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Wireless Ammonia Sensor System for Distributed Wireless Monitoring Platform using Heltec Wifi LoRa 32 (V2)

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Abstract: The Distributed Wireless Monitoring Platform (DWMP) is a system available for water quality monitoring (WQM) at several locations within a large range using wireless technology. The goal of this project is to research and design a wireless sensor system that use low-powered devices and uses a wireless connection which will deployed in river in forest area. Heltec Wifi Lora 32 (V2) is used as the main device for the wireless ammonia sensor system that will then functions to detect the analog value of the sensor and send the data to gateway part for monitoring operation. Experiments have been conducted to evaluate the performance of the sensor system. RSSI or signal strength and the power used by the sensor node are observed and accessed on the gateway or receiver part. Power consumed by the sensor device is determined during the device is in running mode and during deep sleep. The parameters such as height and distance between sensor node and gateway is varies and can achieved up to 500 m if the sensor node is on the ground level and about 800 m in the height is increased to 2.5 m from the ground. To conclude, results from the experiments shows that the design implementations using LoRa technology from Heltec Wifi LoRa 32 (V2) are capable to be used for real time monitoring operations at a larger radius which is suitable for DWMP system.

Keywords: DWMP, WQM, Wireless Sensor, LoRa, Gateway, RSSI, Deep Sleep

1. Introduction

Water contamination is a serious issue and has a negative effect on the sustainability of water supplies. Not just that, it gives effect on living things like plants and animals. The wellbeing of the people and the economy are also impacted. Numerous causes of waste have been caused by human activities, but some came from sources of pollutants that are natural. There have been several recorded

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cases of river contamination over the years. Abidin et al. reported that in 2018, Selangor experienced extreme river contamination due to ammonia leakage in Sungai Langat, which triggered the closure of the water treatment facility and took almost two months to go back to normal [1]. This contamination shows that infrastructure such as the control of water quality is still not ideal and that further progress is needed to stop this incident from occurring in the future.

The method for water quality monitoring has followed a basic workflow for several years, involving manually obtaining water samples and then delivering them to a laboratory for examination to detect pollutants and microbial pollutants [2]. Nowadays, water quality monitoring (WQM) measurement systems have evolved from conventional laboratory-based sensors to in-situ sensors capable of evaluating on-site water quality parameters in real-time [3][4]. Due to the development of sensors, the quality of water can be detected at a real time and it will be a great advantage if can detected the water quality at different locations at the same time.

Distributed Wireless Monitoring Platform (DWMP) is a system or project intended to track the sensors value at many locations at a large range by using wireless technology such as LoRa, GSM, Wifi, Bluetooth and Zigbee modules. A study is conducted to choose the device with suitable wireless technology for the system. The device will use a wireless technology that can transmit data at a long range with low power consumption. This is because the wireless sensor will be deployed at any water sources especially rivers located at far away places from monitoring station meanwhile the monitoring is still performed. The sensor nodes will detect the quality of the water, and measurements from the sensors will be taken to check the quality of the water. The information obtained by the sensor nodes is transmitted to the database and will be viewed by the users in real time.

1.1 Problem Statement

For the data monitoring operation, it will need the sensor that will detect the ammonia in water and the device to collect the data from sensor and to send the data to the user. The chosen device platform for this project should be less maintenance as the wireless ammonia sensor system need to be deploy in the far away places such as rural areas or forest areas which is hard to access.

In this Internet of Things era, many projects used IoT that basically use wifi or internet for data monitoring and transmitting data but it is not suitable this project since the wireless technology used for this system needs to be adapted to the project situation, which will be located at forest area. The use of battery is compulsory for this system as there is no other power supply can be used if deployed in forest area. So, the low power usage of the device is need to be considered. The cover or casing for the device should also be considered as it will be placed in an open area that will exposed to sunlight and bad weather.

For the firmware design, the ammonia sensor system will need to send the data to the user two times per day or depends on the situation. The device that can be programmed to be only turn on when transmitting the data is an advantage to be chosen for this project. This is because the system needs to use the lowest power possible since it will be using battery for the main supply. The location of the sensor node placed should be taken into account the obstruction of the tree trunk which may interfere with the signal strength of the data transmission.

1.2 Project Objective

- To study methods to detect the level of ammonia in water from various locations using wireless technology.
- To design the hardware and firmware of the wireless ammonia sensor system.
- To evaluate the performance of wireless ammonia sensor system in terms of signal strength and power consumption with different distances and locations.

2. Related Studies

Ahumada et al. designed a system for monitoring and operating irrigation networks [5]. The communication of the system uses LoRa communications from Heltec Wifi LoRa 32. Arduino MKR1200 is also used for the system and ThingSpeak IoT platform is used for the monitoring operation. The range is tested and can achieved up to 900 m between the nodes. This system uses low power consumption because the sensor device can use deep sleep function [5].

For the project from Murdyantoro et al., the system is designed for a weather station which is for monitoring the temperature, humidity, air pressure, detection of moisture and wind speed [6]. This system also uses LoRa wireless technology but uses LoRa Shield and Arduino UNO for the device platform. Monitoring operation also been done on ThingSpeak platform. The advantage for this system is it has an open-source library that allows to send data and reach very long range to send data [6] but it does not have the deep sleep function.

Gonzalez et al. studies about LoRa sensor development for air quality monitoring [7]. Heltec Wifi LoRa 32 (V2) which uses LoRa wireless technology is used for this project for detecting the gas leakage events. The sensor data is sent to The Things Indoor Gateway and monitored in The Things Network website. The tested range of the wireless sensor is 130 m. This system provides multiple devices connected at the same time while uses low power consumption and can use deep sleep function for the wireless sensor device [7].

Saparudin et al. in their paper design a system for the application for water quality monitoring by using Wifi communication for the system [8]. Device platform for the sensor for this project is by using Raspberry Pi which then send data to ThingSpeak web server for monitoring purposes by the users. This system is cost effective, quickly deployable and user friendly with wireless capabilities [8] and one downside for this project is it needs internet connection for the sensor device to send data.

In summary, from the literature studies that have been done, LoRa wireless technology from [5][6][7] will be used for this project as it can transmit data at a long range while still using low power consumption. The Lora wireless technology is suitable to be implemented to this project since this project will deploy the sensor node in far away places and will be using only battery for the whole system. The wifi wireless technology in [8] is not suitable because the internet connection cannot be accessed if the sensor node is deployed in the forest area. For the sensor device, the Heltec Wifi LoRa 32 (V2) from [5] and [7] is used for this project because it has the deep sleep function which compared to [6], which doesn't have the function for the device. By using the deep sleep feature, since it can conserve power used by the battery, the use of the sensor system can last longer. The matter will be checked in this project in order to prove it.

3. Methodology

This segment will provide the descriptions of the circuit links and the software flow map for the implementation of the system. Figure 1 shows the overview block diagram of DWMP which is the overall system for monitoring water quality specifically for ammonia detection in the river for this project.

There are several parts to the success of this DWMP system which are the wireless sensor system part, the monitoring station part or gateway system part and the part for power supply system for the monitoring station. For the monitoring station part, it will be consisted of gateway system that will be integrated with Raspberry Pi as the gateway platform. The data by the wireless ammonia sensor system will be gathered here in monitoring station and will stored in the cloud-based internet server for monitoring operation by the users. Then, for the power supply system part, it will use a solar panel system as the main supply for the monitoring station as the monitoring station will be operating for 24 hours a day. The parts explained are conducted by other students.

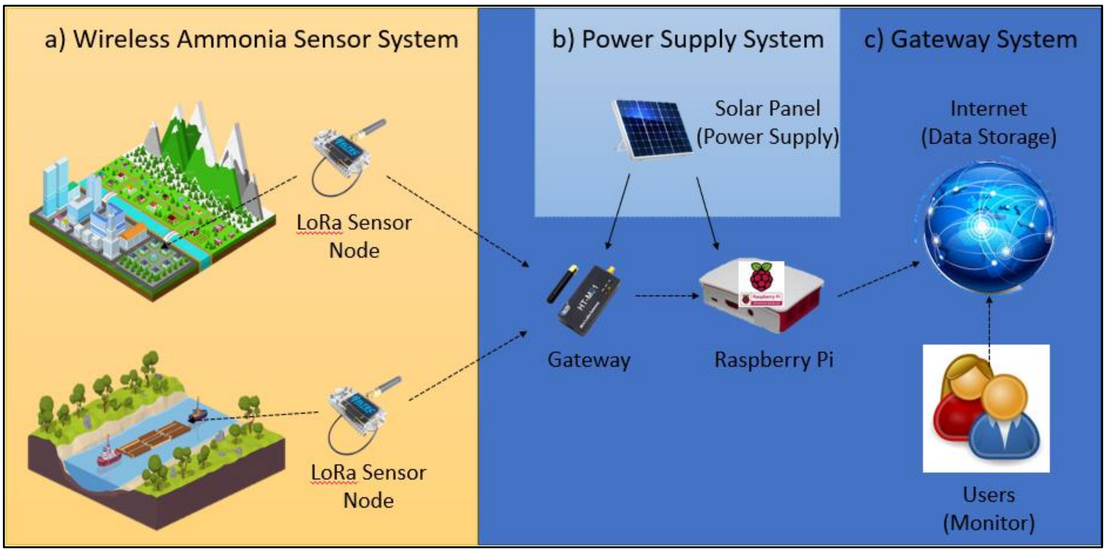

Figure 1: Overview Block Diagram of DWMP

3.1 Flowchart

Figure 2 shows the flowchart of the project. This will show the progress of the project from the start until its completion.

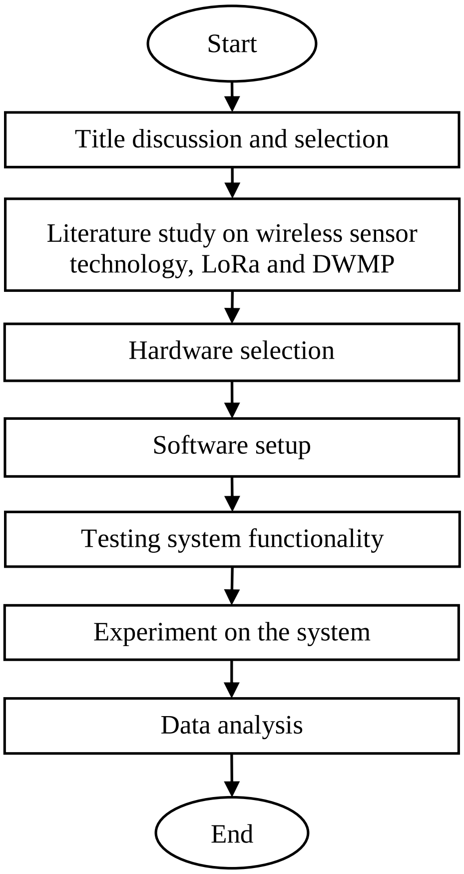

Figure 2: Flowchart of the project

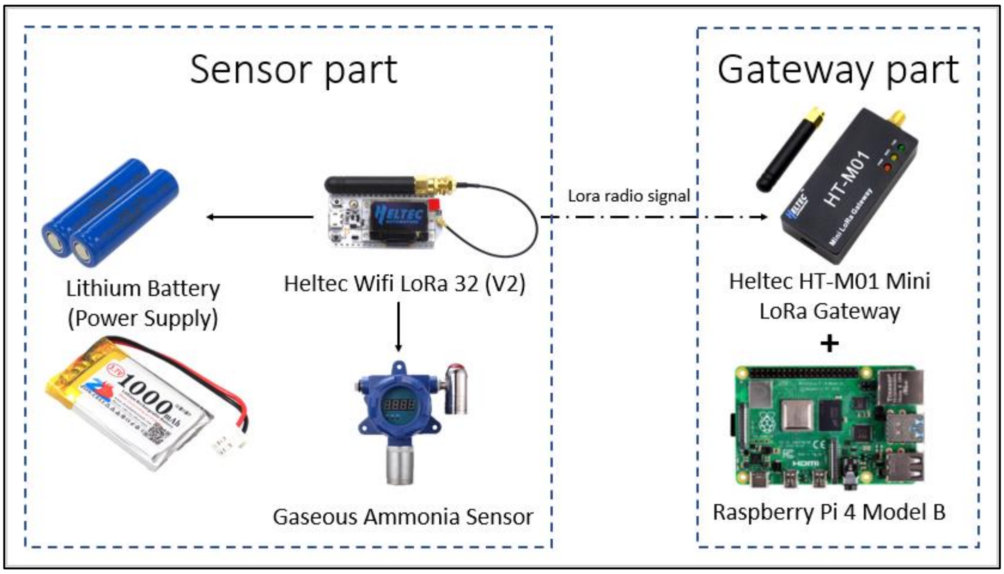

Figure 3: Block Diagram of Sensor Node

This project is done in a few stages in order to achieve the objectives and to show the progress of this project. First of all, the title selection for the project is discussed between student and supervisor. The literature study mainly focusing about wireless sensor technology, LoRa and DWMP. After that, the suitable hardware for the project is selected and the software is setup corresponding to the implementation of the project. This will determine the overall functionality of the system. The device should be able to read the analog value from sensor as the sensor will give the output value in analog signal. The next stage for this system is it can send the value from the sensor node to the gateway part or receiver part.

Next, the functionality of the device is tested and two experiment have been conducted to evaluate the performance of the wireless ammonia sensor system. The first experiment will place the sensor node on ground level and the OLED panel is turned on while in second experiment, the sensor node is placed at 2.5 height and the OLED panel is turned off. The device performance will be determined based on the signal strength and output power during data transmission. The signal strength is measured in terms of RSSI value and is tested by changing the distance of the sensor node from the receiver node. RSSI value is tested on 10 different distance from the sender node which increased 50 m from the sender node for each place. Lastly, data analysis has been done to compare the results from the experiments. The devices used in this project can be referred in Figure 3.

For the system to be fully function, it needs the two important part for the whole system which is the sensor node part and the gateway part. This project is mainly focused on sensor node’s part for the wireless ammonia sensor system and it will be consisted of:

- Heltec Wifi LoRa 32 (V2)
- Ammonia sensor
- Lithium battery

3.2 Analog value of the sensor

For the first stage, the project is set to detect the analog value of the sensor. The project required the Heltec Wifi LoRa 32 (V2) board, 1 lithium-ion battery to power up the board and variable resistors. One of the variable resistors will act as the sensor to detect the analog value. The analog value is programmed to give digital value by the program code uploaded in the Heltec Wifi LoRa 32 (V2). Figure 4 shows the wiring diagram of the project.

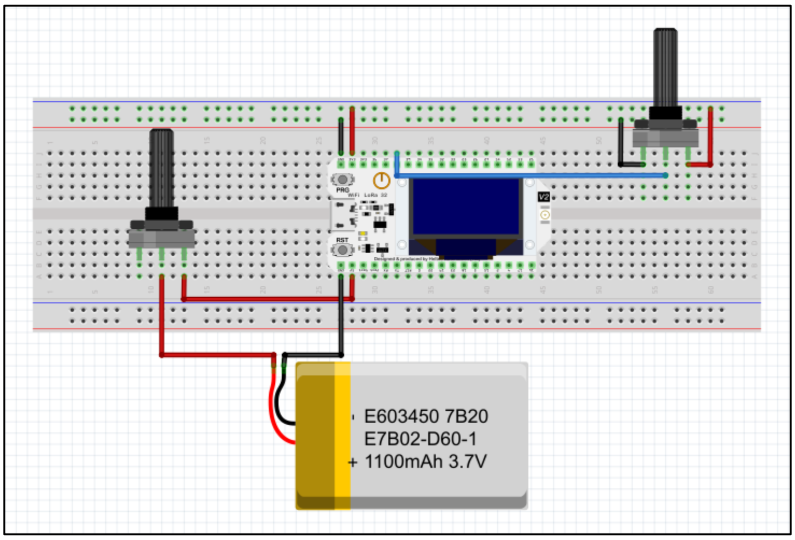

Figure 4: Wiring Diagram of Sensor Node

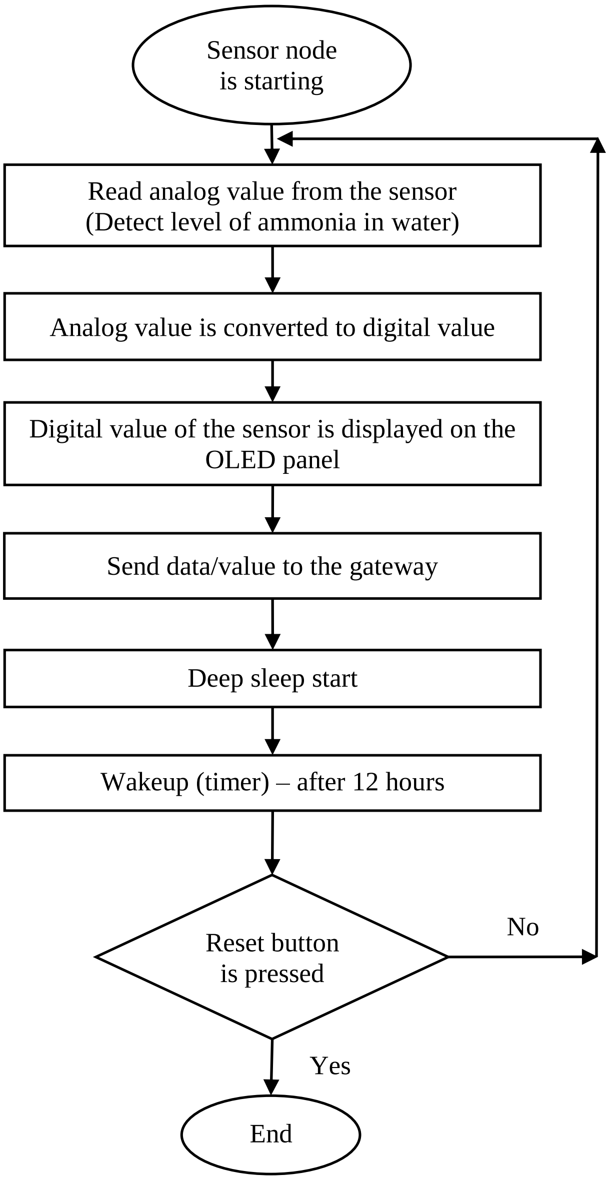

Figure 5: Flowchart of the Sensor Node

3.3 Connection between two Heltec Wifi LoRa 32 (V2)

The Heltec Wifi LoRa 32 (V2) can acts as sender node and receiver node. It can be programmed corresponding to its usage. In this project, the Heltec Wifi LoRa is also used and programmed as a gateway part or receiver node to receive the data. Data from sender node is sent node to the receiver node wirelessly by a LoRa radio signal. The sensor node is also programmed to stays at deep sleep mode when not transmitting the data. This is to preserve the data sent by the sender node can be displayed on the receiver node. The flowchart of the sensor node is shown on Figure 5. This stage of the project has a few limitations which is only data from one sender node can be send to the receiver node and lower range for transmitting the data if compared with the use of real gateway.

4. Results and Discussion

In this section, the evaluation of the results and the discussion of this project is presented. The discussion is based on the results of this project. The final hardware design is also presented as shown in Figure 6.

4.1 Results

Results can be presented in the form of tables, figures, charts and diagrams. The results section is divided into two parts. The first part of data analysis is to determine the functionality of the device to read analog value of the sensor and the second part is the experiment to evaluate the performance of the Heltec Wifi LoRa 32 (V2) when transmitting data.

4.1.1 Analog Value for Sensor

This part will show the successful result of the reading of the analog value for the sensor on Arduino IDE Serial Monitor and the results is as shown in Figure 7.

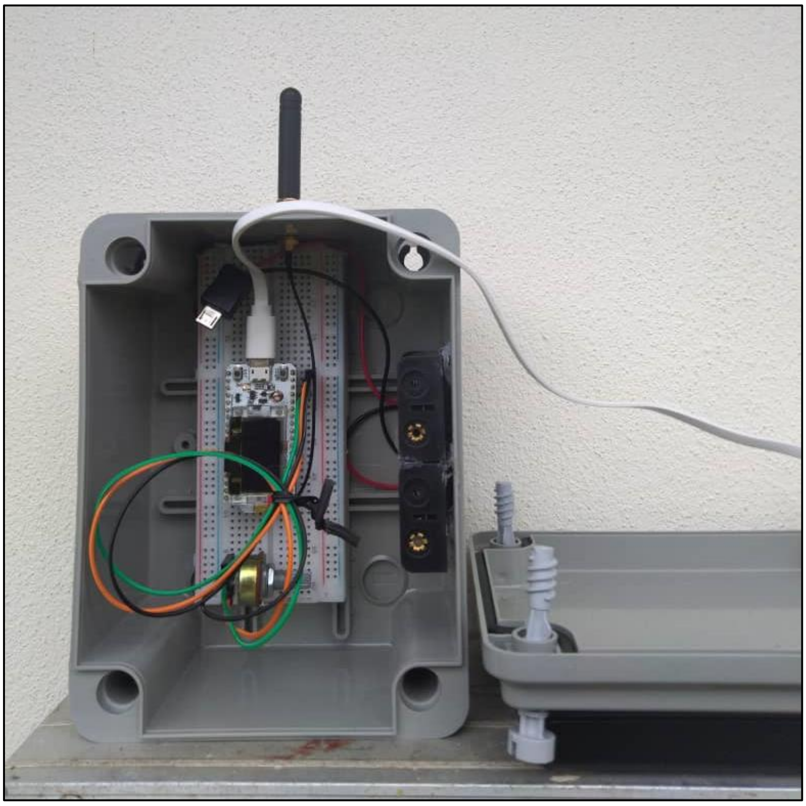

Figure 6: Hardware Design of Wireless Ammonia Sensor System

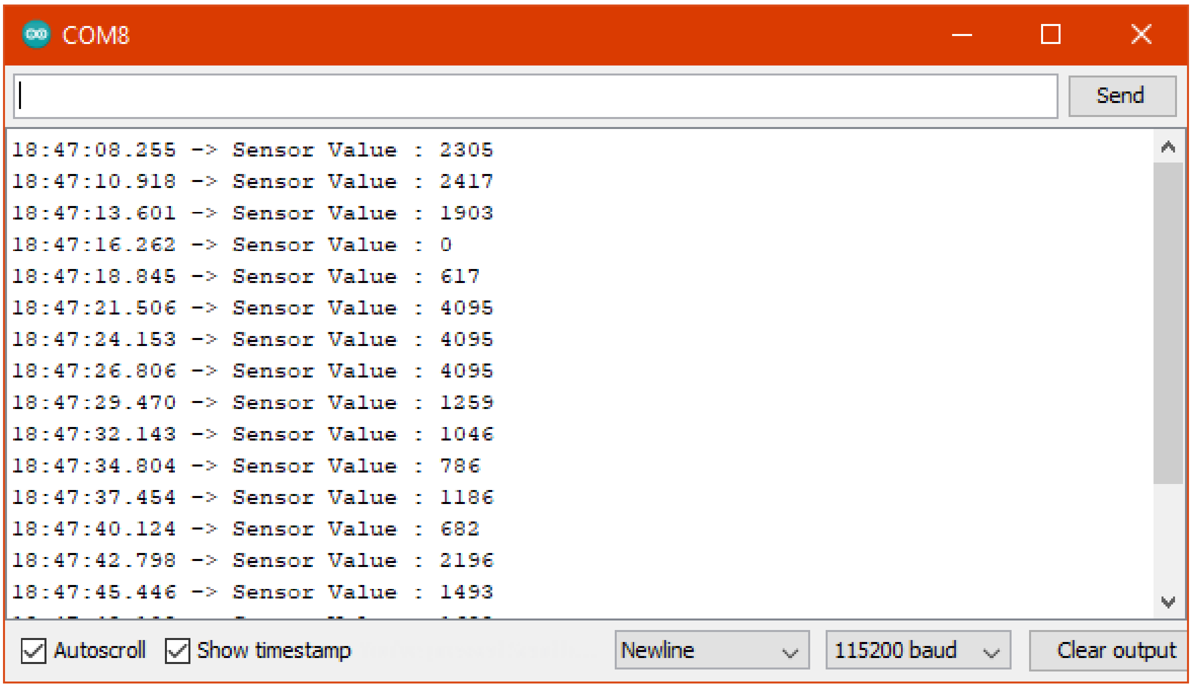

Figure 7: Sensor's value on Arduino IDE Serial Monitor

4.1.2 Connection between two Heltec Wifi LoRa 32 (V2)

The result obtained from RSSI value from these experiments show differently in term of their communicated to other nodes due interference on infrastructure, vehicle noise and etc. From the data, RSSI value is transform into a graphical result which could see in line graph in Figure 8 and Figure 9.

Table 1 and Figure 8 shows the result for Experiment 1 while Table 2 and Figure 9 shows the result for Experiment 2. The difference of Experiment 1 and Experiment 2 is the height of sensor node. The height of sensor node for Experiment 1 and Experiment 2 is 0 m and 2.5 m respectively from the ground level.

For both expriments, the ouput power of the device is also measured. The power used by the sensor node is evaluated. It is evaluated in terms of the condition of the sensor node which is in running and sleep mode. The display on the OLED panel at the receiver node for both conditions are shown on Figure 10 and Figure 11.

Table 1: Results for maximum distance for Experiment 1

Condition	Normal/Running	Sleep
Max Distance	500 m	500 m
RSSI (dBm)	-129	-131
Transmit Power (mW)	7.60	0.24
Transmit Current (mA)	44.7	7.89

Table 2: Results for maximum distance for Experiment 2

Condition	Normal/Running	Sleep
Max Distance	800 m	800 m
RSSI (dBm)	-128	-129
Transmit Power (mW)	7.41	0.23
Transmit Current (mA)	43.6	7.69

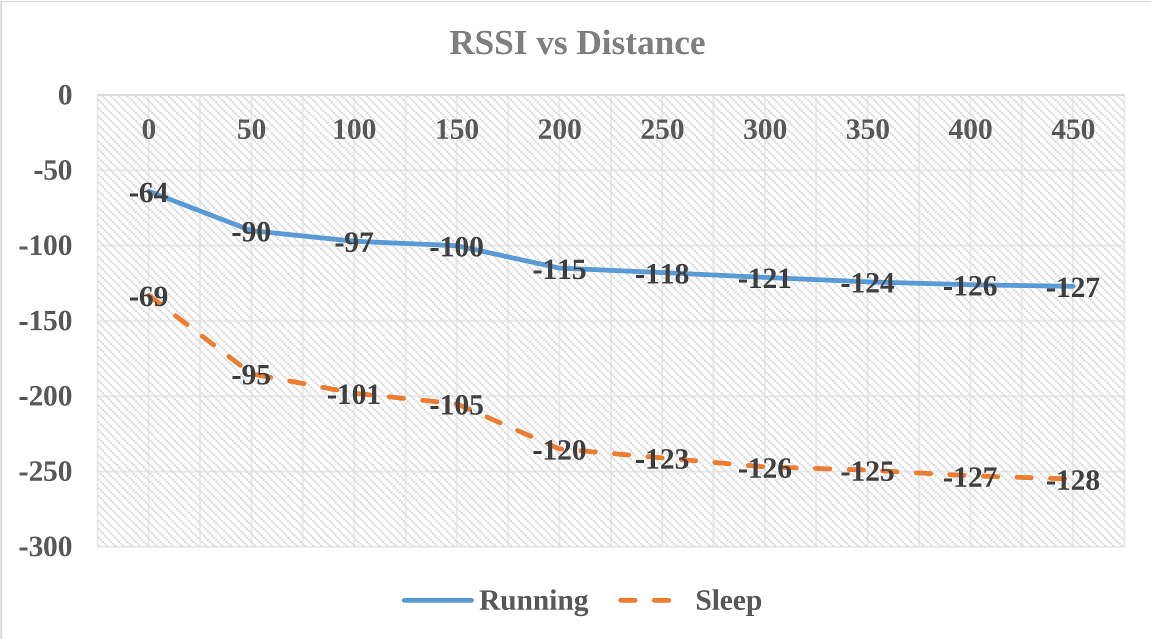

Figure 8: Graph for RSSI versus distance for Experiment 1

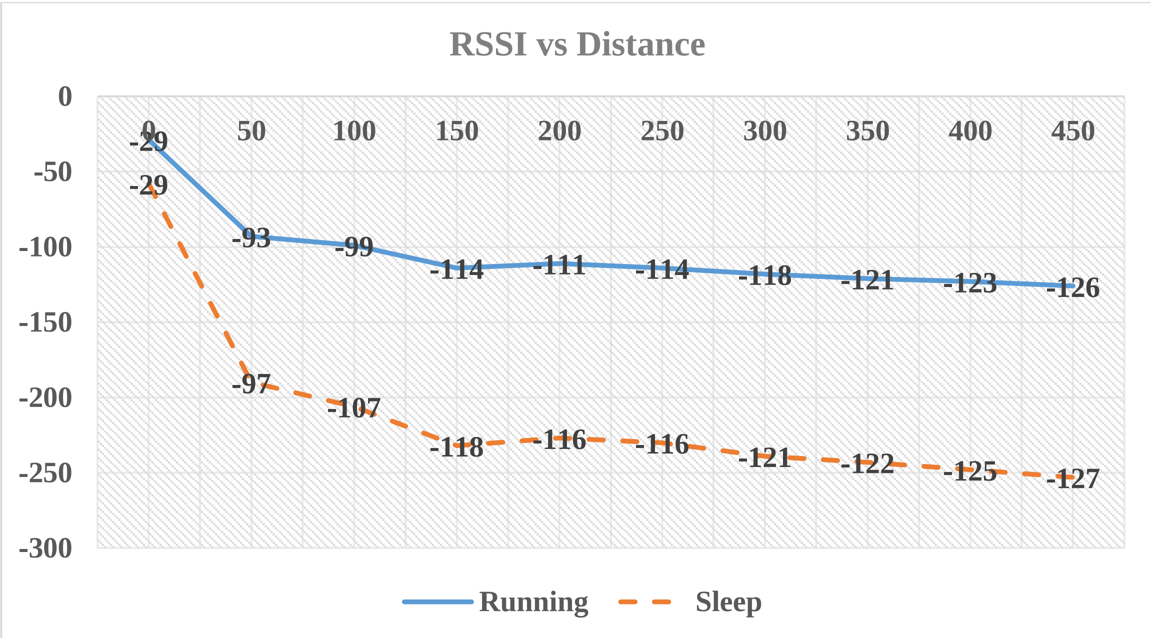

Figure 9: Graph for RSSI versus distance for Experiment 2

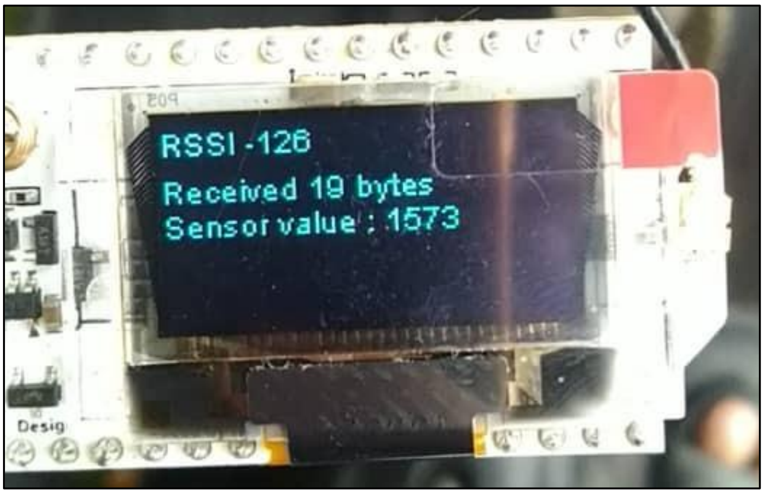

Figure 10: Receiver Node's OLED panel display (Running mode)

Figure 11: Receiver Node's OLED panel display (Sleep mode)

4.2 Discussions

Based on the results, the RSSI value in the height difference of sensor node tested in two experiments for same location were compare the differences of RSSI and the output power which there been involvement of LoS along the communication. The different height of the sensor node also gives the differences in distance for the sensor node could send data and maximum recorded distances is 500 m for the Experiment 1 and 800 m for Experiment 2, where beyond that distance, the signal was not sent any indicator or the strength of signal had no power to thrust the infrastructure between the sensor node and receiver node.

For Experiment 1, the sender node is initially placed on the ground level while at 2.5 m height for experiment 2. The RSSI value from the receiver node is gathered from 10 different distance from the sender node which increased 50 m from the sender node for each place. The transmit current shows that it still the same although the range between the sender and receiver node is increased. Moreover, the performances of the device are also compared during running and deep sleep mode. Power used during sleep mode is far lower than when transmitting the data which is proven to save the power used from the battery for longer use. For the RSSI value, the result shows that the RSSI value is decreasing as the distance is increased. The further the value is to 0, the weaker the received signal has been. Lastly, from results, it shows that the height difference plays an important role in signal transmission

5. Conclusion

In conclusion, higher height of sensor node can increase the range of transmitted data between sensor node and receiver node. Results from the experiments show that about 800 m maximum distance between the sensor node and the gateway or receiver part is achieved when the height of the sensor node is at 2.5 m from ground level and only 500 m when at ground level. The results show that the design implementations using LoRa technology from Heltec Wifi LoRa 32 (V2) are capable to be used for real time monitoring operations at a larger radius and it is suitable for DWMP system. The wireless ammonia sensor system is a success as the key components to make this project a success is obtained which is the Heltec Wifi LoRa 32 (V2) can successfully read analog values from sensor and send the value to the receiver node or the gateway part. Besides that, the signal strength is decreasing when the distance from sensor node is increased. The results from experiments also shows that the use deep sleep mode and turning off the OLED panel will have lower power consumption by the device.

5.1 Recommendation

In order to improve this system for future work, there are some recommendation that might be considered to increases effectiveness of project to change the collection and monitoring scenario to a better one. As future work, the system design presented in this paper can be expanded in a number of different aspects such as functionality and reliability. Here are some expected outcomes for this project:

- The connection of the wireless sensor nodes to the gateway system such as Heltec HT-M01 Mini LoRa Gateway to obtain better range for transmitting data and for sensor value from multiple devices can be gathered at the same place.
- The usage of more Heltec Wifi LoRa 32 (V2) with the real ammonia sensor to get the actual value the ammonia as it need to deploy more sensor nodes in many locations for the real implementation of this project.
- The connection of the wireless sensor node which is the Heltec Wifi LoRa 32 (V2) and the gateway system with a cloud base server such as The Things Network or ThingSpeak for better monitoring from many sensor nodes.
- Lower power usage in deep sleep mode as stated in the datasheet and high quality third party anthenna for better range of testing.

With the achievement of the above recommendations in the future, this project will be able to provide many benefits to the local community.

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