Development of Flood Monitoring System

by

Chua Yean Fang

18479

Dissertation submitted in partial fulfilment of the requirements for the Degree of
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

____

(Dr. Azrina bt Abd Aziz)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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CHUA YEAN FANG

ABSTRACT

Flood is one of the natural disasters that occurs every year in Malaysia. It destroys the infrastructure and causes fatalities. Flood monitoring system can monitor the flood level and warn people upon the danger of the flood. Existing flood monitoring techniques include hydrological modelling, image classifications and wireless sensor networks are the current measure control. Unlike the existing systems, this project intends to develop a more robust and durable system which can withstand the wet weather condition. It aims to monitor the water level and water velocity then alert the communities in the future implementation whenever there is risk of flood occurrence. In order to do this, the system needs to have the basic information such as water conditions, water level and water velocity. Two major components consisting of the sensor network and the data transmission were designed in this project. Wireless Sensor Network (WSN) based on ZigBee network protocol is used to transmit and receive related data. By having an effective real time flood monitoring system, actions can be carried out instantaneously to save lives and reduce the damages caused by flooding.

ACKNOWLEDGEMENT

Along the period of my final year project, there are few person who I would like to express my deepest gratitude. First and foremost, I would like to thank my supervisor Dr. Azrina bt Abd Aziz for the endless support, guidance, motivation and time throughout the completion of this project. She always gives me the best guidance and assists me whenever I have any doubts or confusions in my project.

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CHAPTER 1

INTRODUCTION

1.1 Background

Natural disasters consist of earthquakes, tsunami, volcano eruptions, typhoons, tornadoes, flood and others, which usually cause financial, environmental and human losses [2]. In Malaysia, flood is the major disaster which can be categorized into two types i.e. flash flood and flood monsoon. Flash flood is not seasonal as it can occur when rain falls rapidly which causes excessive water fills the land in a short time, about several minutes to hours. It also happens at urban areas when the hard surface like road and concrete resists the water drains away into the ground causing surface overflow and clogged drainage system, thus lead to flash flooding [3]. Meanwhile, monsoon flood occurs annually during November to March (Northeast Monsoon) at east coast of peninsular Malaysia, while Southwest Monsoon happens from May to September at west coast of Malaysia [4]. Monsoon flood occurs during local tropical wet season that is characterized by heavy and regular rainfall which lasts for several days or perhaps a month. Monsoon flood is classified into normal flood and major flood, where the residents in rural areas will not be affected by normal flood as the water level does not exceed the limit while major flood is severe and unpredictable as it can cause damage to properties as well as loss of life [4].

The worst flood cases in decades happened from 15 December 2014 to 3 January 2015 had given an adverse effect on three main states i.e. Kelantan, Terengganu, Pahang. The Star stated about 26000, 22000 and 11000 people from Kelantan, Terengganu and Pahang respectively were forced to evacuate their home [5]. Besides, severe damages in Kelantan, Terengganu and Pahang were expected to cost over RM 204 million while 21 people were killed due the massive flood [1]. Other than three states involved in the tragedy, other states such as Perak, Johor, Sabah, Sarawak, Perlis and Kedah also experienced the misfortune. As a result of the flood tragedy, communities suffer from loss of lives and properties, poor health condition and safety issue. Hence, flood control measures such as monitoring, forecasting, simulation, evaluation and analysis are crucial in reducing losses due to flooding.

However, several existing monitoring techniques such as telemetry system which requires transmitters and repeaters to transmit the information to a central terminal is highly cost and non-reliable as there will be malfunction equipment at remote area [6]. Therefore, this project focuses on monitoring as the flood control measure. A flood monitoring system is proposed, with the aim of monitoring the changes of the water level associated with the flow rate water that can contribute to flood occurrence. The system comprises of two main operating sections i.e. data transmission, and data gathering and processing. For the system to operate properly, the flood monitoring system uses main components such as ultrasonic sensor, flow sensor, Arduino Uno, XBee modules, XBee shield and buzzer. Furthermore, data transmission of the system involves communication between the transmitter and receiver will be managed by Wireless Sensor Network (WSN) architecture based on ZigBee Network protocol. In general, the collected data from the sensors will be transmitted to the receiver via XBee modules. While Arduino Uno, the main controller of the system sends command to the sensors, transmit and receive data from sensor nodes through the wireless network. The data received will be recorded and analyzed, then buzzer will be activated once there is the risk of flood. After all, the developed system is to be used for flood prediction in the future.

Further discussion on how the entire system is designed will be described in following chapter.

1.2 Problem Statement

Flood happens unpredictably has caused damages, loss of lives and properties and devastation of agriculture and livestock. An effective real-time system that can monitor and give early warning system to alert the communities on the risk of flood is significant to save human lives. However, several existing monitoring techniques such as telemetry system which requires transmitters and repeaters to transmit the information to a central terminal is highly cost and non-reliable. Therefore, a cost-effective and reliable system using wireless sensor network is proposed.

1.3 Objectives

- To develop a prototype of the proposed flood warning system
- To develop a system that can detect water level and water velocity by using related sensors
- To perform data transmission using ZigBee network protocol

1.4 Scope of study

This study focuses on designing a flood monitoring system that is capable of detecting flood as well as warning the community to take necessary actions. Although the long-term planning is to develop a flood forecasting, the scope of this work is to build a hardware design that is able to provide robust monitoring. Hence, the scope of study for this project covers understanding and designing of wireless network communication for transmitting and receiving data, interfacing between hardware and software, software development involving programming, data gathering and processing.

CHAPTER 2

LITERATURE REVIEW

2.1 Flood in Malaysia

As we have discussed in Chapter 1, there are two types of flood that usually happen annually in Malaysia which are flash flood and monsoon flood. The main causes of flood are due to the combination of physical factors and natural factor such as elevation, its proximity to the sea and local weather changes during monsoon period. Flash flood can occur even if there is no rain, as this is due to failure of levees or dams, or after sudden release of water by debris. The water from upstream flows into the river with high velocity causes the river water level to rise dramatically and burst the river bank causing flooding valley floor [7]. On the other hand, monsoon flood occurs due to its weather changes during monsoon period where the precipitation of rain increases eventually thus reducing the capacity of the river. The water level will rise and water spills over the banks of the river. The impact can be fatal if the water overflow rapidly that causes lots of damages, loss of lives and properties as well as affect the environment. Thus, it is essential to have a monitoring and early warning system that can notify the communities to take safety precautions in advance.

2.2 Related Works

This section discusses on how this project is related to other literature that had been done by other researchers. There are some techniques of flood monitoring system that had been developed in some other countries. The techniques are image classification, hydrological modelling and wireless sensor network (WSN).

Image Classification Technique

Image classification technique is a complex image processing method used to extract high-resolution remote sensing information for flood monitoring system. In general, the pixels of the picture are extracted and grouped to represent land cover features. Multi-temporal is a useful tool to detect changes of land surface in SAR (Synthetic Aperture Radar) imagery. This technique requires two images which are before flood and after flood for comparative study. Furthermore, this image processing method combines spectral information with spatial information in term of shape, size, texture and neighbourhood relations to improve classification abilities [1]. The evaluation of the extracted results is then performed using root mean square and receiver operating characteristics. Hence, flooded area can be monitored using this technique yet the accuracy of this technique is low as disturbances such as noise appears in radar images [8].

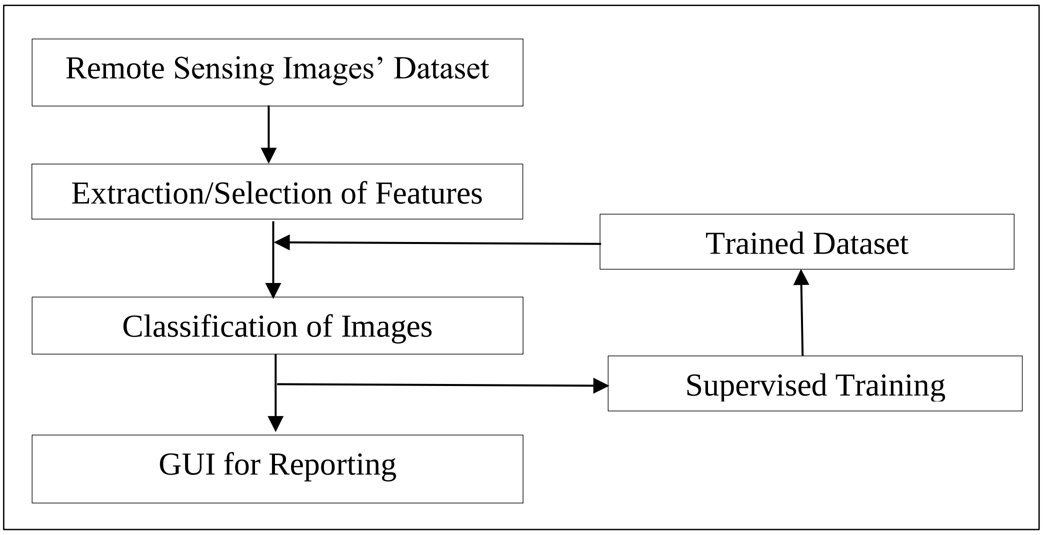


Figure 1. Classification Process [1]

Figure 1 above shows the process of image classification, where remote sensing images' dataset is the input dataset to the flood monitoring system. Next, feature extraction or selection on the image dataset is required to define the proper input to the image classifier. The images are then classified with trained dataset under supervised classification which is a tool used to extract quantitative information from remotely sensed image data. Lastly, Graphical User Interface creates the reports for flood monitoring and control if there is a risk of flooding occurrence [1].

Hydrological Modelling Technique

Hydrological modelling has been used in Malaysia for flood monitoring system, which uses empirical method in hydrology to predict direct rainfall run-off and simulate flood levels [9]. The simulation of rainfall run-off of the floodplains and the quality of river water before and after flood run by InfoWorks River Simulation (IWRS) software [9]. The data obtained can be used to predict flood level and model river system to avoid unexpected flood. However, this hydrodynamic model is unable to model many features of high-magnitudes floods [10]. Besides, some models such as fully distributed model, two-dimensional overland routing approach, semi-distributed or lumped approach are used in hydrological modelling (refer to Figure 2). However, a fully distributed model gives better results compared to semi-distributed model because it does not consider variability of processes, boundary condition, and watershed geometric characteristic. This can help to control run-off and enhance the predictability of hydrologic processes that can causes flooding.

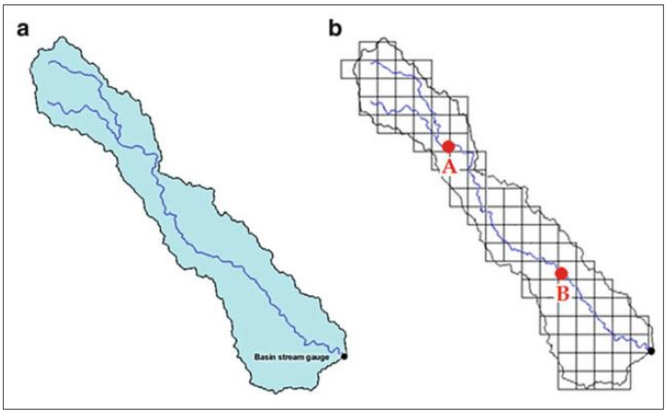


Figure 2. a) Lumped Model; b) Distributed Model [11]

Flood Monitoring based on WSN

Lastly, wireless sensor network (WSN) is another technique that has been widely used in flood monitoring. It is a wireless technology that comprises of many sensor nodes that interact with hardware. WSN plays an important role for remote data sensing, environmental data collections, which has been widely used in various applications such as health monitoring, security, object tracking, environmental engineering and etc [12]. Generally, a sensor node may consist of sensors, a microcontroller board and a wireless transmission medium, thus the input data obtained from sensor nodes are transmitted to the base station for data processing.

By comparing those three techniques as discussed above, WSN is chosen in this proposed design as it provides wireless data transmission which has higher flexibility, lower operation cost and easy interfacing as compared to the other two techniques which require high operation cost as specific tools and software are required. Besides, WSN provides real-time data as the data will be updated from time to time. Furthermore, image classification technique is more complex as it needs sufficient parameters to classify the images plus it consumes time when processing large data [1]. On the other hand, hydrological modelling has limitation in terms of storage for output, model accuracy, inconsistency of parameters and etc. that results of inconsistent output [9]. Apart from that, image classification and hydrological modelling technique give non-real time data which is the major disadvantage as the condition of the water level need data to be monitored and updated from time to time to get early warning. Therefore, wireless sensor network is proposed to be used in this design system.

2.2.1 Flood Monitoring System with Wireless Sensor Network (WSN)

The wireless sensor network for flood monitoring system has been implemented in Korea Peninsula by installing water level sensor, flow sensor, wave height sensor and precipitation sensor at 14 rivers located at Ulleung-do and Doko-do [13]. The system is designed to measure the condition of the river and weather through the sensor nodes.

Figure 3 below shows the overview of the system architecture. Typically, each of 14 rivers consists of one sensor network which has one or two sensor nodes and one base station as shown in Figure 3. The base station has a gateway and a base node, which it collects the packets from sensor nodes and transmits them to back-end server via CDMA/ADSL (Code-Division Multiple Access/Asymmetric Digital Subscriber Line) protocol. Back-end server then verifies the measured data delivered from the sensor nodes in real-time. The data is then being stored in database for analyzing and comparison with previous data. GUI-based (Graphical User Interface) web service provides 3D model, data graph, and send early warning or necessary information of flood to user [13].

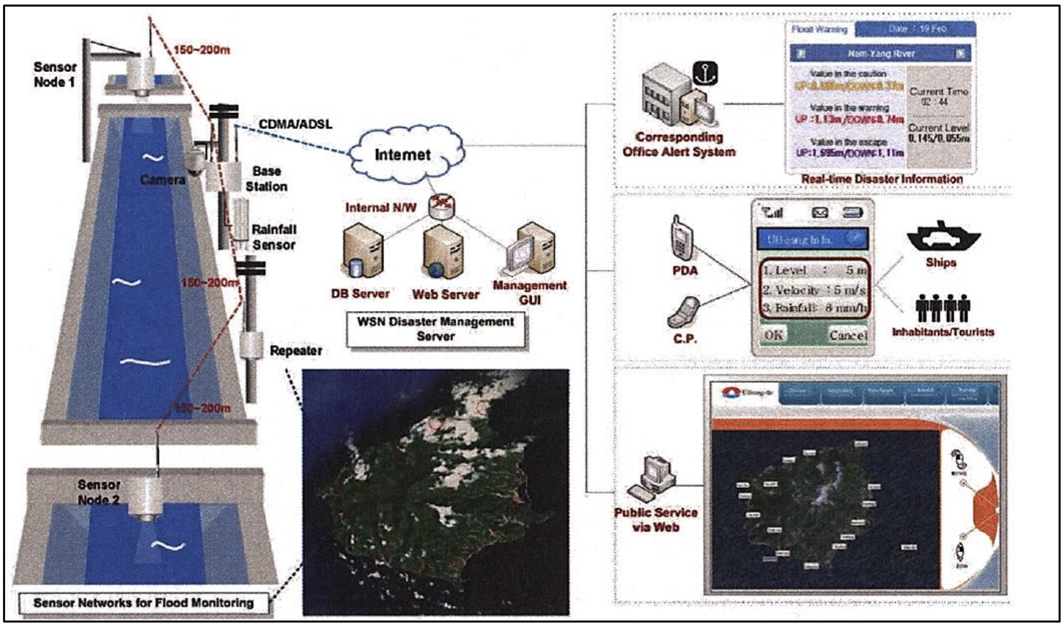


Figure 3. Overview of System Architecture [13]

In overall, this system utilizes wireless sensor network to send the data collected at sensor node to back-end server via CDMA/ADSL as the communication medium. If there is risk of flood, the communities will receive warning and view the data through mobile phone or web service.

2.3 Components Used

In this proposed system, sensors such as ultrasonic sensor and flow rate sensor will be used as to obtain the input.

2.3.1 Ultrasonic Sensor

Ultrasonic sensor is used to measure the distance of water level from the surface of the river. The sensor works when the two transducers send out high-frequency sound pulse and the pulse reflects as it hits the surface of the water level. Ultrasonic sensor provides precise, non-contact distance measurement from about 2cm to 400cm with accuracy of 3mm while the water level sensor can provide up to 14m of distance measurement and accuracy of 0.5% range at constant temperature [14] [15]. However, the sensor selection depends on the distance and the application used.

2.3.2 Flow Rate Sensor/ Flow Sensor

Flow sensor will be installed underneath the river to determine the flow rate of the water especially during heavy rain as it may contribute to flooding. The output of the sensor depends on the speed of the water flows through the rotor, as rotor rotates at high speed, the flow rate of the water is high. However, the common flow sensor as shown in Figure 4 below can only provide working flow rate up to 30 liters/minute, which is equivalent to 0.0005 m^3/sec. The study of river flow condition in year 2010 shows the velocity of the river Pahang is ranged from 153.282 m^3/sec to 439.684 m^3/sec during rainy season whereas lower flow ranges from 52.071 m^3/sec to 304.485 m^3/sec during dry spell [16]. Hence, we can see that the flow sensor is more applicable in water management system. However, this sensor can be used for proof-of-concept in this project as less flow rate water is required.

Figure 4. Common Water Flow Sensor [17]

Figure 5. STARFLOW Sensor [18]

STARFLOW sensor or known as STARFLOW Ultrasonic Doppler Instrument is one type of flow sensor, was proposed in the past literature to measure water velocity. It is a tool to measure the velocity and depth of water in drainage channels, large pipes, and in rivers and streams [18]. The sensor detects the water velocity by STARFLOW ultrasonic Doppler principle where the suspended particles or small air bubbles in the water reflect the ultrasonic detector signal. Besides, the measurement range of the sensor is 21mm/s to 4500mm/s with resolution of 1mm/s and accuracy of 2% [19]. As compared to water flow sensor, this sensor is more applicable to the proposed system but it is more expensive.

Further researches and studies are required to look for other suitable sensor though STARFLOW sensor is more applicable compared to water flow sensor.

2.3.3 Arduino Board, Xbee Modules and Xbee Shield

Arduino board is proposed as the microcontroller in this design system to integrate the sensors with XBee shield and XBee modules. Arduino will gather the input data from the sensor before it is transmitted as the output data to coordinator. XBee modules send and receive data over a serial port that are compatible to both PC and Arduino. To do so, an XBee shield is needed to connect the XBee modules on the PC and the Arduino board. The advantages of using XBee modules over other wireless network such as WIFI and Bluetooth, are cost-effective, low power consumption, low data rates transmission, security and reliability as well as the suitability in application of monitoring and control [20] .

CHAPTER 3

METHODOLOGY

This chapter explains on how the proposed flood monitoring and warning system is to be developed.

3.1 System Architecture

The flow chart of prototype development of flood monitoring system is shown in Figure 6 below. In order to transmit the data from the transmitter to the coordinator, both XBee transmitter and coordinator must be configured in order for them to communicate with each other. Then, the coding of the XBee transmitter and coordinator is uploaded to Arduino board and data is transmitted from the transmitter to the coordinator. Lastly, the Arduino board receives data through XBee modules and process to execute the task. The entire system architecture and operation will be discussed later.

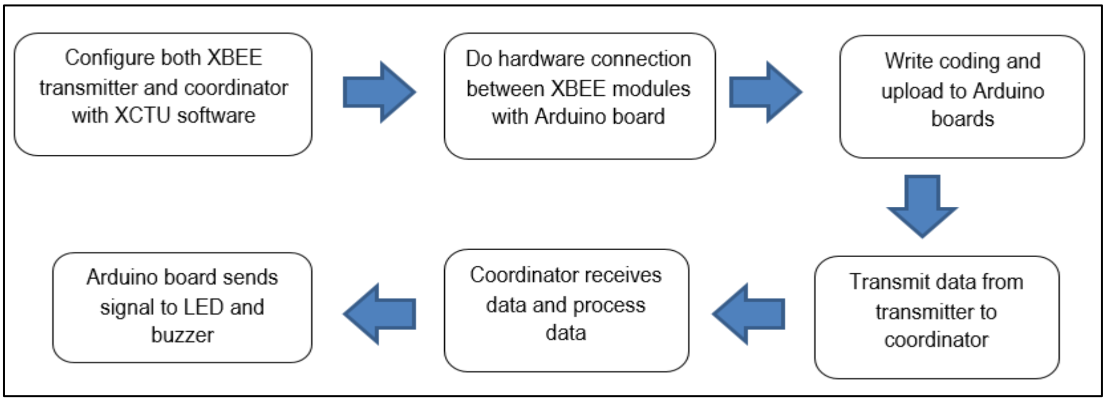


Figure 6. Flow Chart Of Prototype Development

Flood monitoring system comprises of three main sections mainly data collection, data processing and alarm system. In data collection, sensors such as ultrasonic sensor, and flow rate sensor play an important role in acquiring the input data such as the water level and water velocity. Whereas data processing is where the current data is analysed and compared with historical data thus give results on whether to activate the alarm system to alert the community, at which this is the role of the alarm system.

Based on Figure 7, the system architecture wireless sensor network (WSN) utilizing ZigBee network topology consists of one sensor node and one coordinator, cloud storage, alarm system. Each sensor node and the XBee coordinator is connected with an Arduino board to control the entire operation.

Sensor node is where data collection or data gathering takes place. The sensor node is connected to ultrasonic sensor and flow rate sensor accordingly. The sensor node get data response to physical parameters to measurable voltage level through respective sensors [12]. The data obtained will be digitalized and the voltage level is coded into network data. The data is then transmitted to the coordinator though ZigBee network topology.

Data processing takes place at XBee coordinator focuses on network topology maintenance, collecting data and analyzing data. The packets received from the transmitter which is also known as sensor nodes are opened, and all data are transferred to the laptop/PC via serial communication. Once the data is analyzed, the alarm/siren/buzzer will be activated if there is risk of flooding to occur.

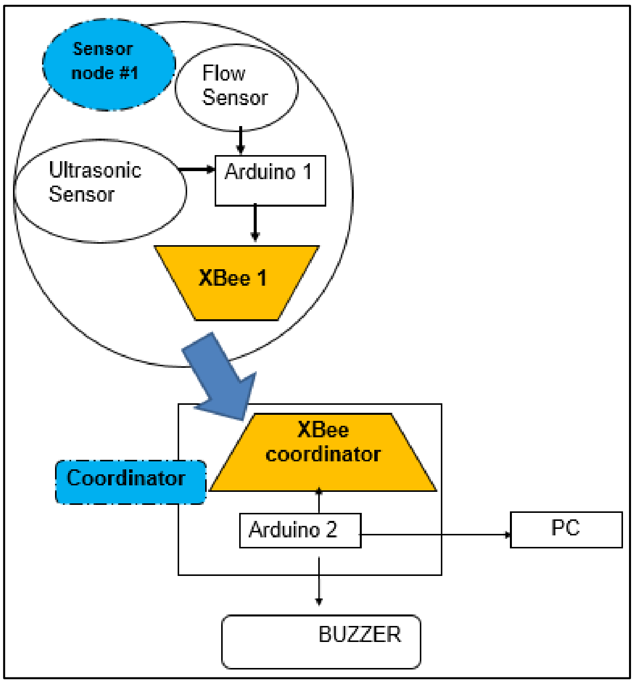


Figure 7. Flood Monitoring System Architecture

3.2 Hardware Connection

This section describes on the hardware connection in each sensor node and the XBee coordinator. Figure 8 shows the connection of the buzzer and XBee module (receiver) to the Arduino Uno board. Dout and Din of the XBee module is connected to pin D1 and pin D0 of Arduino respectively, where D1 is the transmitter pin while D0 is the receiver pin. Buzzer is then connected to the digital pin (pin D12) of the Arduino. The buzzer will be activated if there is risk of flood occurrence.

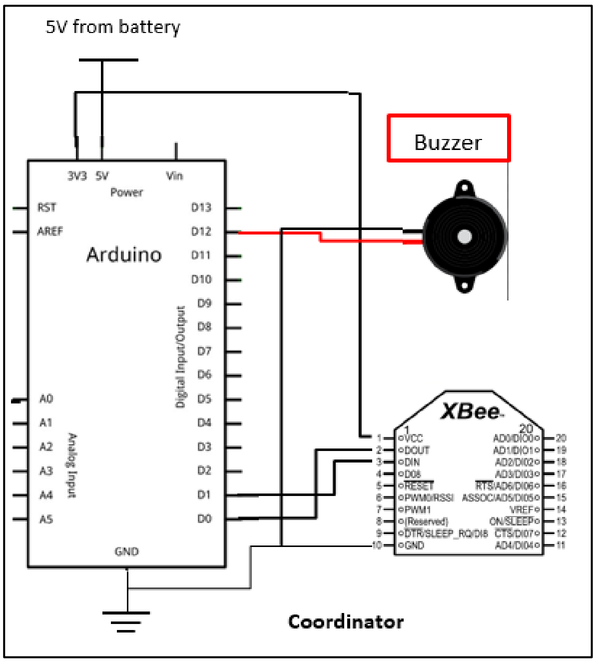


Figure 8. Coordinator

Whereas Figure 9 shows the connection of the ultrasonic sensor and flow rate sensor to the Arduino Uno. As we can see from Figure 9, trigger pin and echo pin of the ultrasonic sensor is connected to pin D9 and D8 respectively. Trigger pin cause the module to send out a ‘Ping, as when the pin goes HIGH then LOW for a period of more than 10µs, the internal clock starts ticking. 8 cycles of 40kHZ audio are sent out of the transmitter and it starts counting how long it takes for the echo to arrive at the detected object. The pulse width of the echo signal is proportional to the measured distance. Distance = high level time * sound velocity (340Ms)/2; where high level time is obtained when the pulse echo pin is HIGH.

Furthermore, flow rate sensor with three pins mainly Vcc pin, Gnd pin and Pulse Output pin are connected to the Arduino Uno as shown in Figure 9. The pulse output pin is connected to digital pin (D6) of the Arduino board. This sensor sits in line with the water ling and contains a pinwheel sensor to measure how much water has moved through it. The water flow rate can be calculated by counting the pulses from the output of the sensor (in-text).

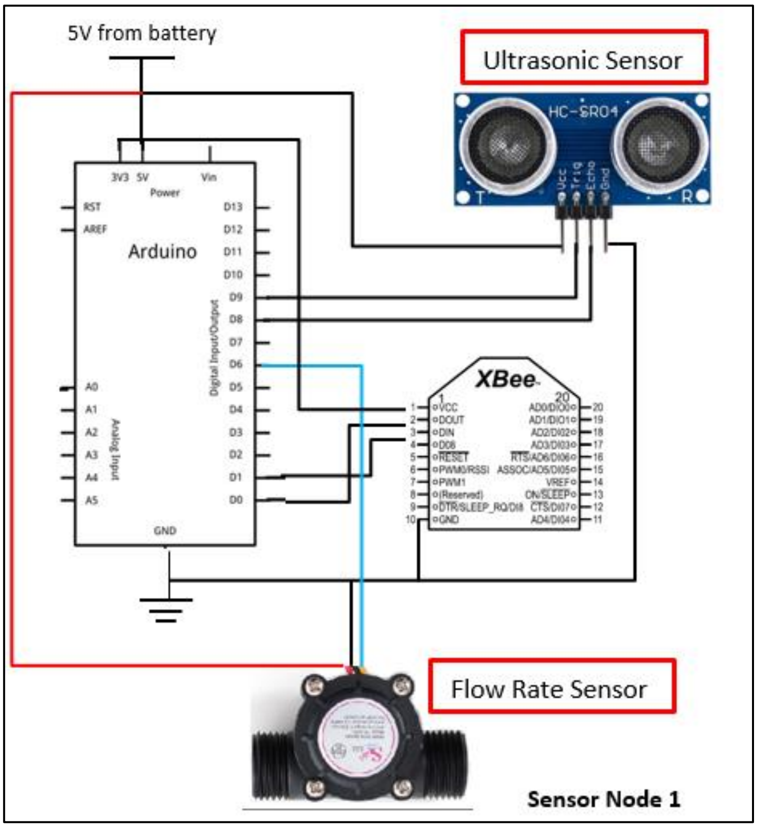


Figure 9. Connection between Ultrasonic Sensor, Flow Rate Sensor and Arduino Uno (Sensor node 1)

3.3 Sensor Calibration

Calibration is done on the ultrasonic sensor, flow rate sensor before implementing them into the actual flood monitoring system. The purpose of the calibration is to determine the accuracy and precision of the measurement sensors. This eliminates or reduces the offset and bias in an instrument's readings over a range for all continuous values.

3.3.1 Calibration on Ultrasonic Sensor

Figure 10 and Figure 11 show the connection of ultrasonic sensor to the Arduino Uno. The calibration is done by varying the distance of the object from the ultrasonic sensor. Based on Figure 12, there are eight markings on the table that shows the distance from

0cm to 60cm. An object is then placed at distance 60cm far from the ultrasonic sensor, and slowly decrease the distance between the object and the ultrasonic sensor. The distance measurements recorded in the serial monitor of Arduino software are compared with the actual measurements which will be discussed in the next chapter. Besides, the range of the distance is set to test if the ultrasonic sensor can detect the object within the range limit precisely. Hence, the LED in Figure 10 will turn on to indicates the object is detected within the limit, which the results will be further discussed in the next chapter.

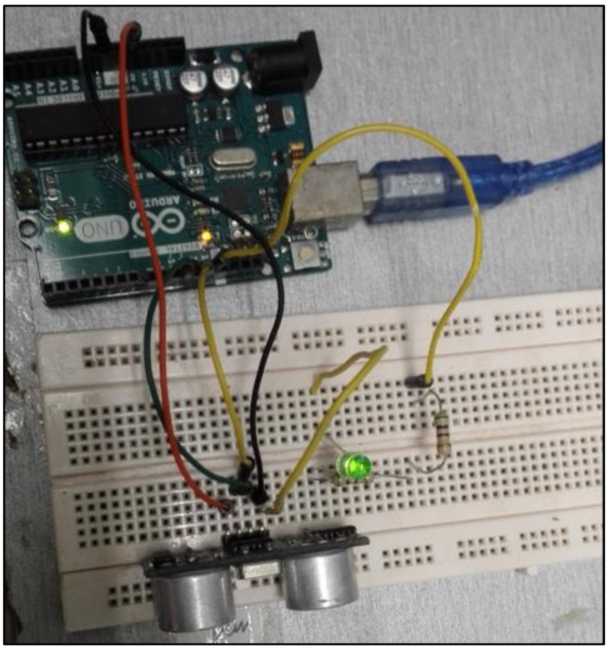


Figure 10. Ultrasonic Sensor Setup

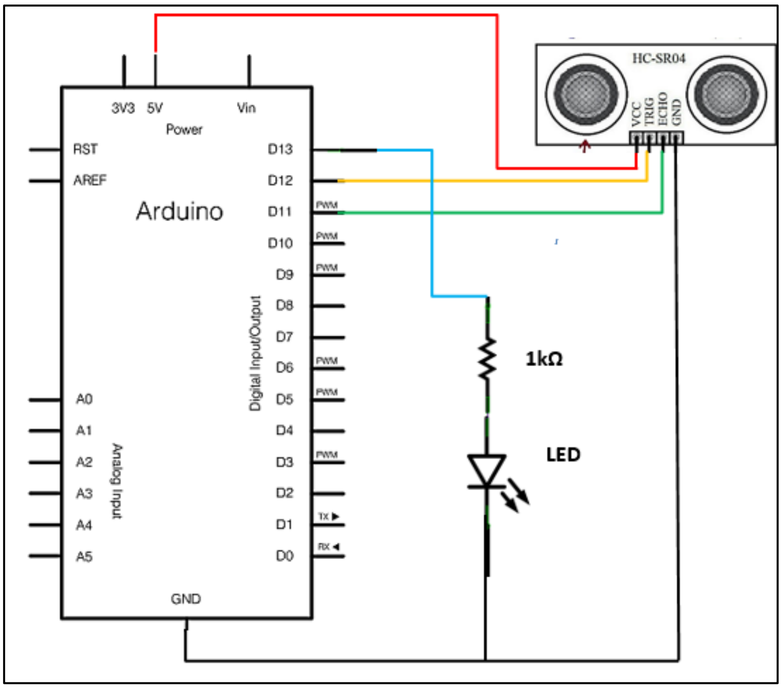


Figure 11. Schematic of Ultrasonic Sensor Connection

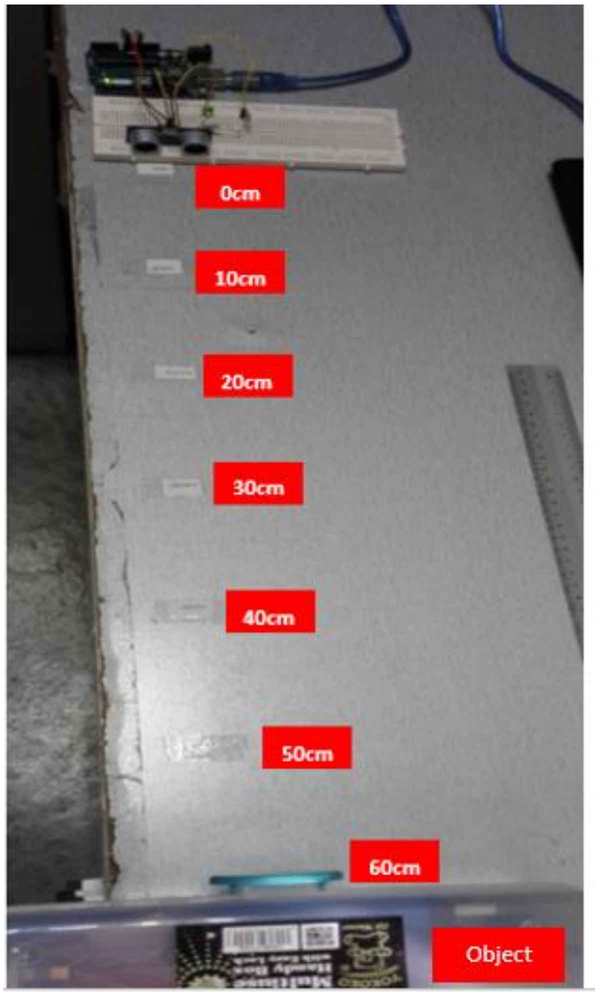


Figure 12. Distance Measurement

3.3.2 Calibration on Flow Rate Sensor

Figure 13 shows how the calibration of the flow rate sensor is done. The sensor is then connected to the Arduino Uno as shown in the schematic diagram (refer to Figure 14). As discussed in previous chapter, the red and black wire of the sensor is connected to Vcc and Gnd of the Arduino board respectively, whereas the yellow wire is connected to digital pin 2 which is the is the pulse output pin. The purpose of this calibration is to observe the flow rate of the water when water flow through the blade of the sensor. It is conducted by pouring 1 Liter of water through the sensor. The flow rate of the water flows is obtained and it is to be discussed in the next chapter.

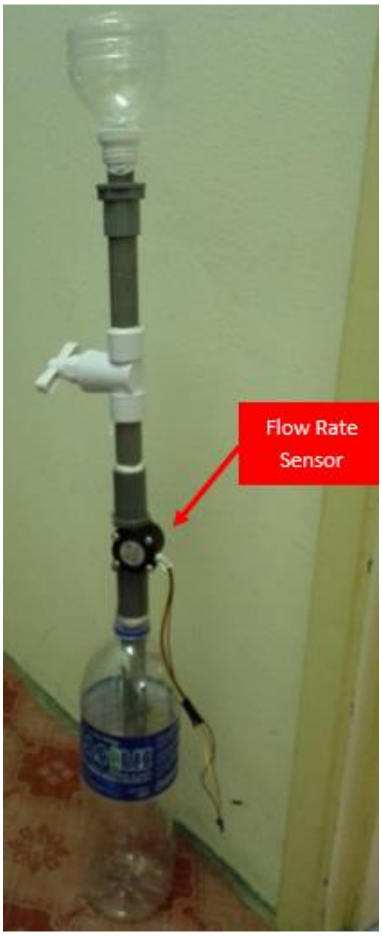


Figure 13. Testing on the Flow Rate Sensor

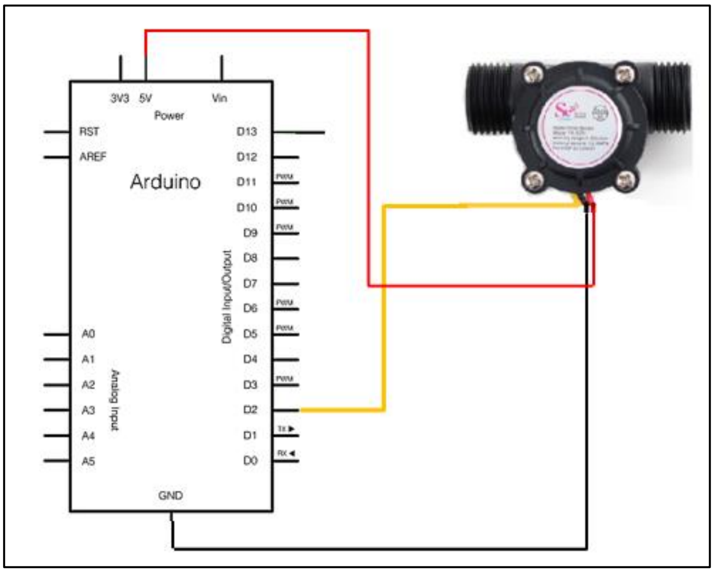


Figure 14. Schematic of Flow Rate Sensor Connection

3.4 Wireless Communication System Testing

Before integrating XBee modules into the system, the modules must be tested to ensure they can communicate with each other. The modules are programmed via X-CTU software which it is a tool that makes easy set-up, configure and test Xbee modules. The configuration of the XBee modules can referred to [21].

Figure 15 below shows the connection of XBee coordinator (C1) with the Arduino board. In this project, an XBee module is attached onto a SKXBEE starter kit to act as the coordinator. The TX and RX pin of the module is connected to RX and TX pin of the Arduino board respectively. Table 1 and 2 explains the pin connections accordingly. A LED connected to the Arduino board indicates the signal of received data.

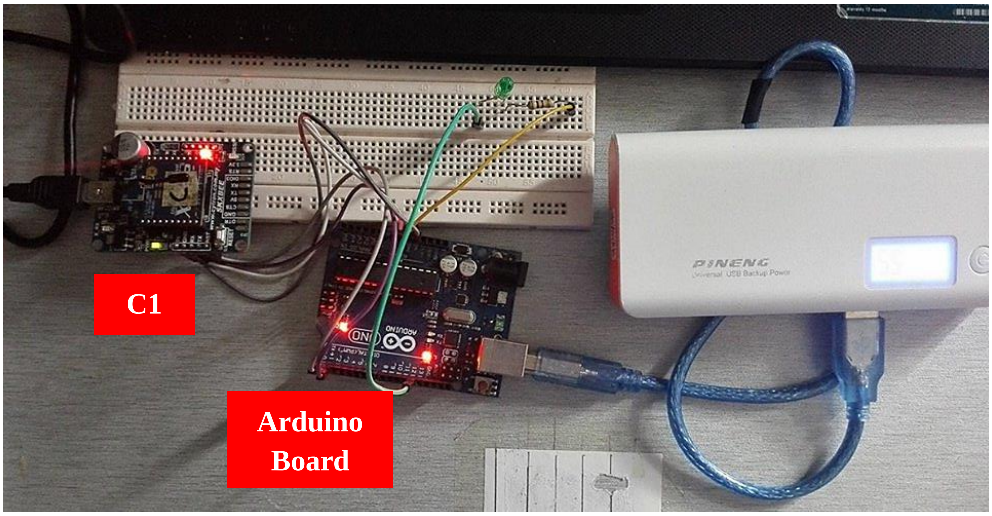


Figure 15. Coordinator Connection

Table 1. Connection of Coordinator and Arduino Board

Pin of Coordinator (C1)	**Pin of Arduino Board**
5V	5V
Gnd	Gnd
TX	RX (D0)
RX	TX (D1)

Table 2. Connection of Arduino Board and LED

Pin of Arduino Board	**LED**
Gnd	-ve terminal
D9	+ve terminal

Meanwhile, Figure 16 below shows the connection of XBee router (R1) with the Arduino board and ultrasonic sensor. In this assembly connection, the XBee module is attached on a XBee shield, then the XBee shield is stacked on the Arduino board. The pin of the ultrasonic is connected to the XBee shield as shown in Table 3 below.

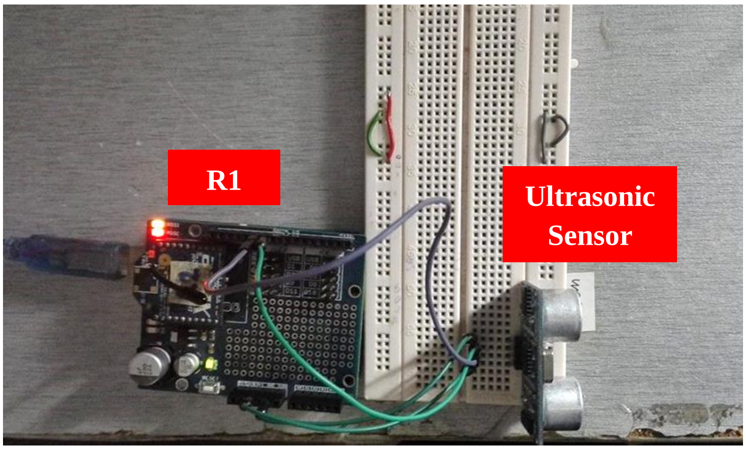


Figure 16. Router Connection

Table 3. Connection between XBee Shield and Ultrasonic Sensor

Pin of Ultrasonic Sensor	Pin of XBee Shield
5V	5V
Gnd	Gnd
Trigger pin	D10
Echo pin	D9

3.5 System Testing

Figure 17 below shows testing on the ultrasonic sensor is done to detect the level of water when an amount of water is poured into the plastic tank through the flow rate sensor. The plastic tank is divided equally into three partitions to indicate three levels of water namely high, medium and low (refer to Table 4). When the water is slowly poured into the tank, the ultrasonic sensor reads the distance between the surface of the water and the ultrasonic sensor. Both data obtained from the ultrasonic sensor and flow rate sensor will be transmitted to the coordinator.

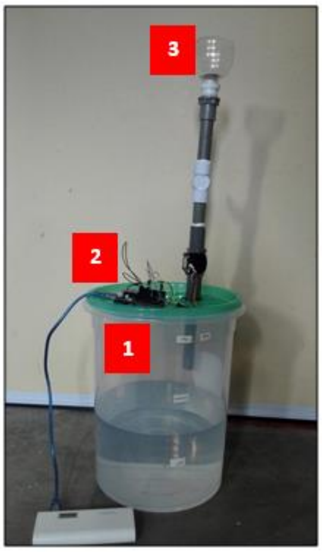
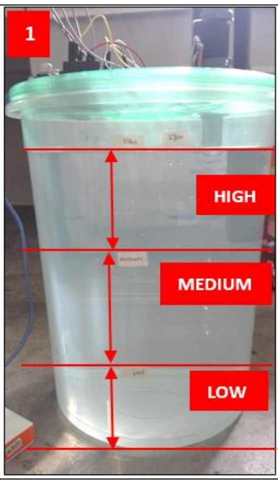
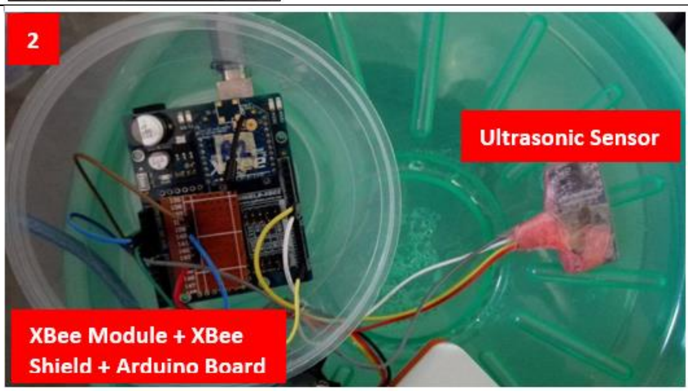


Figure 17. Prototype Development

Table 4. Components/Parts at Transmitter Side

Label	Description	
1	Plastic tank	
2	Ultrasonic Sensor + XBee Module + XBee Shield + Arduino Board	

3	Flow Rate Sensor	

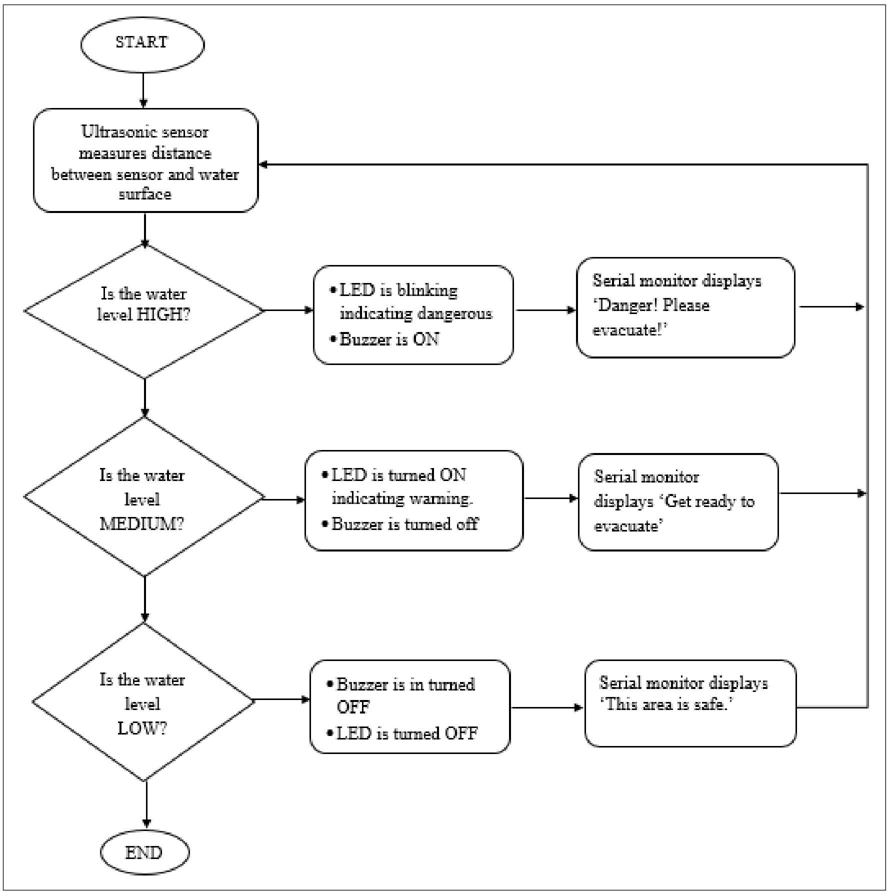


Figure 18. Flow Chart of Ultrasonic Sensor

Figure 18 shows the algorithm of the ultrasonic sensor operates in the flood monitoring system. When the water level increases and reaches certain range, the Arduino board at the coordinator side will send signal to turn on LED and buzzer and necessary actions are taken. Further discussion on the operation will be explained in the next chapter.

3.6 Gantt Chart & Key Milestone

Table 5. Gantt Chart & Milestone for FYP I

Details/ Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**
Research on project topic **Literature review** -Background of topic, problem statement, objectives, scope of study														
Submission of extended proposal														
Research on project methodology -Research on ZigBee network protocol works -Research on the integration between software and hardware -Study how sensors work														
Survey parts/components used -Survey flow rate sensor														

Proposal Defence														
Purchase parts/components														
Test setup for sensors -Calibrate ultrasonic sensor and flow rate sensor														
Develop a basic data transmission -Test with XBee modules and sensors one by one -Transmit data from sensor node to computer														
Submission of draft interim report														
Submission of interim report														

Milestones

Progress

Table 6. Gantt Chart & Key Milestone for FYP II

Details/ Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**	**Week 15**
Debugging of algorithm															
Testing on software and hardware -Testing on sensors															
Communication Test -Test on XBee modules -Integrate XBee modules and sensors															
Deployment and finalization of the system															
Submission of Progress Report															
Pre-sedex Presentation															
Submission of Draft Final Report															

Submission of Dissertation														■	
Submission of Technical Paper														■	
Viva															■

■ Milestones

■ Progress

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and Discussion of Ultrasonic Sensor Calibration

Table 7. Actual Distance vs Distance Recorded by Ultrasonic Sensor

Actual Distance (cm)	Distance recorded in serial monitor (cm)	Condition of LED	Percentage error (%)	Accuracy (%)
10	10	OFF	0	100
15	15	OFF	0	100
20	20	OFF	0	100
25	24	OFF	4	96
30	29	OFF	3.3	96.7
35	36	OFF	2.9	97
40	38	OFF	5	95
45	43	**ON**	4.4	95.6
50	48	**ON**	4	96
55	52	**ON**	5.5	94.5
60	57	**ON**	5	95
65	63	OFF	3.1	96.9

The experiment of the calibration is carried out by placing an object at a certain distance from the ultrasonic sensor. A LED then turns on when the object is placed between the range from 40cm to 60m and turns off when the distance of the object is less than 40cm or more than 60cm. However, the LED does not turn on when the object is placed 40cm away from the ultrasonic sensor as the reading in Table 7 shows deviates from the actual measurement which contributes to percentage error.

Figure 19 and Figure 20 below illustrates the percentage error and accuracy of the readings respectively. We can say that the percentage error of the readings is zero when the object is placed between 10cm to 20cm with the accuracy of 100%. Moreover, the experimental readings start to differ at least 1cm and at most 3cm from the actual reading and hence results in inconstant percentage error and accuracy. This is due to the behavior of the ultrasonic sensor which can sometimes give fluctuated readings.

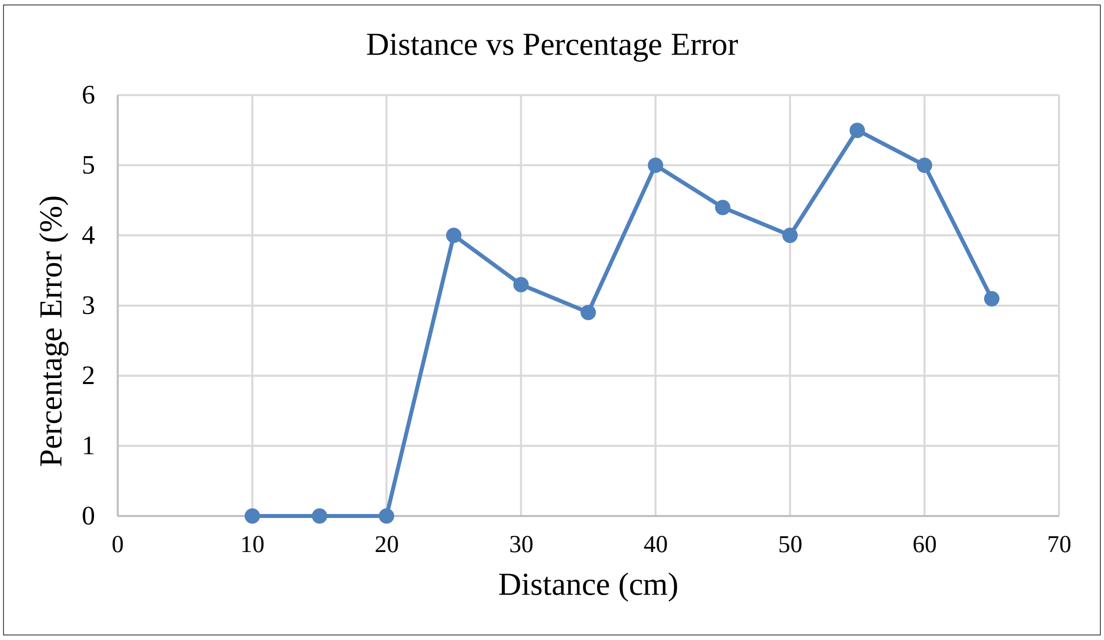


Figure 19. Percentage Error of Calibration on Ultrasonic Sensor

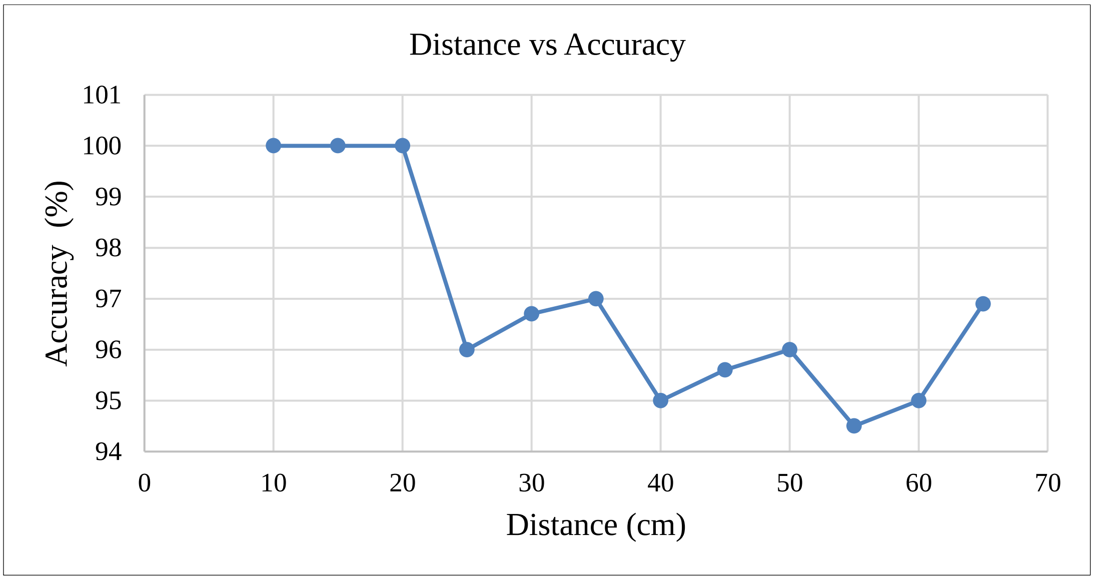


Figure 20. Accuracy of Calibration on Ultrasonic Sensor

4.2 Results and Discussion of the Flow Rate Sensor Calibration

```
Flow rate: 1.1L/min
Flow rate: 2.2L/min
Flow rate: 2.2L/min
Flow rate: 2.6L/min
Flow rate: 3.1L/min
Flow rate: 3.3L/min
Flow rate: 3.3L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.9L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.9L/min
Flow rate: 3.7L/min
Flow rate: 3.9L/min
Flow rate: 3.7L/min
Flow rate: 3.9L/min
Flow rate: 3.7L/min
Flow rate: 3.7L/min
Flow rate: 3.9L/min
Flow rate: 3.9L/min
Flow rate: 3.7L/min
Flow rate: 4.2L/min
Flow rate: 3.9L/min
Flow rate: 4.2L/min
Flow rate: 3.9L/min
Flow rate: 3.9L/min
Flow rate: 4.2L/min
Flow rate: 3.9L/min
```

Figure 21. Flow Rate of 1L Water

1 Liter of water is poured into hose of the sensor and Figure 21 above shows the recorded flow rate of the water when it flows through the fan of the sensor. We can see that the average flow rate of the water is 3.7L/min while the output liquid quantity shown in Figure 21 is 1.3L which differs from the actual value as the accuracy provides up to ±3% as mentioned in the datasheet. According to the formula stated in the coding, the amount of water flow into the sensor will be divided by 60 minutes to determine how many liter have passed through the sensor in 1 second interval.

4.3 Communication Test between XBee Modules

XBee modules are configured and tested to ensure they are able to communicate with each other. For this testing, XBee coordinator is set to Coordinator AT which its MAC address is 0013A20040A23536 while the end device where the sensors is set to Router AT with its MAC address of 0013A20040A7955C.

In the console log shown in Figure 22 below, the characters in blue colour are sent from the router to the coordinator through air. On the coordinator side, (refer to Figure 23) the character in red colour indicates received data. By typing different character into the coordinator's console log, the data is transmitted in the other way, to router side. Hence, this has proven that the communication between the router and coordinator is working properly.

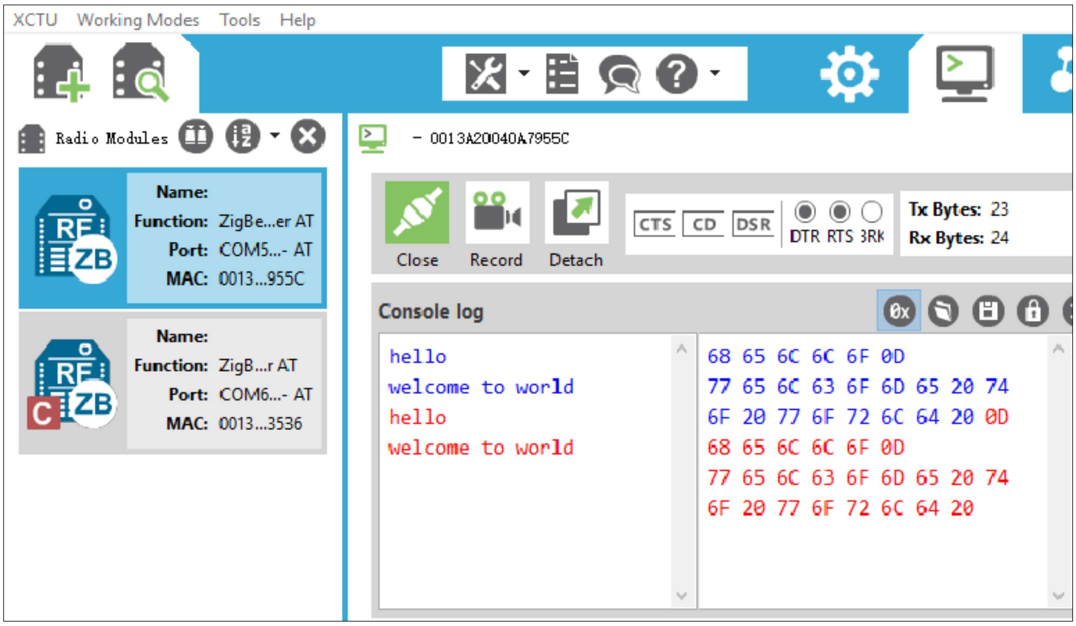


Figure 22. Router's Console Log

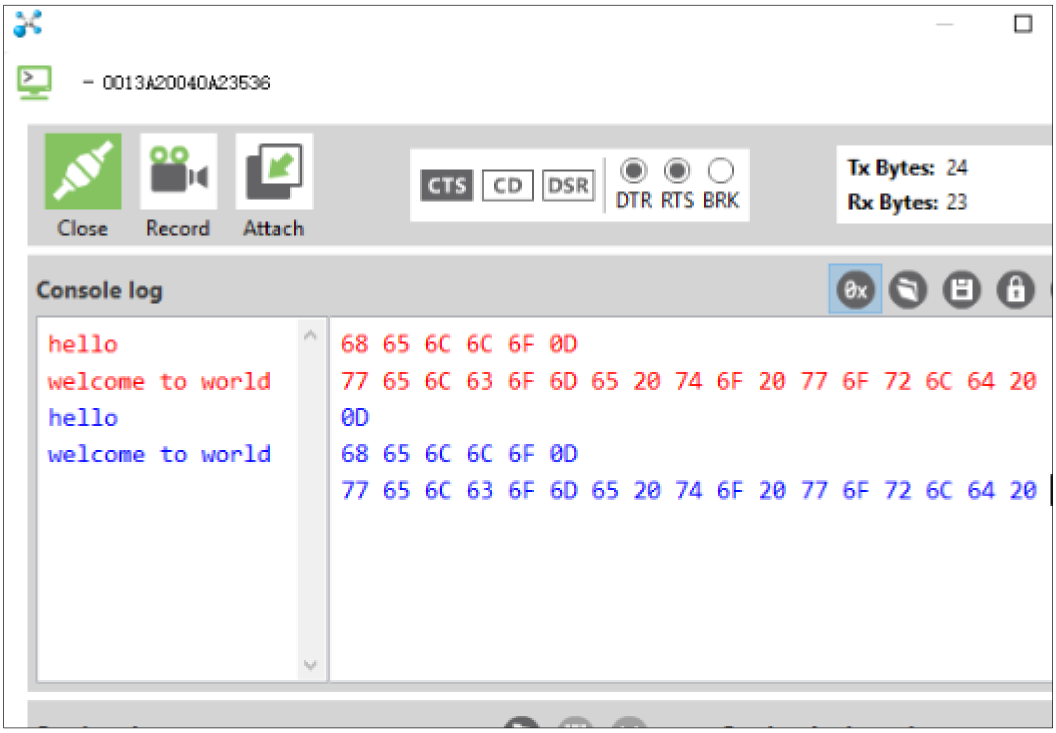


Figure 23. Coordinator's Console Log

4.4 System Testing Result

The ultrasonic sensor consists of a transmitter and a receiver where the transmitter transmits electromagnetic signal in pulses towards the water surface. When the signal touches the water surface, the signal is reflected and collected by the receiver. The sensor then records the travelling time taken for the signal to propagate from the transmitter to the receiver.

The ultrasonic sensor measures the distance between the water surface and the ultrasonic sensor. To implement this, a pre-determined threshold values has been initialized in the source code. Table 8 below shows the threshold value that is used to indicates the water level.

Table 8. Threshold Value for Water Level

Distance between water surface and ultrasonic sensor	Water level	Condition	Action Taken
20cm to 30cm	LOW	LED =OFF BUZZER = OFF	Do nothing
10cm to 19cm	MEDIUM	LED = ON BUZZER = OFF	Get ready for evacuation
2cm to 9cm	HIGH	LED is blinking BUZZER = ON	Evacuate

Figure 24 shows the tank with the height of 30cm is used as prototype testing. Referring to Table 8 above, when the distance between the water surface and ultrasonic sensor is in the range from 20cm to 30cm, the possibility of flood to occur is the least as the water level indicates LOW. For instance, Figure 24 shows the measurement of the distance from the ultrasonic sensor to the water surface, where the distance is 20cm away from the ultrasonic sensor. However, when the water level increases up to MEDIUM level, with distance in between 10cm to 19cm, the system turns the LED on to indicate 'get ready for evacuation' for future flood monitoring planning. Evacuation is needed when the water level increases up to HIGH level, which is dangerous zone where the flood occurs. At this moment, the range distance between the ultrasonic sensor and water surface is set from 2cm to 9cm.

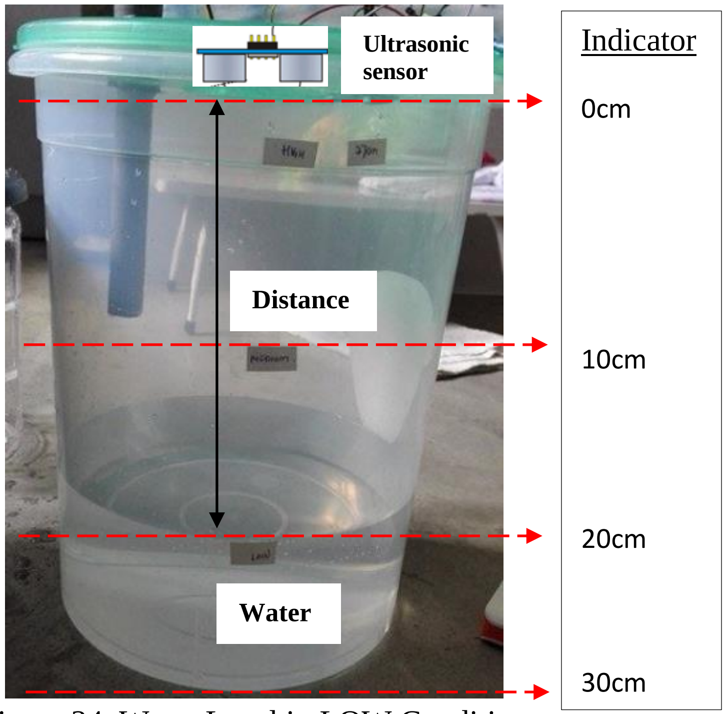


Figure 24. Water Level in LOW Condition

The distance between the ultrasonic sensor and water level is recorded in real-time by using CoolTerm software. The data obtained from the serial communication at coordinator side is recorded and exported to Excel for analysis (refer to Appendix C). Figure 25 shows the graph plotted after data is extracted from coordinator side.

From the graph below, we can see that the distance between the ultrasonic sensor and water surface changes per minute. The distance decreases eventually as time passes which indicates the water level increases from time to time. For instance, the initial distance of the ultrasonic sensor and the water surface is 29cm at time, 9:2:38pm where during this state, the water level is still LOW. Slowly, the distance decreases to 15cm after 4 minutes (time is 9:26:13pm) which is MEDIUM state while the water level is HIGH when the distance decreases till 3cm at 9:30:00pm.

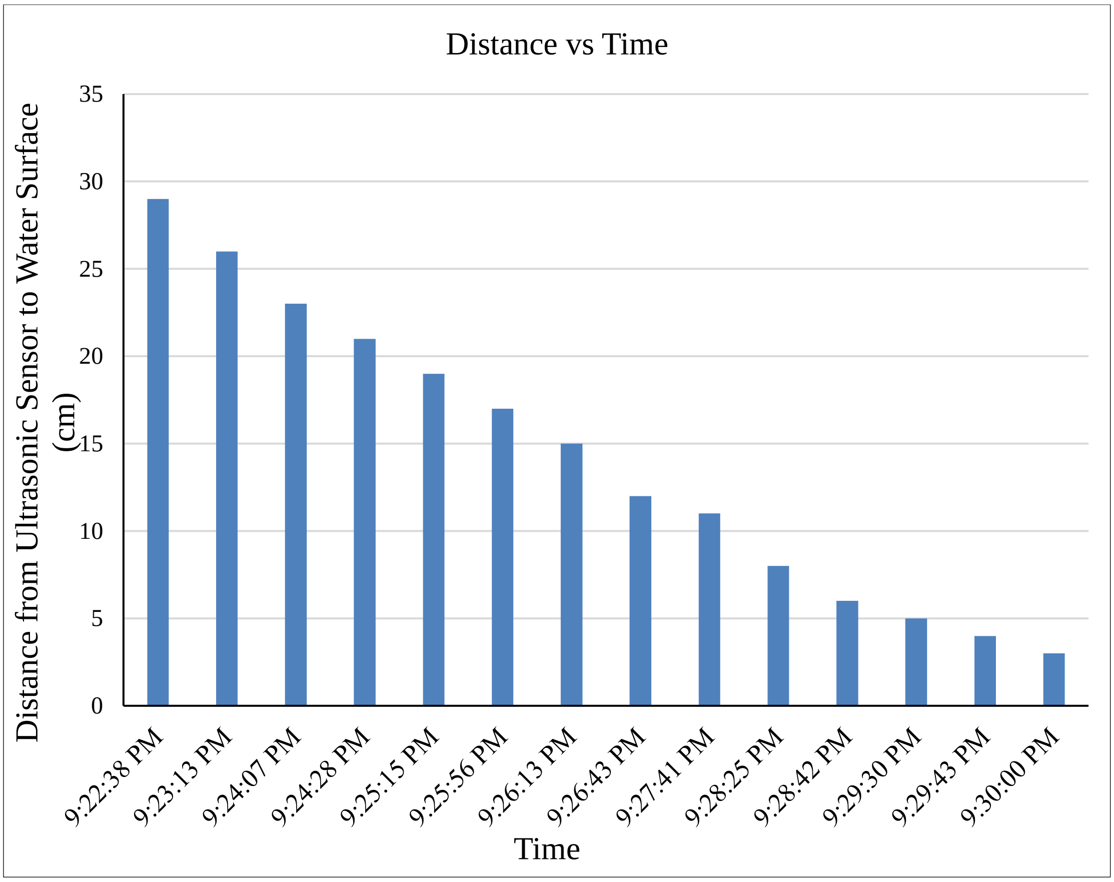


Figure 25. Changes of Distance with respect to Time

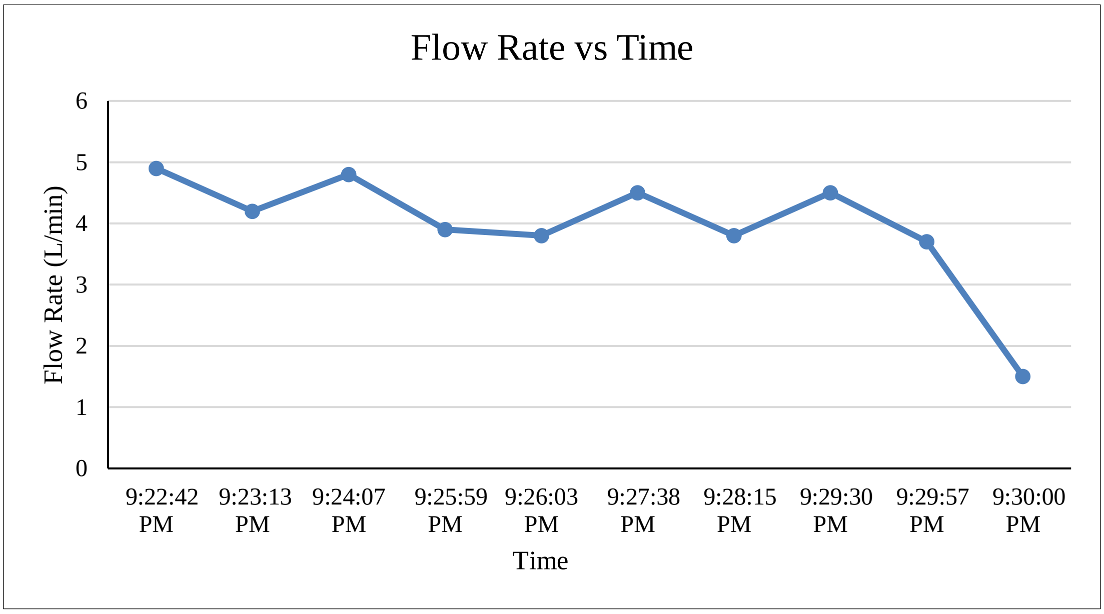


Figure 26. Changes of Flow Rate with respect to Time

The objective of this testing is to ensure the functionality of the sensor. The experiment of obtaining flow rate measurement is done by pouring manually a certain amount of water into the sensor. Figure 26 shows the flow rate of water changes with respect to time which is 1 minute. The flow rate of the water is approximately 5L/min when the time is 9:22:38pm and it decreases as time passes. However, the water is poured through the flow rate sensor, and the reading gains back to 4.9L/min at 9:40:07pm. The reading from the graph fluctuates as the water flows in and out from the flow rate sensor. To maintain the increment of the water level in the tank, the water need to be poured continuously. However, the reading of water velocity in this project is less significant compared to water level detection because the changes in water level is easier to be detected and compared to flow of water.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Flood monitoring system using Wireless Sensor Network (WSN) technology is proposed in this project to meet the objectives: to develop a prototype of the proposed flood warning system, to detect water level and water velocity using ultrasonic sensor and flow rate sensor respectively in real time, to perform data transmission from sensor nodes to coordinator via ZigBee network protocol.

For future implementation, this proposed design is expected to be able to analyze the received data from remote sensor area and predict the risk of flooding thus gives warning to the communities nearby. It is believed that real-time flood monitoring, prediction and warning system can alert the communities in advanced and hence minimize the loss of properties and lives.

5.2 Recommendation

The system can be improved by storing all relevant in a web-server for easy updating from time to time. Besides, the warning system can be improved by using GSM technology with a GSM shield attaching on the Arduino board. The purpose of GSM shield is to process the data in form of SMS and send the SMS to alert the communities in early stage regarding the flood. This warning system is more reliable compared to alarm warning system, as people around flooding area might away from their house when the flood is predicted to happen.

Other than that, a solar panel can be integrated to supply the power to the entire system especially during day time. At the same time, the solar panel can charge the battery for night use. It is recommended to use a 12 volt and 4 Watt polycrystalline solar panel as it is sufficient to charge the battery.

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APPENDICES

Appendix A: Source Code of XBee Coordinator

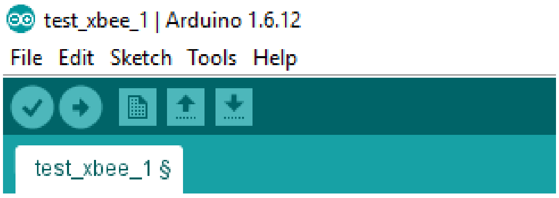
coordinator_xbee | Arduino 1.6.12

File Edit Sketch Tools Help

coordinator_xbee §

```
//code of receiver side, coordinator
#include <SoftwareSerial.h>
SoftwareSerial xbee(0,1); //pin RX,TX

//set led pin,buzzer
const int ledpin=9;
//const int buzzer=8;

void setup() {
  // put your setup code here, to run once:
  pinMode(ledpin, OUTPUT);
  pinMode(buzzer,OUTPUT);
  Serial.begin(9600);
  xbee.begin(9600);
}

void loop() {
  // put your main code here, to run repeatedly:
  if (xbee.available());
  {
      //digitalWrite(ledpin, HIGH);
      //delay(100);
      int distance = xbee.read();

      Serial.print("Distance: ");
      Serial.print(distance);
      Serial.println("cm");
      if (distance > 20){    //led no light up,figure out !!!
        tone(buzzer,4000);
        digitalWrite(ledpin,HIGH);
        delay(500);
      } else {
        digitalWrite(ledpin,LOW);
        noTone(buzzer);
        delay(500);
      }
  }
}
```

Appendix B: Source Code of XBee Router




```
#include <SoftwareSerial.h>

SoftwareSerial xbee(0,1); //pin RX,TX

//define pins number

long duration;
int distance;
const int buzzer=8;
const int ledpin=11;


//setup pin for u/s sensor
void setup()  {
   pinMode(trigPin, OUTPUT);
   pinMode(echoPin, INPUT);
   xbee.begin(9600);
   Serial.begin(9600);
}

//get distance reading from u/s
void loop() {
  // Clears the trigPin
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  // Sets the trigPin on HIGH state for 10 micro seconds
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);//delay(1000);//delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration = pulseIn(echoPin, HIGH);

  // Calculating the distance
  distance= duration*0.034/2;
 Serial.print("Distance: ");
 Serial.print(distance);
 Serial.println("cm");
 delay(300);


}
```

Appendix C: Data extracted and exported to Excel file

Time	Distance from Ultrasonic Sensor to Water Surface
9:22:38 PM	29
9:23:13 PM	26
9:24:07 PM	23
9:24:28 PM	21
9:25:15 PM	19
9:25:56 PM	17
9:26:13 PM	15
9:26:43 PM	12
9:27:41 PM	11
9:28:25 PM	8
9:28:42 PM	6
9:29:30 PM	5
9:29:43 PM	4
9:30:00 PM	3