Enhancing Fishing Efficiency with Geographic Information System and Optimized Methods

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ABSTRACT

Traditional fishing techniques frequently lack efficiency and optimization, resulting in fishermen obtaining unsatisfactory yields. This study presents a novel approach by incorporating Geographic Information System (GIS) technology, notably utilizing Leaflet, to improve fishing techniques. The suggested system incorporates a LoRa node tool that logs the journeys of fishermen, offering comprehensive itineraries and data on the distribution of fish and unfavorable weather conditions. Notable outcomes were attained by employing the haversine approach to compute distances between the LoRa Gateway and different data points. The approach exhibited a negligible error margin of 0.157% in contrast to the calculations performed in Excel. In addition, the GPS accuracy testing produced remarkable results, with latitude and longitude errors of 0.000116% and 0.000002%, respectively. The LoRa system demonstrated a range of RSSI performance, with values ranging from -57 dBM at 50 meters to -121 dBM at 1500 meters. This range of performance guarantees dependable transmission of data over significant distances. The findings underscore the GIS-based strategy's efficacy in enhancing the effectiveness and precision of conventional fishing methods, presenting a promising technical improvement for the fishing sector.

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1. INTRODUCTION

Recent breakthroughs in diverse academic disciplines have contributed significantly to creating technology and approaches that apply to fishing practices and environmental monitoring [1]. The study utilized computer vision techniques to track many fish in a water tank, showcasing the promise of modern imaging technology in aquatic research. A separate inquiry was conducted to analyze the effectiveness of GPS/GPRS tracking devices, explicitly investigating the influence of predetermined time intervals on the efficacy of the devices [2]. This factor is of utmost importance in ensuring precise and dependable tracking. The significance of quality attributes in traditional food processing processes has been underscored by Sensory Profiling analysis on Meat and Fish Products [3]. This analysis has demonstrated how sensory evaluation can provide valuable insights for enhancing food quality. Furthermore, a study on the Integrity Concept for Position Sensors in Maritime Autonomous Surface Ships emphasized the need for sensor reliability in autonomous maritime systems, which is crucial for advancing self-governing vessels [4]. The use of Global Positioning System (GPS) trackers in the artisanal fishery has highlighted the significance of geographical information in effective fishing management in fisheries management [5]. Moreover, the combination of GPS and Mobile Radio Frequency Identification in the study of habitat utilization in streams demonstrates the application of technology in ecological research, offering valuable information on habitat patterns and preserving biodiversity.

Advancements in predictive modeling have been made by introducing a new evolutionary time series model for streamflow prediction [6]. This model has demonstrated better accuracy and reliability [7]. In precision agriculture, there has been a focus on minimizing power usage in wireless sensor networks [8]. This highlights the need for energy-efficient solutions in technological applications. Studies on the Precision and Dependability of GPS Receivers have yielded vital knowledge on positioning technology, which is crucial for various applications, including navigation and animal tracking [9]. Data analytics from the Vessel Monitoring System has improved the precision of predicting fishing locations, emphasizing the significance of data analysis in fisheries management [10].

Computational intelligence has shown the ability to enhance the accuracy of time series forecasting in service computing through innovative approaches [11]. The study examined agroecological fish culture systems designed explicitly for aquaculture technology for underprivileged households to showcase the societal effects of technical progress [12]. Multi-Receiver GPS Positioning with Kalman Filtering has been implemented to improve navigation accuracy, demonstrating progress in geospatial technology [13]. Comparative analyses of Recreation-grade and Mapping-grade GPS Receivers have identified discrepancies in precision in various situations, offering valuable guidance for choosing suitable instruments for specific purposes [14]. The utilization of GPS Biologging Technology for Spatial Ecology Studies has demonstrated significant advancements in the monitoring and tracking of wildlife, hence making valuable contributions to conservation initiatives [15]. The utilization of speed data has been investigated to detect fishing events in small-scale fisheries, leading to the development of novel techniques for recognizing fishing operations [16]. A Time Synchronisation System employing GPS and IEEE 1588 has been devised to guarantee perfect timing in vital infrastructure, underscoring the significance of accurate timekeeping [17].

Lane Determination with GPS Precise Point Positioning has showcased advanced techniques for mapping lanes [18]. An analysis has been conducted in aviation to improve navigation systems, specifically focusing on utilizing Global Navigation Satellite Systems [19]. The accelerated Emergency Response with Smartphone Geolocation Data demonstrates the practical uses of geolocation in emergency services [20]. Moreover, examining the role of P-Glycoprotein in fish has significant implications for assessing toxicity and monitoring the environment, providing valuable insights into environmental well-being [21]. An assessment has been conducted on the precision of medical referrals to Orthoptic Departments, highlighting the importance of accuracy in healthcare [22]. A significant advancement in satellite timing technology has been showcased by meticulously assessing the timing comparison between BDS-3 and GPS [23]. By analyzing these diverse and groundbreaking research articles, individuals engaged in the fishing industry, environmental sciences, technology development, and related fields can gain valuable insights into the latest advancements, methodologies, and technologies shaping the future of fishing practices and environmental monitoring.

2. RESEARCH METHOD

2.1. System Design

Figure 1. summarises the workflow for our cutting-edge fishing information system, which improves upon conventional fishing techniques through sophisticated technology. Initially, LoRa

Node indicators are strategically positioned on traditional fishing vessels. These boats have cooperated in the Gisik Cemandi region. Before deploying the tool, it is imperative to verify that the GPS on every node is linked to the gateway. There are three methods to monitor this connection:

1. The system will detect latitude and longitude positions by connecting to SPIFFS (192.168.4.1) over WiFi.
2. A ship icon will be displayed instantly upon connection by accessing the map feature on the website (http://iothink.space/).

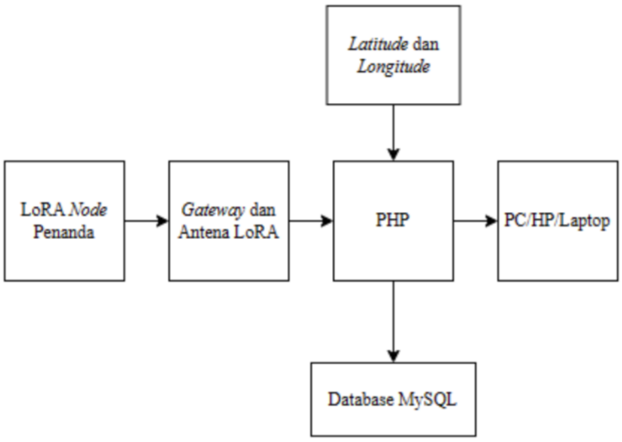

Figure 1. System planning flow

After establishing a connection between the GPS and gateway, the marker node becomes operational and can be utilized by fishers. The procedure is user-friendly: pressing button one for a duration of 15 seconds can indicate the presence of fish, while pressing button two for the same duration will indicate unfavourable weather conditions. Furthermore, the gateway and LoRa antenna have been positioned on the coastline and are being powered by a 5V power source derived from a power supply. Assuming the GPS is linked, the gateway may obtain data from the marker node and send it to the database utilizing a 5V power supply from a power bank. Data transmission is continuous as long as the LoRa node and gateway maintain their connection. If there is a loss of signal, the data will be stored in SPIFFS and can be subsequently retrieved in CSV format.

Furthermore, the database acquires up-to-the-minute data from the gateway, encompassing latitude and longitude coordinates and status updates triggered by pressing a button. The iothink.space website presents this data, along with records of ship voyages and details regarding fish distribution and adverse weather conditions. The iothink.space website is now available to the general public on mobile phones, PCs, tablets, and laptops. The interactive map, utilizing Leaflet JavaScript, exhibits green symbols representing fish dispersal points and red icons indicating unfavorable weather information. The data is refreshed at a frequency of 15 seconds. In addition, the website's Timelapse feature enables viewers to observe the historical paths of fishermen, showcasing the lengths between the starting point and fish distribution points or areas affected by adverse weather conditions through the utilization of the haversine function. This technique greatly improves the effectiveness and security of conventional fishing methods by utilizing advanced technology to deliver essential real-time information and historical analysis.

2.2. Data Flow Diagram (DFD)

Figure 2. presents a Data Flow Diagram (DFD) for a Fishing Information System. It showcases the interaction among fishermen, a meteorological data source, and other data-

gathering methods. The major stakeholders in the system are the fishermen, who act as the principal consumers, and the weather data provider, an external institution that supplies weather-related information. The diagram illustrates three primary processes: data acquisition from fishermen, weather data retrieval from the weather data source, and information presentation to the fishermen. Fishermen contribute data to the system, which is then gathered and saved as "Fisherman Data." At the same time, the weather data source provides information collected and saved as "Weather Data." Subsequently, the system utilizes the gathered meteorological data to present pertinent information to the fishermen, empowering them to make well-informed choices. The information flow is two-way: Fishermen provide data to the system and retrieve the weather data presented by the system. The DFD clearly represents how the Fishing Information System integrates and utilizes data from fishermen and weather sources to facilitate fishing activities.

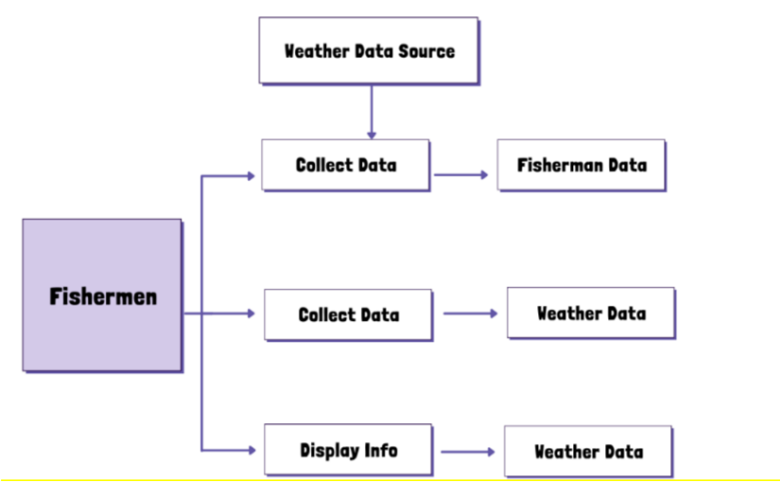

Figure 2. Data Flow Diagram (DFD) for a Fishing Information System

2.3. Data Collection Method

Figure 3. comprehensively depicts the data transmission architecture employed in our fishing information system. This flowchart depicts the process of processing and transmitting information on the distribution of fish and adverse weather conditions.

The relevant push button is activated when the system detects fish dispersion information (X1) or bad weather information (X2). Push button 1 is utilized to allocate fish, whereas push button 2 is employed to indicate unfavorable weather conditions. Subsequently, the system verifies whether the corresponding push button has been depressed. The information is transmitted over LoRa to the gateway after pressing the button. Otherwise, the data is directly stored in the logger. The transmitted data comprises the latitude and longitude coordinates of fish dispersal locations or adverse weather conditions. The data is transmitted to a PHP server linked to MySQL, which functions as the web server, and MariaDB, which serves as the database server. The fishing boat's map display interface utilises the Leaflet framework, while communication between the marker node and the gateway is facilitated using LoRa.

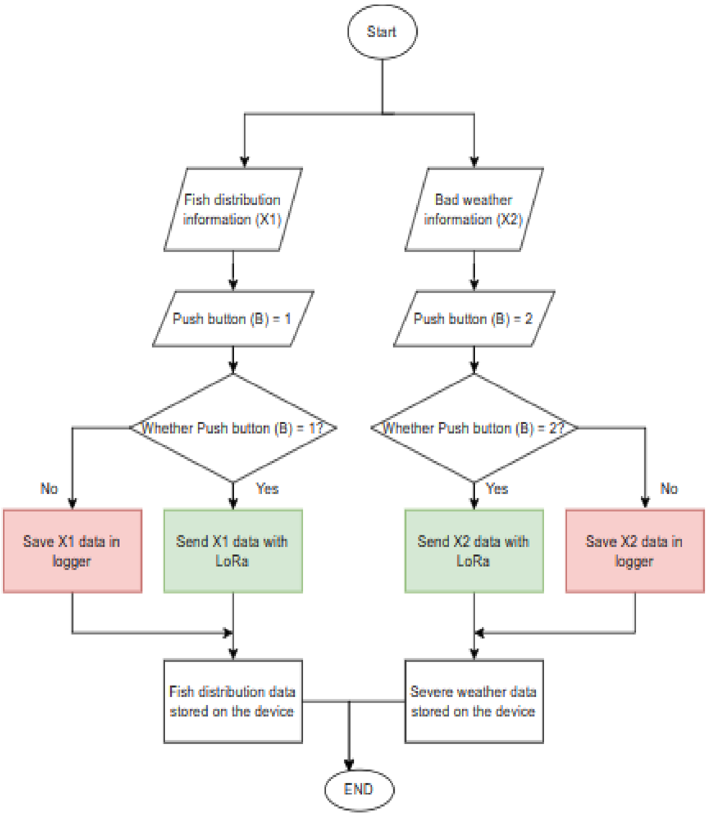

Figure 3. Data Transmission System Flowchart

The logger records the historical trajectory of the conventional fishing vessel. The utilization of a push button achieves control of data transmission. When the value of the push button is zero, the logger saves the data using the ESP32 media with the SPIFFS function. Subsequently, this data is exhibited on the website and archived in the database. This technology guarantees the effective and precise transfer of data, improving fishermen's capacity to monitor fish distribution and track unfavorable weather conditions in real-time. This system represents a substantial advancement over conventional fishing techniques due to the incorporation of cutting-edge technology such as LoRa, PHP, MySQL, MariaDB, and Leaflet.

2.4. LoRa

In this research, LoRa technology is implemented through the deployment of LoRa nodes on fishing boats and gateways along the coastline in Gisik Cemandi, Sidoarjo.

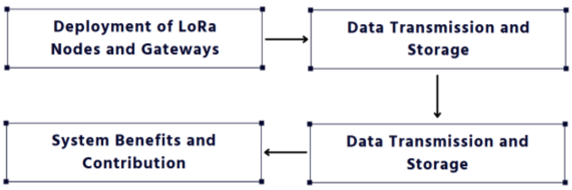

Figure 4. LoRa Works and Contribution

In Figure 4, LoRa technology is implemented through the deployment of LoRa nodes on fishing boats and gateways along the coastline in Gisik Cemandi, Sidoarjo. The nodes collect data on fish locations and weather conditions, which is then transmitted to the gateways and sent to a cloud server via 4G LTE for storage. When internet connectivity is unavailable, data is temporarily stored on the node's internal storage and uploaded later. The collected data is visualized on a web-based map, aiding fishermen in planning effective routes and avoiding dangerous weather. This system enhances fishing efficiency, improves safety, and offers a cost-effective solution for tracking fish distribution. By integrating LoRa technology, this research provides a robust and reliable method for improving traditional fishing practices and ensuring the safety and efficiency of fishermen's activities.

3. RESULTS AND ANALYSIS

3.1. Hardware Design Results

The device's design in Figure 5. incorporates multiple essential components to guarantee optimal functionality and performance. The LoRa node consists of an ESP32 microcontroller, a LoRa RFM95 module, and a GPS device. The LoRa Gateway has an ESP32, a SIM7600CE module, and an RFM95 module. The presence of these fundamental components is crucial for the device's proper functioning; the absence of any element can greatly hinder the system's performance. Aside from the main components, the gadget incorporates other auxiliary components to augment its functionality. The components consist of two push buttons, one designated for marking fish distribution (push button 1) and the other for notifying severe weather conditions (push button 2), a LoRa antenna, and a USB downloader. The LoRa gateway is essential for transmitting data to the database, which is subsequently showcased on the website.

Figure 5. LoRa Node and LoRa Gateway tools

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Incorporating these other elements, although not essential, greatly enhances the efficiency and dependability of the system. The push buttons facilitate user-friendly data input, while the LoRa antenna guarantees reliable wireless connectivity. The USB downloader simplifies the process of updating firmware and debugging. Collectively, these elements provide a thorough and dependable system for overseeing and controlling fishing operations, rendering it an invaluable instrument for fishermen.

3.2. Data collection

Figure 6. LoRa Gateway installation site on Suramadu bridge

Figure 6 is the location of the LoRa gateway installation, which will be installed around the Suramadu bridge with a LoRa antenna height of approximately 8 meters with a max gain of 8dBi.

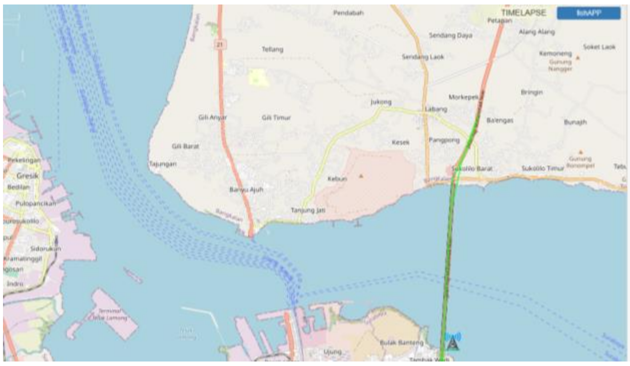

Figure 7. The results of the travel record around Suramadu

Figure 7 is the overview distance of the travel route stored and displayed through the iothink. space website, the optimal distance in this experiment is 7.72 Km. These results, with minimal obstacles, are close to the RFM95 datasheet, which is 8 km.

Download CSV

No	Timestamp	Fisherman ID	Latitude	Longitude	Status
1	13 Jul 2023 16:44:4	00004-00001	-7.278911	112.795183	2
2	13 Jul 2023 16:44:1	00004-00001	-7.278911	112.795183	2
3	13 Jul 2023 16:43:58	00004-00001	-7.278911	112.795183	0
4	13 Jul 2023 16:43:55	00004-00001	-7.278911	112.795183	0
5	13 Jul 2023 16:43:52	00004-00001	-7.278911	112.795183	0
6	13 Jul 2023 16:43:49	00004-00001	-7.278911	112.795183	0
7	13 Jul 2023 16:43:46	00004-00001	-7.278911	112.795183	0
8	13 Jul 2023 16:43:43	00004-00001	-7.278911	112.795183	0
9	13 Jul 2023 16:43:40	00004-00001	-7.278911	112.795183	0
10	13 Jul 2023 16:43:37	00004-00001	-7.278911	112.795183	0
11	13 Jul 2023 16:43:34	00004-00001	-7.278911	112.795183	0
12	13 Jul 2023 16:43:31	00004-00001	-7.278911	112.795183	0

Figure 8. Website display for downloading SPIFFS files

Figure 8 is an overview of the website for downloading SPIFFS files used in the LoRa Node Marker tool. How to use SPIFFS is, if the LoRa Node Marker with LoRa gateway is on / used to retrieve data, SPIFFS is automatically active, then connect to WiFi SPIFFS with a smartphone or laptop, open IP 192.168.4.1 on the website, the data will appear as shown above. The file can be downloaded in CSV format; if the timestamp is still invalid on the serial monitor, SPIFFS cannot display the latitude, longitude, and time points. The use of SPIFFS in this study is to be able to continue to store data when there is no signal. Status in the table with the number "1" indicates fish distribution, and "2" indicates bad weather.

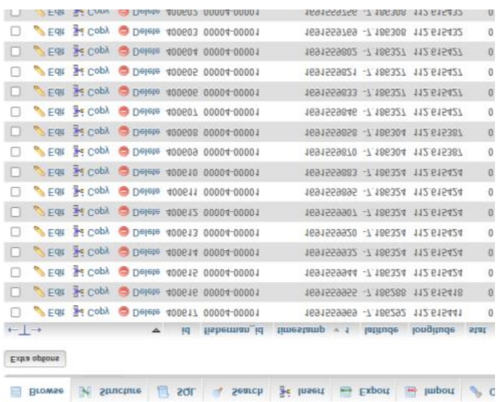
Figure 9. Display of data storage on phpMyAdmin

Figure 9. is a view of the database obtained when retrieving data. ID is the order of the data retrieved, fisherman_id is the LoRa node ID used, timestamp which contains the month and time, latitude and longitude obtained when retrieving data, and status obtained if "0" there is no information, "1" if there is fish distribution information, "2" if there is bad weather information.

3.3. Results of Using the Haversine Method

The following is the Haversine Formula method program used in Visual Studio PHP to get the desired distance between the LoRa gateway and the position of fish distribution and bad weather.

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi 1 \cdot \cos\varphi 2 \cdot \sin^2(\Delta\lambda/2) \quad (1)$$

$$c = 2 \cdot \mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)}) \quad (2)$$

$$d = R \cdot C \quad (3)$$

where φ is latitude, λ is longitude, R is the radius of the earth (average radius = 6,371 km); $1° \times \pi/180 = 0.01745$ rad

Haversine code in Visual Studio:

```
lat1 = x;
lat2 = lat_gateway;
lon1 = y;
lon2 = long_gateway;

// haversine
let R = 6371e3; // metres
let pi1 = lat1 * Math.PI/180; // φ, λ in radians
let pi2 = lat2 * Math.PI/180;
let delta_pi = (lat2-lat1) * Math.PI/180;
let delta_lambda = (lon2-lon1) * Math.PI/180;

let a = Math.sin(delta_pi/2) * Math.sin(delta_pi/2) +
        Math.cos(pi1) * Math.cos(pi2) *
        Math.sin(delta_lambda/2) * Math.sin(delta_lambda/2);
let c = 2 * Math.atan2(Math.sqrt(a), Math.sqrt(1-a));

let d = R * c
```

Table 1. Method Testing Data

No	Tanggal	LoRa *Gateway*		Node Penanda		Gambar
		Latitude	*Longitude*	*Latitude*	*Longitude*	
1.	14 Juli 2023	- 7.278987	112.794969	-7.279916	112.785098	
2.	14 Juli 2023	- 7.278987	112.794969	-7.278923	112.790624	

3.	14 Juli 2023	- 7.278987	112.794969	-7.278932	112.794988	
4.	14 Juli 2023	- 7.278987	112.794969	-7.277446	112.795342	
5.	14 Juli 2023	- 7.278987	112.794969	-7.277996	112.794101	
6.	13 Juli 2023	- 7.278987	112.794969	-7.278911	112.795183	
7.	20 Juni 2023	- 7.278987	112.794969	-7.278962	112.794915	

Table 1 compares the distances displayed using the PHP program, including the latitude and longitude points of the distance between the gateway to the fish information point in green circles and the bad weather information in red circles.

Table 2. Method Testing Data

No	Haversine Program Distance (Km)	Haversine Excel Distance (Km)	Error (%)
1.	1.0936	1.093649428	0,005%
2.	0.4793	0.479301849	0,000%
3.	0.0065	0.00646483	0,541%
4.	0.1762	0.176221477	0,012%
5.	0.1460	0.145975551	0,017%
6	0.0251	0.025071185	0,115%
7.	0.0066	0.006572927	0,410%
Average Error (%)			0,157%

The results of the distance comparison calculation in Table 2 show that the percentage error in using the haversine method for distance measurement with the program and Excel has a percentage error of 0,157%.

3.4. GPS Accuracy Testing Results

Quetcel LC86L GPS Accuracy Testing uses the GPS coordinate application on a smartphone to help compare coordinates; testing is done at 10 different points. Table 3 is a table of GPS comparison results.

Table 3. Comparison of GPS Calculations

No	GPS QUECTEL LC86L		GPS COORDINATES		*ERROR* (%)	
	LATITUDE	*LONGITUDE*	*LATITUDE*	*LONGITUDE*	*LATITUDE*	*LONGITUDE*
1.	- 7.289.762	112.784.612	- 7.289.761	112.784.610	0,000014%	0,000002%
2.	- 7.289.734	112.784.492	- 7.289.733	112.784.491	0,000014%	0,000001%
3.	- 7.289.729	112.784.451	- 7.289.729	112.784.451	0,000000%	0,000000%
4.	-7.290.290	112.800.321	-7.290.289	112.800.320	0,000014%	0,000001%
5.	-7.290.474	112.800.290	-7.290.472	112.800.288	0,00027%	0,000002%
6.	-7.290.504	112.800.306	-7.290.496	112.800.301	0,000110%	0,000004%
7.	-7.290.521	112.800.290	-7.290.501	112.800.288	0,000274%	0,000002%
8.	-7.290.562	112.800.254	-7.290.545	112.800.251	0,000233%	0,000003%
9.	- 7.281.563	112.780.966	- 7.281.553	112.780.964	0,000137%	0,000002%
10.	- 7.281.468	112.780.987	- 7.281.461	112.780.986	0,000096%	0,000001%
Average Error (%)					0,000116%	0,000002%

The calculation results in Table 3 show the percentage of GPS error using GPS Quectel LC86L, and the application on the coordinate GPS smartphone shows that at latitude, the percentage error is 0.000116%, and the percentage error at longitude is 0.000002%.

3.5. Results from RSSI Testing on LoRA

Tests are conducted in various areas to assess the performance of this tool. The results of these tests are used as a reference to assess the tool's performance and determine the extent of the LoRa signal range, as indicated in Table 4.

Table 4. Method Testing Data

No	Distance	RSSI(dBm)	Quality of Signal
1.	100 m	-57	Excellent
2.	500 m	-87	Excellent
3.	700 m	-101	Good
4.	1000 m	-117	Medium
5.	1500 m	-121	Poor

Table 4 presents the outcomes of RSSI tests conducted on LoRa in several places where the distances varied. Various places with distance intervals of 100 m, 500 m, 700 m, 1000 m, and 1500 m. The data above indicates that the RSSI value ranges from -57 dBM to -121 dBM. These values were obtained from distances ranging from 100 m to 1500 m. This implies that as the distance between the LoRa gateway and the LoRa node increases, the RSSI value decreases, indicating a weaker signal. Conversely, the RSSI value increases as the distance decreases, indicating a stronger signal. The decline observed in this experiment is not highly substantial and has a somewhat consistent pattern.

4. CONCLUSION

This study presents an innovative information system designed to assist fishermen by providing easy access to boat trip history, fish distribution points, and weather conditions. Leveraging LoRa technology and the iothink.space platform, the system allows fishermen to effortlessly obtain data on fish distribution and adverse weather conditions through a simple button interface: button "1" for fish distribution and button "2" for weather updates. The system demonstrates high accuracy, with an error margin of just 0.157% using the haversine method and even smaller errors in GPS accuracy for latitude and longitude. Performance assessments at various distances (50 m, 100 m, 500 m, 700 m, 1000 m, and 1500 m) reveal that signal strength decreases with distance, aligning with established wireless communication principles. This robust system not only supports existing theories but also provides a practical solution to enhance safety and efficiency for fishermen, advancing the application of modern technology in the fishing industry.

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