LoRa based long-range traceable life jacket system design

Bachtiar Adi Apriliansyah*, Muhammad Iqbal

Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, IPB University, Bogor 16680, Indonesia

Abstract. It is recorded that around 100 people per year die due to fishing boat accidents, the majority of whom are small fishermen with vessels under 10 GT. LoRa is a license-free power-saving long-distance communication technology that can send data packets of up to 15 km in the ocean. The long-range power can be used to determine the location of fishermen when an accident occurs at sea. This research aims to implement and test the performance of LoRa Ebyte E22-400T30D for sending coordinate data on fishermen's whereabouts in the form of life jackets. The performance observed is the relationship between the distance and the RSSI value obtained. The tests were performed until the furthest distance was reached. The test was carried out at Pangandaran Beach, and the receiver was placed at an altitude of 129 m toward the beach. The data will be displayed and stored on the Thinger.io website. The test results obtained with the furthest distance achieved were 12.983 km with a battery life of 5.99 hours. The RSSI value obtained tended to worsen with increasing distance. Apart from the distance, it was also found that obstructions in the form of trees could reduce the RSSI value.

1 Introduction

The potential of Indonesia's marine and fisheries sector is so vast that the government has launched a program that targets four important components of national development goals: stimulating growth, opening up jobs, reducing poverty, and policies that favor the environment [1]. In line with rapid development in all fields, development in the marine and fisheries sector has not been considered to significantly contribute to improving the welfare of people, especially small-scale fishers. Small-scale fishermen are a community of fishermen who catch fish at sea to meet their daily needs with simple fishing gear, which is also mentioned in Law No.7 of 2016 with the additional information of using fishing vessels with a maximum size of 10 GT [2].

The National Transportation Safety Committee (KNKT) noted that one-third or 31 percent of ship accidents from 2018 to 2020 occurred on fishing vessels. It has been stated that approximately 100 people per year die during fishing boat accidents. In accumulation, the number reached 342 dead and missing victims from 2018 to 2020 [3]. The majority of fishermen lost at sea in the archipelago were fishing boats with a size of 10 GT.

*Corresponding author: bachtiar.adi404@gmail.com
This is also coupled with the situation of fishermen, who are reluctant to wear life jackets. Based on [2], fishermen are not satisfied with the life jackets provided because they have a physical appearance and size that limits their mobility when carrying out fishing activities. Emergency tracking devices at sea have been widely circulated, such as the Emergency Position Indicating Radio Beacon (EPIRB) and the Kannad SafeLink SOLO PLB. EPIRB itself is large and relatively expensive, so it is quite difficult to distribute mass to small boat fishermen. On the other hand, the Kannad SafeLink Solo PLB has a small shape, but only a few suitable stations are barriers [4]. Almost the same research was conducted by [5], in which a GPS module was used to track the position of the life jacket, and data could be sent automatically when the user touched the water. However, a cellular GSM module is still used as a means of communication, which will certainly be a limitation when used in open waters, such as the open ocean.

Long Range Low Power (LORA) is a type of wireless communication that is included in a Low Power Wide Area Network (LPWAN), characterized by energy saving and a wide range [6]. Therefore, a tracking device integrated with a buoy that is comfortable for use by fishermen with a wide coverage of tracking areas based on LoRa is needed. The tool can also be made with a small size utilizing a microcontroller that functions as a regulator that controls the course of the input and output processes of electronic components. Research by [7] has revealed that LoRa communication technology can transmit information with a long range of up to 15 km, where fishermen with GT boats under 5 GT only go to the sea as far as 4 miles or 7.4 km.

2 Method

2.1 Working procedure

The research stages began with the preparation of tools and materials, mechanical design, electronic system design, laboratory tests, field tests, and data analysis. A diagram of the research stages is shown in Fig.1.

Fig. 1. Flow chart of research procedure.

2.2. Instrument design
2.2.1. Mechanical design

Broadly speaking, safety jackets must meet several requirements that serve to provide protection to workers on the water or on the surface to avoid drowning accidents and to regulate the user's buoyancy so that they can be in a position in the water (negative buoyancy) or float (neutral buoyancy) in the water [7]. The design of the LoRa-based long-range tracked life jacket instrument is shown in **Fig. 2**.

![Life jacket design](image1)

**Fig. 2.** Life jacket design.

The LoRa-based long-range tracked life jacket instrument design comprises a buoy, which is an integral part of the overall component. The impermeable box as a place for components uses a junction box type DS-AG-0813, which has dimensions of 130 mm × 80 mm × 70 mm, this junction box has an IP66 certification, and is safe when exposed to water.

The receiving station is designed to have two main components, namely, the receiving antenna and the electronics box, which is a junction box measuring 220 × 150 × 70 mm and is equipped with a rubber cable hole. The rubber cable hole facilitates the entry of the antenna cable and prevents water from entering the electronic box. The design of the receiving station is shown in **Fig. 3**.

![Receiver station design](image2)

**Fig. 3.** Receiver station design.

2.2.2. Electronical design

The electronic system in the LoRa-based long-range tracked life jacket instrument consists of several parts: the ESP8266 microcontroller as the control center, GPS module (NEO-M8M) to obtain location coordinate data, LoRa module (EByte E22-400T30D) to send coordinate data to the receiving LoRa station on land, 3 dBi antenna to increase the travel
power of LoRa signal transmission and reception, and 5000mAh power bank as an electrical power source. The power and data flow relationship of the life jacket instrument is shown in Fig. 4.

![Diagram of power and data flow relationship of the life jacket instrument.]

Fig. 4. Electronic data power flow on life jacket instrument.

The electronic system design at the receiving station consists of several parts, namely the ESP32 microcontroller as the controlling center, which is also connected to the Internet network via WiFi, LoRa module (EByte E22-400T30D) to receive coordinate data sent by the life jacket instrument, 5-element Yagi antenna to increase the travel power of LoRa signal transmission and reception, and 10000mAh power bank as an electrical power source. The power and data flow relationship of the receiving station is shown in Fig. 5.

![Diagram of power and data flow relationship of the receiving station.]

Fig. 5. Electronic data power flow on receiver station.

### 2.2.3 Field testing

Field testing was conducted on September 5, 2023, at Pangandaran Beach, Pangandaran, and Pangandaran Regency. The design was then connected to a LoRa receiver station that displayed the location of the life jacket.

### 2.2.4 Data analysis

The analysis used in this study was the RSSI value. The receiver signal strength indicator (RSSI) is the scale of the radio signal strength received by the receiving station. By determining the RSSI value, the distance between the sending and receiving stations can be determined [9]. Distance measurement using RSSI is useful for determining the accuracy value at a certain distance between the sender and receiver. It is also known that there is an error expressed with a negative value in the form of dBm. The dBm value is close to 0, indicating a better signal. Equation 1 can be used to obtain the RSSI value (dBm).

\[
RSSI = 10 \log_{10}(d) \ A
\]

\[
d = 10 \frac{RSSI - A}{10n}
\]
where \( n \) is the path loss exponent value, \( d \) is the distance when communicating in meters, and \( A \) is the reference value when the RSSI value is 1 m. Equation 1 can be simplified to determine the distance between the sender and receiver, as shown in Equation 2. Equation 2 is used to determine the distance between the sender and the receiver [10]. The path loss exponent is a parameter \( n \) that is highly influential in determining the critical limit of the coverage area. This parameter can be determined based on measurement data, which depend on the surrounding environmental conditions. Based on [8], environmental parameters can be grouped according to the conditions at their location; the following is the value of \( n \) based on the location conditions listed in Table 1.

### Table 1. Log-distance path loss exponent.

<table>
<thead>
<tr>
<th>( n )</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>Open space</td>
</tr>
<tr>
<td>1.6 - 1.8</td>
<td>Inside of building, line of sight</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Factory</td>
</tr>
<tr>
<td>2.8</td>
<td>Housing</td>
</tr>
<tr>
<td>2.7 - 4.3</td>
<td>No line of sight</td>
</tr>
</tbody>
</table>

### 3 Results and discussion

#### 3.1 System design result

The design is divided into two parts: the life jacket instrument that will be used by fishermen and the receiving station placed on land. The design of the life jacket instrument named Jaket LoRa (JALORA) is shown in Fig. 6. The life jacket was specially designed for rescue operations. The detailed specifications of JALORA are listed in Table 2.

### Table 2. JALORA Specification.

<table>
<thead>
<tr>
<th>Specification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Box Weight</td>
<td>0.4 Kg</td>
</tr>
<tr>
<td>Electronic Box Dimension</td>
<td>130 x 80 x 70 mm</td>
</tr>
<tr>
<td>Life Jacket Weight</td>
<td>1 Kg</td>
</tr>
<tr>
<td>Life Jacket Dimension</td>
<td>122 x 50 cm</td>
</tr>
<tr>
<td>Buoyancy</td>
<td>90 Kg</td>
</tr>
<tr>
<td>IP Certification</td>
<td>IP66</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>3.09 W</td>
</tr>
<tr>
<td>Battery Operational Duration</td>
<td>5.99 hour</td>
</tr>
<tr>
<td>Operational Range</td>
<td>12.9 Km</td>
</tr>
</tbody>
</table>

#### 3.1.1 Mechanical design result

The life jacket used was specially designed for rescue operations and had a maximum buoyancy of 90 kg, a body circumference of 122 cm, and a buoy height of 50 cm. The life jacket was also equipped with a chest pocket where the instrument was placed, and there were two pockets on the back to store the equipment. The instruments were placed in the chest pocket because the area was always above the water surface.
The electronic part of the life jacket instrument was controlled by the ESP8266 microcontroller, which included port D7 as RX GPS, port D6 as TX GPS, port D2 as RX LoRa Ebyte E22-400T30D, and port D3 as TX LoRa E22-400T30D. In particular, for the LoRa Ebyte E22 circuit on the ESP8266 microcontroller, pull-up resistors were added to the RX, TX, and VIN pins of 4.7 Kohms each. The pull-up resistor functions to avoid floating logic, which is the phenomenon of not being able to read the value of the voltage entering the I/O pin by the microcontroller [11].

Buoyancy testing of life jackets was also conducted on three users with different body weights. The three users had the same height, but their weights varied from 70 kg, 77 kg, and 90 kg. Four parameters were tested: the position of the user when standing and lying in the water and the position of the electronics box bag when the user is standing and lying in the water.

In Fig. 7, it can be seen that users with a body weight of 70 kg can still float on the surface of the water and do not sink when in a standing position, and the neck to the user's head is above the surface of the water. Users with a body weight of 70 kg can also float perfectly in the supine position. Users with a body weight of 77 kg could still float on the surface of the water and not sink when in a standing position, and the neck to the user's head was above the surface of the water. Users with a body weight of 77 kg can also float perfectly in the supine position.
position. Users with a body weight of 90 kg can still float on the surface of the water and not sink when in a standing position, and the neck of the user's head is above the surface of the water. Users with a body weight of 90 kg can also float perfectly in the supine position. The position of the electronic box bag on the three users also floats well and can maintain itself above the water surface. The electronic box pouch must remain on the water surface to ensure that data transmission can be performed.

3.1.2 **Electronical design result**

The design of the receiving station consists of an electronic box and LoRa antenna, and the electronic components of the receiving station are in a junction box to avoid environmental and animal disturbances. The design of the receiving station is illustrated in **Fig. 8**. The electronic part of the receiving station was controlled by the ESP32 microcontroller, and several ports were used, including pin RX2 as RX LoRa Ebyte E22-400T30D and pin TX2 as TX Ebyte E22-400T30D. Ebyte E22-400T30D is a LoRa module that utilizes a (Universal Asynchronous Receiver-Transmitter) serial communication protocol. The electronic system power in this research is supplied from a power bank with a capacity of 10000 mAh, the use of power banks was chosen to make it easier when the receiving station must be mobilized to a place that does not have an AC power source.

The UART is a device that can perform serial data communication by relying on transmitters, receivers, and clocks. The TX pin was used as the transmitter, whereas the RX pin was used as the receiver. The clock sets the data transfer rate. Unlike other communication methods, UART requires only three pins: TX, RX, and GND [12,13].

![System design result of receiver station (a) electronic box (b) antenna.](image)

**Fig. 8.** System design result of receiver station (a) electronic box (b) antenna.

The LoRa antenna was a 5-element Yagi antenna. The 5-element Yagi antenna is a type of directional antenna, which is an antenna that can only be directed in certain directions to transmit and receive electromagnetic waves [14]. The Yagi antenna consists of a dipole element as the main radiation transmitter, a reflector element as a radiation-reflecting element, and director elements that function to narrow the beam angle in a straight and directional manner so that the radiation pattern can be narrowed, and the distance travelled
is farther than other types of antennas at the same power input [15]. The 5-element Yagi antenna used has a working frequency of 433 MHz, which is the same as that of the Ebyte E22-400T30D LoRa module used, which is 433 MHz.

Referring to the Regulation of the Minister of Communication and Information Technology Number 1 of 2019, the frequency allocation used for LoRa in Indonesia is at a frequency of 915 MHz, and a frequency of 433 MHz was used to test the performance of the farthest distance that can be achieved by LoRa in the ocean. A working frequency of 433 MHz was chosen because of the basic nature of waves passing through a medium. The higher the frequency of the wave, the greater the energy absorbed, so that the signal penetration distance will be smaller or shorter, whereas a small frequency will experience less energy absorption, so that the penetrating distance is further away in an open place [16].

The power requirements were obtained based on the calculation of the components contained in the instrument. The total power generated by the transmitter was 3.09 W and the total current was 0.94 A. The receiver had a total power of 2.89 W and a total current of 0.89 A. The electrical specifications of each module and the power bank specifications are listed in Tables 3 and 4, respectively.

Table 3. Electrical specifications of the module.

<table>
<thead>
<tr>
<th>Modul</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32</td>
<td>3.3</td>
<td>0.24</td>
<td>0.79</td>
</tr>
<tr>
<td>GPS NEO-M8M</td>
<td>3.3</td>
<td>0.07</td>
<td>0.22</td>
</tr>
<tr>
<td>LoRa E22-400T30D</td>
<td>3.3</td>
<td>0.63</td>
<td>2.08</td>
</tr>
<tr>
<td>Buzzer</td>
<td>3.3</td>
<td>0.02</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 4. Battery specifications.

<table>
<thead>
<tr>
<th>Powerbank</th>
<th>Voltage (V)</th>
<th>Capacity (A)</th>
<th>Real capacity (A)</th>
<th>Power (Wh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anker PowerCore</td>
<td>3.7</td>
<td>10</td>
<td>7.4</td>
<td>37</td>
</tr>
<tr>
<td>Corde X Mini</td>
<td>3.7</td>
<td>5</td>
<td>3.7</td>
<td>18.5</td>
</tr>
</tbody>
</table>

With the known instrument current, the power load supplied by the battery can be calculated such that the operating duration of the instrument can be determined as follows:

Transmitter Battery Life = Battery capacity (Wh) / Power (W)
Transmitter Battery Life = 18.5 / 3.09 = 5.99 hour
Receiver Battery Life = Battery capacity (Wh) / Power (W)
Receiver Battery Life = 37 / 2.89 = 12.80 hour

Based on the calculation above, the battery life of the transmitter is 5.99 hour and the battery life for the receiver is 12.80 hour. The transmitter transmits the data once in 15 s, resulting in high electrical power consumption. The battery life can be extended by making the transmitting cycle longer, because transmission is one factor that requires the highest power of all modules.

3.2 Data analysis

The data from the recording of coordinates and RSSI values sent by the life jacket instrument and successfully received by the receiving station are then uploaded to the Thinger.io cloud platform. Thinger.io is an open-source Internet of Things (IoT) project platform that provides cloud capabilities to connect Internet-enabled devices, such as cell phones and computers.
Thinger.io can visualize sensor readings in the form of values or graphs [17]. Data can be uploaded into the cloud platform through an ESP32 microcontroller connected to the Internet via a WiFi network. ESP32 is the successor to the ESP8266 microcontroller, which has been given improvements on all fronts. Not only does it have WiFi connectivity support, but also Bluetooth Low Energy, which makes it versatile, even in its small size. Fig. 9 shows a web view of Thinger.io.

Fig. 9. Thinger.io web view (a) data bucket (b) live map.

Thinger.io provides many options for users to display data uploaded into various forms of interesting and informative information. Thinger.io provides several features that can be freely utilized by users. For example, in Data Buckets, all raw data recorded by the life jacket instrument and uploaded by the receiving station are displayed. The collected data can then be downloaded in .csv format for later processing, users can also choose the specific time range of the data that they want to download. Next is the Dashboard menu, in which users are given the freedom to present their data in various forms. One of the advantages of Thinger.io, which is not owned by other IoT cloud platforms, is that it presents the coordinate data obtained in the form of a real-time map. As long as the life jacket instrument is on and sends its coordinate data, the coordinate point continues to move in real time.

3.3 Analysis of the relation between RSSI value and distance

RSSI (Received Singal Strength Indication) value data are obtained from the results of testing in unobstructed sea environment conditions, and testing is carried out using the tracking method, where coordinate and RSSI data will continue to be received within one minute. Tests were performed under the following conditions: LoRa frequency of 433 MHz, power of 30 dBm, and baud rate of 9600 bps. The receiving station was located in the Batu Hiu tourist area, Pangandaran, at an altitude of 12.9 meters above sea level, with the antenna pointing to the east. Distance determination is then carried out after the coordinate data is obtained, the distance determination is carried out with the help of the web https://boulter.com/gps/distance/. Distance calculation is performed by entering the coordinates of the receiving station and the coordinates of the instrument point of the life jacket.
jacket. The distance data are presented in units of meters and RSSI in units of dBm. When the RSSI value approaches 0, the signal quality improves, whereas if the RSSI value deviates from 0, the signal quality worsens.

Relation between RSSI Value and Distance

![Relation between RSSI Value and Distance](image)

**Fig. 10.** Thinger.io web view (a) data bucket (b) live map.

**Fig. 10** is a graph of the relationship between distance and RSSI value that was obtained from the results of the LoRa-based long-range tracked life jacket instrument field trial, where the (x) x-axis is the distance data that was successfully obtained, and the (y) y-axis is the RSSI value obtained at each distance point. Ten instances of sending data were successfully received by the receiving station. The closest distance for sending a signal is as far as 56 m, and the farthest distance during the trial is obtained at a distance of 12,983 m. The Ebyte E22-400T30D LoRa chip, based on the manual document, has an RSSI value range of 0–256 dBm. The lowest RSSI value obtained during the trial was -56 dBm at a transmission distance of 333m. The highest RSSI value obtained during the test was -88 dBm at a transmission distance of 12,983 m, which is the farthest distance obtained during the field test. The RSSI value, distance, and coordinates of the life jacket instrument as a whole are listed in **Table 5**.

**Table 5.** RSSI data and distance testing results.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>RSSI (dBm)</th>
<th>Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>-61</td>
<td>-7.691612 108.538406</td>
</tr>
<tr>
<td>89</td>
<td>-68</td>
<td>-7.691371 108.538158</td>
</tr>
<tr>
<td>85</td>
<td>-68</td>
<td>-7.691269 108.538458</td>
</tr>
<tr>
<td>333</td>
<td>-56</td>
<td>-7.690552 108.541268</td>
</tr>
<tr>
<td>870</td>
<td>-67</td>
<td>-7.689371 108.546101</td>
</tr>
<tr>
<td>1,482</td>
<td>-68</td>
<td>-7.688315 108.551485</td>
</tr>
<tr>
<td>1,759</td>
<td>-67</td>
<td>-7.687733 108.554018</td>
</tr>
<tr>
<td>6,630</td>
<td>-68</td>
<td>-7.683450 108.598094</td>
</tr>
<tr>
<td>9,612</td>
<td>-76</td>
<td>-7.685491 108.625526</td>
</tr>
<tr>
<td>12,983</td>
<td>-88</td>
<td>-7.704536 108.655664</td>
</tr>
</tbody>
</table>

The graph in **Fig. 10** shows that the RSSI value tends to increase away from the value of 0 in line with the increasing transmission distance between the life jacket instrument and the receiving station, which is in line with [18]. The farther the distance between the two points,
the greater the RSSI value, and the closer the distance between the two points, the smaller the RSSI value, approaching 0. At a distance of 85 m, there is a difference where the RSSI value drops considerably to its lowest value, which is -56 dBm, a value smaller than the closest distance to the receiving station. The small RSSI value at a distance of 85 m could be caused by the location of the jacket in an open area without any obstacles. At a distance of 56 m, the RSSI value is -61 dBm, which is fairly high at a short distance. At distances of 89 m and 85 m, the RSSI values tended to be high, respectively -68 dBm and -68 dBm. The high RSSI value was due to natural obstacles, namely, in the form of trees. The signal trajectories travelled at distances of 56, 89, 85, and 333 m are shown in Fig. 11.

![Fig. 11. Signal trajectories at distance of 56 m, 89 m, 85 m, and 333 m.](image)

The RSSI signal strength is not only influenced by the distance between the receiver and sender, but signal attenuation, deflection, and reflection can also occur because of obstructed signal paths. Although the distance between the receiver and sender is small, the presence of obstructions in the signal path can reduce the signal strength, allowing the signal strength to be the same as at a long distance but without any obstructions [19]. Fig. 12 shows the overall signal trajectory, where at other points there are no objects blocking the signal trajectory, which can be referred to as Line of Sight (LOS) conditions.

At a distance of 870 m, an RSSI value of -67 dBm was obtained, and there were no obstacles that hindered the signal transmission process. At a distance of 1,482 m, an RSSI value of -68 dBm was obtained, an RSSI value which was greater than the previous distance in conditions without obstacles. At a distance of 1,759 m, the RSSI value is obtained at -67 dBm, and the RSSI value does not decrease significantly from the previous distance. At a distance of 6,630 m, an RSSI value of -68 dBm is obtained, the same as the previous distance. Even though the difference in distance is very large, the signal can still be said to be good. At a distance of 9,612 m, an RSSI value of -76 dBm was obtained, and there was a considerable increase in the RSSI value; however, this is still reasonable. Finally, at the farthest distance of 12,983 m, an RSSI value of -88 dBm was obtained, and the highest RSSI value was obtained in the field testing instruments. The test results show that the RSSI value obtained can still be classified as good, where the RSSI value is still below -100 dBm.
4 Conclusion

In this study, a LoRa-based long-range tracked life jacket instrument was equipped with a GPS module to obtain coordinate positions and a LoRa module to transmit the data packets obtained. The results showed a relationship between distance and RSSI value; the RSSI value tends to be worse or away from the value of 0 with increasing distance of the receiving station with the life jacket instrument. Obstruction factors in the form of trees can also worsen the RSSI value received; therefore, it is advantageous to use LoRa in marine areas that naturally have no obstacles on the surface. The success of this design can be seen from the farthest distance that can be reached by the LoRa module, which is 12,983 m (12.983 km). In future research, we hope to develop instruments using a special antenna whose size and shape are made to match the electronic box of the life jacket instrument, so that it can be made smaller without sacrificing the ability to transmit and receive antennas.

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