# Implementation of an Early Warning System Integrated with AIS-POLBENG Remote Base Station for the Safety of Traditional Ships in the Malacca Strait

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**Abstract.** Referring to the Indonesian Minister of Transportation Regulation No. PM 7 of 2019 and IMO regulations on the use of AIS devices, it is stated that AIS devices must be installed on passenger ships, cargo ships with a minimum size of 35GT, and fishing vessels of at least 60GT. However, smaller vessels under 60GT are also highly recommended to equip AIS devices to enhance maritime safety and security. This recommendation is based on several maritime accidents involving traditional fishing vessels, which often lack safety equipment such as navigation tools and AIS devices. Therefore, the role of AIS devices is crucial for the safety of fishermen at sea, especially in preventing ship collisions, illegal fishing, and supporting SAR (Search and Rescue) operations. The high cost of AIS equipment presents a challenge for small-scale fishermen to afford these devices. This research aims to develop a more affordable alternative AIS device based on Lora technology, which offers similar functionality to standard AIS devices. The developed Lora Transponder can also be integrated with the existing AIS-POLBENG system, thereby facilitating monitoring activities and providing early warnings of potential hazards during sailing activities to traditional fishing vessels equipped with the device. The system implementation results show that the Early Warning System operates as expected. The maximum coverage of AIS Transponder data transmission is 49.87 Nautical Miles (92.36 Km). On the other hand, 3 units of lora transponder devices have successfully sent sensor and location data to the gateway every 30 seconds with the device set at class C and recommended using binary format for more efficiency.

**Keywords:** AIS, Lora Transponder, Early Warning System, Traditional Fishing Vessels, Maritime Safety

## INTRODUCTION

Referring to the Ministry of Transportation Regulation Number PM 7 of 2019 and IMO regulations regarding the use of AIS devices, it is stated that AIS devices must be installed on passenger ships, cargo ships with a minimum size of 35 GT, and fishing vessels with a minimum size of 60 GT [1]. However, for fishing vessels smaller than 60 GT, it is also highly recommended to have AIS equipment to enhance safety and security, especially when fishing at night. Moreover, AIS devices can also function as tools to monitor ships' locations when they are sailing and docking in harbor channels or strategic routes like the ALKI (Indonesian Archipelagic Sea Lanes) that are governed by international maritime conventions [2], the use of AIS can also facilitate the monitoring of illegal activities such as smuggling, illegal fishing, or assist SAR (Search and Rescue) operations and investigations in the event of a ship accident because with AIS, SAR teams can easily pinpoint the ship's location and movement.

There are two types of AIS devices, namely AIS Class A, which is generally installed on Indonesian-flagged ships that meet the SOLAS (Safety of Life at Sea) convention, and AIS Class B, which is usually installed on non-convention passenger and cargo ships. There is a price difference between AIS Class A and Class B devices, with AIS Class A being relatively more expensive than Class B. According to a survey from an online store, AIS Class A devices are priced between IDR 25 million and IDR 50 million per unit, while AIS Class B devices are priced between IDR 7.5 million and IDR 20 million per unit.

**Figure 1.** Examples of AIS Class A (Left) and AIS Class B (Right)

In principle, both AIS Class A and Class B work similarly by sending static and dynamic data to the AIS Remote Base Station via radio frequency signals using a VHF (Very High Frequency) antenna. The AIS antenna is a VHF radio antenna with 2 channels, namely 87B and 88B. Channel 87B, also known as channel A, operates at a frequency of 161.975 MHz, while channel 88B, known as channel B, operates at 162.025 MHz. The AIS radio signal transmission range is about 35 miles (56.3 km), provided there are no obstructions between the transmitting and receiving antennas. This radio signal is an analog wave, which is converted by the AIS Receiver into raw AIS data, such as AIS AIVDM & AIVDO NMEA messages. This raw data is formatted into a special structure (AIVDM & AIVDO), which needs to be translated using a decoder application library to produce useful information about a vessel, such as the ship's name, type, weight, cargo, source and destination, heading, altitude, speed, and more. This encoded data is divided into two categories: dynamic data (latitude, longitude, speed, heading, course, draught, destination route, ETA, etc.) and static data (MMSI, IMO number, call sign, vessel name, dimensions, etc.) [3].

The main function of the AIS device installed on ships is to simplify access and share the same information between devices, thus preventing potential hazards at sea, such as ship collisions. Therefore, AIS devices are highly recommended for ships operating at sea, especially traditional fishing vessels. According to data from Destructive Fishing Watch (DFW) Indonesia, 42 maritime accidents occurred between December 2020 and June 2021, resulting in 83 missing fishermen. Of these 42 incidents, 142 people were affected, with 83 missing, 14 deceased, and 42 survivors [4]. On average, seven incidents per month affect fishermen, often resulting in casualties. The high number of incidents involving fishing vessels indicates the vulnerability of fishermen at sea. Traditional fishermen generally work without personal protection and lack safety equipment such as navigation tools and AIS. Additionally, the National Transportation Safety Committee (NTSC) recorded that 31% of total ship accidents from 2018 to 2020 were dominated by fishing vessels. NTSC also noted that fishing vessel accidents outnumbered general cargo and passenger ship accidents. NTSC identified eight factors in fishing vessel accidents, including issues with construction, safety equipment, navigation tools, communication devices, manning, management, supervision, and regulations [5].

The absence of AIS equipment can lead to maritime accidents, such as the case of a fishing vessel from Teluk Papal Village, Bengkalis Regency, which was struck by a tanker while spreading its fishing net, resulting in three casualties, with two survivors and one fatality [6]. This collision could have been avoided if an early warning system had alerted the vessel's owners to sail on a safer route, as another ship was present on the same course. Another incident occurred in North Rupat, Bengkalis Regency, where a fishing vessel carrying three fishermen capsized in the waters of Tanjung Senepis, Rupat Utara [7]. The evacuation and rescue process could have been faster if SAR teams had received information on the ship's coordinates. The importance of AIS devices for the safety of fishermen is immense, especially as navigation and communication tools. Therefore, every fisherman planning to go to sea should have an AIS device to enhance maritime safety. However, the reality is quite different; according to interviews with 10 fishermen in Bengkalis, only one had an AIS device, highlighting the high risks fishermen face at sea. There are two main reasons cited by fishermen: first, the high cost of AIS devices, and second, a lack of understanding of how AIS works.

Several studies have been proposed to address these issues. A lightweight vessel tracking and monitoring system using LoRa (Long Range) technology is one potential solution. LoRa technology, with its long-range transmission and low power consumption, is suitable for small boats with limited energy. Experiments showed good results in terms of transmission range, link reliability, and low power consumption. Two LoRa configurations were tested: Spreading Factor (SF) 7 and SF12, balancing data speed and transmission reliability. The experiment achieved a reliability rate of up to 97% with a transmission range of up to 4 km, sufficient for tracking activities around the harbor or near the coast [8]. Another study developed a Mini-SART-DMOM prototype for detecting lost fishing vessels at a lower cost than market-available SART devices. The prototype used LoRa technology for long-range data transmission and GPS for location coordinates. The tests showed a limited range of only 50 meters, even though LoRa is generally capable of reaching up to 40 km. The study recommended adding an antenna signal booster for better performance at sea [9].

Another development is the LoRa-based e-fisherman prototype, which enables fishermen to report maritime violations, access weather information, fishing locations, market prices, and communicate with the mainland via an Android phone. Testing in urban areas of Bandung showed a maximum range of 5 km under Line of Sight (LoS) conditions and around 2 km under Non-Line of Sight (NLoS), with data packet loss rates varying from 16.67% to 57.47% [10]. A multi-gateway LoRa-based small fishing vessel tracking system for traditional fisheries in Indramayu was also developed. It ensures wide coverage and promising system performance in real conditions. The study concluded that 15 gateways would be needed to cover a 20 km coastline, with a maximum NLOS range of 1.35 km per gateway [11]. Another study applied LoRa technology to monitor fishing vessels in Padang, covering ships between 10GT and 30GT, with a maximum range of 3 km [12]. An IoT-based traditional fishing vessel tracking system has also been developed. The results showed that the movement of two fishing vessels weighing 5GT was successfully detected within a 3 km range from the coastline, using wemos devices to capture location data every 2 seconds, along with wind speed and temperature information, displayed on a web-based monitoring system [13].

Based on the issues mentioned, this study developed an affordable AIS device accessible to fishermen at a lower cost while maintaining the same functionality as standard AIS. The communication module used as an alternative for transmitting and receiving data is the LoRa module, which has been experimentally proven to have a range of up to 22 km (13.67 miles) under clear Line-of-Sight (LOS) conditions [14]. Additionally, using the LoRa module is believed to improve battery efficiency, extending battery life, and supporting two-way communication for both sending and receiving data. LoRa technology offers better energy efficiency compared to VHF radio communication technology, with nearly the same transmission range [8]. The developed LoRa transponder is also integrated with the AIS Remote Base Station (RBS) at the Bengkalis Polytechnic, which can capture AIS Class A and Class B signals with a reception range of approximately 100 km [15]. An interactive map-based web interface was also developed to display AIS data captured by the Polbeng RBS. The web application works well on various platforms, including desktop, Android mobile, and tablets [16].

It is hoped that this LoRa-based AIS device will provide a more affordable alternative for traditional fishermen, with an estimated production cost of less than IDR 3 million. Additionally, this device can assist stakeholders like port authority officers in monitoring and overseeing maritime traffic, particularly fishing vessels at sea.

## METHODS

The system design used refers to the design of an early warning system that has been developed previously [17].

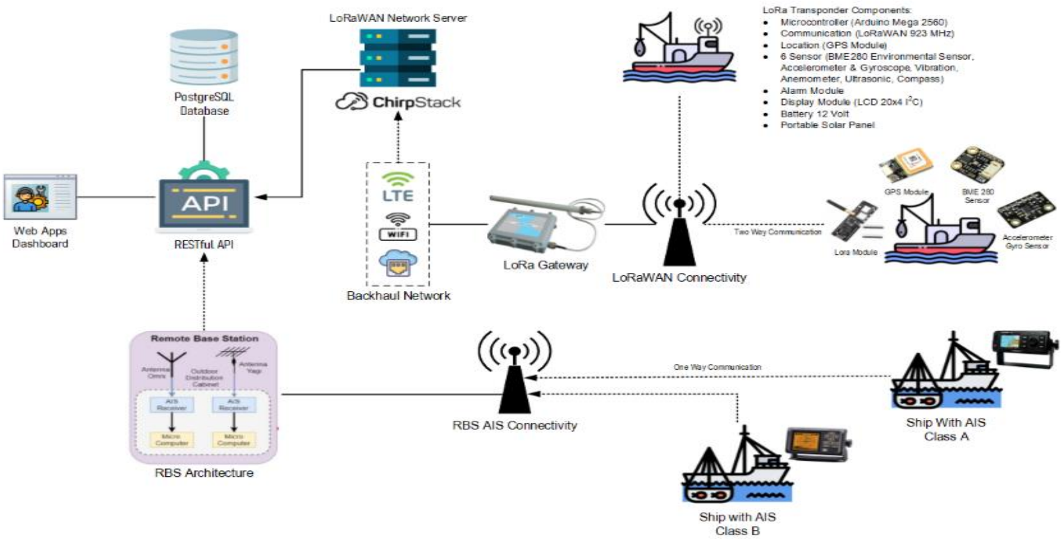


**Figure 2.** LoRaWAN-based Early Warning System Architecture Integrated with AIS

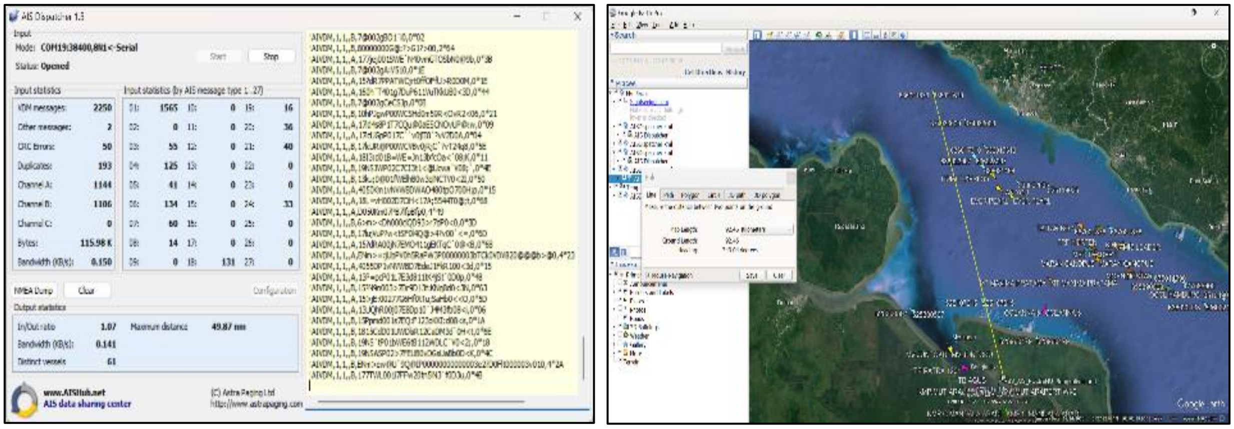
There are several architectural components, starting from the LoRa Transponder end device installed on the vessel, LoRa Gateway, Backhaul Network, Chirpstack LoRaWAN Network Server, Restful API, Remote Base Station Architecture, AIS Class A/B, PostgreSQL Database, and Web Application Dashboard. The working mechanism of this EWS begins with sensor and location data from the LoRa Transponder device being sent to the nearest gateway located by the shore. The data received by the gateway is forwarded to Chirpstak LNS via a backhaul network (LTE 4G, WiFi, or Ethernet LAN). Chirpstak LNS communicates with the AIS POLBENG Server through a web service built using RESTful API. Meanwhile, AIS Transponder data (either Class A or B) received by the Remote Base Station (RBS) AIS POLBENG is also sent to the web service. The data from both the LoRa Transponder and the AIS Transponder are processed by the web service and combined before being stored in a PostgreSQL database. The data stored in the database can be utilized by the application in real-time to display an interactive web map interface.

## RESULTS AND DISCUSSION

## AIS AND LORA TRANSPONDER DEVICE PROTOTYPE

**Figure 3.** AIS Antenna Installation (Left), RBS Installation at Polbeng AIS Research Lab (Center), AIS Class B Device (Right)

The AIS antenna is installed at a height of 20 meters above ground level, and the RBS AIS devices have been installed in the AIS research room at Polbeng. The installation of the Polbeng RBS has been tested and successfully read AIS data from both Class A and Class B vessels effectively. The AIS Class B device was also tested to determine the maximum range or signal reception distance of the Polbeng RBS AIS. Below are the results of the AIS data readings in the AIS Dispatcher application 1.5.


AIS Dispatcher 1.5

Input
Mode: COM19:38400,8N1<-Serial
Status: Opened

Input statistics
VDM messages: 2250
Other messages: 2
CRC Errors: 50
Duplicates: 193
Channel A: 1144
Channel B: 1106
Channel C: 0
Bytes: 115.98 K
Bandwidth (KB/s): 0.150

Input statistics (by AIS message type 1..27)

| | | | | | |
|---|---|---|---|---|---|
| 01: | 1565 | 10: | 0 | 19: | 16 |
| 02: | 0 | 11: | 0 | 20: | 36 |
| 03: | 55 | 12: | 0 | 21: | 40 |
| 04: | 125 | 13: | 0 | 22: | 0 |
| 05: | 41 | 14: | 0 | 23: | 0 |
| 06: | 134 | 15: | 0 | 24: | 33 |
| 07: | 60 | 16: | 0 | 25: | 0 |
| 08: | 14 | 17: | 0 | 26: | 0 |
| 09: | 0 | 18: | 131 | 27: | 0 |

Output statistics
In/Out ratio 1.07
Maximum distance 49.87 nm
Bandwidth (KB/s): 0.141
Distinct vessels 61

**Figure 4.** AIS Data Reading Results using AIS Dispatcher (left) and Google Earth Pro (right)

After a 15-minute observation, it was found that the POLBENG AIS Remote Basestation device was able to capture AIS signals transmitted by ships with an estimated coverage radius of 49.87 Nautical Miles, or approximately 92.36 km.

The next step is the installation of the LoRaWAN Gateway device, and the following are the installation and configuration steps:

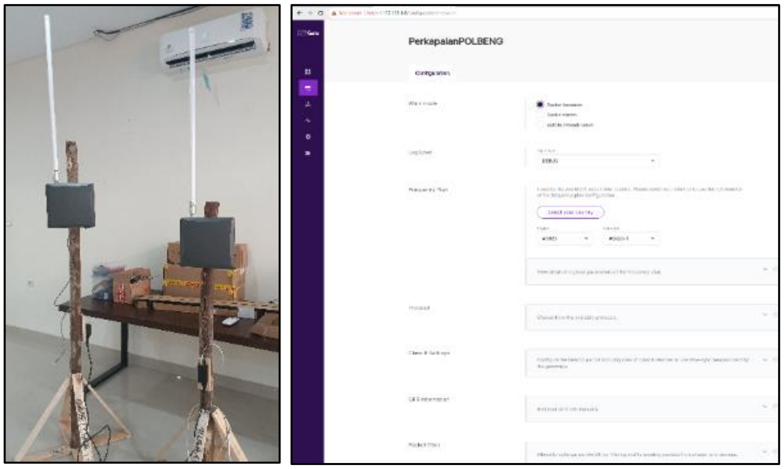


**Figure 5.** Lorawan Gateway Configuration Result as Packet Forwarder

The LoRaWAN gateway device will forward packets to the LoRaWAN network server (Chirpstack) installed on a Raspberry Pi device using the 'Packet Forwarder' mode configuration, AS923 working frequency, 'Semtech UDP GWMP' protocol, and a 30-second statistics interval.

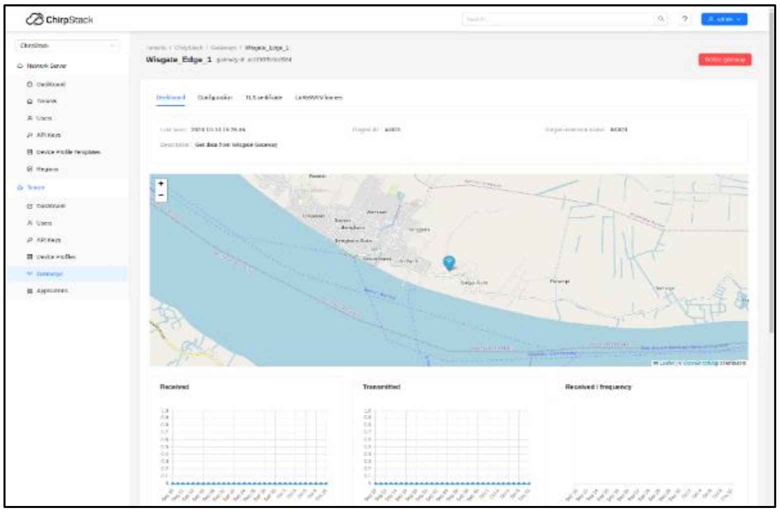
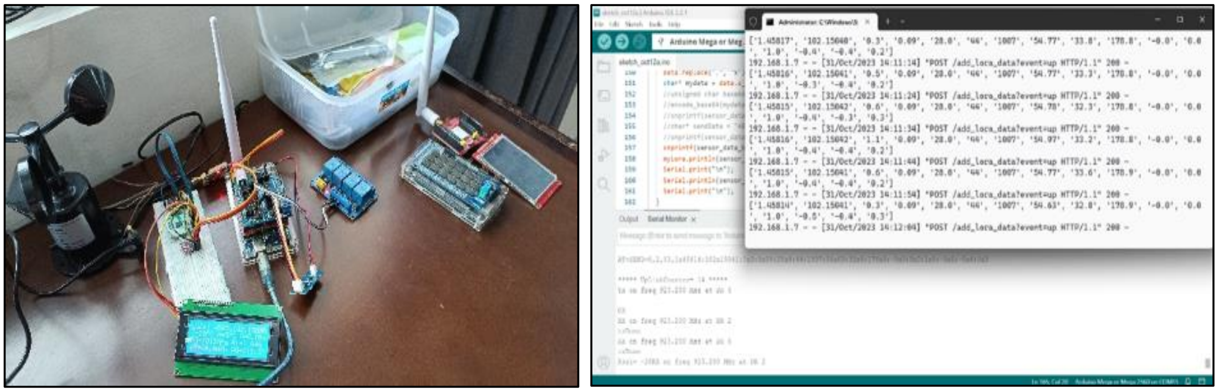


**Figure 6.** Results of Adding the LoRaWAN Gateway Device in the ChirpStack Application

After the gateway device is installed and configured, the next step is to set up three units of LoRa transponder devices. Here are the results:



```
['1.45817', '102.15040', '0.3', '0.09', '28.0', '44', '1007', '54.77', '33.8', '178.8', '-0.0', '0.0
', '1.0', '-0.4', '-0.4', '0.2']
192.168.1.7 - - [31/Oct/2023 14:11:14] "POST /add_lora_data?event=up HTTP/1.1" 200 -
['1.45816', '102.15041', '0.5', '0.09', '28.0', '44', '1007', '54.77', '33.3', '178.8', '-0.0', '0.0
', '1.0', '-0.3', '-0.4', '0.2']
192.168.1.7 - - [31/Oct/2023 14:11:24] "POST /add_lora_data?event=up HTTP/1.1" 200 -
['1.45815', '102.15042', '0.6', '0.09', '28.0', '44', '1007', '54.78', '32.3', '178.8', '-0.0', '0.0
', '1.0', '-0.4', '-0.3', '0.3']
192.168.1.7 - - [31/Oct/2023 14:11:34] "POST /add_lora_data?event=up HTTP/1.1" 200 -
['1.45816', '102.15042', '1.1', '0.09', '28.0', '44', '1007', '54.97', '33.2', '178.8', '-0.0', '0.0
', '1.0', '-0.4', '-0.4', '0.2']
192.168.1.7 - - [31/Oct/2023 14:11:44] "POST /add_lora_data?event=up HTTP/1.1" 200 -
['1.45815', '102.15041', '0.6', '0.09', '28.0', '44', '1007', '54.77', '33.6', '178.9', '-0.0', '0.0
', '1.0', '-0.4', '-0.4', '0.2']
192.168.1.7 - - [31/Oct/2023 14:11:54] "POST /add_lora_data?event=up HTTP/1.1" 200 -
['1.45814', '102.15041', '0.3', '0.09', '28.0', '44', '1007', '54.63', '32.8', '178.9', '-0.0', '0.0
', '1.0', '-0.5', '-0.4', '0.3']
192.168.1.7 - - [31/Oct/2023 14:12:04] "POST /add_lora_data?event=up HTTP/1.1" 200 -
```

**Gambar 7.** Figure 7. LoRa Transponder Prototype results (left), Data Reading via Arduino Console (right)

The LoRa Transponder device is configured as follows to send data to the gateway.

**Table 1.** LoRa Transponder Device Configuration

| No | Cofiguration Parameter | Value | Description |
|---|---|---|---|
| 1 | Interval | 30 second | Data Transmit/Receive Time Interval |
| 3 | Default RX Data Rate | 2 | Default user-defined RX Data Rate |
| 4 | fPort | 2 | Port used to communicate to the gateway, each device must have a different port to avoid possible data collisions |
| 5 | Adaptif Data Rate (ADR) | True | Adaptive data rate works according to environmental conditions |
| 6 | Data Format | Base 64 | Data format that will be sent to the Gateway |
| 7 | Frecuency | 923.200 MHz | LoRaWAN network working frequency |
| 8 | Network Join Mode (NJM) | OTAA | Activation method to LoRaWAN network |
| 9 | LoRaWAN Class | C | LoRa device class |

The data is sent at intervals of every 30 seconds, with a data size of 86 bytes in string format and 37 bytes in binary format, by three units of LoRa Transponder devices. The data is received by the Gateway and then forwarded to Chirpstak LNS, with the results as follows:

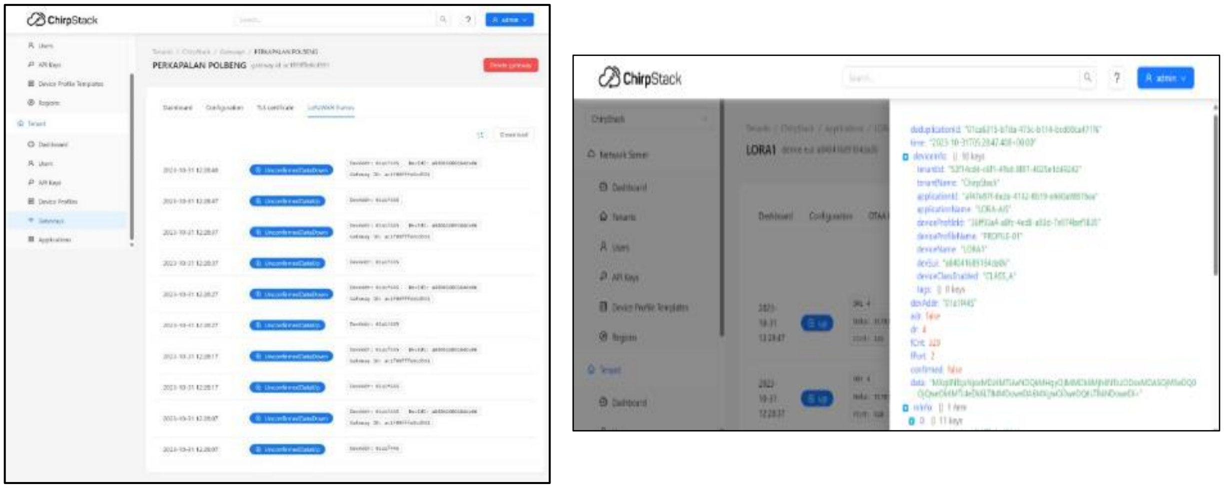


**Figure 8.** LoRa Data Reception Results in Chirpstack LNS

Based on the experiment conducted, the results show that all sensor data from the three LoRa Transponder devices were successfully read and sent to the Gateway in base64 format.

## CONCLUSIONS

The automated early warning system has been integrated and its functionality tested. The results show that the system operated well after being put into use. Data from the end devices, whether LoRa Transponders or AIS Transponders, successfully entered the developed monitoring system. The maximum range of data transmission from the AIS Transponder that was readable by the system was 49.87 Nautical Miles, or approximately 92.36 km. On the other hand, the connectivity between the LoRa Transponder devices and the Gateway was also tested, with all three LoRa Transponder devices successfully sending sensor data to the Gateway at 30-second intervals in either string or binary format. The binary data format proved to be the best option for sending data packets over the LoRaWAN network, being 57% more efficient in terms of data size compared to the string format.

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