DESIGN AND ANALYSIS LORA-BASED SENSOR SYSTEM FOR AQUACULTURE

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DESIGN AND ANALYSIS LORA-BASED SENSOR SYSTEM FOR AQUACULTURE

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
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DECLARATION

I declare that this report entitled “Design and Analysis LoRa-Based Sensor System For Aquaculture” is the result of my own work except for quotes as cited in the references.

Signature :

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Date : 25 JUNE 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature :

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Date : 25 JUNE 2021

ABSTRACT

This thesis presents a development of LoRa-Based Sensor System for Aquaculture. The quality of the aquaculture can be maintained by good quality of water. Real-time monitoring, analyzing and observation can improve the quality index of water. A lot of places within Malaysia is now trying to venture into this Aquaculture industry. However, environmental, water quality and parasite can affect the habitat of aquaculture. In producing the system, a 915MHz LoRa Shield is used as the medium of data transmission. The system is consisting of two parts which the first part is the transmitter where LoRa Shield, DHT11, DS18B20 and Total Dissolved Solids Sensor is attached to Arduino UNO. Another part is the receiver part which LoRa Shield is attached to Arduino UNO and connected to personal computer. Three sensors are used which are to detect humidity, temperature, water temperature and total dissolved solids and then will be sent to receiver through wireless communication. An actual test had been done where the Received Signal Strength Indicator with maximum value of -74dBm and minimum value of -110dBm and Signal-Noise Ratio with maximum value of -9dB and minimum value of -7.75dB is acquired for every 100m of 1.5km distance. As per the parameters, all the data is gathered for 48 hours at each of individual locations. The data can be concluded that the performance of each sensor is accurate

due to results gathered. The prototype system can improve the aquacultural technology monitoring system to help reduce human energy consumption and quickly solve problems in the event of a disaster.

ABSTRAK

Tesis ini membentangkan pembangunan Sistem Sensor Berasaskan LoRa untuk Akuakultur. Kualiti akuakultur dapat dikekalkan dengan kualiti air yang baik. Pemantauan, penganalasan dan pemerhatian masa nyata boleh meningkatkan indeks kualiti air. Banyak tempat di Malaysia kini cuba menceburi industri Akuakultur ini. Walau bagaimanapun, alam sekitar, kualiti air dan parasit boleh menjejaskan habitat akuakultur. Dalam menghasilkan sistem ini, Perisai LoRa 915MHz digunakan sebagai medium penghantaran data. Sistem ini terdiri daripada dua bahagian yang bahagian pertama adalah pemancar di mana LoRa Shield, DHT11, DS18B20 dan Total Disssolved Solids Sensor dipasangkan kepada Arduino UNO. Bahagian lain adalah bahagian penerima di mana LoRa Shield dipasangkan ke Arduino UNO dan disambungkan ke komputer peribadi. Tiga sensor digunakan iaitu mengesan kelembapan, suhu, suhu air dan jumlah pepejal terlarut dan kemudian akan dihantar kepada penerima melalui komunikasi tanpa wayar. Ujian sebenar telah dilakukan di mana Penunjuk Kekuatan Isyarat Diterima dengan nilai maksimum -74dBm dan nilai minimum -110dBm dan Nisbah Isyarat-Gangguan dengan nilai maksimum 9dB dan nilai minimum -7.75dB diperolehi untuk setiap 100m sepanjang 1.5km. Mengikut parameter, semua data dikumpulkan selama 48 jam di setiap lokasi individu. Data

boleh disimpulkan bahawa prestasi setiap sensor adalah tepat kerana keputusan yang dikumpulkan. Sistem prototaip boleh meningkatkan sistem pemantauan teknologi akuakultur untuk membantu mengurangkan penggunaan tenaga manusia dan menyelesaikan masalah dengan cepat sekiranya berlaku bencana.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

LoRa	:	Long Range
RSSI	:	Received Signal Strength Indicator
SNR	:	Signal-Noise Ratio
WSN	:	Wireless Sensor Network
WAN	:	Wide Area Network
PS#	:	Problem Statement #Number
LPWAN	:	Low-Power Wide-Area-Network
dBm	:	Decibels per milliwatt
dB	:	Decibels

CHAPTER 1

INTRODUCTION

1.1 Background of the Project

Aquaculture industry has gained a lot of attention lately. Malaysia is the 66th largest country by total land area, with a land area of 329,613 km^2. From the total land area, 1,200 km^2 or 0.37% is made up of water such as lakes, rivers, or other internal waters. Malaysia has a total coastline of 4,675 km. The aquatic ecosystem in Malaysia is from saltwater fish and freshwater fish. The daily protein diet for Malaysia citizen is aquatic. The average 20 percent of their food is fish. Fish consumed index in 2011 is 53.1kg and expected to increase to 61.1kg in 2020 [1].

It is a known fact that Malaysians used to live along the coastline. Therefore, seafood has been so close to us, Malaysians. A good quality index is a must since water is the environmental habitat for the aquaculture. The fish regulate system can be affected by the different type of environmental.

The long-range communication is one of advantage for suburban and urban area. Especially in towards era due to development of tall and massive buildings. The wireless sensor network acts as a communication node that connects the transmitter and receiver, resulting in the gathering and monitoring of information via radio signal. LoRa WAN is useful and efficient in wireless network as it receives and transmits data and also consume less power. LoRa modules will be connected to microcontroller and sensors in order for the data to be transmitted and received by the Nearby Computing Resources via Cloud as can be seen in Figure 1.1.

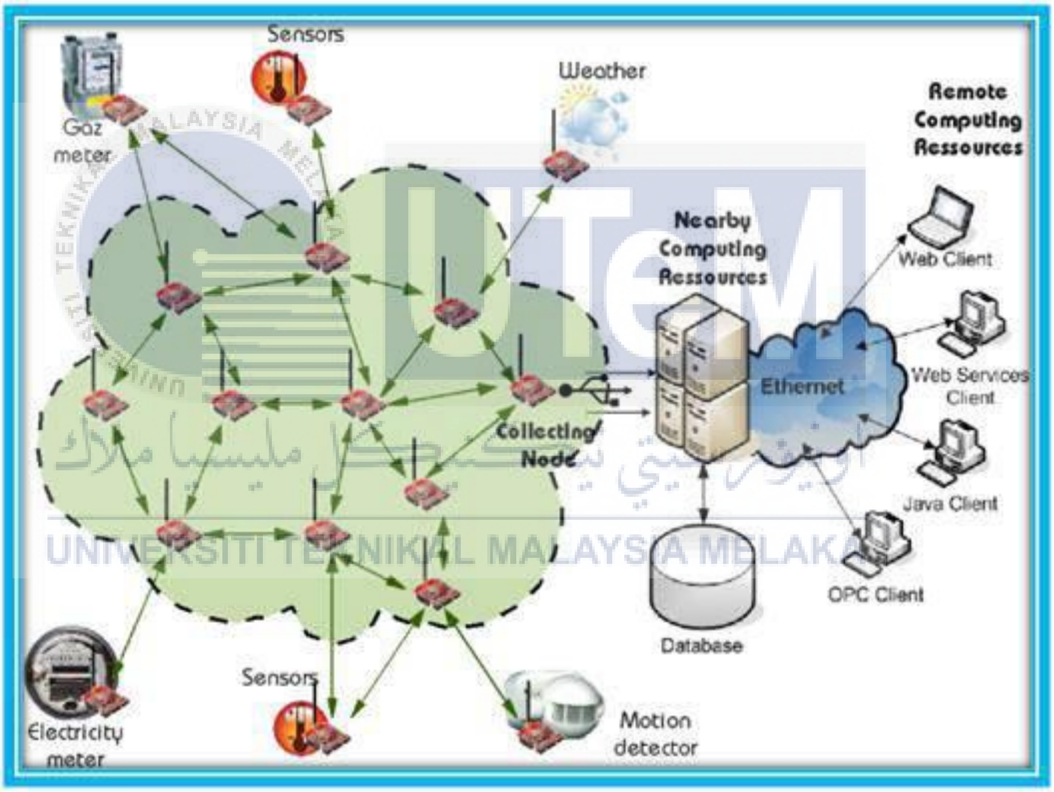


Figure 1.1: Architecture of the Wireless Network

1.2 Problem Statement

In recent days, aquaculture farming has become a blooming sector around the world. Maintaining a good aquaculture farming environment is crucial in order to grow healthy fish, achieve satisfactory production and improve culture efficiency. However, it is important to acknowledge that aquaculture farming faces drawbacks causing several technical difficulties to arise. Among the common difficulties faced in aquaculture farming include conventional ways of checking total dissolved solids and temperature levels are heavily reliant on manual measurements therefore may lead to inaccuracy in measurements [PS1] and is heavily time consuming [PS2]. In addition, traditional aquaculture practices also face difficulties in maintaining optimum water conditions for a healthy aquaculture environment [PS3].

1.3 Objectives of the Project

The aim of the research is to monitor the water quality index for aquaculture by using wireless sensor network with low power consumption. The main objectives to be achieved in this research are:

1. To design a prototype of a system to monitor the characteristics of the aquaculture farm.
2. To analyze the sensing technique in aquaculture farm.
3. To study the effect of power transmission on LoRa signal strength and coverage.

1.4 Significance of the Project

The research significant is to create an environmental monitoring device for real time monitoring with lower power consumption in the future. The research of aquaculture can continuously monitor the water quality index from time to time. Finally, a research regarding water quality index for long range communication with lower power consumption will be generated.

1.5 Scopes and Limitations of the Project

In the research, the objective is to create a system for water monitoring in long range communication. The sensor will be located in different area to analyze the data of water. This research will be studied the objective and cover and cover following aspect:

1. The data analysis for water quality index in aquaculture environmental.
2. The power consumption for sensors.
3. The long-range communication of LoRa.

The limitations happen due to its performances and the way it operates form specific of task. The limitation for this project is:

1. Wide area

The suburban area is far from the urban area for network coverage. The coverage to cover will be limited and the obstacles to data transmit will increase such as tree and building.

2. Battery Lifetime

The sensors depend on the battery to transmit the data. The data taken is limited due to the battery lifetime. The battery needs to be charged every time which causing the delay in capture the output.

1.6 Chapter Summary

This chapter introduces the background, problem statement, objectives, significant, scopes and limitation of the project. In this chapter, the introduction is a brief introduction to the environmental aquaculture project. More information will be briefly presented in the next chapter.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

In this chapter, the project background study, and literature analysis clarified for a deeper understanding of the work. The previous similar research discussed to gain relevant and useful knowledge regarding this research.

2.2 Wireless Network

The wireless network is a method of transmission for sending and receiving data to replace the use of wired data. A wire transmitting is disadvantageous for wide area coverage, which raises the price. The wireless sensor network is a delivery network with a wide number of random nodes that create data and transceiver data for memory storage and communication. WSN operates in an unattended mode to gather data from its area. In order to observe the characteristics of the aquaculture, a sensor node equipped with LoRa communication modules was developed, whereby the integration between Wireless Sensor Network and cloud-based computing platform was used to manage the storage and processing of the data accumulated. In addition to that, the process also required a device that had the capabilities link the sensor node devices to the cloud platform. The device will mainly function to retrieve detected sensors from the sensor nodes through the LoRa communication modules, which will then trigger a message to be transmitted to the cloud-based data storage server via MQTT protocol [1].

Table 2.1: Differences between data transmission [12]

	Wi-Fi	**RF Module**	**GSM**	**LoRa**
Coverage	200m	8km	10km	10km
Frequency	2.4GHz – 5GHz	2.4GHz	900GHz – 1800GHz	919MHz – 923MHz
Advantage	- Low cost - High Speed	- Variation of signal - Immune to noise	- Support roaming - Wide distribution	- Low power consumption - Higher speed
Disadvantage	High power consumption	- Low speed - Complex	- High power consumption - Low speed	- Low bandwidth - Wide distribution

2.2.1 LPWan Technology

Low-Power Wide-Area-Network (LPWAN) is a type of wireless technology used in distributed telemetry networks, inter-machine interaction and the Internet of Things to relay small quantities of data over long distances. Data from various instruments, such as meters, sensors or gauges, may be obtained by LPWAN. LPWAN technologies allow the transfer of long-distance and energy-efficient data. LPWAN focuses on applications involving long-range transfers of small data packets where network autonomy and independent power supply are crucial. The main areas of application of LPWAN are wireless sensor networks, automatic collection of meter readings, industrial monitoring and control systems [6].

Table 2.2: Differences between Technologies [5]

	SigFox	**NB-IoT**	**LoRa**
Bandwidth	100Hz	200kHz	125kHz
Data Rate	100bps	200kbps	50kbps
Bi-Directional	Limited	Yes	Yes
Built in Security	No	Yes	Yes
Cost	Low	Moderate	Low
Advantage	- Consume low power - Supports a wide coverage	- Good coverage - Faster response time	-Easily set up - Perfect for single-building applications
Disadvantage	- Not mobile - Constrained capacity	- Difficult to implement - Network and tower handoffs	- Lower data rates than NB-IoT - Requires gateway

2.2.2 LoRa and LoRaWAN

LoRa, is the physical layer or modularity (wireless), which creates a long-distance communication link. As the LoRa Alliance said, LoRaWAN is about the communication protocol and the architecture of the network system. LoRa is a proprietary modulation based on spread spectrum technology, developed by Semtech. In this type of modulation, the bandwidth expansion is accomplished by "chirps"[11,12]. The LoRa frequency allows to enter the national area that it can sense and use, and it can send and receive processes at the same time. The sensors installed in modern vehicles today can be optimized using the latest technology, such as the On-Board-Diagnostic (OBDII) system. In the past, communication between people or machines [15]. Finally, compared to other technologies used in LPWAN, LoRa technology has two advantages. Since the modulated signal is constantly changing in frequency, it is more tolerant of clock imprecision, and can also tolerate the Doppler shift caused by movement between the transmitter and the receiver [13].

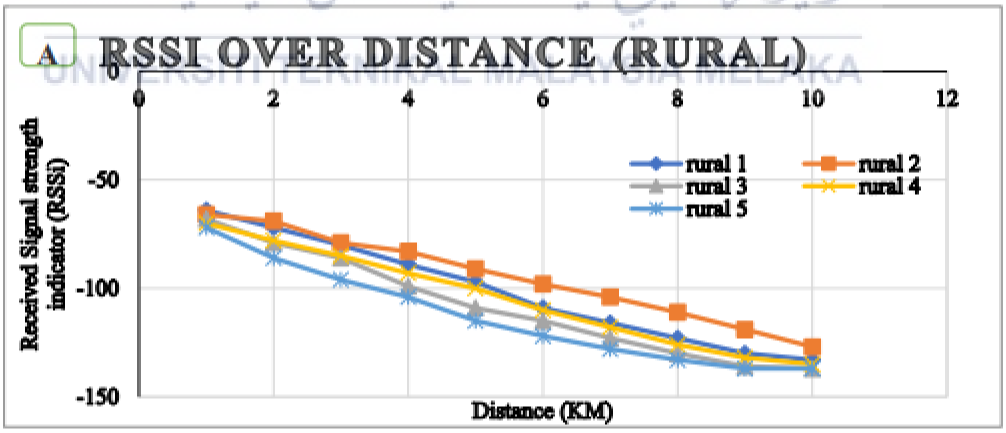


Figure 2.1: RSSI over Distance [15]

2.3 Water Quality

Water quality monitoring is an essential aspect in the aquaculture system in order to ensure healthy growth and vitality of the fishes and other present organisms. Water quality is highly influenced by factors related to acidity (pH), turbidity, dissolved oxygen and temperature level. Due to its sensitive nature, a wireless sensor network (WSN) system can be used to substitute traditional farmers, as an effort to achieve better efficiency, accuracy, and enable remote access. In this research, wireless sensor nodes are utilized to monitor water conditions. Due to its efficient power usage and wide transmission range the LoRa module was chosen to act as the communication protocol between node sensor and the gateway. This is seen as appropriate as aquaculture systems are commonly located in remote locations with limited electricity resources. Based on its functionality tests, the sensor nodes were capable in adapting appropriately to changes in the environment. When tested, the best delay was recorded to be 189,4ms, which was recorded at a 40m communication range using 82bytes of data. The increase in value range resulted in a linear increase of packet loss [3].

Water quality is a crucial aspect in maintaining a stable aquaculture environment. The improvement of water quality is highly dependent on analytic real-time monitoring and observations. In Malaysia, Sungai Pahang is deemed as the largest river that contributes to the freshwater aquaculture industry. Unfortunately, water quality can be easily affected by factors including its surrounding environment and presence of parasites. In most cases, pollution occurs due to bauxite pollution, deforestation, and climate changes. Hence, this research aims to observe turbidity, solubility of solid and temperature of the water using a wireless sensor network. It is hypothesized that higher percentage of solid solubility and turbidity in the water, the lower the percentage of oxygen [4].

2.3.1 National Water Quality Standards for Malaysia

Water quality is measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), or the amount of material suspended in the water (turbidity). Each nation has a standardized quality of water need to be followed as set by the Department of Environment. Same goes to our country, Malaysia. A set of parameters of water quality has been listed for our country to follow by [3].

Table 2.3: National Water Quality Standards for Malaysia

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
pH	-	6.5 – 8.5	6 – 9	6 – 9	5 – 9	5 – 9	-
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-

2.3.2 Class of Water

Class I, Class IIA or Class III can be used to describe the water quality range. Class III is fitting for their habitat, mainly for aquaculture farm. In Malaysia, for the Marine Department, the water has been listed for the Guideline for tracking the water's current state. The type of ecosystem for fish is different by class of water [3].

Table 2.4: Class of Water

CLASS	USES
I	Conservation of natural environment Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species
IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species
IIB	Recreational use with contact body
III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking
IV	Irrigation
V	None of the above

2.4 Previous Studies on Aquaculture Environmental with Wireless Sensor Network

2.4.1 Comparison of Study Research

Table 2.5: Comparison of Study Research

Reference	Methodology	Network and Sensors	Limitation
Design and Development of Water Quality Monitoring System Based on Wireless Sensor Network in Aquaculture [7]	The researchers design the structure of the wireless sensor network and develop monitoring software to analyze data	-Zigbee -pH Sensor -Water Level -Temperature Sensor -Dissolved oxygen Sensor	-Need more nodes to provide long-term monitoring -Slightly inaccurate system monitoring
Need of water quality monitoring in shrimp culture [8]	The researcher measure, record and manage the water quality index for shrimp through all four seasons.	- pH sensor - Temperature - Dissolved Oxygen Sensor - Ammonia sensor	- The data collected in lab. Unable to do real time monitoring
A wireless sensor network-based monitoring system for freshwater fishpond aquaculture [9]	The researchers measure environmental variables in freshwater fishpond aquaculture. The hardware of Wireless Sensor Network nodes, topology of Wireless Sensor Network also designed in this research.	-Zigbee -pH Sensor -Temperature Sensor -Dissolved Oxygen Sensor	-Limited functions of the system - Energy consumption -Battery wastage
Water quality monitoring system using 3G network [10]	The research monitoring system through the acquisition of data parameters such as temperature, pH level, turbidity and	-Temperature sensor -pH level -Turbidity -Dissolved oxygen - Gizduino - Raspberry Pi	- Battery lifetime - The limit of 3G network coverage.

	amount of dissolved oxygen.	- 3G pocket Wi-Fi	
Design and deployment of wireless sensor networks for aquaculture monitoring and control based on virtual instruments [11]	This research has developed and implemented low-cost short-range wireless sensor network modules based on standard ZigBee and virtual instrument technologies for real-time monitoring and control of an aquaculture system.	-Zigbee -pH Sensor -Water Level -Temperature Sensor -Dissolved oxygen Sensor	-Add GPRS Module -Monitoring program should be linked to the web server
The real time monitoring of water Quality in IoT environment [26]	Raspberry Pi sends the data to the IoT module. The IoT module send the data to internet using cloud computing and also to WIFI for accessing mobile devices. The monitoring parameters of the water from the sensors are transmitted through IoT module to the gateway.	-USR WiFi 232 -Temperature Sensor -Turbidity Sensor -pH Sensor -Conductivity Sensor -Dissolved Oxygen Sensor	-Implement biological parameter of the water -Install the system in several location
Water Quality Monitoring System Based on IOT [27]	The hardware part has sensors which help to measure the real time values, another one is Arduino atmega328 converts the analog values to digital one & LCD shows the displays output from sensors, Wi-Fi module gives the connection	-ESP8266 WiFi Module -pH Sensor -Temperature Sensor -Flow Sensor	-Add more sensors -Interface with relay

	between hardware and software.		
Water Quality Monitoring with Internet of Things (IoT) [28]	There are two main parts in the proposed system which are the sensor node and network gateway. The parameters to be measured in this proposed system are the pH level and ambient temperature. This proposed network gateway is connected to the internet connection by using the IoT module, Arduino Ethernet Shield.	-RF Module -Temperature Sensor -pH Sensor	-Mobile application for other mobile device OS
Reconfigurable Smart Water Quality Monitoring System in IoT Environment [29]	This paper presents a reconfigurable smart sensor interface device for water quality monitoring system in an IoT environment. The smart WQM system consists of Field Programmable Gate Array (FPGA) design board, sensors, Zigbee based wireless communication module and personal computer (PC). The FPGA board is the core component of the proposed system and it is programmed in very high-speed	-Xbee Wireless -pH Sensor -Water Level Sensor -Temperature Sensor -Carbon Dioxide Sensor -Turbidity Sensor	-Extend more coverage range -Comprise more nodes

	integrated circuit hardware description language (VHDL) and C programming language using Quartus II software and Qsys tool.		
Water Quality Monitoring System Using IOT [30]	Estimation of the pollution content in and amount of oxygen level in the water for future purification of water. At the oxygen centralization surpasses those ordinary extent our convenient oxygen focus identification What's more screen framework will inform the client promptly. This plan is simple will perused Also know the extent to which oxygen centralization will be exhibit buzzing around.	-GSM Module -pH Sensor -Turbidity Sensor -Temperature Sensor	-Display other parameters -Sends other parameters data

2.5 Chapter Summary

The criteria for aquaculture technology are continuously growing in order to improve the direction and scale of aquaculture. High requirements for parameters such as dissolved oxygen content and the PH value of water quality in the aquaculture process makes monitoring of water quality a crucial link in aquaculture. At present, however, most of the conventional monitoring systems for water quality have revealed several drawbacks, including cable laying, troublesome upkeeping, and lack of capable management and control behaviour. To add to that, considering that the characteristics of the long-node propagation distance of large waters areas, this paper suggests a LPWAN water quality monitoring system based on LoRa communication through long single-hop transmission distance. The respective system includes high durability, efficient power consumption, straightforward network protocol and topology, along with low costs in deployment and maintenance [2].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, details for the sensor and wireless technology for the project is introduced. The block diagram, flow chart, hardware development and cost. Hence, this chapter will elaborate about the procedure of the project.

3.2 Block Diagram

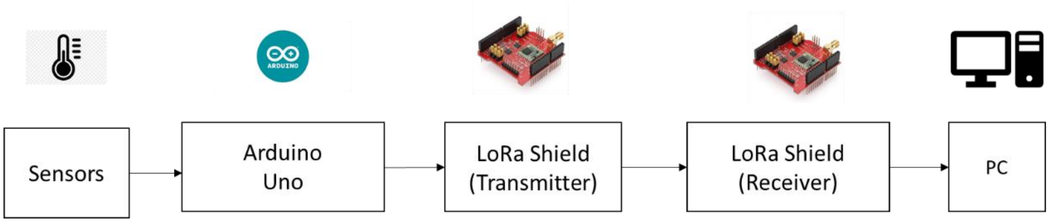


Figure 3.1: Block Diagram of the Project

Figure 3.1 shows few sensors are set to be used in this project such as temperature sensor, waterproof temperature sensor and total dissolved solids sensor. These sensors will be placed onto an Arduino microcontroller board and a LoRa shield will be attached to it too. Once the data are registered to the Arduino, the data will be transmitted to another LoRa shield which would be placed inside the office of the user. The user then needs to log in to the server to receive all the data stored in the cloud.

3.3 Flowchart

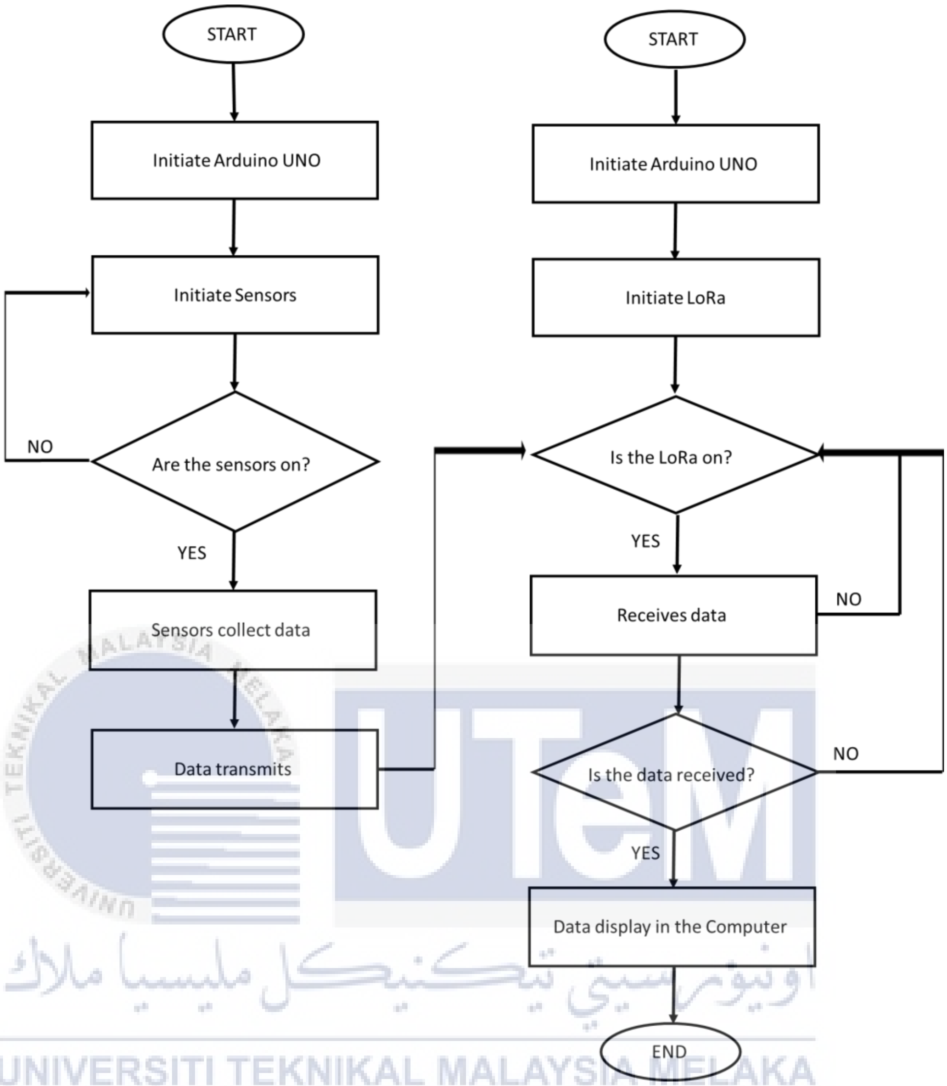


Figure 3.2: Flowchart of the Project

In Figure 3.2, the overall flowchart of the project is shown. The main process in the system is sensors, Arduino UNO and LoRa Shield. The flowchart shows on how the operation supposed to be functioning.

For the hardware setup, 3 sensors which are DHT11 Humidity and Temperature, DS18B20 Waterproof Temperature and Total Dissolved Solids sensor are connected to Arduino board. LoRa shield which works as transmitter is also connected to the Arduino board.

Next, on the receiver part, LoRa Shield is connected to an Arduino UNO. Then, Arduino UNO is then connected to Personal Computer in order to observe the data transmitted and received in the process.

3.4 Research Hardware

3.4.1 Arduino UNO

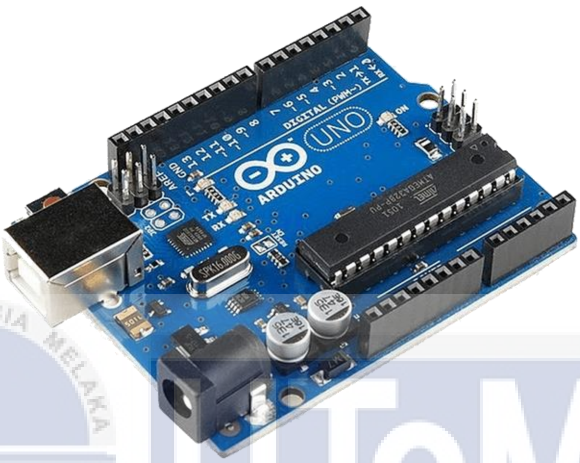


Figure 3.3: Arduino UNO Microcontroller

Arduino UNO is used as the main controller for this project. Arduino Uno is simple circuit platform based on I/O port that implements of processing language. C++ language is the language embedded in this Arduino. DHT11 Humidity and Temperature sensor, DS18B20 Waterproof Temperature sensor and Total Dissolved Solids is controlled by the Arduino to collect and store the data.

Table 3.1: Specifications of Arduino UNO

Type	ATMega328P
Operating Voltage	5V
I/O Port	14 Digital input 6 Analogue input
Input Voltage	7-12V
Flash Memory	32KB
Clock Speed	16MHz

3.4.2 DHT11 Humidity and Temperature Sensor

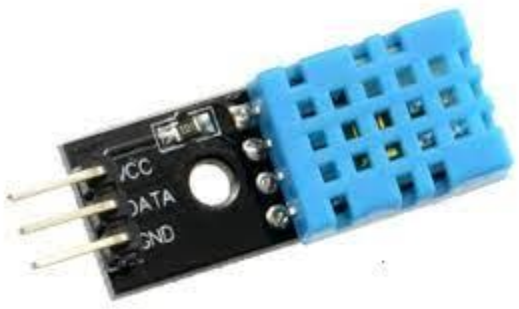


Figure 3.4: DHT11 Humidity and Temperature Sensor

The DHT11 is a basic digital temperature and humidity sensor with a modest price tag. It measures the ambient air with a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin (no analogue input pins needed). It is simple to use, but data collection necessitates careful timing.

Table 3.2: Specifications of DHT11 Humidity and Temperature Sensor

Voltage	3V – 5.5V
Accuracy	±0.2℃
Temperature	0 to 50℃
Humidity	20% to 90%
Current Consumption	2.5mA during conversion
Output	Serial data

3.4.3 DS18B20 Waterproof Temperature Sensor

Figure 3.5: DS18B20 Waterproof Temperature Sensor

In this project, temperature sensor is used to detect the temperature of the water. The temperature of the water may affect the lives of aquaculture inhabitants.

Table 3.3: Specifications of DS18B20 Waterproof Temperature Sensor

Voltage	3V – 5.5V
Accuracy	±0.5°C Accuracy from -10°C to +85°C
Temperature	-55 to 125°C
Pin	Requires only one digital pin
Length	90cm
Diameter	4mm

3.4.4 Total Dissolved Solids Sensor

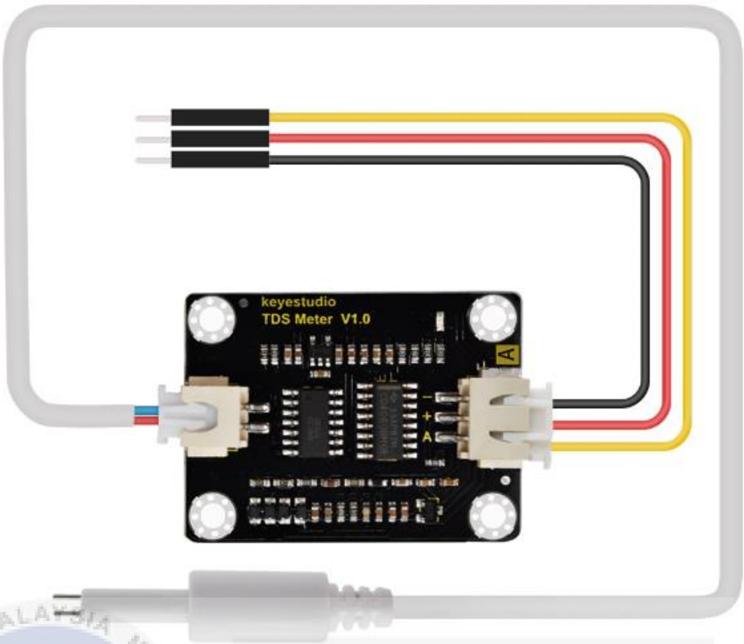


Figure 3.6: Total Dissolved Solids Sensor

Total dissolved solids consist of an inorganic fraction (silts, clays, etc.) and an organic fraction (algae, zooplankton, bacteria, and detritus) that are carried along by water as it runs off the land. The concentration of total dissolved solids affects the water balance in the cells of aquatic organisms. The method of measuring suspended solids is by weight. To measure TDS, a water sample is filtered, dried, and weighed.

Table 3.4: Specifications of Total Dissolved Solids Sensor

Voltage	3.3 ~ 5.5V / 3
Current	6mA
Range	0 ~ 1000ppm
Accuracy	± 10% F.S. (25 ℃)
Size	42 * 32mm / L: 83cm
Interface	PH2.0-3P

3.4.5 LoRa Shield

Figure 3.7: LoRa Shield

LoRa Shield which is short formed for Long Range Shield is a device to connect the microcontroller towards the LoRa Gateway. The module used in this project supports up to 915MHz.

Table 3.5: Specifications of LoRa Shield

Processor	32bit MCU
Receiver Sensitivity	As low as -137.5dBm
Coverage	15km suburban area 5km urban area
Frequency in Malaysia	919MHz – 923MHz
Power Transmission	Adjustable up to 19.15dBm via AT command

3.5 Research Software

3.5.1 Arduino IDE

Figure 3.8: Arduino IDE

Arduino Software (IDE) is an open-source software used to write code and upload it to the board. It runs on almost every operating system such as Windows, Linux and Mac OS. Arduino program can be written and uploaded onto a physical programmable circuit board and on another simulation software.

3.5.2 Microsoft Excel

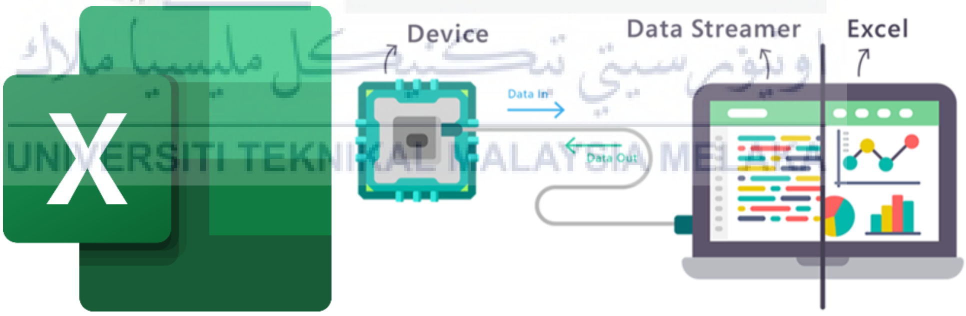


Figure 3.9: Microsoft Excel

Microsoft Excel is a data storage, organisation, and manipulation tool for computers. All data for this research project is imported to the Microsoft Excel to be analyzed. Data Streamer is an Excel add-in that streams live data from a microcontroller into Excel and delivers data back to the microcontroller. Connect a sensor to a microcontroller linked to a Windows 10 PC to collect data from it into an Excel worksheet.

3.5.3 Fritzing

Figure 3.10: Fritzing Software

Fritzing is an open-source hardware program that allows anyone to use electronics as a creative medium. In the spirit of Processing and Arduino, Fritzing provides a software tool, a community website, and services that build a creative ecosystem that allows users to document their prototypes, share them with others, teach electronics in a classroom, and layout and manufacture professional Printed Circuit Board (PCB).

3.6 Hardware Development

3.6.1 Project Circuit

This project circuit is made by using Fritzing application. This is used to help to see the connection between all the sensors, LoRa Shield and Arduino UNO for the transmitting end. As for the receiving end, only LoRa Shield and Arduino UNO is required.

3.6.1.1 Receiver

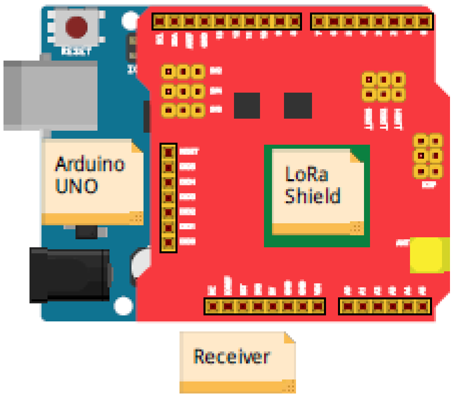


Figure 3.11: Diagram of Receiver

In Figure 3.18, a LoRa Shield is attached to Arduino UNO. Next, Arduino UNO is connected to Personal Computer and data can be observed through Data Streamer of Microsoft Excel.

3.6.1.2 Transmitter

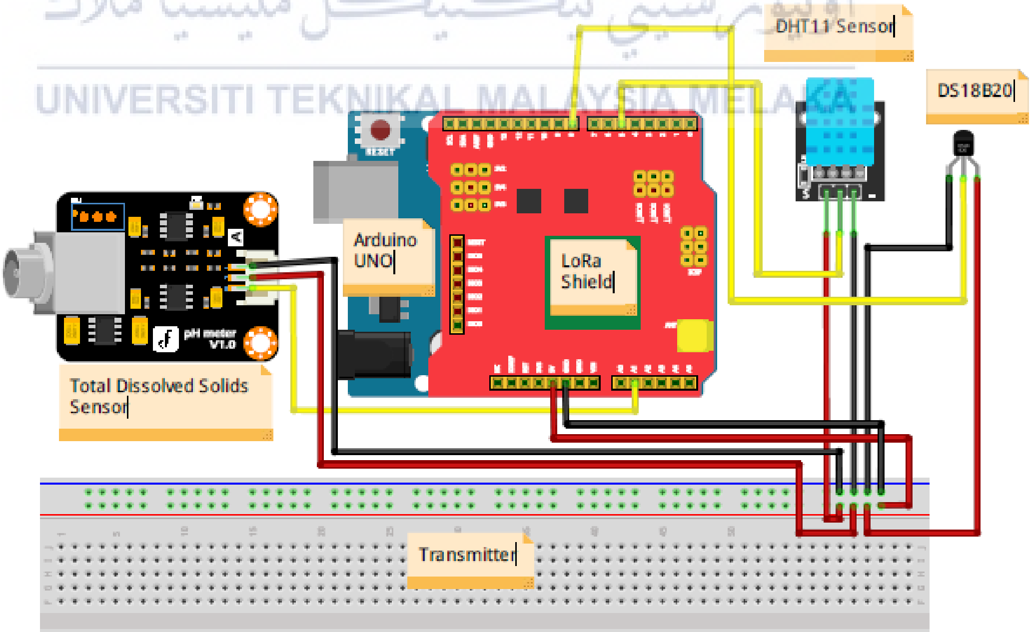


Figure 3.12: Diagram of Transmitter

In figure 3.19, LoRa Shield is stacked on top of Arduino UNO. DHT11 Humidity and Temperature sensor, DS18B20 Waterproof Temperature sensor and Total Dissolved Solids sensor is then connected to Arduino UNO to the pin of 5, 8 and A1 respectively. All the Vcc of sensors are connected to 5V pin of Arduino. The Ground of all sensors connected to the Ground of Arduino.

3.7 Software Development

3.7.1 Arduino IDE

The program of the LoRa Shield, DHT11 Humidity and Temperature Sensor, DS18B20 Waterproof Temperature Sensor and Total Dissolved Solids sensor to communicate to the LoRa Shield can be written and embedded into the microcontroller.

3.7.1.1 LoRa Code

```
rx
#include <SPI.h>
#include <LoRa.h>

void setup() {
  Serial.begin(9600);
  while (!Serial);
  Serial.println("LoRa Receiver");
  if (!LoRa.begin(915E6)) {
    Serial.println("Starting LoRa failed!");
    while (1);
  }
}

void loop() {
  // try to parse packet
  int packetSize = LoRa.parsePacket();
  if (packetSize) {
    // received a packet
    Serial.print("Received packet '");

    // read packet
    while (LoRa.available()) {
      Serial.print((char)LoRa.read());
    }

    // print RSSI of packet
    Serial.print("' with RSSI ");
    Serial.println(LoRa.packetRssi());
    Serial.print(" SNR '");
  }
}
```

Figure 3.13: Receiver Code

This LoRa receiver code is started by including the library of SPI and LoRa. Serial.begin() is then used to establish the connection between Arduino UNO and the computer used. In LoRa.begin, 915MHz is used depends on the frequency band of LoRa Shield used in the project. In order to extract the Received Signal Strength Indicator (RSSI) data, Serial.println(LoRa.packetRssi()) is embedded into the Arduino UNO.

tx

```
#include <SPI.h>
#include <LoRa.h>

int counter = 0;

void setup() {
  Serial.begin(9600);
  while (!Serial);
  Serial.println("LoRa Sender");

  if (!LoRa.begin(915E6)) {
    Serial.println("Starting LoRa failed!");
    while (1);
  }
}

void loop() {
  Serial.print("Sending packet: ");
  Serial.println(counter);
  // send packet
  LoRa.beginPacket();
  LoRa.print("hello ");
  LoRa.print(counter);
  LoRa.endPacket();
  counter++;
  delay(5000);
}
```

Figure 3.14: Transmitter Code

At this transmitter end, same library is used as the receiver end which are SPI.h and LoRa.h. The frequency band of the transmitter is also 915MHz which depended on the model that is used to transmit the RSSI data. Once the data received, the serial terminal will show “hello1”, “hello2” and so on sequentially.

3.7.1.2 DHT11 Temperature and Humidity Sensor Code

DHT11

```
#include "DHT.h"
#define DHTPIN 5     // what digital pin we're connected to
#define DHTTYPE DHT11   // DHT 11

DHT dht(DHTPIN, DHTTYPE);

void setup()
{
  Serial.begin(9600);
  dht.begin();
}

void loop()
{
  float h = dht.readHumidity();
  float t = dht.readTemperature();
  float f = dht.readTemperature(true);
//  Serial.print("Humidity: ");
  Serial.print(h);
//  Serial.print("%\t");
  Serial.print(", ");
//  Serial.print("Temperature: ");
  Serial.print(t);
//  Serial.println("°C");
  Serial.println();
   delay(5000);
}
```


Figure 3.15: DHT11 Temperature and Humidity Sensor Code

DHT.h library is included to run this set of code. Digital pin then is chosen depends on any vacant pin which in this case is pin 5. In void loop, humidity and temperature code are extracted for the data to be observed.

3.7.1.3 DS18B20 Waterproof Temperature Sensor Code

```
DS18B20
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 8

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

 float Celcius=0;

void setup(void)
{
  Serial.begin(9600);
  sensors.begin();
}

void loop(void)
{
  sensors.requestTemperatures();
  Celcius=sensors.getTempCByIndex(0);
  Serial.print(" C  ");
  Serial.print(Celcius);

  delay(1000);
}
```


Figure 3.16: DS18B20 Waterproof Temperature Sensor Code

Libraries such as OneWire.h and DallasTemperature.h are needed to run this set of code. Digital pin is then chosen depends on any vacant pin available which in this case is pin 8. sensors.requestTemperatures() is then called to get the data of underwater temperature. The difference between DS18B20 and DHT11 sensor is DS18B20 can be used to detect the temperature of underwater area.

3.7.1.4 Total Dissolved Solids Sensor Code

tds

```
#define TdsSensorPin A1
#define VREF 5.0
#define SCOUNT 30
int analogBuffer[SCOUNT];
int analogBufferTemp[SCOUNT];
int analogBufferIndex = 0, copyIndex = 0;
float averageVoltage = 0, tdsValue = 0, temperature = 25;

void setup()
{
  Serial.begin(9600);
  pinMode(TdsSensorPin, INPUT);
}

void loop()
{
  static unsigned long analogSampleTimepoint = millis();
  if (millis() - analogSampleTimepoint > 40U)
  {
    analogSampleTimepoint = millis();
    analogBuffer[analogBufferIndex] = analogRead(TdsSensorPin);
    analogBufferIndex++;
    if (analogBufferIndex == SCOUNT)
      analogBufferIndex = 0;
  }
  static unsigned long printTimepoint = millis();
  if (millis() - printTimepoint > 800U)
  {
    printTimepoint = millis();
    for (copyIndex = 0; copyIndex < SCOUNT; copyIndex++)
      analogBufferTemp[copyIndex] = analogBuffer[copyIndex];
    averageVoltage = getMedianNum(analogBufferTemp, SCOUNT) * (float)VREF / 1024.0;
    float compensationCoefficient = 1.0 + 0.02 * (temperature - 25.0);
    float compensationVolatge = averageVoltage / compensationCoefficient;
    tdsValue = (133.42 * compensationVolatge * compensationVolatge * compensationVolatge - 255.86 *
    compensationVolatge * compensationVolatge + 857.39 * compensationVolatge) * 0.5;
    Serial.print("TDS Value:");
    Serial.print(tdsValue, 0);
    Serial.println("ppm");
  }
}
int getMedianNum(int bArray[], int iFilterLen)
{
  int bTab[iFilterLen];
  for (byte i = 0; i < iFilterLen; i++)
    bTab[i] = bArray[i];
  int i, j, bTemp;
  for (j = 0; j < iFilterLen - 1; j++)
  {
    for (i = 0; i < iFilterLen - j - 1; i++)
    {
      if (bTab[i] > bTab[i + 1])
      {
        bTemp = bTab[i];
        bTab[i] = bTab[i + 1];
        bTab[i + 1] = bTemp;
      }
    }
  }
  if ((iFilterLen & 1) > 0)
    bTemp = bTab[(iFilterLen - 1) / 2];
  else
    bTemp = (bTab[iFilterLen / 2] + bTab[iFilterLen / 2 - 1]) / 2;
  return bTemp;
}
```


Figure 3.17: Total Dissolved Solids Sensor Code

Total Dissolved Solids (TDS) pin is set to A1 since it requires analog.Read function. When the data need to be converted in ppm unit, it will need to be calculated by using the algorithm stated in the code. Once the data is calculated, it will be converted into ppm value and stated in the serial terminal.

3.7.1.5 Integrated Code

3.7.1.5.1 Receiver Code

LoRaReceive

```
#include <SPI.h>
#include <RH_RF95.h>
#include <Wire.h>

RH_RF95 rf95;
unsigned long int millisBefore;
int turn = 0;
int h, t, Celcius, tdsValue;

void setup()
{
   Serial.begin(9600);
   delay(10);
  while (!Serial) ; // Wait for serial port to be available
  if (!rf95.init())
    Serial.println("init failed");
  rf95.setFrequency(915.0);
}

void loop()
{
  uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
  uint8_t len = sizeof(buf);
  if (rf95.waitAvailableTimeout(500))
  {
    if (rf95.recv(buf, &len))
    {
      String dataTotal = (char*)buf;
      explode(dataTotal);
    }
    else
    {
      Serial.println("recv failed");
    }
  }

}
```

```
void explode(String req)
{
  char str[40];
  req.toCharArray(str, 40);
  char * pch;
  pch = strtok (str, "-");
  while (pch != NULL)
  {
  String sementara = pch;
  turn++;
  if (turn == 1)
  {
    Serial.print("Humidity: ");
    Serial.println(pch);
    h = sementara.toFloat();
  }
  if (turn == 2)
  {
    Serial.print("Temperature: ");
    Serial.println(pch);
    t = sementara.toFloat();
  }
    if (turn == 3)
  {
    Serial.print("Water Temperature: ");
    Serial.println(pch);
    Celcius = sementara.toFloat();
  }
      if (turn == 4)
  {
    Serial.print("Total Dissolved Solids: ");
    Serial.println(pch);
    tdsValue = sementara.toFloat();
  }
  pch = strtok (NULL, "-");
  delay(100);
}
turn = 0;
}
```


Figure 3.18: Integrated Receiver Code

In this integrated receiver end, few libraries such as SPI.h, RH_RF95.h and Wire.h are used. In line 8 which is started with int for int “h” is for humidity, “t” is for temperature, “Celcius” is for water temperature and “tdsValue” is for total dissolved solids. In void loop, data is called from void explode where in the void explode, all the sensors’ data is gathered from the transmitter end.

3.7.1.5.2 Transmitter Code

LoRaTransmit

```
#include "DHT.h"
#include <SPI.h>
#include <RH_RF95.h>
#include <OneWire.h>
#include <DallasTemperature.h>

#define ONE_WIRE_BUS 8
#define DHTPIN 5     // what digital pin we're connected to
#define DHTTYPE DHT11   // DHT 11
#define TdsSensorPin A1
#define VREF 5.0 // analog reference voltage(Volt) of the ADC
#define SCOUNT 30 // sum of sample point

int analogBuffer[SCOUNT]; // store the analog value in the array, read from ADC
int analogBufferTemp[SCOUNT];
int analogBufferIndex = 0, copyIndex = 0;
float averageVoltage;
float tdsValue;
float Celcius = 0;
int temperature = 25;

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
DHT dht(DHTPIN, DHTTYPE);
RH_RF95 rf95;

void setup()
{
  Serial.begin(9600);
  pinMode(TdsSensorPin, INPUT);
  sensors.begin();
  dht.begin();
  if (!rf95.init())
    Serial.println("init failed");
  rf95.setFrequency(915.0);
}
```

```
void loop()
{

  static unsigned long analogSampleTimepoint = millis();
  if (millis() - analogSampleTimepoint > 40U)
  {
    analogSampleTimepoint = millis();
    analogBuffer[analogBufferIndex] = analogRead(TdsSensorPin);
    if (analogBufferIndex == SCOUNT)
      analogBufferIndex = 0;
  }
  static unsigned long printTimepoint = millis();
  if (millis() - printTimepoint > 800U)
  {
    printTimepoint = millis();
    for (copyIndex = 0; copyIndex < SCOUNT; copyIndex++)
    analogBufferTemp[copyIndex] = analogBuffer[copyIndex];
    averageVoltage = getMedianNum(analogBufferTemp, SCOUNT) * (float)VREF / 1024.0;
    float compensationCoefficient = 1.0 + 0.02 * (temperature - 25.0);
    float compensationVoltage = averageVoltage / compensationCoefficient;
    tdsValue = (133.42 * compensationVoltage * compensationVoltage * compensationVoltage - 255.86 *
    compensationVoltage * compensationVoltage + 857.39 * compensationVoltage) * 0.5;
    datatransfer();

  }
}

int getMedianNum(int bArray[], int iFilterLen)
{
  int bTab[iFilterLen];
  for (byte i = 0; i < iFilterLen; i++)
    bTab[i] = bArray[i];
  int i, j, bTemp;
  for (j = 0; j < iFilterLen - 1; j++)
  {
    for (i = 0; i < iFilterLen - j - 1; i++)
    {
      if (bTab[i] > bTab[i + 1])
      {
        bTemp = bTab[i];
        bTab[i] = bTab[i + 1];
        bTab[i + 1] = bTemp;
      }
    }
  }
  if ((iFilterLen & 1) > 0)
    bTemp = bTab[(iFilterLen - 1) / 2];
  else
    bTemp = (bTab[iFilterLen / 2] + bTab[iFilterLen / 2 - 1]) / 2;
  return bTemp;
}
```

```
void datatransfer()
{
  static unsigned long printTimepoints = millis();
  if (millis() - printTimepoints > 800U)
  {
    printTimepoints = millis();
    float h = dht.readHumidity();
    float t = dht.readTemperature();
    float f = dht.readTemperature(true);
    sensors.requestTemperatures();
    Celcius = sensors.getTempCByIndex(0);
    if (isnan(h) || isnan(t) || isnan(tdsValue) || isnan(Celcius))

    Serial.print("Humidity: ");
    Serial.print(h);
    Serial.println("%\t");
    Serial.print("Temperature: ");
    Serial.print(t);
    Serial.println("°C");
    Serial.print("Water Temperature: ");
    Serial.print(float(sensors.getTempCByIndex(0)));
    Serial.println("°C");
    Serial.print("Total Dissolved Solids: ");
    Serial.print(tdsValue);
    Serial.println("ppm ");
    String data = String(h) + "-" + String(t) + "-" + String(Celcius) + "-" + String(tdsValue);

    int dataLength = data.length(); dataLength++;
    uint8_t total[dataLength]; //variable for data to send
    data.toCharArray(total, dataLength); //change type data from string ke uint8_t
    Serial.println(data);
    rf95.send(total, dataLength); //send data
    rf95.waitPacketSent();
    delay(5000);
  }
}
```

Figure 3.19: Integrated Transmitter Code

For the transmitting end, five libraries are used which are gathered from each different individual code. The libraries used are DHT.h, SPI.h, RH_RF95.h, OneWire.h and DallasTemperature.h. The pins also are used just as from the previous Arduino files which are pin 5, pin 8 and pin A1. At the end of the code where it says rf95.send(total, dataLength), it is to transmit the data to the receiver.

3.8 Research Development

The hardware equipment used to build this project is Arduino UNO, Dragino LoRa Shield, temperature and humidity sensor, water temperature sensor and total dissolved solids sensor. All the result obtained from this research is real time experiment and real implementation network. To obtain the data, the experiment is conducted in different type of water and distance to get the data measurement and comparison of the result.

3.8.1 Project Hardware

3.8.1.1 Receiver

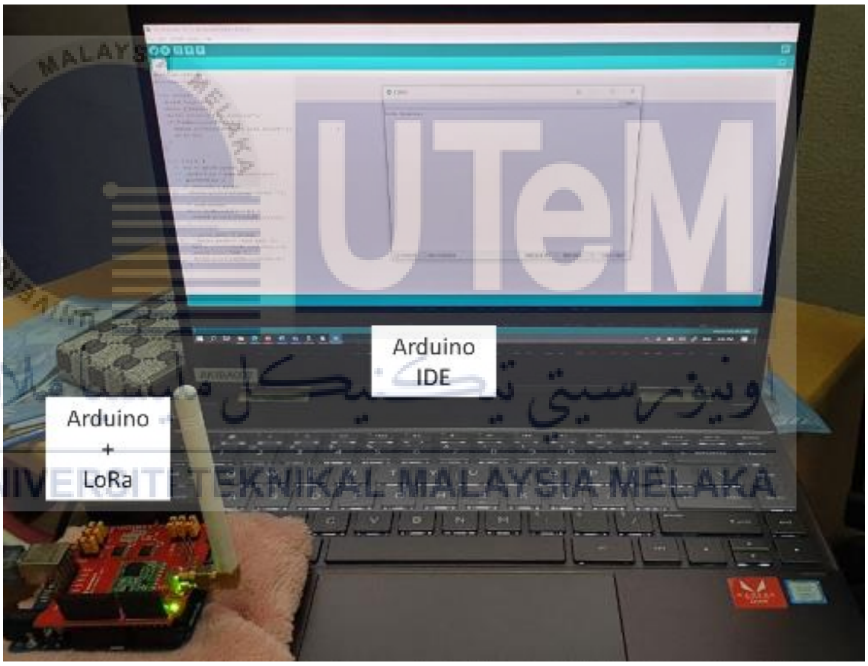


Figure 3.20: Hardware Setup of Receiver

Figure 3.20 shows that Arduino UNO and LoRa Shield is connected to Arduino IDE and next to Microsoft Excel.

3.8.1.2 Transmitter

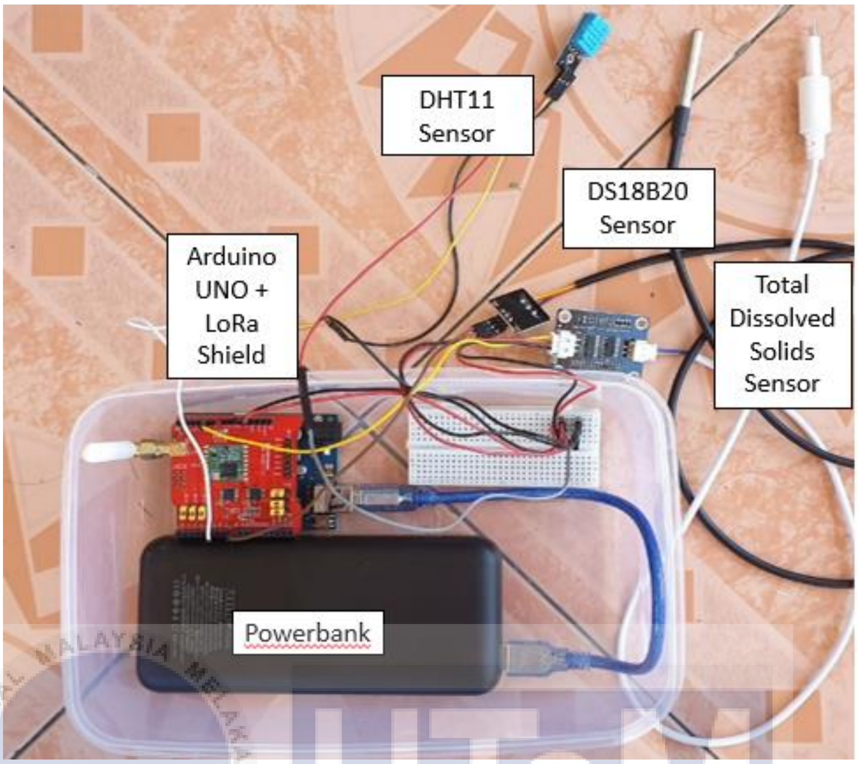


Figure 3.21: Hardware Setup of Transmitter

Figure 3.21 shows that LoRa Shield is stacked on top of Arduino UNO. Arduino UNO is connected to a powerbank. All the sensors are connected to Arduino UNO pins, Vcc to 5V pin of Arduino UNO and Ground to Ground pin of Arduino UNO.

3.8.2 Project Location

This project is conducted in two ways which one is to test the sample of 3 types of water which are catfish pond, lobster pond and silver catfish pond Another project conducted is to test the distance of LoRa Shield communication. This project is carried on with distance of 1.5km along the road in Durian Tunggal.

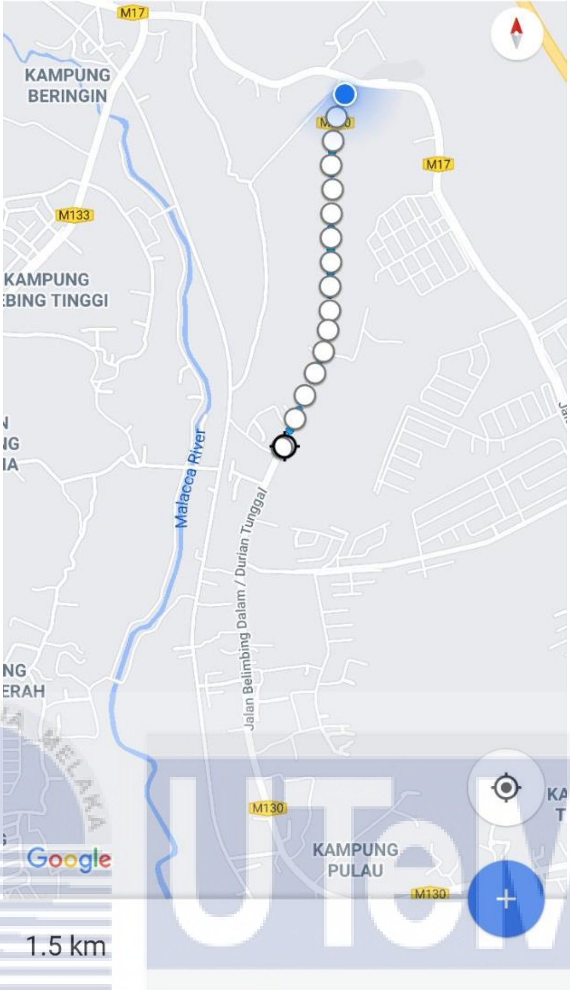


Figure 3.22: Map of total distance

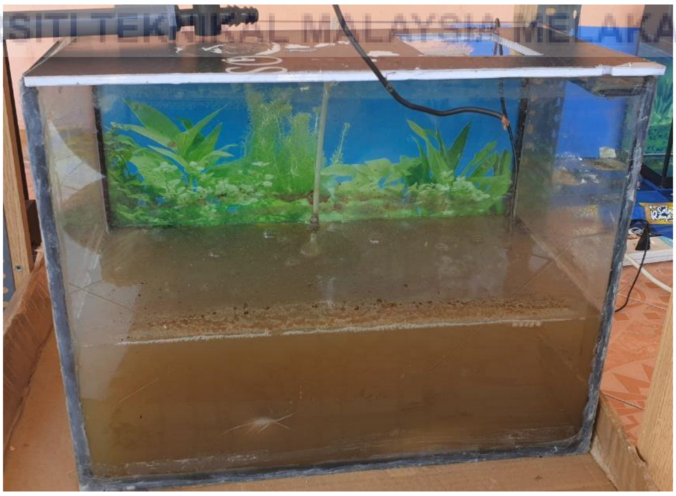


Figure 3.23: Catfish Pond

Figure 3.24: Lobster Pond

Figure 3.25: Silver Catfish Pond

3.8.2.1 Transmitter

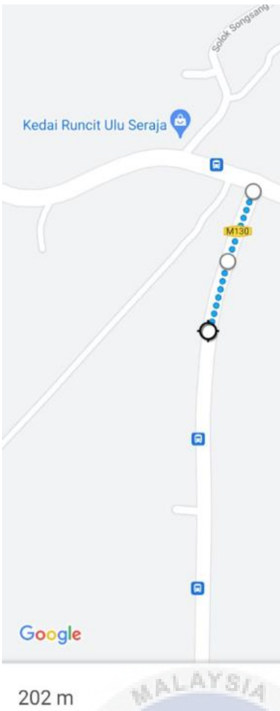
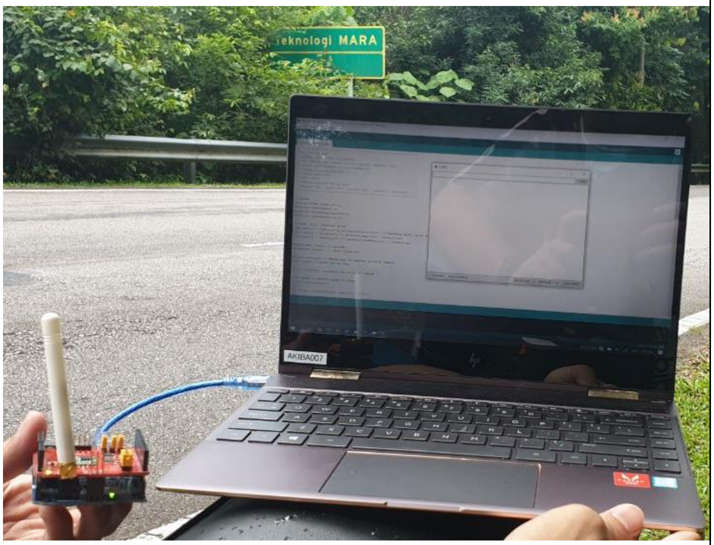
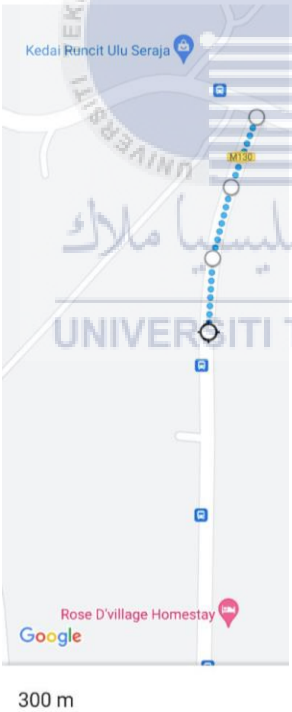
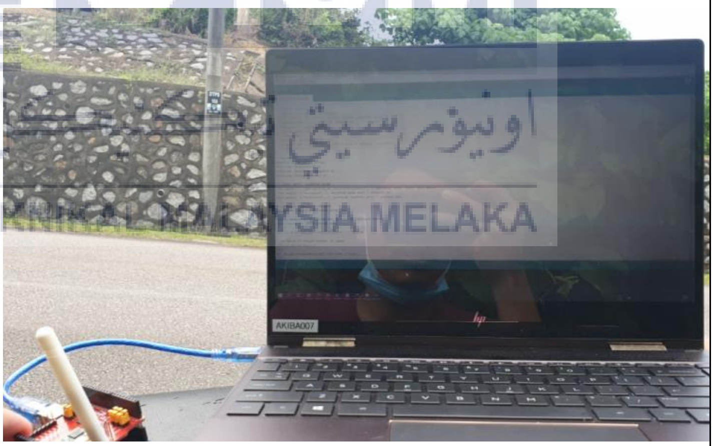
Figure 3.26: The landmark of Transmitter

The project's Received Signal Strength Indicator and Signal-Noise Ratio is carried along 1.5km of distance of Durian Tunggal. The transmitter is left at a "Starfruit" monument right before Sekolah Kebangsaan Parit Melana.

3.8.2.2 Receiver

Table 3.6: Distance and landmark of Receiver

Distance	Figure
 101 m	 Connection: Established

	 Connection: Established
	 Connection: Established

<table>
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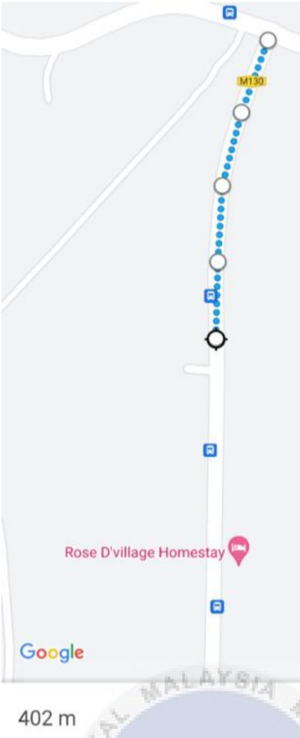
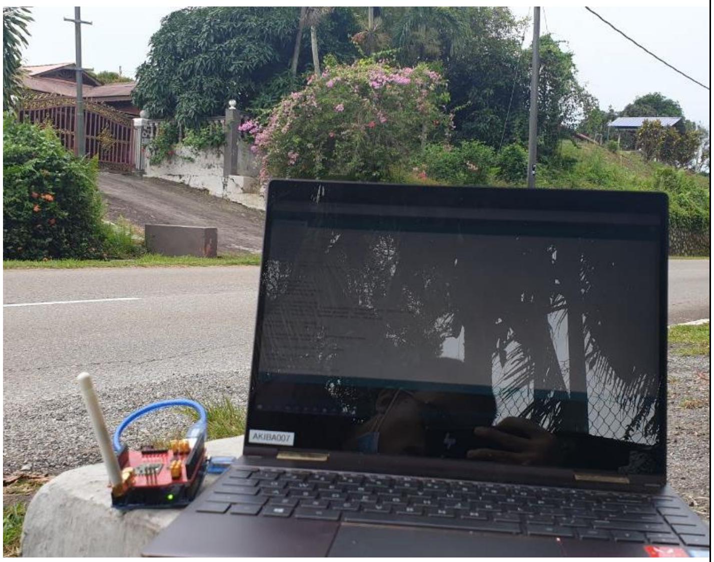
<td>
</td>
<td>
Connection: Established</td>
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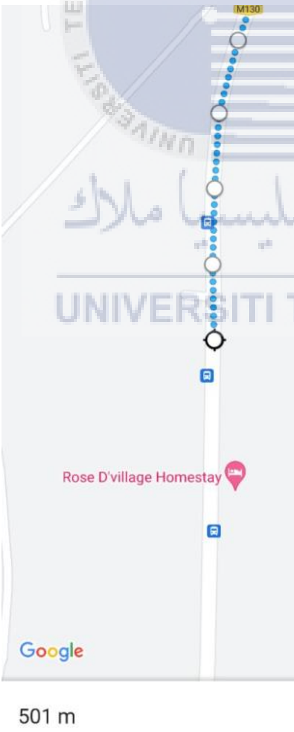
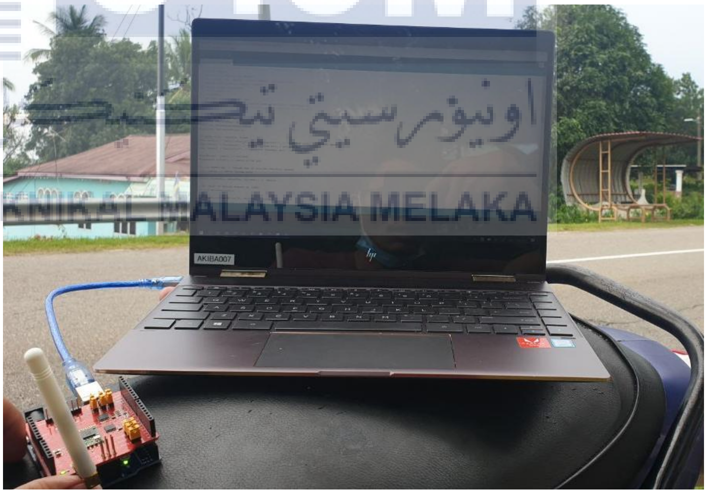
<td>
</td>
<td>
Connection: Established</td>
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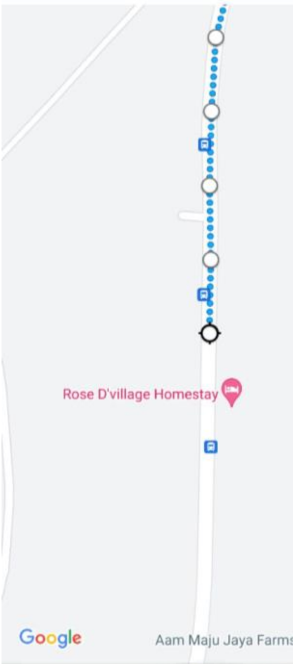
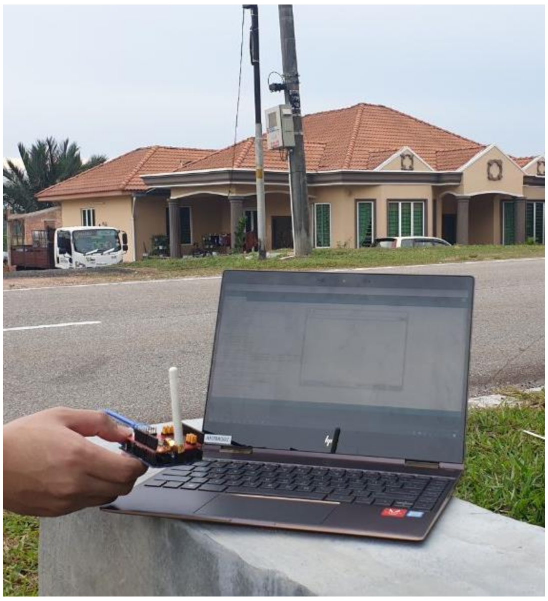
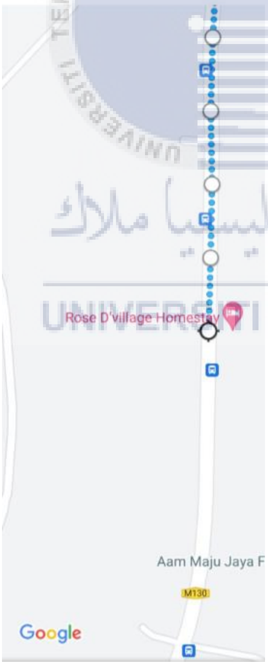
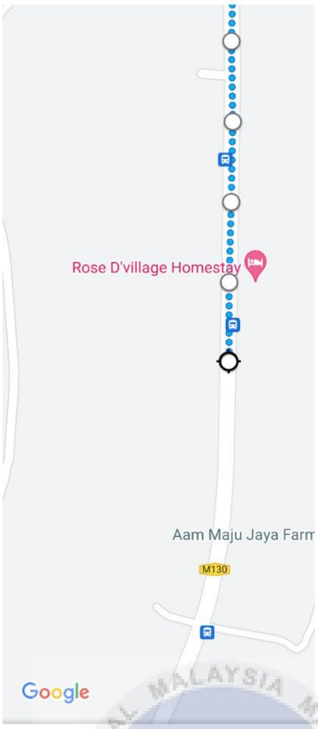
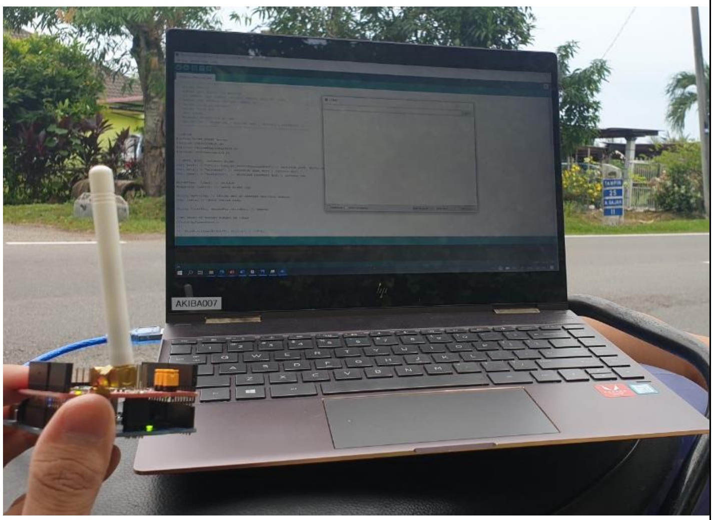
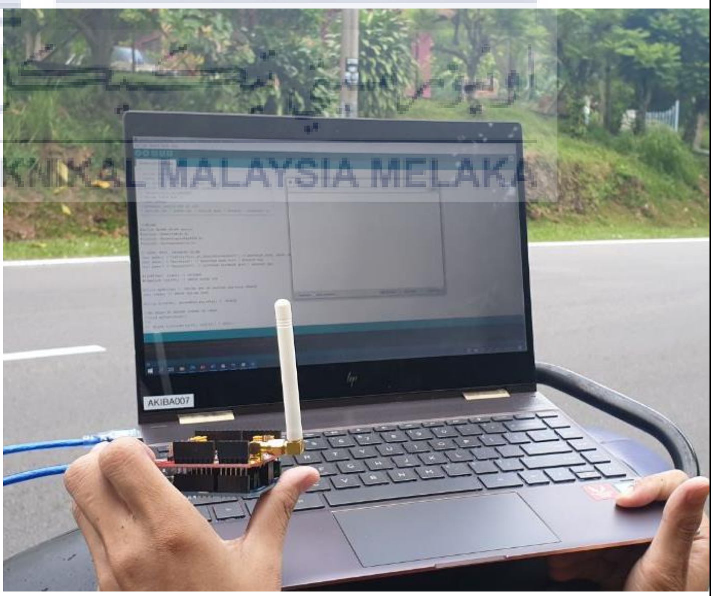
 601 m	 Connection: Established
 701 m	 Connection: Established

 801 m	 Connection: Established
 902 m	 Connection: Established

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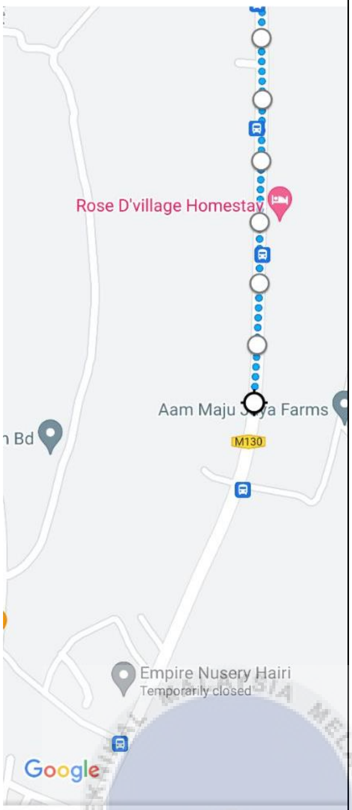
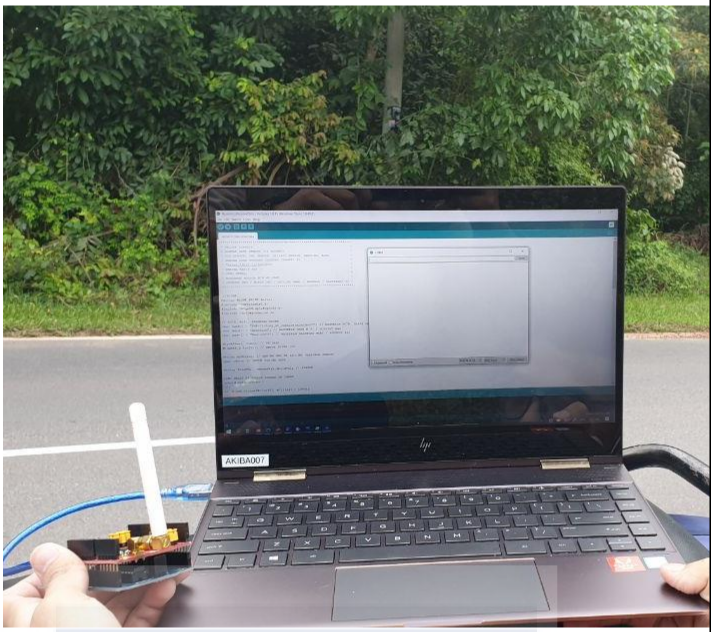


1.0 km
</td>
<td>

Connection: Established
</td>
</tr>
<tr>
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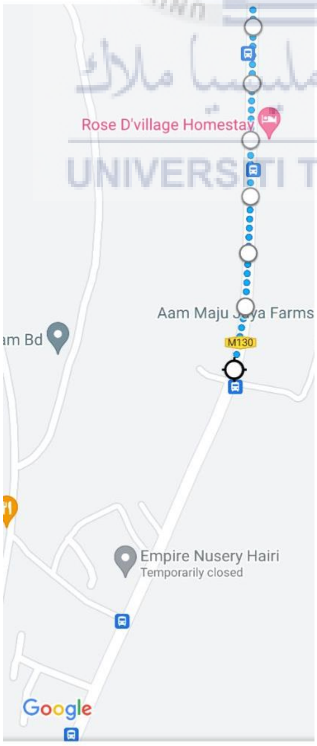
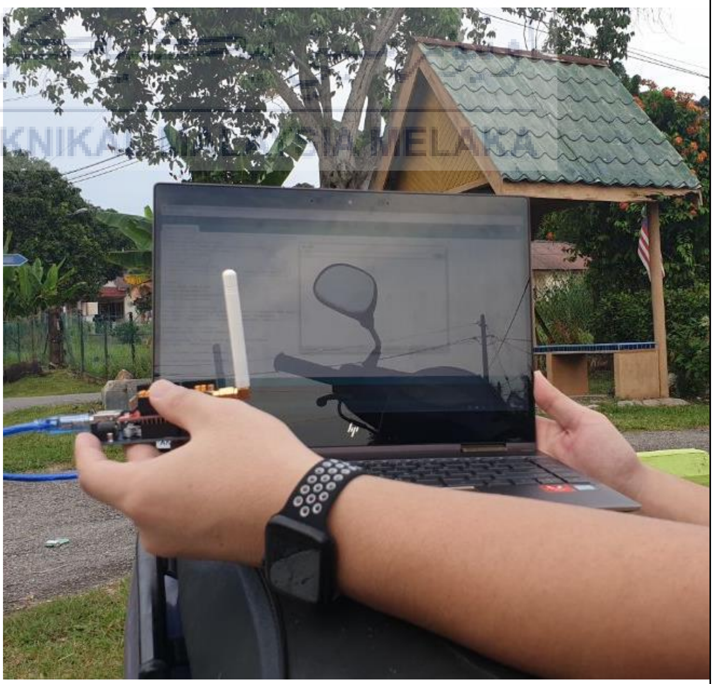


1.1 km
</td>
<td>

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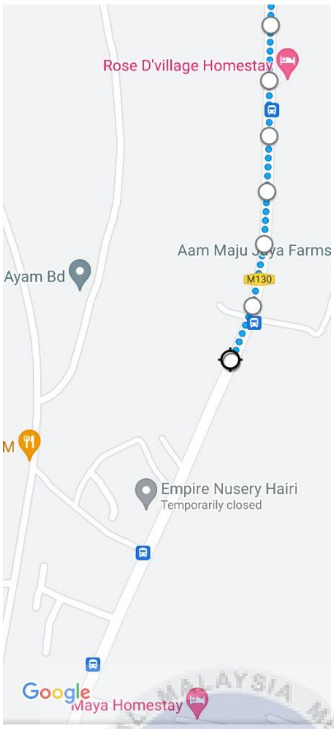
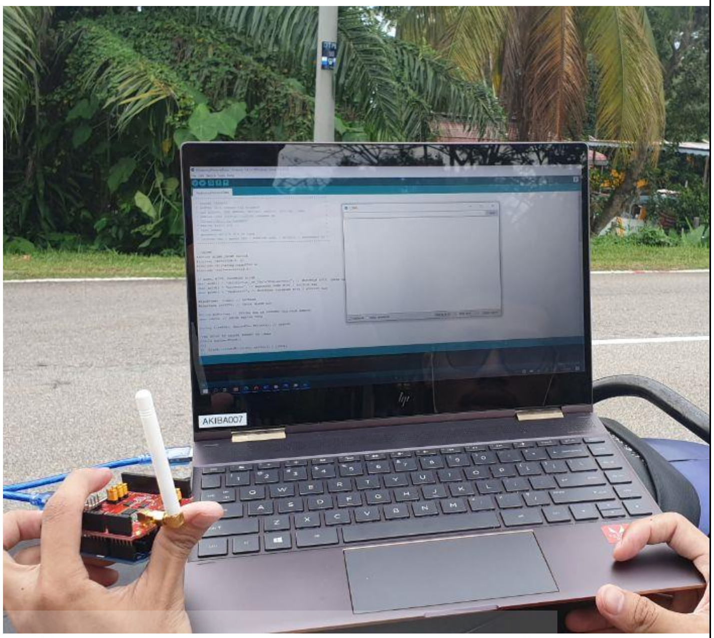
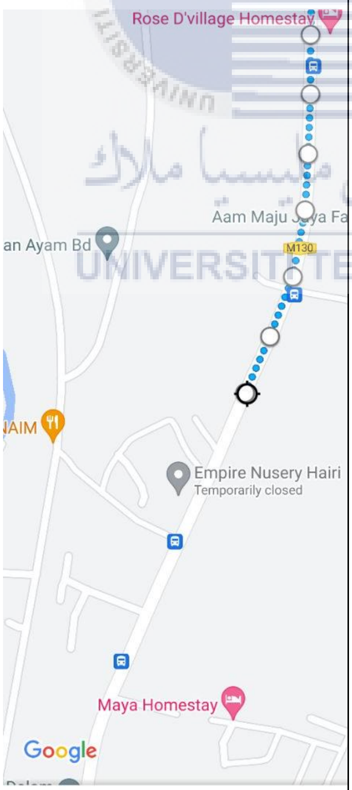
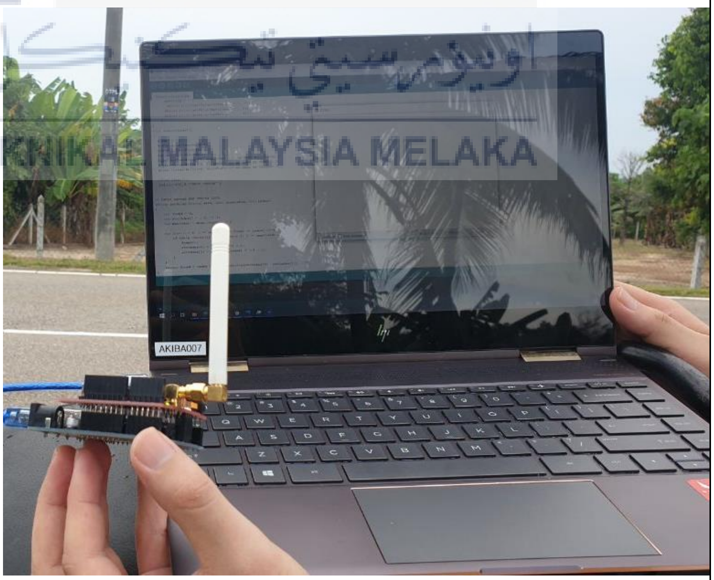
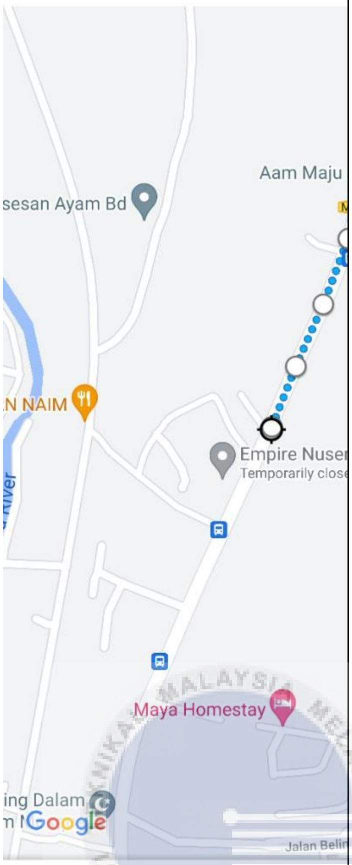
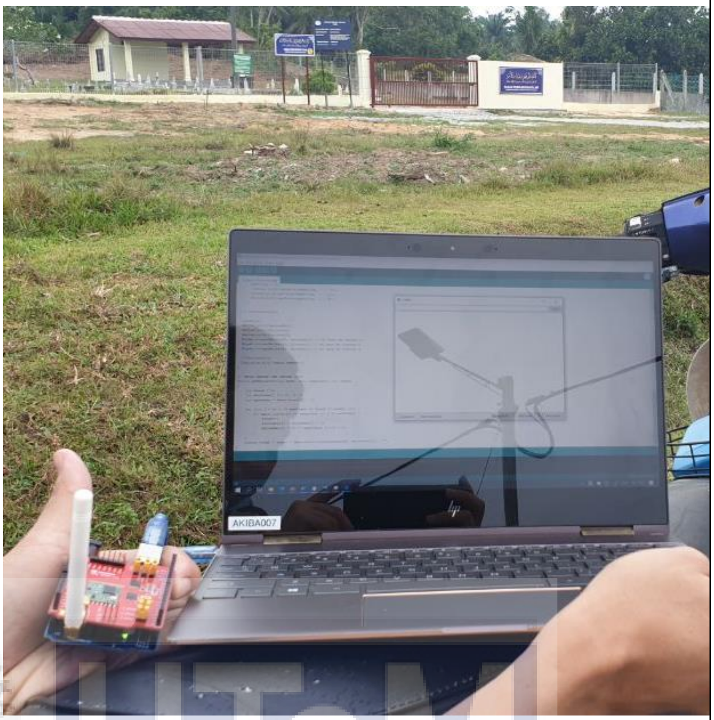
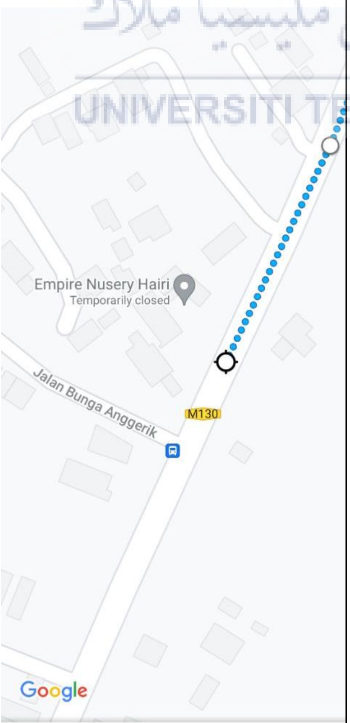


1.2 km
</td>
<td>

Connection: Established
</td>
</tr>
<tr>
<td>


1.3 km
</td>
<td>

Connection: Established
</td>
</tr>
</table>

 1.4 km	 Connection: Established
 1.5 km	 Connection: Established

This receiver part is tested at every 100m along 1.5km of road in Durian Tunggal. At 100m, the landmark that can be seen in the table is the “Parit Melana” signboard. Next at 200

m, the green “Universiti Teknologi Mara” signboard is the landmark. The electrical pole is the next landmark which is at 300m. At 400m, the house with the sloped entrance is used as the landmark. The green house is the landmark for the distance of 500m from the “Starfruit” monument. Next at 600m, the orangish house with the electrical pole in front of the house is the landmark. The bus stand is used for the 700m landmark. Next, the kilometer stone that is used as the landmark is located at 800m. At 900m, the electrical pole is the landmark used for the distance. Next at 1km distance from the receiver, the electrical pole is marked as the landmark. At 1.1km, a stone hut is the landmark for the distance. At the distance of 1.2km, an electrical pole is considered as the landmark. Next, another electrical pole is marked as the landmark of the distance of 1.3km. At 1.4km, the graveyard site is the landmark. Lastly, at the distance of 1.5km, the bus stand as shown in the picture is used as the landmark for the furthest distance.

3.9 Chapter Summary

In this chapter, the process on how the project is developed is explained through the block diagram and the flow chart. The hardware and software have been introduced for creating a prototype for this project in final year project.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will analyze and discuss the data collected from the project carried out according to the result. All data were tabulated and designed graph showed a different of the data display. The data analyzed and discussion will be explained further throughout this chapter.

4.2 Software Data Measurement

There is various type of data output been collected. The data will manually update in Microsoft Excel for better viewing. The software for the data is collected by serial monitor Arduino IDE and Microsoft Excel.

4.2.1 Arduino IDE

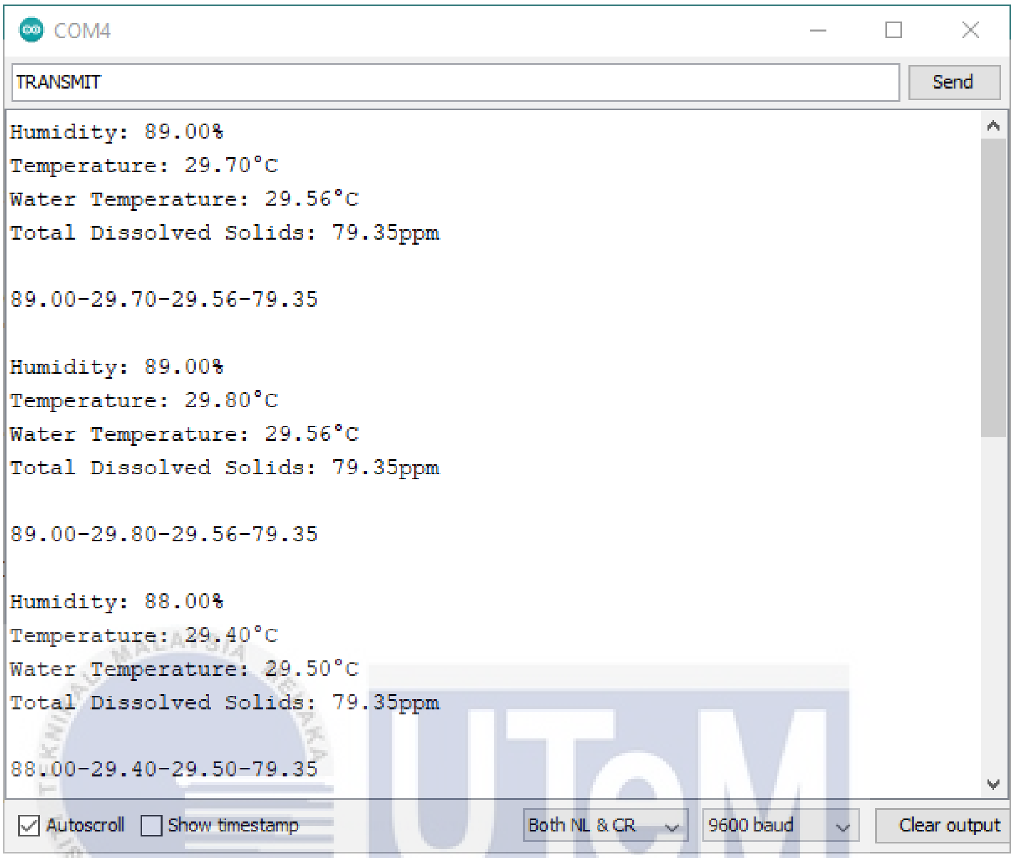


Figure 4.1: Transmitter Result

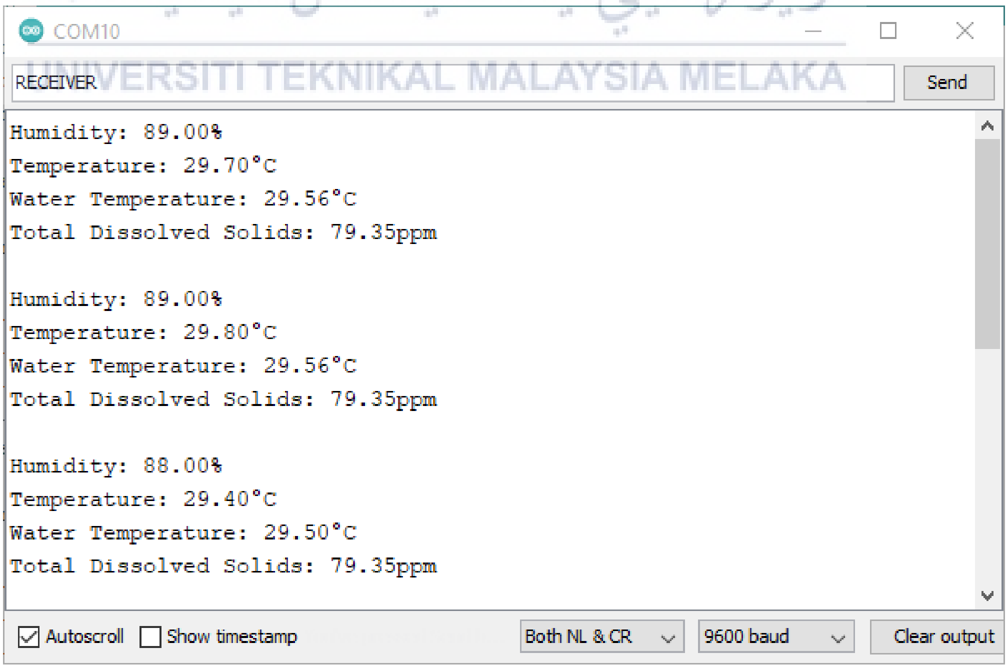


Figure 4.2: Receiver Result

A sample of how the transmission between of Transmitter and Receiver is as shown as in Figure 4.1 and Figure 4.2 respectively. Data are transmitted at real time and in the order of time where the latest data is always on top.

4.2.2 Excel

Data In (From Arduino Uno (COM3))

Data coming from the current data source will appear below as it is received.

Current Data

TIME	CH1	CH2	CH3	CH4
3:14:02.28	89	29.9	28.63	458.08

Historical Data

TIME	Humidity (%)	Temperature (°C)	Water Temperature (°C)	Total Dissolved Solids (ppm)	
3:14:02.28	89	29.9	28.63	458.08	Newest
3:13:56.60	89	30.1	28.63	458.08	
3:13:50.92	89	30.1	28.63	458.08	
3:13:45.25	89	30.2	28.63	458.08	
3:13:39.57	89	30.1	28.63	458.08	
3:13:33.89	89	30	28.63	458.08	
3:13:28.22	89	30.2	28.63	458.08	
3:13:22.54	89	29.9	28.63	458.08	
3:13:16.86	89	30	28.63	458.08	

Sheet1 | Data In | Data Out | Settings | Manifest

Figure 4.3: Data transmitted into Microsoft Excel

Figure 4.3 shows a sample of how Microsoft Excel Data Streamer extract the data transmitted to the receiver. Four channels are used which are Humidity Channel, Temperature Channel, Water Temperature Channel and Total Dissolved Solids Channel. All the data coming from the current data source will appear as it is received.

4.3 Data Measurement & Analysis

In subtopic 4.3.1, the data is collected at a distance of 1.5km. RSSI is monitored and data is tabulated. Next, for subtopic 4.3.2, 4.3.3, 4.3.4 and 4.3.5, the data is collected using three different type of water which are from catfish pond, lobster pond and silver catfish pond. The collection of data is done in real time within the same time interval. Each of the water type is monitored and measured in term of humidity, temperature, water temperature and total dissolved solids.

4.3.1 LoRa

Table 4.1: Received Signal Strength Indicator and Signal-Noise Ratio

Distance(km)	Received Signal Strength Indicator	Signal-Noise Ratio
0.1	-74	9
0.2	-78	9.5
0.3	-87	8.5
0.4	-94	8.75
0.5	-96	8.5
0.6	-100	7
0.7	-103	4.75
0.8	-105	4.5
0.9	-107	-6.5
1	-110	-7.5
1.1	-106	-7.25
1.2	-106	-3.2
1.3	-110	-5.75
1.4	-110	-5.25
1.5	-111	-7.75

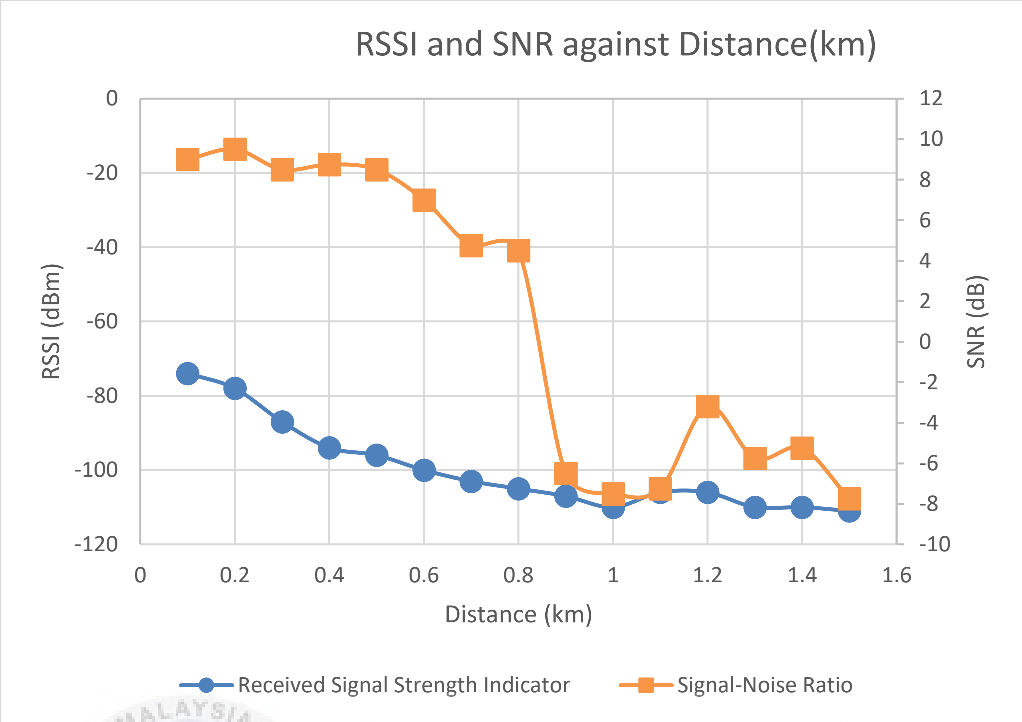


Figure 4.4: RSSI and SNR against Distance(km) graph

As can be seen in Figure 4.4, data shown in blue is RSSI against distance (km). the data is collected alongside the road of Durian Tunggal as in Figure 3.26 and Table 3.6. At a distance of 100m, a maximum RSSI is gained which is at -74. The further the LoRa Shield between each other, the lower the RSSI become. The signal indicator in the area was mostly disrupted by the interference of winding road and uneven area structure that occurred the recorded RSSI value.

4.3.2 Humidity

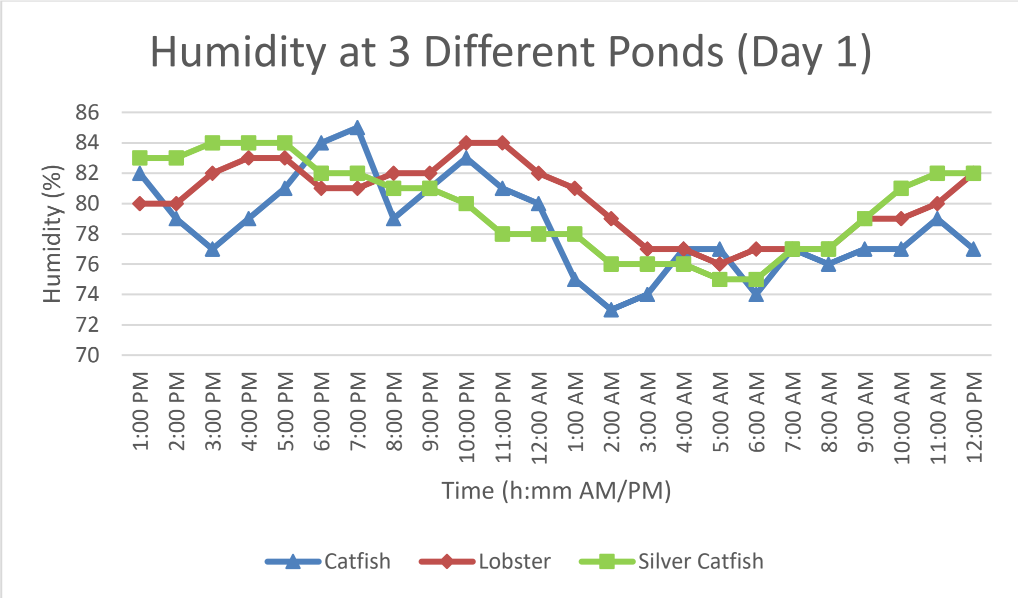


Figure 4.5: Humidity Graph (Day 1)

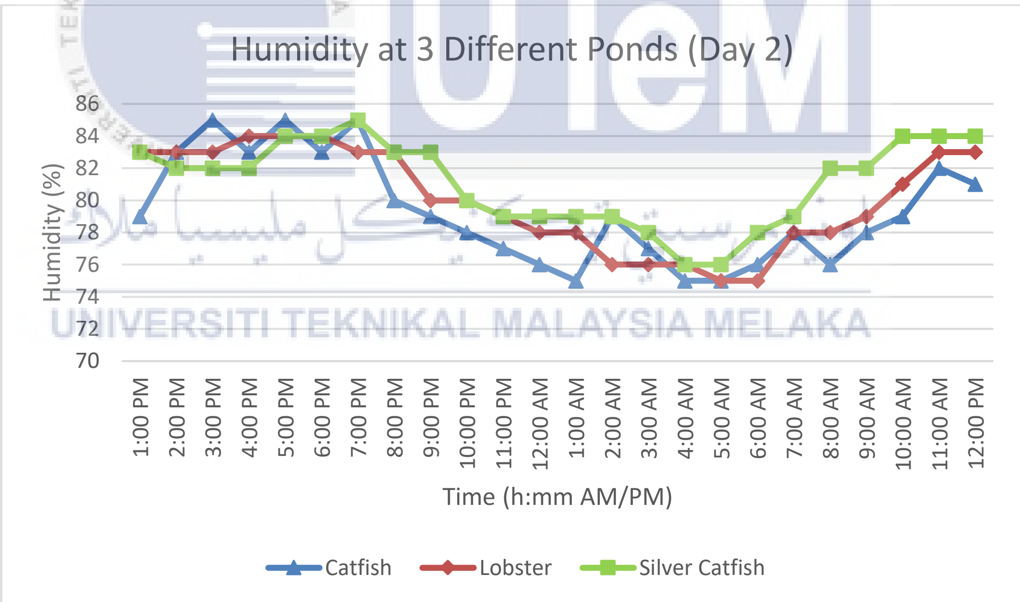


Figure 4.6: Humidity Graph (Day 2)

The data collected is at 3 different ponds which are Catfish Pond, Lobster Pond and Silver Catfish Pond. The data ranges at the maximum of 85% to a minimum of 73%. By science, it is stated that hot air has the capacity to hold more water than cooler air, therefore the humidity is higher during the day and lower during the night. Hence when it is night, the humidity percentage drops to at least 78%.

4.3.3 Temperature

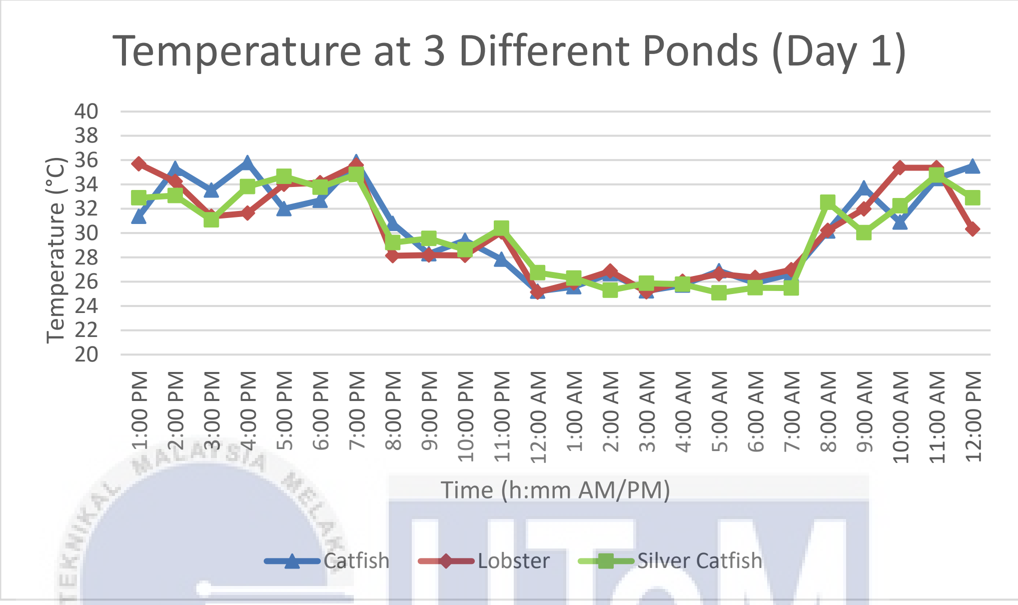


Figure 4.7: Temperature Graph (Day 1)

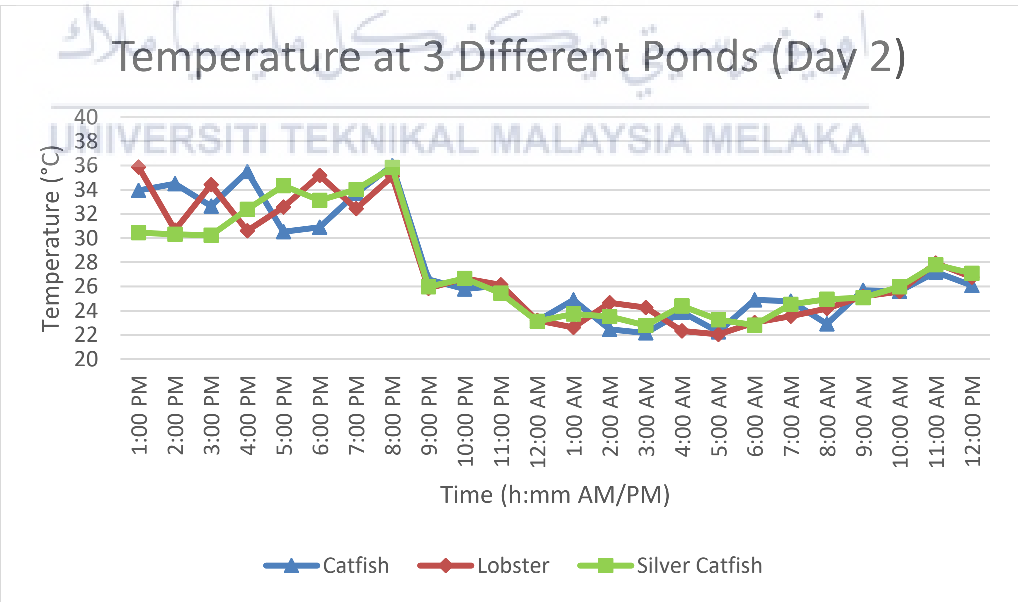


Figure 4.8: Temperature Graph (Day 2)

The data collected is at 3 different ponds which are Catfish Pond, Lobster Pond and Silver Catfish Pond. A maximum of 35°C and a minimum of 25°C is recorded throughout the process. It is a known fact that the temperature is slightly higher in the day rather than in night. Therefore, the temperature in the day is higher than most of the nights.

4.3.4 Water Temperature

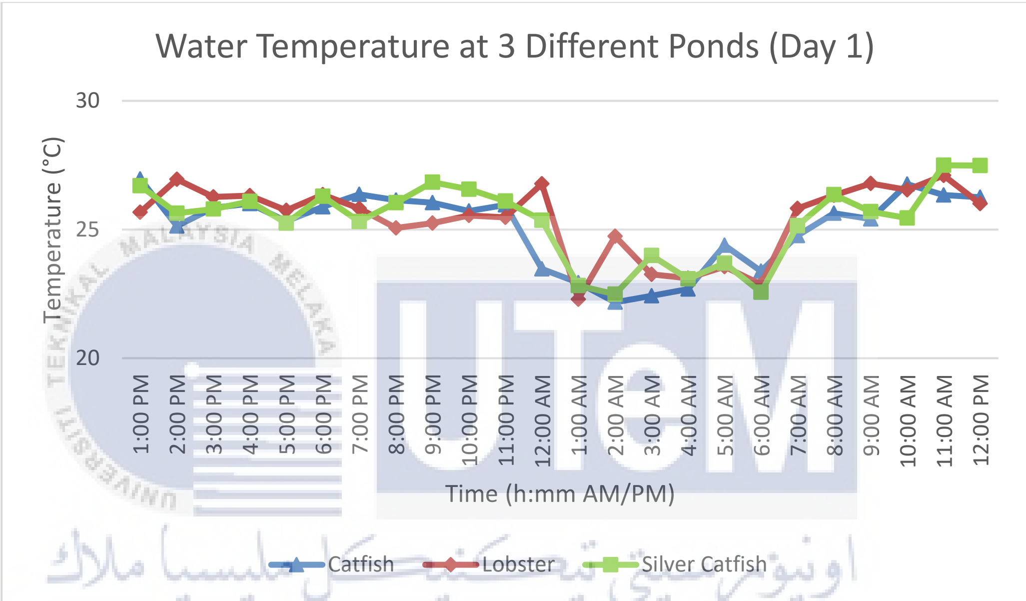


Figure 4.9: Water Temperature Graph (Day 1)

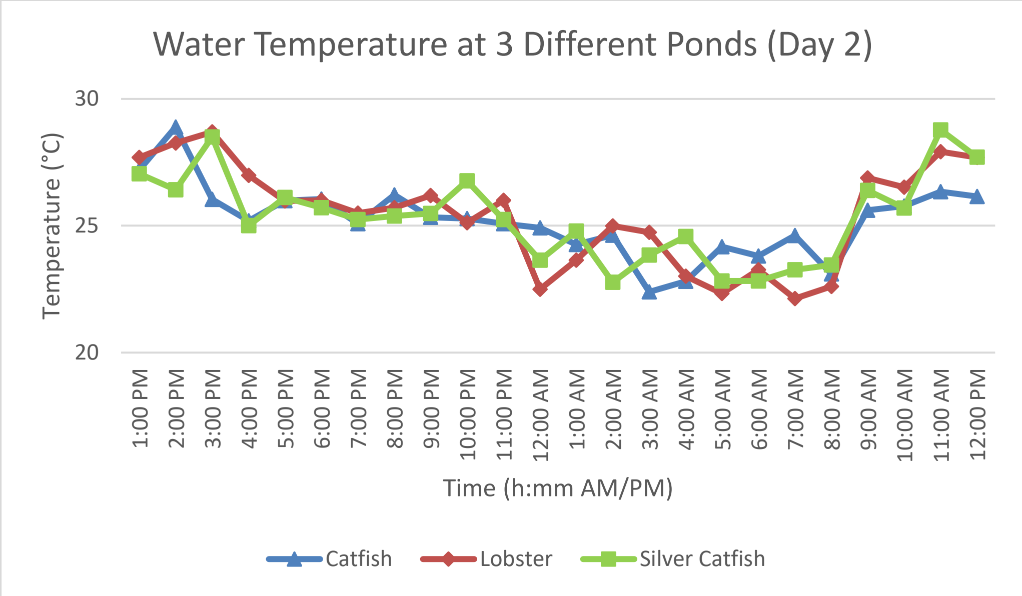


Figure 4.10: Water Temperature Graph (Day 2)

In Figure 4.9 and Figure 4.10, the water temperature usually is affected by the external temperature. Hence, the graph in Figure 4.9 and Figure 4.10 shows almost the same result. The recorded maximum temperature is 29°C and the minimum temperature is 22°C.

4.3.5 Total Dissolved Solids

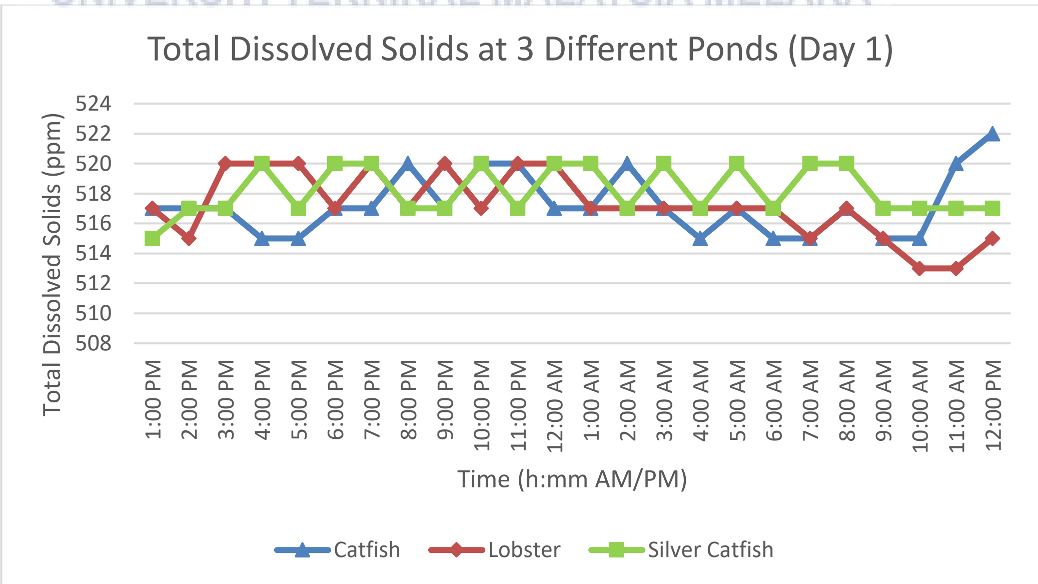


Figure 4.11: Total Dissolved Solids Graph (Day 1)

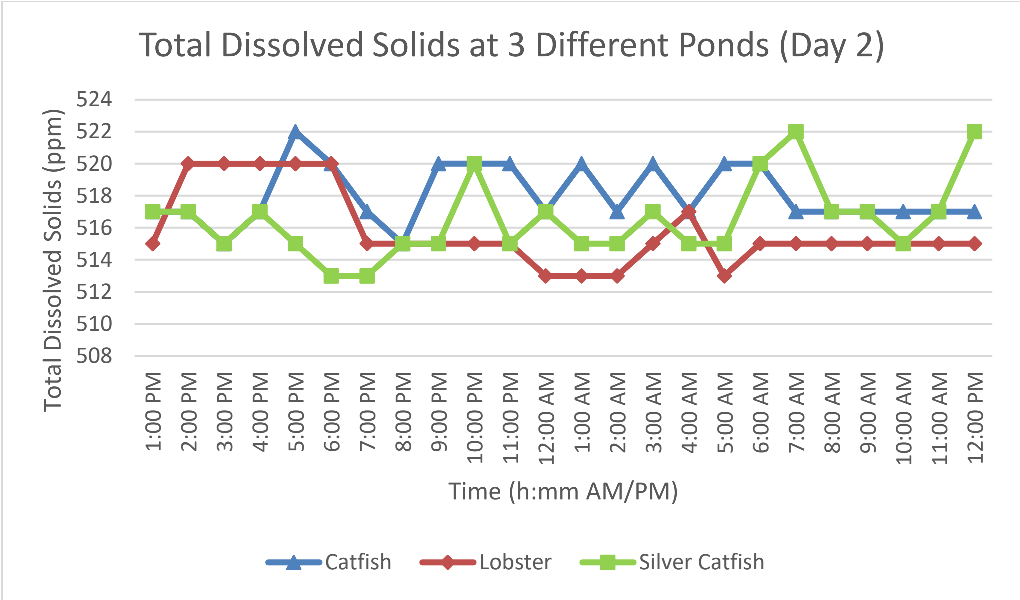


Figure 4.12: Total Dissolved Solids Graph (Day 2)

Total dissolved solids sensor picks up different type of minerals contained in the ponds. The more the minerals in the water, the higher the ppm. The number of total dissolved solids will keep on getting higher unless the pond is cleaned up. Based on Figure 4.11 and 4.12, the graph is seen as increasing and decreasing randomly. This is due to the fish consumes the zooplanktons living under the water.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

The chapter briefs the discussion regarding the conclusion of the overall research and the future recommendation for future works. The conclusions will summarize the overall finding based on objectives of the project. The recommendation will be stated for better project development in future.

5.2 Conclusions

As a conclusion, the project of Design and Analysis LoRa-Based Sensor System for Aquaculture has been successfully designed and tested. The system has been developed by integrating features of entire hardware and software used.

In addition, the hardware and software architecture of the system is designed to improve previous system. Arduino UNO that has been used in the system is one of the modern processors that can control the operation for collecting data from the sensors used.

The objectives that were set in the beginning of this project were successfully achieved which are to design a prototype of a system to monitor the characteristics of the aquaculture farm, to analyze the sensing technique in aquaculture farm and to study the effect of power transmission on LoRa signal strength and coverage.

To summarize, RSSI and SNR are much related to distance covered. This is due to when the further the distance between a transmitter and a receiver, the lower the decibels per milliwatt (dBm) as can be seen in Figure 4.4. As per the parameters, all the data is gathered for 48 hours at each of individual locations stated in Figure 3.23, Figure 3.24 and Figure 3.25. The data can be concluded that the performance of each sensor is accurate due to results gathered.

5.3 Environmental and Sustainability

In line with Sustainability Development Goals by United Nation, this project shows a significance in supporting few of the goals. One of it would be no poverty. As the farmers need not to observe and spend their whole time checking on their ponds, they could manage the extra time in doing some other works. Next Sustainable Development Goals that could be achieved in this project would be Sustainability Development Goals #2 which is zero hunger. Once the pond is in mint condition maintained by the farmers, the fish in the pond would grow large and the farmers could benefit from the product of the pond.

This project also shows a big advantage in terms of environmentally friendly. This is due to less usage of electricity as it requires no internet connection, hence the abandonment of using router. Besides that. The users also do not to install some other software to run the program as they could manage it by using Microsoft Excel that would be commonly installed in their personal computer.

5.4 Recommendations

From the final prototype of the project design, there are improvement ideas in term of hardware design that can be applied to make a better project in the future.

The signal strength is limited due to the location in suburban area. By adding more nodes for long distance can improve the signal strength. Besides that, by using a better external LoRa antennas also could improve the signal strength between each LoRas. The other improvement which could be improvised is adding more sensor such as pH sensor, dissolved oxygen sensor, turbidity sensor and ammonia sensor. The current sensor in this project is focusing more on temperature and dissolved solids. By adding those sensors, the output data can be more accurate to classify the water index quality.

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