LoRaWAN-Based Fishing Zone Violation Monitoring System for Traditional Fishing Vessels in the Malacca Strait

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Abstract. The fisheries and marine sectors are among the potential sectors that Indonesia possesses. Fishermen, as the primary drivers of the maritime field, play an important role in the country's economy. As a sovereign nation, the government is expected to ensure and protect the safety of fishermen, particularly traditional fishermen who carry out fishing activities in Indonesian territorial waters. However, there are still many issues encountered in the field. One of them is the violation of fishing zones by traditional fishing vessels. With the numerous cases of fishing zone violations occurring, at least two main factors contribute to these violations: the lack of information regarding the permitted fishing zones that are still within Indonesia's territorial waters and the limited availability of navigation tools such as GPS and AIS, which many fishermen do not possess, preventing them from accurately knowing their position while fishing and whether they have exited the permitted zones. A fishing zone violation monitoring system is greatly needed to provide solutions to this problem. This study aims to design a monitoring system for fishing zone violations by traditional fishing vessels using LoraWAN technology as a communication device. The designed system will automatically provide early warnings from the Lora-Gateway to traditional fishermen who are fishing outside the designated zones through the Lora-Transponder device installed on the fishing vessels. The system will monitor every movement of vessels violating the fishing zone by utilizing the mapping data of Fishing Zone coordinates, stored in a real-time coordinate database. The monitoring system will also automatically send notifications as an early warning system if there are traditional fishing vessels that exit the legally established fishing zones by the government, referring to Indonesia's Exclusive Economic Zone (ZEE) of 200 nautical miles from the baseline coast. With this real-time monitoring system, it is expected to assist government agencies and stakeholders in monitoring the fishing activities of traditional fishing vessels, especially in the Malacca Strait region.

Keywords: Fishing zone violation monitoring, LoRaWAN, Traditional Fisherman, Realtime Tracking, ZEE

INTRODUCTION

The Malacca Strait Sea area is one of the Fisheries Management Areas of the Republic of Indonesia, also known as WPPNRI, which directly borders the territorial waters of two neighboring countries, namely Malaysia and Singapore [1]. The Malacca Strait Sea area is one of WPPNRI where illegal fishing practices by local fishermen are most frequently encountered. This is due to the Malaysian government claiming its maritime boundaries using the Continental Shelf principle, where the boundary is determined by the trench or areas below the seabed. In Indonesia, the Exclusive Economic Zone, commonly referred to as ZEE, is an area that extends 200 nautical miles from the baseline of the coastline [2].

WPPNRI refers to the fisheries management areas designated for fishing and aquaculture, which include: Indonesian waters, Indonesia's ZEE, rivers, lakes, reservoirs, swamps, and other water bodies with potential for development within the territory of the Republic of Indonesia [3]. This WPPNRI serves as a reference for fishermen to conduct fishing activities in Indonesian territorial waters. According to WPPNRI, the fishing areas permitted by the Indonesian government are based on the reference of the ZEE. If fishermen catch fish outside the designated ZEE or violate the established regulations for fishing, they will be apprehended and interrogated by the authorities, both from the local government and from other countries, for violating international maritime law.

Several cases of fishing zone violations experienced by fishermen generally occur in Indonesian waters that directly border neighboring countries. One of the areas with frequent violations is the waters of the Malacca Strait. Because the Malacca Strait directly borders neighboring countries, namely Malaysia and Singapore. Many fishermen in the Riau Coastal and Riau Islands regions are apprehended for violating fishing zone boundaries, whether intentionally or unintentionally. This is often due to circumstances beyond their control while carrying out fishing activities at sea, such as engine failure, strong waves, and other unforeseen events.

In recent years, there have been numerous cases of fishing zone violations by fishermen in the Riau Coastal and Riau Islands regions. According to data from the daily newspaper Kompas, since 2019, more than 100 fishermen from the Malacca Strait coastal areas have been detained by the Malaysian Maritime Police [4]. One notable case involved the capture of eight fishermen from Serasan Island, Riau Islands, who were apprehended and detained by the Malaysian police for allegedly violating fishing zone boundaries [5]. Another case involved six fishermen from Bintan, Riau Islands, who were captured by Malaysian police while at sea. Incidents of detention involving these fishermen have occurred repeatedly. This is because the waters around Awor Island in the Riau Islands are indeed a border area that directly adjoins Malaysian waters [6].

In another case, five traditional fishermen from Langkat Regency, North Sumatra, were reported to have been apprehended by Malaysian maritime police. The five fishermen were suspected of crossing the territorial boundary between Indonesia and Malaysia. It was reported that the fishermen were detained on Penang Island, Malaysia, on Tuesday, September 25, 2018. Initial suspicions indicate that the fishermen were still within Indonesian waters, as they were equipped with GPS navigation tools that allow them to know the territorial boundaries of fishing zones in Indonesian waters. However, when the arrest occurred, the fishermen were taken into Malaysian waters. Based on the facts of international maritime law, the fishermen were already in Malaysian territorial waters [7].

In other news, at least 23 fishermen from the Riau Islands Province have been arrested for illegal fishing in Malaysian waters over the past six months. The first arrest occurred in November 2023, when nine fishermen were apprehended by the Malaysian Coast Guard, also known as the Malaysian Maritime Enforcement Agency. As of 2024, a total of 14 Indonesian fishermen have been arrested in the waters of Sarawak, Malaysia. Four fishermen were arrested on March 9, 2024, and their case is currently undergoing trial. The latest case, which occurred just a few weeks ago, involved eight Indonesian fishermen who were arrested and accused of illegally fishing in the waters of Sarawak, Malaysia. This issue needs to be addressed from both upstream and downstream perspectives. It cannot solely rely on the Indonesian Consulate General to rescue fishermen apprehended by Malaysia. Local governments must actively socialize the importance of not engaging in illegal fishing in Malaysian waters. To prevent similar incidents from recurring, outreach activities should be conducted for fishermen, especially those in border areas, to educate them about national boundaries and how far they are allowed to fish. Even if fishermen use simple compasses, they should at least understand the limits of their national waters.

The numerous cases of fishing zone violations can be attributed to at least two main factors: the lack of information about the permitted fishing zones that still fall within Indonesian waters, and the limited access to navigation devices such as GPS and AIS, which many fishermen do not possess when fishing. As a result, they are unaware of their exact position while engaging in fishing activities. In reality, fishermen often rely on makeshift equipment for fishing, using their instincts and experience to catch fish in areas they believe are still within Indonesian waters. Consequently, when they are apprehended, they cannot prove their position, whether they are still in Indonesian waters or not. The implementation of an automatic monitoring system is essential to provide a solution to this issue. Below are several previous studies that discuss the utilization of monitoring systems in the maritime sector.

A vessel traffic monitoring system in the Malacca Strait has previously been proposed by Enda et al. This system utilizes ship data transmitted via AIS transponder devices. The received ship data is filtered using a proposed algorithm, resulting in a storage efficiency of 18.45% [8]. The next study involves the development of a front-end application for monitoring vessel traffic in the Malacca Strait based on AIS data. The developed monitoring system is web-based and visualizes ship data into interactive maps. The monitoring system has been tested and functions as intended, with the application interface performing well on desktop, tablet, and mobile devices [9]. A vessel traffic monitoring system in restricted areas based on AIS data has also been developed. The monitored restricted areas include vital infrastructure or zones in the waters, such as underwater pipes and cables. This system is designed to detect vessels entering prohibited zones in real-time, thereby preventing damage to critical infrastructure due to activities like anchoring or accidents. AIS data is utilized to track ships, comprising static information such as ship names and destinations, as well as dynamic information like position and speed [10].

An early warning system integrated with the Automatic Identification System (AIS) for the safety of vessels in the Bengkalis Strait has been proposed to reduce the number of maritime accidents involving traditional fishermen. This system utilizes LoRa technology integrated with AIS as a more affordable alternative for traditional fishermen, considering the numerous maritime accidents involving fishing vessels due to a lack of safety equipment. The LoRa end devices (transponders) will transmit data from various sensors, including environmental sensors, accelerometers, vibration sensors, and anemometers, which can provide additional information beyond standard AIS data [11]. The design of a Real-Time Automatic Identification System (AIS) aims to prevent fishermen from crossing international maritime borders and avoiding vessel collisions. This system is intended to enhance fishermen's awareness when approaching the territorial waters of other countries and provide early warnings through AIS devices integrated with GPS and VHF. The system employs various components, including a sound module, ultrasonic sensors, and an embedded PIC16F877A system to detect and alert when a vessel approaches the border line. If fishermen disregard the warning, the system automatically transmits the vessel's position information to the coast guard. Implementation was conducted through simulations along the maritime boundary between India and Sri Lanka, demonstrating improved results in preventing border violations and reducing collision risks compared to other methods, such as RF and GSM-based GPS [12].

This research proposes a monitoring system that can be utilized to track the position of traditional fishing vessels and notify them when they exit the permitted fishing zones. The fishing zones refer to Indonesia's Exclusive Economic Zone, which extends 200 nautical miles from the coastline. To relay information from the Monitoring System to the vessels, each traditional fishing boat will be equipped with an end device known as a LoRa-based transponder as the communication protocol. The LoRa transponder will form a LoRaWAN network to ensure that each device can communicate with a gateway over a wider range at a lower cost.

The developed monitoring system is expected to provide a solution to the issues of fishing zone violations committed by traditional fishermen. The presence of an early warning system for fishing zone violations can assist traditional fishermen who lack adequate navigation devices, such as AIS, while operating at sea. Additionally, the tracked vessel position data within this monitoring system can serve as supporting evidence for defense when fishermen are apprehended by authorities from other countries.

METHODS

To ensure that the research process is focused and structured, the procedures of this study begin with literature review, needs assessment, design, system development, testing, and system implementation. The research procedures can be seen in **Figure 1**.

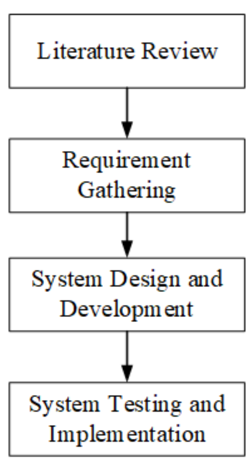

Figure 1. Research Procedures

This research procedure will be divided into several research stages, namely, the initial step is a literature review, looking for research reference data that is useful to support problem solving, the second stage is collecting system requirements, system requirements are divided into functional and non-functional requirements. These requirements data are used as a reference for creating a monitoring system design. After creating a system design, the next step is the system creation stage, then testing and analyzing the results of the monitoring system design that has been created to obtain the level of system performance when it will be implemented later. The final step is implementing the system in a real environment.

RESULTS AND DISCUSSION

REQUIREMENT GATHERING

Requirement analysis is conducted to identify user requirements, describe the system's functional and non-functional requirements, and create a prioritized list of functional requirements. From the preliminary analysis conducted, the following functional requirements list has been obtained:

Table 1. Functional Requirements List

No	Code	Functional Requirements	Priority
1	FR-01	Users can add coordinate point data of fish catch zones	High
2	FR-02	Users can change the coordinate point data of the fish catch zone	High
3	FR-03	Users can delete fish catch zone coordinate point data	High
4	FR-04	The system can display the coordinate point data of the fish catch zone	Medium
5	FR-05	The system can provide information on vessels that leave the fishing zone	Medium
6	FR-06	The system can provide information on the number of vessels leaving the fishing zone	Low

The non-functional requirements of the application are as follows:

Table 2. Non-Functional Requirements List

No	Code	Non-Functional Requirements	Priority
1	NFR-01	The system can display the coordinate point data of the fish catch zone in the form of a table	Medium
2	NFR-02	The system can display the coordinate point data of the fish catch zone on maps	Tinggi
3	NFR-03	The system can print a report of fish catch zone coordinate point data	Low

After getting some of the required system requirements, the next step is system design.

SYSTEM DESIGN AND DEVELOPMENT

System architecture provides a descriptive description of how a system works, how the system units are integrated with each other to achieve application goals. The following is the result of the proposed LoRaWAN network-based fishing zone violation monitoring system architecture design.

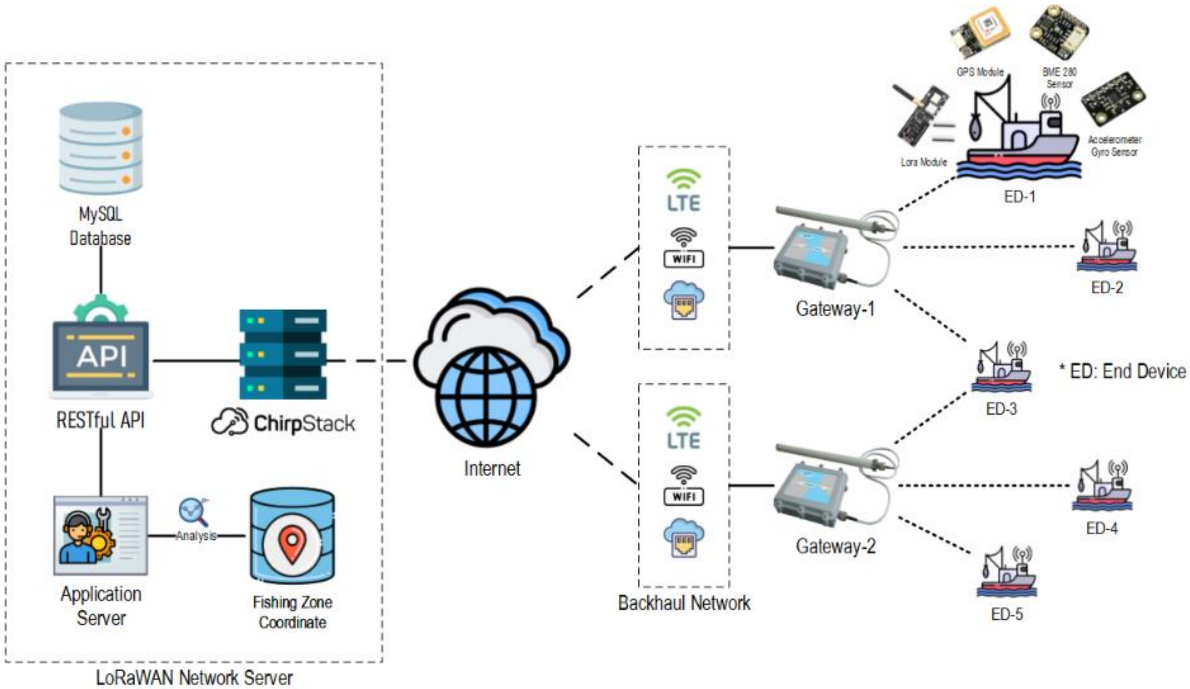

Figure 2. Fishing Zone Violation Monitoring System Architecture

Each ship will be installed with a end device called LoRa transponder. This LoRa transponder is equipped with several sensors such as GPS location sensor, accelerometer sensor, BME280 module, compass module, wind speed sensor, vibration sensor, and alarm module. The data acquired through the installed sensors will be sent to the gateways reached by each end device. The data collected at the gateways will then be sent to the LoRaWAN Network Server (LNS) using an internet network connection. Internet connection options available at the gateway include 4G LTE network, WiFi, and Ethernet LAN called Backhaul Network. The LNS used is open source, namely Chirpstack. Chirpstack was chosen because it can facilitate the development team in creating applications quickly, due to its high flexibility to be integrated with the application to be developed. Chirpstak LNS will then forward data from the gateway device to the Restful API to store the data in the PostgreSQL database. The server application will use the data stored in the database to display it on the interactive maps page.

Furthermore, based on the location sensor data read on each vessel, the monitoring system will automatically detect each vessel that leaves the fishing zone by analyzing the device coordinate point data with the fishing zone data that has been stored in the coordinate database. If any vessel coordinate data is detected out of the fishing zone, the system will provide feedback in the form of an alarm that has been installed on the LoRa transponder end device installed on the fishing boat.

The monitoring system is developed using the php programming language based on the laravel framework, both for building APIs and front-end applications. To display interactive maps, the application uses a leaflet library based on the javascript programming language. The database technology used is MySQL, with the database of fishing zone coordinates stored in a geojson file.

The following are the results of the designed transponder lora device prototype:

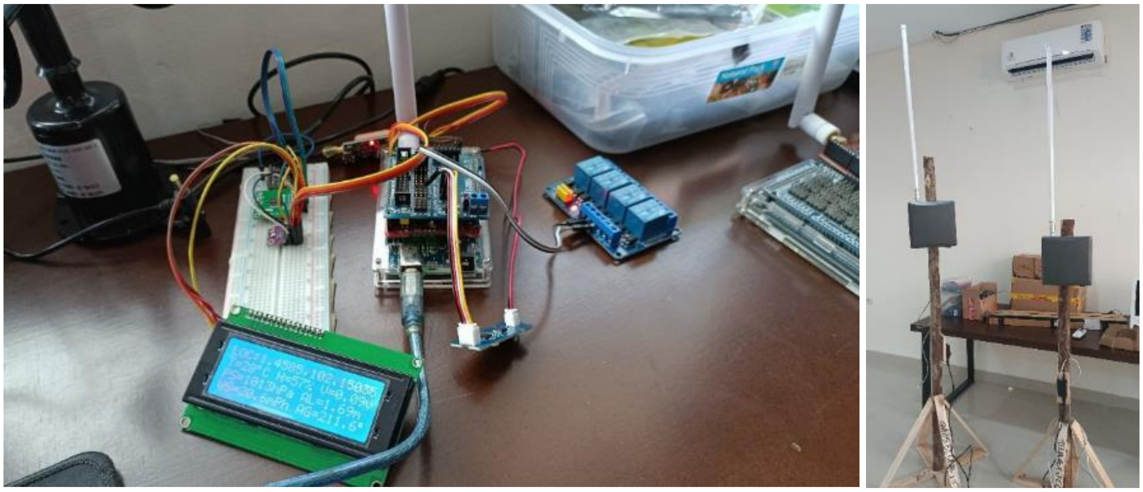

Figure 3. Prototype LoRa Transponder Device (Left) and LoRa Gateway Device (Right)

This LoRa Transponder device prototype is equipped with an Arduino microcontroller to control the work of the installed sensors. To display data, this device is equipped with an I^2C LCD module. The system alarm is activated using a relay module that is directly connected to the alarm module. The gateway device is assembled as shown in **Figure 3** right to collect data from the LoRa transponder device and forward it to the LoRa Network Server.

SYSTEM TESTING AND IMPLEMENTATION

The system was tested by sending data from the Lora transponder end device to the gateway, to be received by the chirpstack LNS and then stored in the MySQL database using the Restful API. Before testing, first integrate the application with the API using the http protocol. The configuration can be seen in **Figure 4** below:

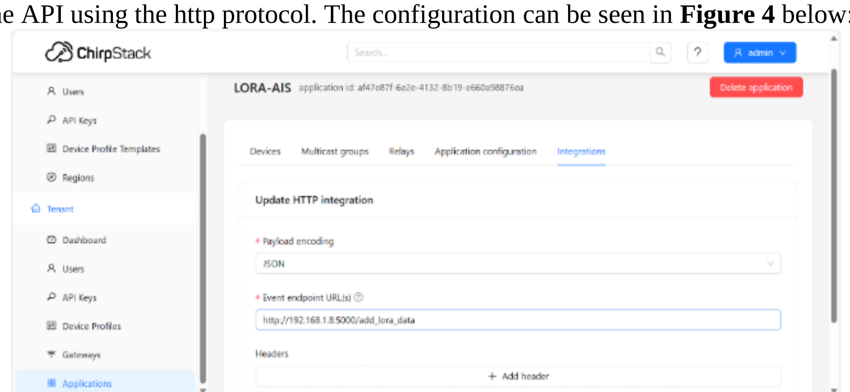

Figure 4. HTTP Integration to Restful API End Point

To integrate the application created with LoRa Gateway, it requires an API that can receive data with JSON encoding format and POST data transfer method. Here it is mandatory to fill in the end point url as the end point of the transferred data in the web application created. First, we must ensure that the data from the LoRa Transponder device has been received properly by the gateway.

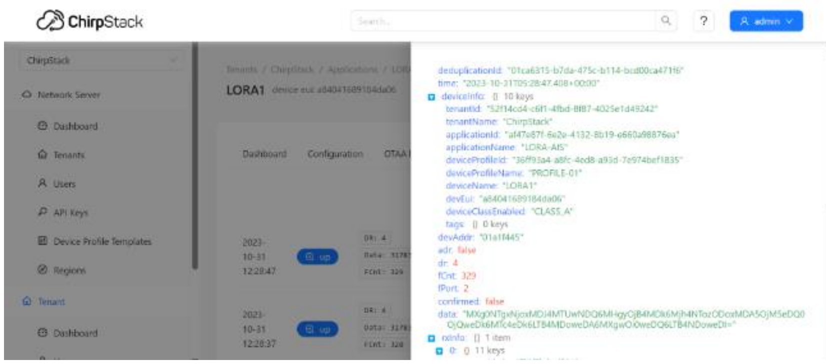

Figure 5. LoRa Data Received by Chirpstack LNS

In **Figure 5** above, data from the Lora transponder device has been successfully received in the Chirpstack LNS application. This data is then forwarded to the web application created with the Restful API intermediary.

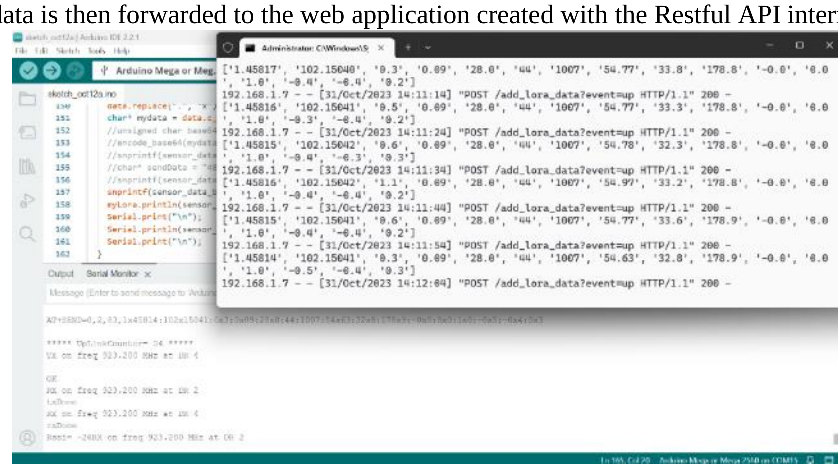

Figure 6. LoRa data received by Restful API

After completing the required configuration we can read the data through the Arduino IDE console terminal, or web application to ensure the data is sent and can be received by the web application properly. This data can also be monitored on the gateway under the LoRaWAN Frames tab.

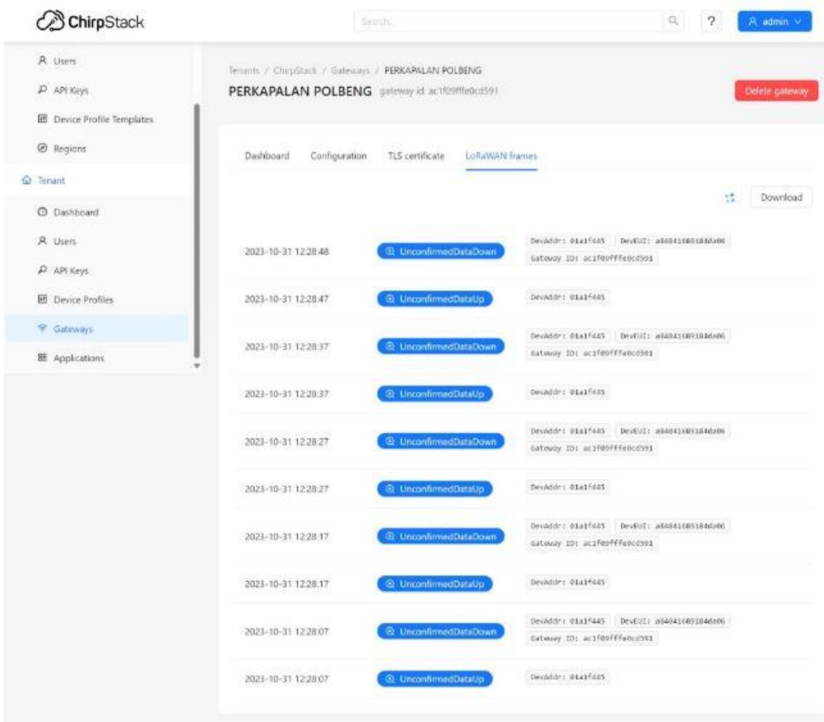

Figure 7. LoRa data received by Perkapalan Polbeng Gateway

Gambar 7 adalah hasil pembacaan data yang terekam di gateway melalui tab LoRaWAN Frames. Setelah memastikan data lora transponder dapat diterima di gateway dan diteruskan ke aplikasi web, tahap selanjutnya memvisualiasasikan hasil data yang dikirim ke aplikasi web yang telah dibuat seperti Gambar 8 berikut.

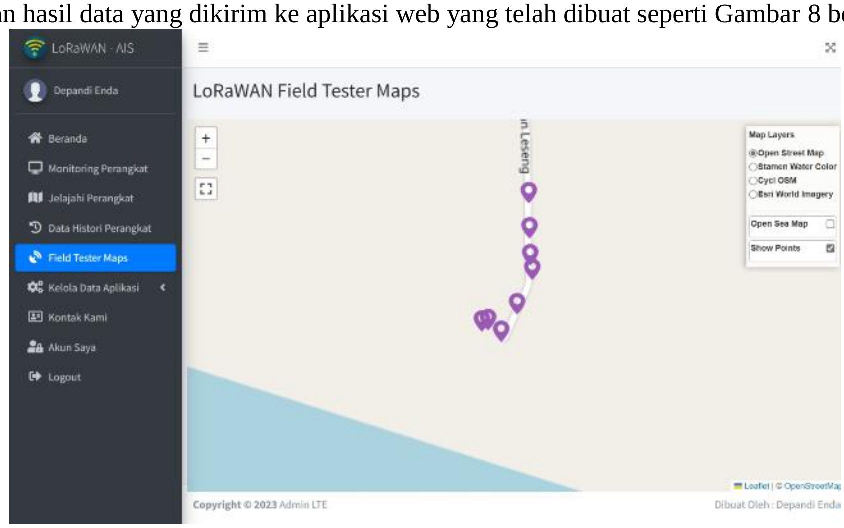

Figure 8. LoRa Data Visualization to Maps View

Figure 8 shows that the historical data of the coordinate points of the Lora transponder device has been successfully visualized into the interactive web maps page properly and correctly.

CONCLUSIONS

Based on the test results, the developed monitoring system has been able to work well, where the monitoring system units have been successfully integrated and are able to carry out tasks according to their respective functions. The lora transponder device successfully sends data to the gateway and the gateway is able to forward the lora data packet to the LNS chirpstack. Furthermore, Chirpstack LNS with integration to http post has successfully sent data to Restful API to store lora data to MySQL database. Finally, the history data stored in the database has also been successfully displayed on the interactive maps page.

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