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Crane monitoring system based on internet of things using long range

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ABSTRACT

The four main causes of crane accidents are overturned, falls, mechanical failure, and contact with power lines. It is important to keep track of the crane's health and condition as it is always too late when a failure of the crane was found. Any abrupt accidents will interrupt or delay the work progress and cause the operational costs to increase. Crane monitoring system is developed using long range (LoRa) technology due to its long range of detections making it suitable for monitoring machines that require large space including the dock area. It also consumes low power and is suitable for battery-operated systems. This paper discusses the design and development crane monitoring system using Arduino Uno together with NodeMCU ESP8266 as the hardware for this project. Temperature, power consumption, lifting activities, and total operating hours will be measured using appropriate sensors. The data will then be sent to the database where users can monitor each crane from a developed Android application using a mobile phone. This project allows users to view, monitor, and analyze real-time or past data in a graph or table view. Experimental results prove the proposed system is applicable and effective.

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1. INTRODUCTION

The condition of the crane will directly affect the chance of an accident happening and the cost to maintain the crane. This is because the cranes are usually exposed to harsh environments and always operate at high-duty cycles. Thus, any problem related to the cranes should be identified before it occurs to prevent tragedy [1]. To solve this problem, a monitoring system will be needed. This monitoring system should be able to monitor four basic information: the running hours, the lifting activity (tonnage), the power consumption, and the temperature of the motor or hydraulic or other similar things. This project is created based on the idea of proposing and building a crane monitoring system that can monitor and inspect the crane's health and utilization at any time using the mobile application. When the utilization percentage of the crane and the health status of the crane are known, then future management, maintenance, and planning will be able to be executed to prevent an unexpected event like crane shutting down or accidents that will cause a delay to the working schedule.

Internet of things (IoT) had been implemented in various monitoring projects using different kinds of wireless technologies and sensors [2]–[12]. Previous research show long range (LoRa) can operate at a maximum distance of around 300 meters due to the types of antennas used in the projects, where normally a good quality of LoRa antenna can reach up to a few kilometers of distances [13], [14]. Few researchers focused on developing and improving the software part of the cranes monitoring system. Yoon *et al.* [15], [16] conducted simulation testing to evaluate mobile crane lift operations using various software platforms. Besides, the latest research proposed optimization of crane operation to improve the performance of cranes [17]–[19]. While the other researchers are focusing on improving the LoRa protocol [20]–[23]. Carmona *et al.* [24] developed a low-cost system for monitoring tower cranes using LoRa, however; the monitoring system is controlled through a website where it has limitations in terms of mobility. Another project developed by [25] proposed a wireless system to monitor and manage the tower crane to control the cranes efficiently and safely. The data information of the crane will be detected by the sensors and general packet radio services (GPRS) module is connected to the internet using UART RS485 to allow the data to be sent to the remote terminal. In the end, the user will be able to monitor and supervise the tower crane's operation via the web platform. The drawbacks of this paper are the web interface is not user-friendly and complex to use. Other than that, the general packet radio service (GPRS) module used in this project is not versatile nowadays which will cause the connectivity problem when the network ping is high.

This paper presents the design and development of a crane monitoring system using LoRa technology. This project is uniquely designed, developed, and targeted to be used in the shipbuilding and heavy engineering industry. LoRa technology has been chosen for wireless connectivity due to its robustness and wider coverage, suitable for wide-area locations for example dock ship areas. Compared to previous research, an android application is created to enable the mobility concept of the monitoring system. The developed application will ease the user to remotely monitor the crane's operation anywhere and anytime.

2. METHOD

Figure 1 shows the block diagram of the system designed. There are two parts which are the transmitter and receiver parts. The sensors will evoke when the crane starts to work. The value of sensors will be sent to Arduino for processing before being passed to LoRa for transmission. The received data will be sent to the designed database using a Wi-Fi connection from the NodeMCU ESP8266 internet module. Finally, the user will be able to view and monitor the crane by running the developed application on the mobile phone.

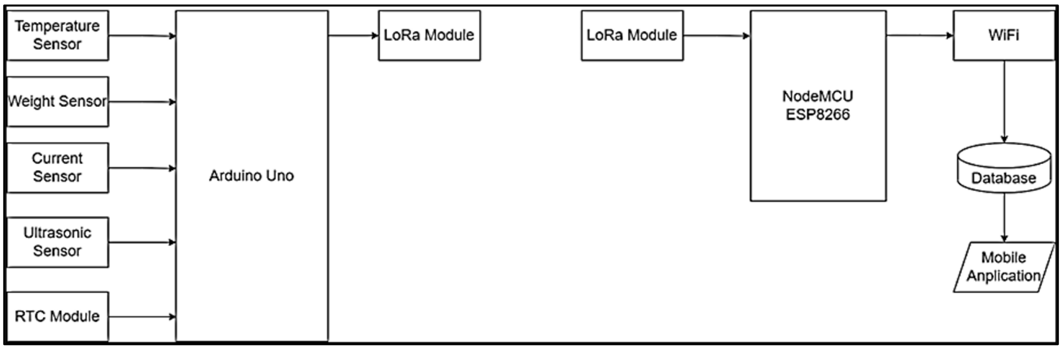

Figure 1. Crane monitoring system block diagram

Figure 2 shows the hardware setup for the transmitter side. In this project, ACS712 was used as the current sensor where TS90a servo motor was connected to the sensor to act as the current sensor's load; to allow current data measurement. An Arduino Nano is used to supply power and program the servo motor to rotate occasionally for every 15 seconds. Besides, the load cell sensor needs a load for measuring the weight data. Thus, an object is added and placed on the load cell sensor to become the weight sensor load. There is also a real time clock (RTC) module used to record the date and time for calculating crane utilization rate. An HC-SR04 Ultrasonic sensor was used to detect the crane's fuel consumption. DHT22 is used as the temperature sensor for detecting any abnormality of the crane. The crane data mentioned in this project are only simulation data, these data are not tested on the real crane, but the data type can be used to monitor the real crane. For example, the temperature data in this project refers to the temperature of the crane, the weight data refers to the load of the crane, and data from the ultrasonic sensor refer to the fuel level of the crane. The close-up figure for current and weight sensors and how there were connected is shown in Figure 3. As mentioned earlier, the current sensor needs a load to show readings. Therefore, a servo motor is used to mimic the real condition. In a real situation, the current sensor will be connected to the crane motor for current measurement. The weight sensor used in this project can detect weight until 5 kg. A robust and precise weight sensor needs to be used for measuring real crane data as it carries a bigger load. Figure 4 shows the receiver side of this project. The receiver side is simpler, it is consisting of a LoRa receiver being connected to ESP8266 for Wi-Fi connections.

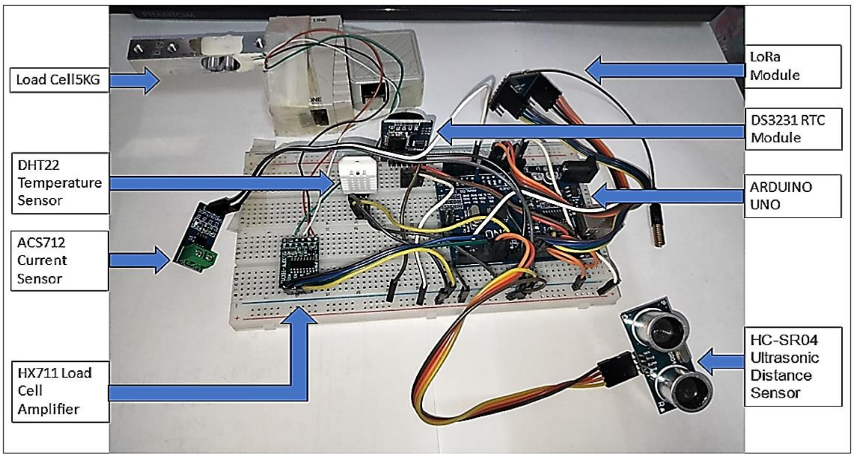

Figure 2. Transmitter side hardware setup

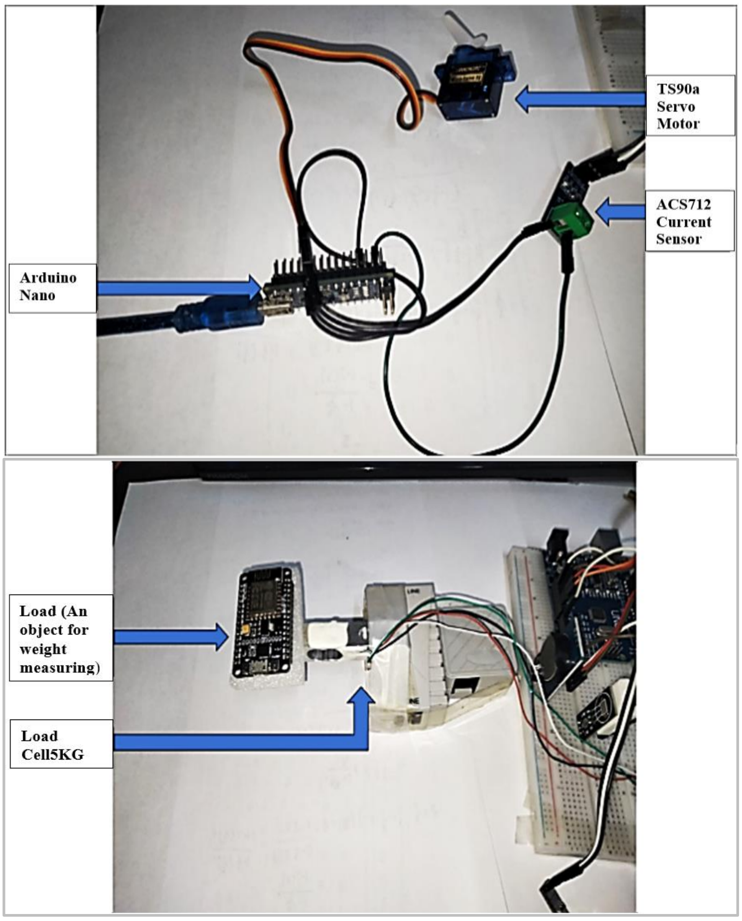

Figure 3. Current and weight sensor setup

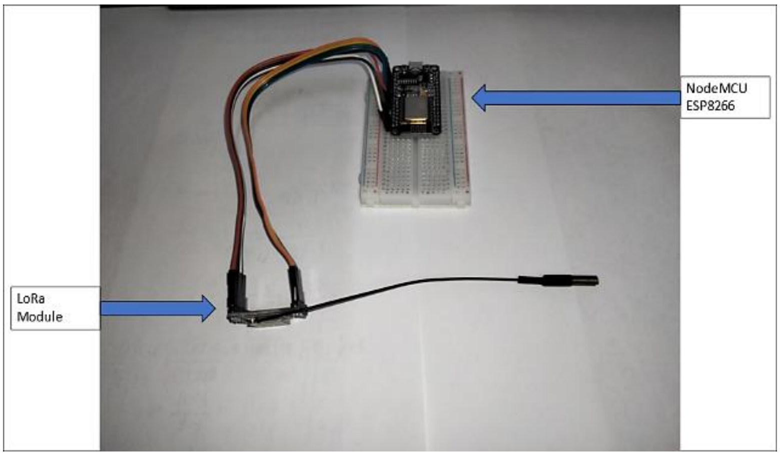

Figure 4. Receiver side hardware setup

3. RESULTS AND DISCUSSION

In this section, the output obtained from the project will be elaborated. This includes the sent and received data through the LoRa transceiver. First, the data will be collected by the sensors on the transmitter side. Then it will be transmitted and received by the LoRa module. Next, the data will be collected and processed on the receiver side. The results will be divided into two sub-sections, the serial data results and the results obtained from the application.

3.1. Results from serial monitor display

Figure 5 shows the display from the serial monitor of Arduino software when a transmitter sends data dan Figure 6 shows the serial monitor from the Arduino software when a receiver receives data. The measured items are current, power, temperature, weight, date and time, a distance that will be used to detect the fuel oil in the crane, and total working time for the crane. In addition, the signal to noise ratio (SNR) and received signal strength indication (RSSI) values of the LoRa module is also displayed in the serial monitor of the receiver side. SNR and RSSI indicate the signal strength for LoRa.

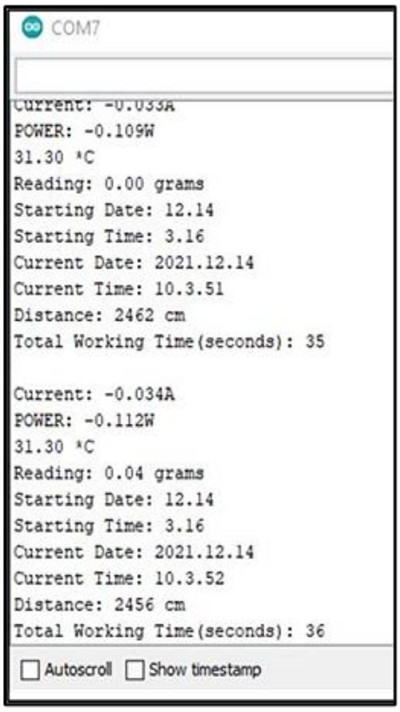

Figure 5. Transmitter's serials monitor display

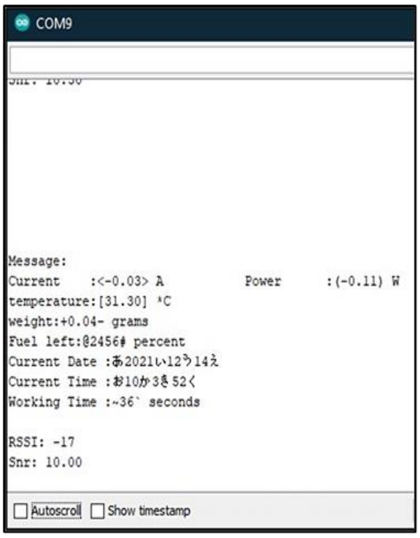

Figure 6. Receiver's serials monitor display

3.2. Results from database

The database has two parts, one is real-time data and another one is recorded data. The reason is due to Google Firebase's is a real-time database but not a structured query language (SQL) database. This means that the data uploaded to the database is in unstructured format and hard to manage compared to SQL data. In the first part, the real-time data will be shown and displayed in real-time but never recorded, while in the second part the SQL database will record and save the data. The data is recorded every second and every hour. Figure 7 shows the hourly view of Google firebase real-time database. By doing this, the data will be able to be analyzed by applying different methods depending on user needs. In this project, the real-time data will be shown directly with the value from the database. On the other hand, a graphical view will be used to display both recorded seconds and hours data obtained from the database. The graph view will be displayed in the android application.

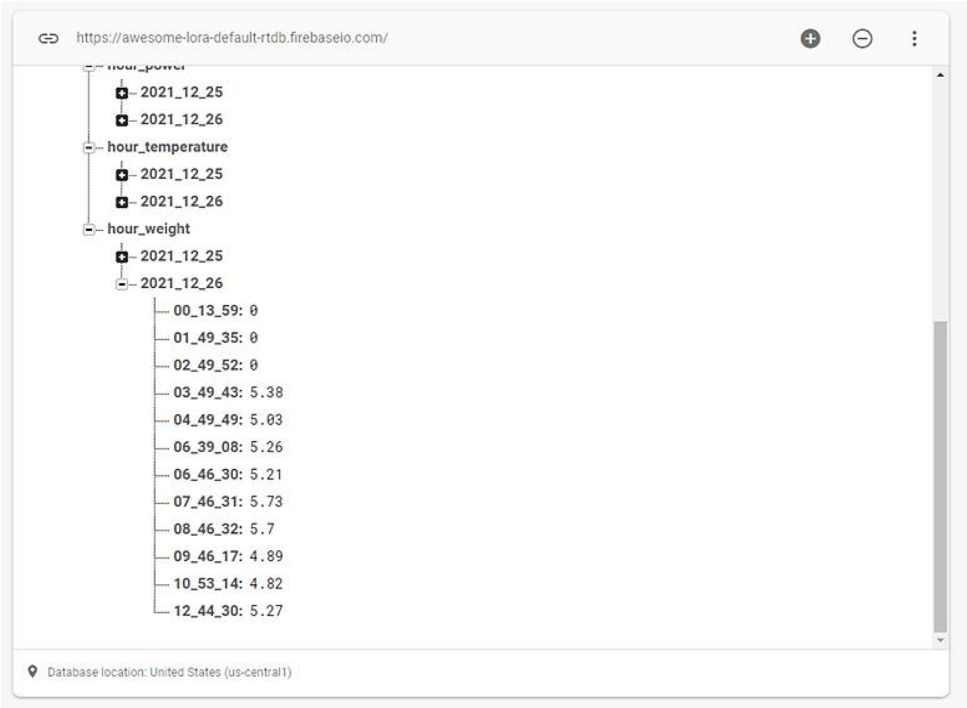

Figure 7. Google firebase real-time database (hours view)

3.3. Results from the application

Figure 8 shows the initial page when a user launches the android application while Figure 9 shows the response when the user clicks on the "Realtime monitoring" icon. To view the graph, the user will need to click on the past record button. By default, there is no data when a user clicks on the past record buttons as in Figure 10. This is due to no data was save previously. The date of the graph needs to be input by the user to show the data in a graph view. On this page, the user will need to enter the date in a specific format and click the "submit date" button. Besides that, there is a button labeled with the name "24H", this button is used to change the data mode between seconds or hours. The default data display mode is in seconds mode which shows all the recorded data in seconds view, while another option is the hours mode which shows the data recorded for each hour. This is useful for long-term analysis. Figure 11 shows the graph view after the date was entered by the user in a specific format.

The user can change what sensor's data they want to monitor by clicking on the spinner. Figure 12 shows the sensors option in the spinner. The available option for the user to monitor is current data, fuel data, power data, temperature data, and weight data. The user can click on a specific measurement to view the details. Besides that, the user able to zoom in and zoom out the graph for a better view experience. Zoom in and out on the graph can be simply done by double-tapping the graph or zooming in out by dragging and pinching the graph. Figure 13 shows the android application interface when the user zooms in on the graph view and selected the temperature measurement. The graph in Figure 13 compared to the graph in Figure 12 is larger after zooming, as the latter one had been enlarged.

Figure 8. On launch interface

Figure 9. Display after icon "Realtime monitoring" was clicked

Figure 10. Display after "Past Record" icon was clicked

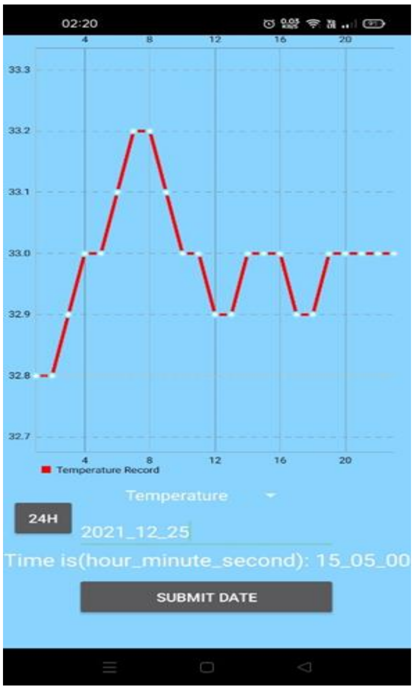

Figure 11. Display after data was entered in specific format and "Submit Date" icon was clicked

Figure 14 shows the current data recorded in seconds between 12:00 to 12:00 p.m. on December 26, 2021. The current value starts with zero because at that time the load which is the servo motor has not yet connected to the current sensor. But after a while, the servo motor starts to move periodically, so the current value increase from zero to 0.05 ampere. Any abnormality from the crane can be observed by workers directly from mobile at any time. Figure 15 is useful for long-term analysis for example to predict the maintenance schedule. The figure shows the fuel data in per hour graph view. An ultrasonic sensor was used to predict the fuel level in the crane. The ultrasonic sensor will detect the range by reading the reflection of the signal. The power and temperature data were shown in Figures 16 and 17 subsequently. The power data of a crane will tell the user how long the crane had been operated and should be stopped after a fixed operating time. This action can help to extend the lifespan of the crane and make the maintenance schedule work easier. Besides that, the crane's temperature is observed for its motor and hydraulic part. If the temperature of the motor keeps increasing, it may cause the system of the crane to fail and stop working normally. Figure 18 shows the weight data in the per hour graph view. In this project, 5 grams of load is being used although the system able to detect up to 5 kg. The weight sensors allow the user to monitor and control the maximum capacity that a crane can lift. Whenever a crane is overloaded, it causes irreversible damage and may cause hazards. The most common case will be the drop of the load or crane is swinging and hard to be controlled.

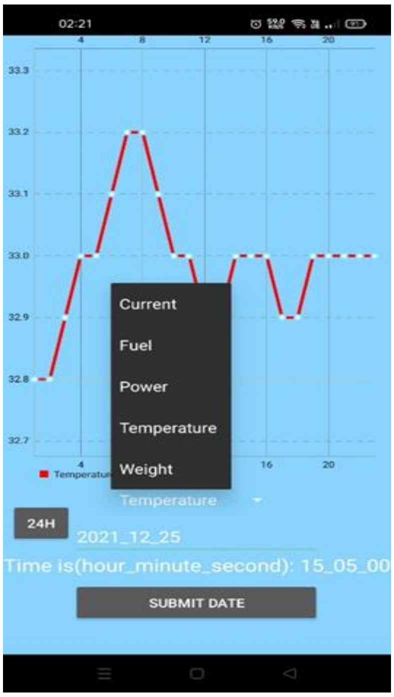

Figure 12. Spinner's sensor option

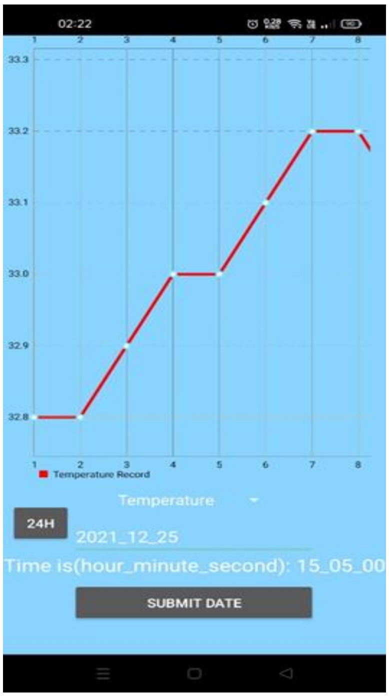

Figure 13. Zoom in option

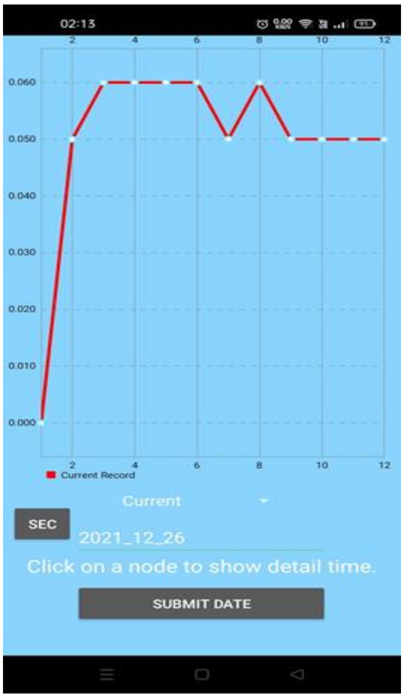

Figure 14. Current per second graph display

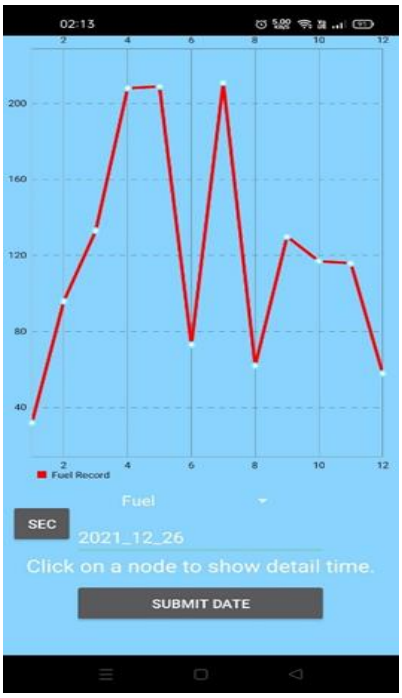

Figure 15. Fuel per hour graph display

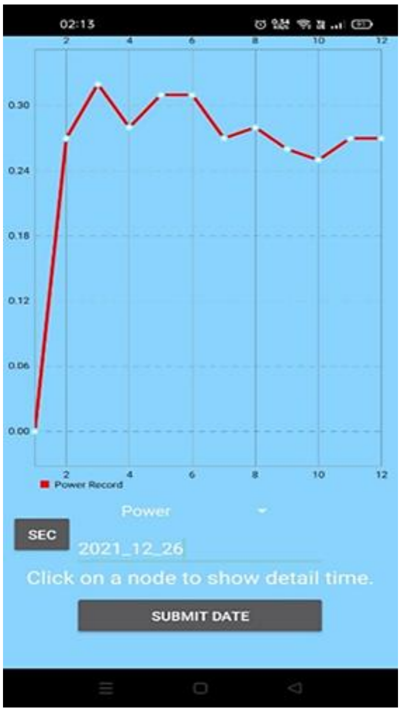

Figure 16. Power per hour graph display

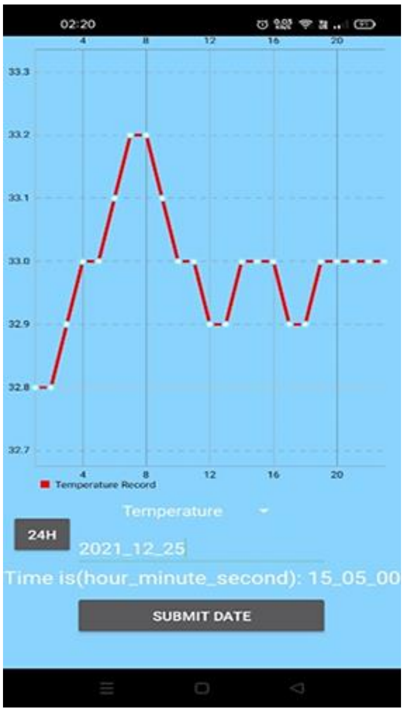

Figure 17. Temperature per hour graph display

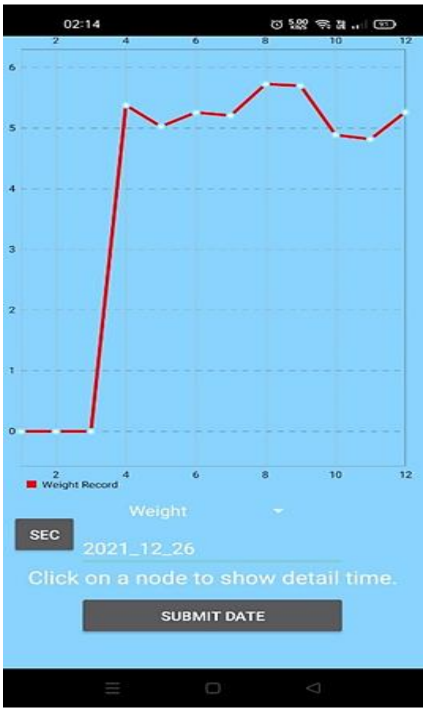

Figure 18. Weight per hour graph display

4. CONCLUSION

In this project, a method had been proposed for implementing cranes utilization monitoring system based on IoT using LoRa. By implementing the monitoring system, the crane can be monitored remotely via smartphone. Few modifications can be done in the future, this includes putting some control on the application for controlling the crane such as on and off buttons. This is needed during an emergency, where the user can be divided into many categories such that only the admin user has permission to interrupt the crane activity. Besides that, the LoRa antenna can be changed to a more robust and durable one to suit the heavy engineering outdoor environment.

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