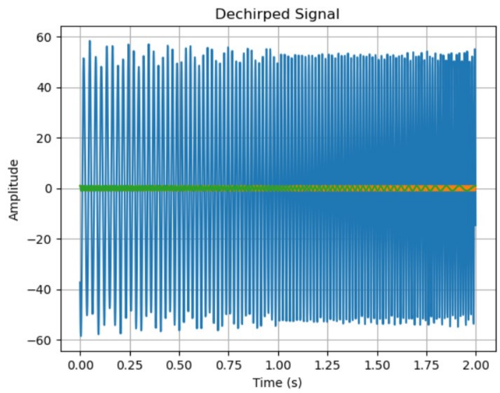


Fig. 19. Dechirped Signal result with a sampling rate of 1000 samples per second

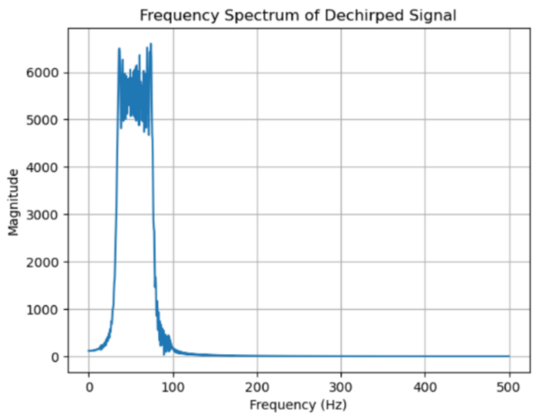


Fig. 20. Frequency Spectrum of Dechirped Signal from 10 Hz to 100 Hz

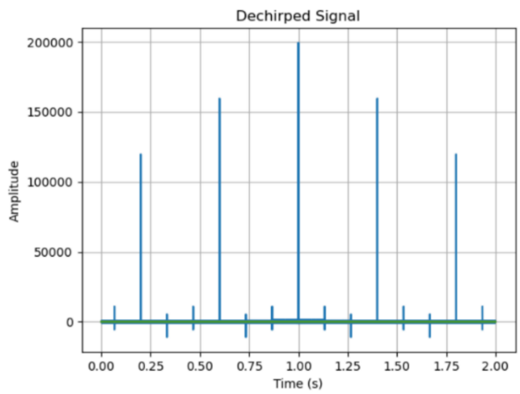


Fig. 21. Dechirped Signal result with a sampling rate of 200000 samples per second

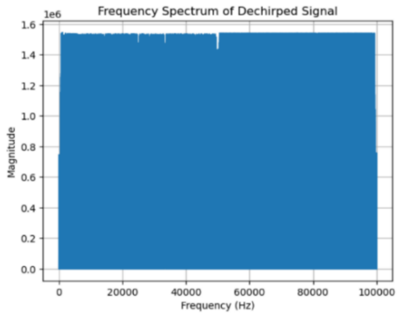


Fig. 22. Frequency Spectrum of Dechirped Signal from 920-923 MHz Freq

Table 7 shows that sampling rate affects signal duration, Frequency offset, and chirp duration; the greater the sampling rate (Hz), the faster the signal duration (s) and Chirp duration (s). Table 5 is a Dechirped of LoRa with different specifications of Sampling Rate (Hz), Signal Duration (s), Frequency offset (Hz), and Chirp Modulation (s). At the same time, Table 8 shows the Dechirped signal parameters for specific areas, e.g., LoRa for IoT, LoRa for Long-Distance, LoRa for in-building communication, and LoRa for Satellite Communication. Each parameter has a different value and is explicitly shown in Fig. 23, Fig. 24, Fig. 25, Fig. 26, Fig. 27, Fig. 28, Fig. 29, and Fig. 30. Chapter 4 focuses on the development of LoRa signal Dechirping analysis.

To find out the output of LoRa Dechirping for all possible LoRa applications such as IoT [1], LoRa for Long-Range communication [2], LoRa for indoor communication [3], and Satellite Communication [4]. Examples of these 4 LoRa Project examples are shown in the various LoRa signal output Dechirping in Chapter 4. For example, the four LoRa parameters used in dechirped LoRa signals are Sampling Rate, Duration, Start Frequency, and End Frequency; sample graphs are shown in Fig.31, Fig.32, and Fig.33. The sampling rate is the number of samples taken every second; the higher the sampling rate value, the more accurate the data will be, but it also requires complex processing. Duration relates to the time it takes to capture more data in seconds or milliseconds. Then, the Start Frequency represents the frequency (Hz) used in LoRa in a certain range allowed by a country's regulations, for example, Indonesia between 920 MHz-923 MHz. 920 MHz Frequency is the Start Frequency, and 923 MHz is the End Frequency.

Table 7. Dechirping LoRa Parameter

No	Parameter			
	Sampling rate (Hz)	***Signal duration (s)***	***Freq offset (Hz)***	***Chirp duration (s)***
1	125000	0.008	1000	0.008
2	250000	0.004	1000	0.004
3	500000	0.002	1000	0.002
4	1000000	0.001	1000	0.001

Table 8. Dechirping LoRa Parameter for Specific Communication Needs

Parameter	Specific Area			
	LoRa for IoT	***LoRa for long-distance***	***LoRa for in-building communication***	***LoRa for satellite communication***
Sampling rate (Sps)	1000000	500000	2000000	10000000
Signal duration (s)	0.002	0.010	0.001	0.1
Frequency offset (Hz)	125000	250000	50000	1000000
Chirp duration (s)	0.001	0.005	0.0005	0.05

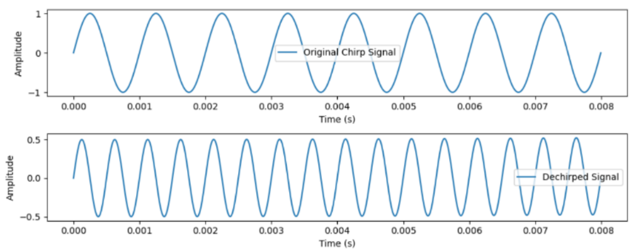


Fig. 23. Dechirped Signal LoRa with Parameter No 1, 125 kHz

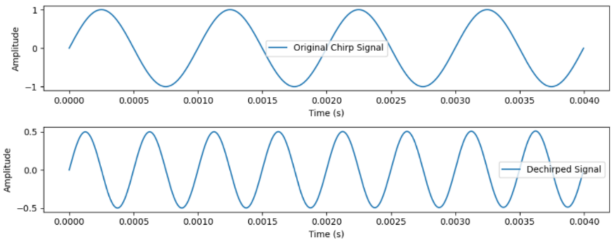


Fig. 24. Dechirped Signal LoRa with Parameter No 2, 250 kHz

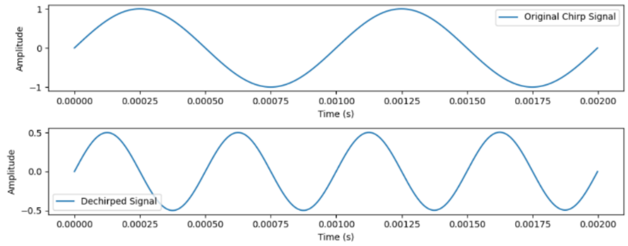


Fig. 25. Dechirped Signal LoRa with Parameter No 3, 500 kHz

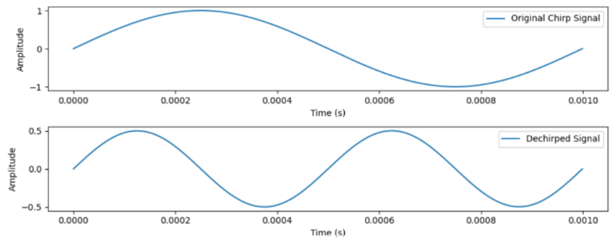


Fig. 26. Dechirped Signal LoRa with Parameter No 4, 1 MHz

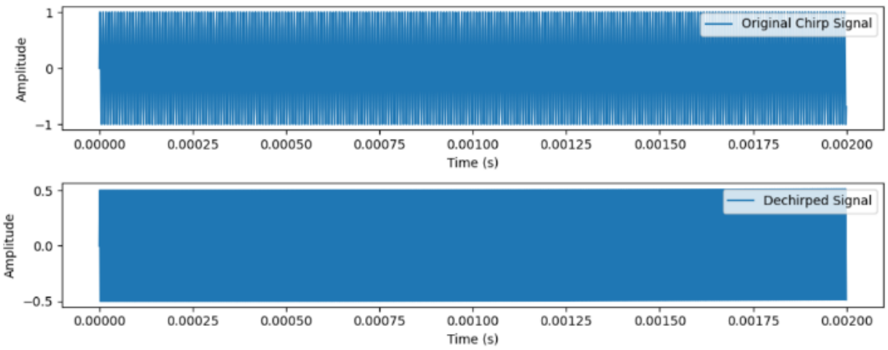


Fig. 27. Dechirped Signal of LoRa for IoT

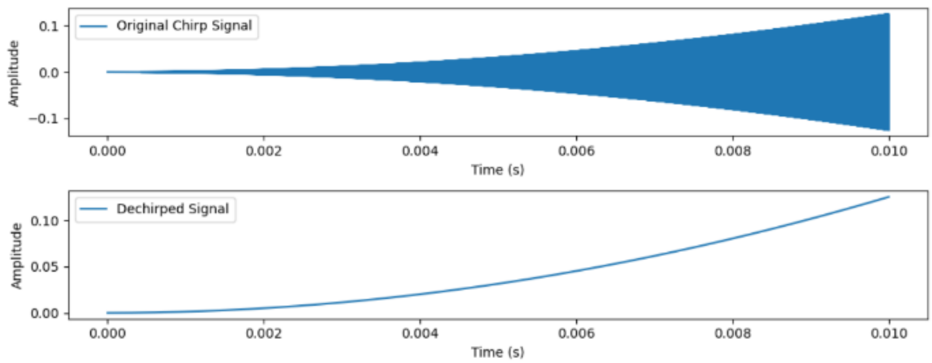


Fig. 28. Dechirped Signal of LoRa for Long Distance

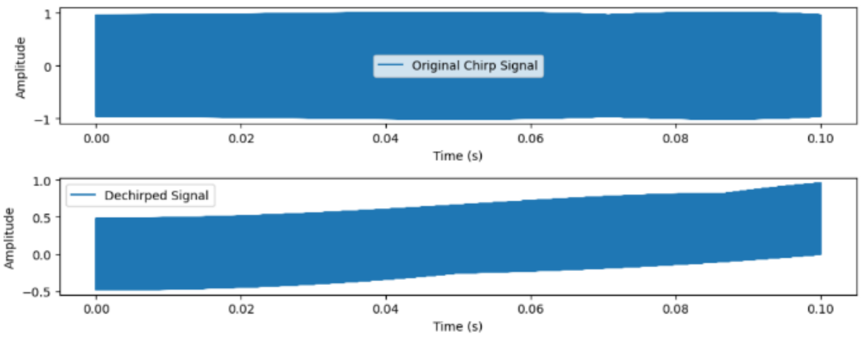


Fig. 29. Dechirped Signal of LoRa for Satelite Communication

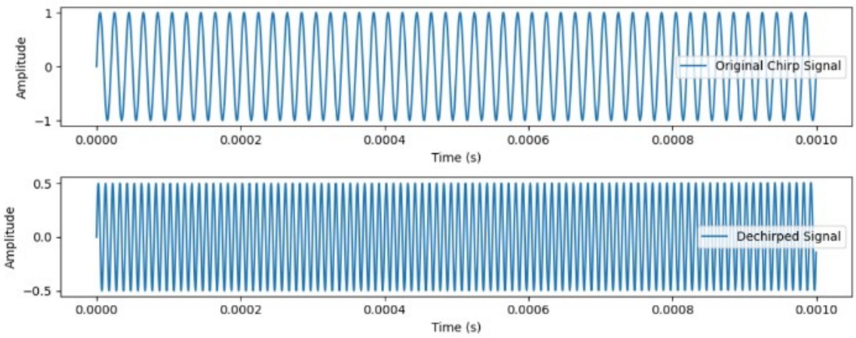


Fig. 30. Dechirped Signal of LoRa for Building Communication

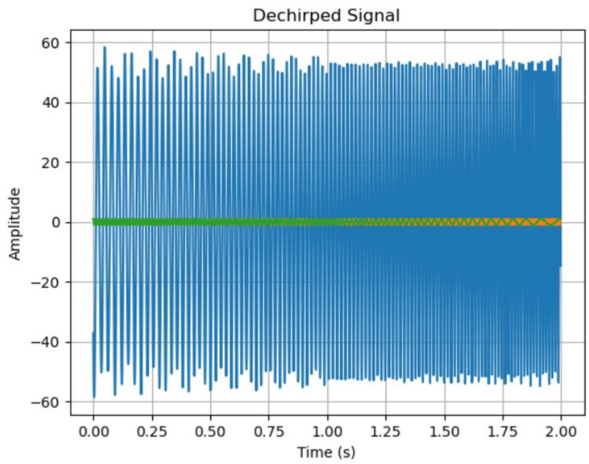


Fig. 31. Dechirped Signal result with a sampling rate of 1000 samples per second

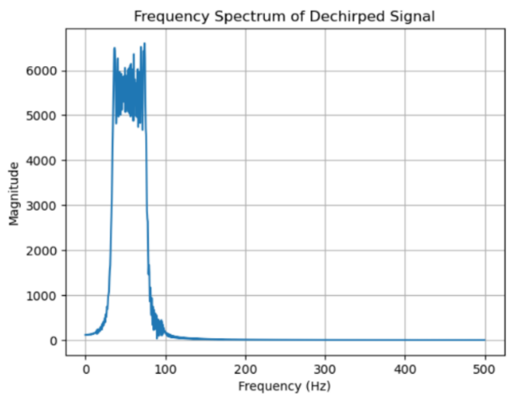


Fig. 32. Frequency Spectrum of Dechirped Signal from 10 Hz to 100 Hz

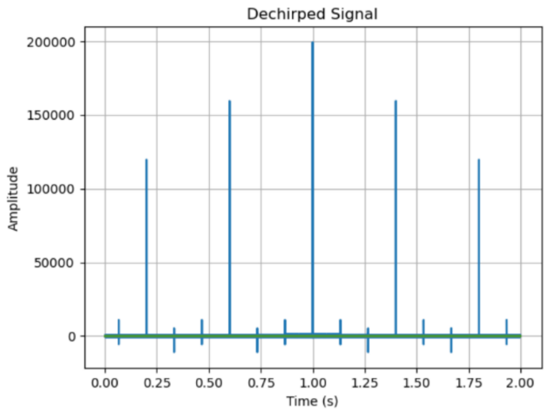


Fig. 33. Dechirped Signal result with a sampling rate of 200000 samples per second

4.3. LoRa Antenna New Design for Optimization This Project

The effort to improve LoRa performance in the scope of IoT for monitoring vaname shrimp objects is to improve the performance of the LoRa antenna used. Please note that this LoRa antenna must be able to transmit data further. One of them is by increasing the Gain. In certain cases, an 8 dBi Omni Directional Antenna is used, which is able to provide a longer distance in addition to the obstacles factor, which is one of the obstacles or causes of Attenuation. LoRa Antenna Design can be seen in Fig. 34.

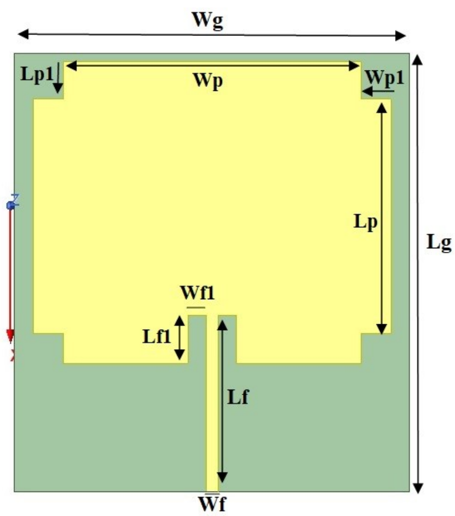


Fig. 34. LoRa Antenna Design

While the analysis results of this LoRa Antenna Design can be seen specifically in the S11 in Fig. 35 and VSWR Graphs in Fig. 36, the LoRa frequency estimation is 920-923 MHz. Accompanied by 2D and 3D [14] Radiation Pattern results. Radiation patterns can be seen in Fig. 37, Fig. 38, and Fig. 39.

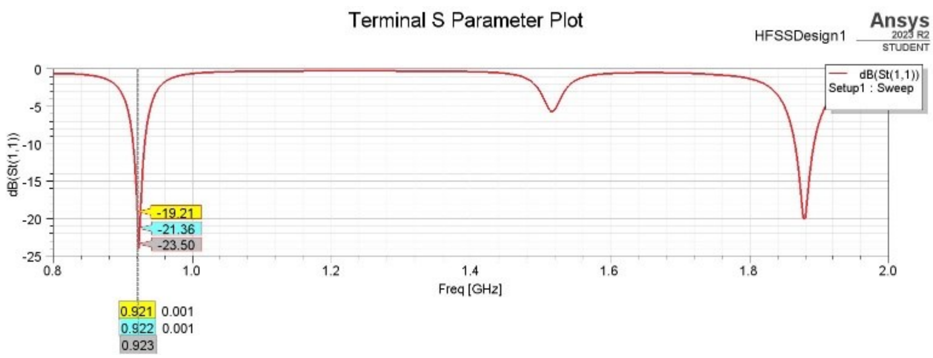


Fig. 35. S11 LoRa 921, 922, dan 923 MHz

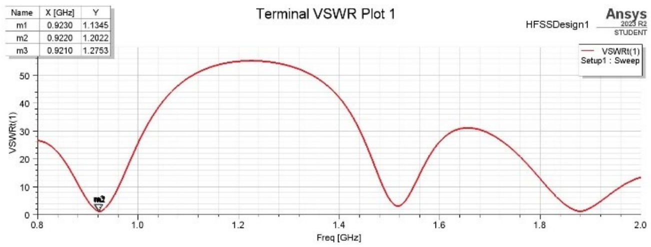


Fig. 36. VSWR LoRa 921, 922, and 923 MHz

Fig. 37. Radiation Pattern 921 MHz 0^{O} dB

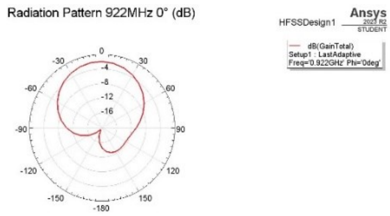
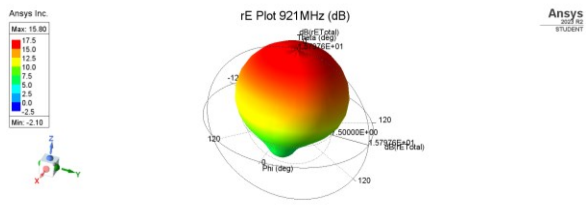
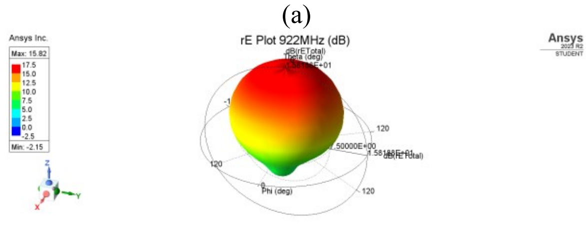


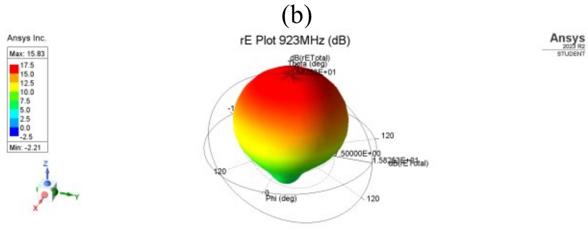
Fig. 38. Radiation Pattern 922 MHz 0^{O} dB



(a)



(b)



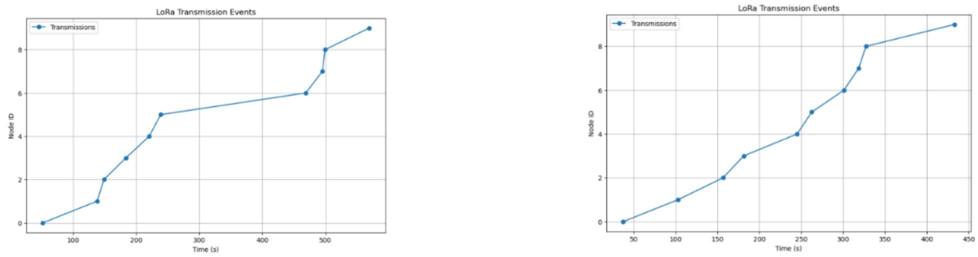
(c)

Fig. 39. (a,b,c) 3D Radiation Pattern for LoRa Frequency 921 MHz. 922 MHz, and 923 MHz

4.4. LoRa Performance Testing of Radio Propagation and Quality of Services

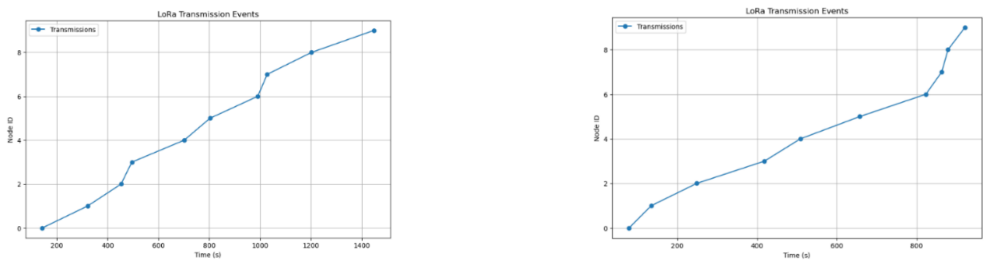
LoRa testing is done by changing the distance between tx and rx based on location; in this test, LoRa is done by moving the Receiver to a Non-Line of Sight (NLOS) position. The data obtained is RSSI or Receive Signal Strength Indicator; Signal Noise Ratio (SNR) data is more complex. The result on transmission of 10 nodes with SF 7 and 8 LoRa can be seen in Fig. 40 while Fig. 41 is LoRa with SF 9 and SF.10, while Fig. 42 is SF 11 and SF 12.

Fig. 43 is Packet Delivery Ratio (PDR) with different SFs, (b) RSSI (-dBm) with different distances (meters) shows the occurrence of attenuation by analyzing the Receive Signal Strength Indicator (RSSI) value with -dBm, with a decreasing value from -30 dBm to -65 dBm with a change in distance of 1 km to 8 km. attenuation is caused by several factors including obstacles that cause Diffraction, Reflection, and Scattering. Meanwhile, Fig. 44 shows that when coupled with the SF approach, the greater the SF, the smaller the value of the bit rate, and the greater the packet loss probability. The greater the SF, the greater the distance (meters). Fig. 45, Fig. 46, and Fig. 47 are examples of research images we did in brackish water ponds in vaname shrimp farming. It has provided specific and real data in transmitting and displaying multi-sensor data consisting of a water pH sensor, water temperature sensor, turbidity sensor, ammonia sensor, salinity sensor, DO Sensor, and Nitrate sensor



(a) (b)

Fig. 40. Transmission 10 Nodes LoRa with SF and BW, (a) 7, (b) 8 and 125 kHz

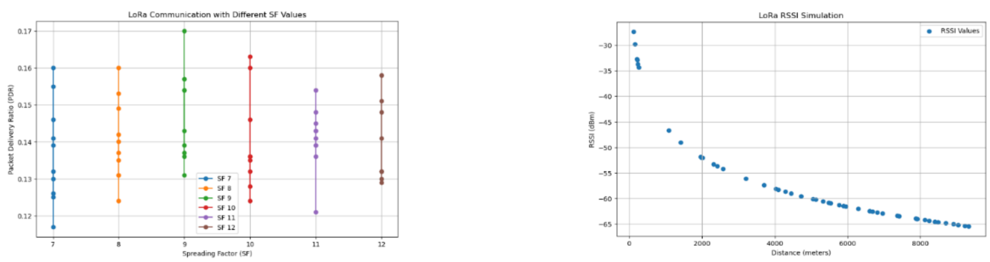


(a) (b)

Fig. 41. Transmission 10 Nodes LoRa with SF and BW, (a) 9, (b) 10 and 125 kHz

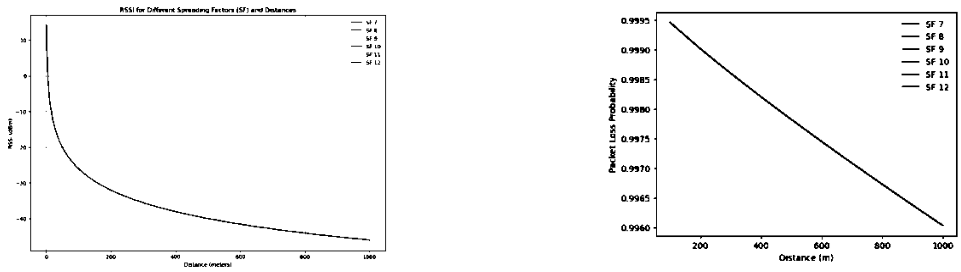
(a) (b)

Fig. 42. Transmission 10 Nodes LoRa with SF and BW, (a)11, (b)12 and 125 kHz



(a) (b)

Fig. 43. Packet Delivery Ratio (PDR) with different SFs, (b) RSSI (-dBm) with different distances (meters)



(a) (b)

Fig. 44. (a) RSSI (-dBm) with different distances (meters), (b) Packet Loss Probability (%) compared with distance (meters)

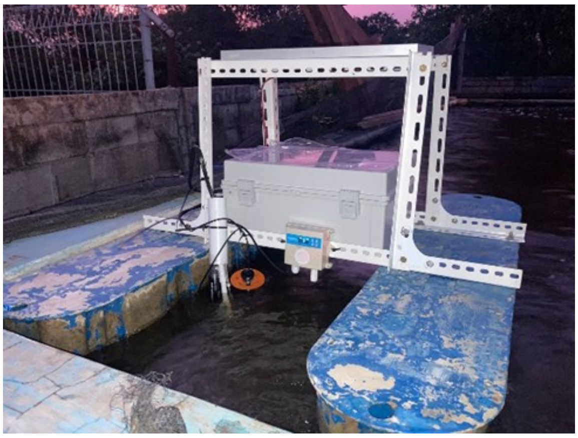


Fig. 45. Prototype produced

Fig. 46. Prototype testing in brackish water environment for vaname shrimp farming

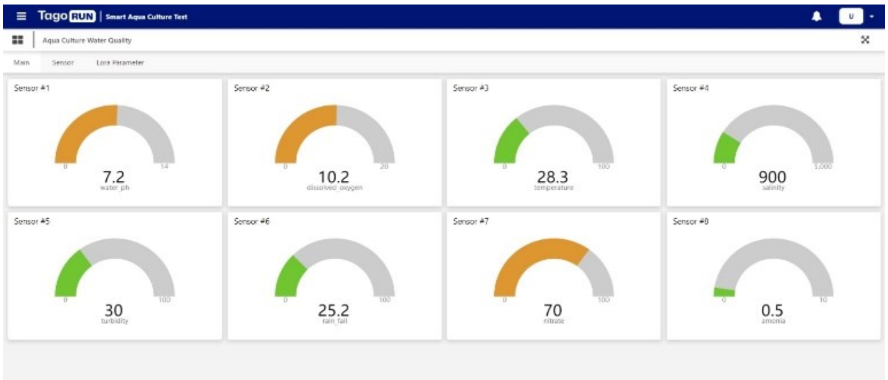


Fig. 47. Output sensor pada system smart aquaculture pada Tago IO

5. CONCLUSION

The research has shown improvements in terms of tests and results but needs to continue to improve the Performance side when the LoRa module transmits multi-sensor data for Agriculture or Aquaculture, especially on Vaname Shrimp objects. Some improvements in this research are specific hardware and software review systems, connection systems or internet networks or LoRaWAN networks, and the LoRa modulation side, which uses the Chirp Spread Spectrum (CSS) modulation system, and how to analyze in detail about Dechirping LoRa signals. Furthermore, the approach to the ability to transmit data is shown by the improvement of the LoRa antenna design used to expand the transmitting area. The Packet Delivery Ratio (PDR) test results in percent (%). The results of transmitting data by comparing distance (km), RSSI, Spreading Factor (SF) differences, and other parameter approaches have provided a detailed analysis in preparing an intelligent Aqua Culture system. In vaname shrimp, it has been able to detect the real environment with the LoRa WAN multi-sensor system and then be able to analyze in detail the impact of different sensor values on real conditions that can affect the condition of vaname shrimp

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