Study of LoRa (Long Range) communication for monitoring of a ship electrical system

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Abstract. This paper presents a study of long range (LoRa) communication for monitoring of a ship electrical system. Three categories of electrical system include generator, power distribution, and navigation are monitored. A low power communication technology of LoRa is used to transmit electrical variables such as current, voltage, and power are logged and sent to the server. Experiments using LoRa SX1278 and Arduino have been inducted to validate the performance of the communication. Three spreading factors 12, 7, 6 have been tested. From experiments results, the performance of the communication has been analysed, if has been found that 97% successful data transmission was achieved with maximum distance. Furthermore, small baud rate communication was more suitable for the application.

1. Introduction

Sea transportation is one of the evolving technology sectors. This can be seen from the number of passengers and goods transported by ships which are increasing every year [1]. Monitoring and management of the electrical system on the ship comes out important. The International Maritime Organization (IMO) uses the Ship Energy Efficiency Operational Indicator (EEOI) to improve the energy efficiency of the operated vessels [2]. The operational conditions of the overall transportation system are related to external environmental factors. As long as optimal management and control of propulsion systems and auxiliary equipment are keys for improving ship energy efficiency [2].

LoRa (Long Range) represents the physical layer or wireless modulation used to build long-distance communication [3]. LoRa is a low-power long-range wireless communication platform. Lora is perfect for battery-powered devices and Wireless Sensor Networks (WSN) implementations [4,5]. One of the transceiver modules that can be used is the SX1278 module produced by Semtech Industries, SX1278 [6].

In recent years, wireless sensor network technology has begun to be developed. On the wireless sensor network there are components that can read sensors called nodes. Sensor data that has been read by the node will be processed by the node and sent to the server [5,7]. This study discusses the use of the SX1278 LoRa which is applied to monitoring and data logging electricity on the ship wirelessly.
2. Literature review

2.1. Electricity ship

The electrical system on the ship is divided into several parts. Including generators, and power distribution. The generator is responsible for generating electricity used for ship needs. While the power distribution system is used to regulate the use of the power load of electrical components on the ship. The electrical component load on the ship includes lighting loads that require a voltage of 220 VAC, the power load requires a 220 VAC / 380 VAC stand, and the navigation / instrumentation load that requires a 24 VDC stand. The electrical system is used for sailing ships.

2.2. Long Range (LoRa) communication

LoRa (Long Range) is a telecommunications technology that requires a fairly small power and has a long transmitting distance so it is very suitable for long distance communication. To get long distances LoRa reduces data transfer speed, uses low frequencies, and limits the number of devices that can communicate [6,8-10]. Compared to wireless telecommunications technologies such as WiFi, Bluetooth, and ZigBee, LoRa has several advantages over such modules with respect to the power consumption, transmission distance, and cover areas [6,11]. Table 1 shows a comparison of several wireless communication technologies [8].

| Type     | Distance | Maximum Rate | Power Consumption |
|----------|----------|--------------|-------------------|
| Bluetooth| 10 M     | 2 M/S        | Low               |
| LoRa     | 0–15 KM  | 600 KB/S     | Low               |
| Wi-Fi    | 0–60 M   | 54 M/S       | High              |
| ZigBee   | 0–1500 M | 250 KB/S     | Low               |

Semtech SX1276, SX1277, and SX1278 are some of the LoRa modules that are usually used. The specifications of the three modules are found in Table 2 below [6].

| Model   | Frequency Range | Spread Spectrum Factor | Bandwidth | Effective Bit Rate | Prediction Sensitivity |
|---------|-----------------|------------------------|-----------|--------------------|------------------------|
| SX1276  | 137 – 1202Mhz   | 6 - 12                 | 7.8 - 500Khz | 0.018 - 37.5Kbps  | -148dBm               |
| SX1277  | 137 – 1202Mhz   | 6 - 9                  | 7.8 - 500Khz | 0.11 - 37.5Kbps   | -139dBm               |
| SX1278  | 137 - 525Mhz    | 6 - 12                 | 7.8 - 500Khz | 0.018 - 37.5Kbps  | -148dBm               |

![Figure 1. Schematic of LoRa SX1278.](image-url)
Figure 1 shows schematics of LoRa SX 1278. SX1278 works in half duplex, the PE4259 analog switch is used to switch modes. By connecting the FEM_CPS level, L1, L2, C3, C4 and R1 are filter circuits of the receiver circuit. L7, C21, C22 and C23 are series resonance circuits from the transmitter circuit. C8, L5, and C8 are parallel resonance circuits [6].

3. Method

Figure 2 shows how the system works in this study. Each load of electrical equipment on the ship is added to a device used to see the voltage and current values. The sensor data is used to calculate the power usage in each electrical load which will then be sent to the user/server using LoRa. On the server data is processed and sent to the database that has been installed on the server to be displayed on the website.

![Diagram block system](image)

**Figure 2.** Diagram block system.

Figure 3 shows the circuit at each node that will be installed on the ship load. In figure 3(a) is a node that is installed on AC power load on this node using Arduino as a microcontroller that processes all data. The sensor used is ACS712 5A as a current sensor and ZMPBT101B as a voltage sensor. Whereas in Figure 3(b) it is installed in DC electrical load. Using a DC voltage sensor.

![Schematic node AC load](image)

![Schematic node DC load](image)

**Figure 3.** (a). Schematic node AC load, (b). Schematic node DC load.
4. Result

In the first test the maximum distance that can be reached by LoRa is tested. By sending messages 1 time and attached to the data as follows.

| No | Spreading Factor | Distance | RSSI  | SNR  |
|----|------------------|----------|-------|------|
| 1  | 6                | 25 meters| -92 dBm| 7.2 dB|
| 2  | 6                | 60 meters| -84 dBm| 4.5 dB|
| 3  | 6                | 135 meters| -103 dBm| -8 dB|
| 4  | 7                | 25 meters| -74 dBm| 8.3 dB|
| 5  | 7                | 60 meters| -95 dBm| 6.4 dB|
| 6  | 7                | 135 meters| -100 dBm| 2 dB|
| 7  | 12               | 160 meters| -103 dBm| -8.3 dB|
| 8  | 12               | 25 meters| -73 dBm| 9.3 dB|
| 9  | 12               | 60 meters| -87 dBm| 4.8 dB|
| 10 | 12               | 135 meters| -99 dBm| 1.3 dB|
| 11 | 12               | 160 meters| -100 dBm| -5 dB|
| 12 | 12               | 200 meters| -102 dBm| -8.5 dB|

Table 3 shows the results of distance testing carried out in a state of Line of Sight (LoS) or without obstruction with 3 values of spread factors, namely 6, 7, 12. Get the furthest distance when using 12 spreads, 200 meters with RSSI -102 dBm and SNR - 8.5 dB. This is because the greater the SF value, the lower the data rate so that the distance obtained will be farther away.

Figure 4 shows chart of value RSSI. RSSI (Receiver Signal Strength Indicator) is a parameter that shows the received power of all signals on the pilot frequency channel band obtained. In the sense that all signal power measured by the receiver is combined using the receiver's rake process. The RSSI is measured in Dbm and is a negative value. The closer to 0 the better signal is. In LoRa the acceptable RSSI value is -30 dBm to -120 dBm, the value of -30 dBm shows a strong signal and -120 dBm shows a weak signal. But in the experiment above the value obtained between -73 dBm to -102 dBm.
Figure 5 shows chart of value SNR. SNR (Signal to Noise Ratio) is the ratio between the received power signal and the noise floor power level. The noise floor is an area of all unwanted interfering signal sources which can corrupt the transmitted signal. SNR less than 0dB indicates the signal is working under the noise floor, while the SNR of more than 0dB indicates the signal is working above the noise floor.

The second test was carried out to get delivery shipments by sending 50 times the maximum distance for each value of the spread factor.

Table 4. The results of testing the success of sending data at maximum distance.

| No | Spreading Factor | Distance | Amount of Total Delivery | Amount of Delivery Success | Percentage |
|----|------------------|----------|--------------------------|----------------------------|------------|
| 1  | 6                | 135 meter| 50 times                 | 50 times                    | 100%       |
| 2  | 7                | 160 meter| 50 times                 | 50 times                    | 100%       |
| 3  | 12               | 200 meter| 50 times                 | 46 times                    | 92%        |

Table 4 shows spreading factor 6, and 7 has a successful delivery of 100% while on spreading factor 12 is 92%. The average of the successful delivery is 97%.

5. Conclusion
This study discusses the use of LoRa which is used to monitor electricity on ships. LoRa can be implemented for communication media on ships, one of which is a means of sending voltage and current data to the server so that it can be viewed centrally. With this device expected. Power on the ship can be seen in real time and the power on the ship can be controlled as needed so that the fuel is not wasted uselessly.

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