LOCALIZATION FOR AD HOC NETWORKS USING ZIGBEE

By

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CERTIFICATION OF APPROVAL

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Approved:

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Dr Azrina binti Abd Aziz

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

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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Muhamad Haris bin Mohd Salehan

ABSTRACT

A new technology development nowadays in wireless sensor network has already achieved to its potential to become complementary to every person in this world. This report shall be present about the progress that have been made and the future works that will be done to finish this project. An ad hoc network is a wireless network which is consists of decentralized structure comprised of nodes. Therefore, there will be no central administration and each node can participate freely in transmission. In order to apply the positioning system in ad hoc network, localization is one of the most essential technologies to obtain accurate location information. There are many methods in localization technologies and one of them is by using the signal strength of each node. GPS (Global Positioning System) is one of the system that using the localization technologies which involved satellites. However, buying a GPS module or device would be expensive and GPS module cannot be used for indoor positioning. Thus, this project's aim is to design a cheap and low cost of localization technique in ad hoc network using ZigBee mesh network. Trilateration, which is one of the localization techniques, will be used based on signal strength measurement of each node.

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1. INTRODUCTION

1.1. Project background

Ad hoc network is a decentralized type of wireless network and it does not require any routers in wired networks or access points in wireless networks. In other words, ad hoc network is a network consisting of wireless devices that can communicate with each other without involving central access point (routers). This type of network tends to work in small group of devices in very close range with each other equipped with sensing, data processing, storage and communication capabilities, transmitter and receiver, and local positioning system.

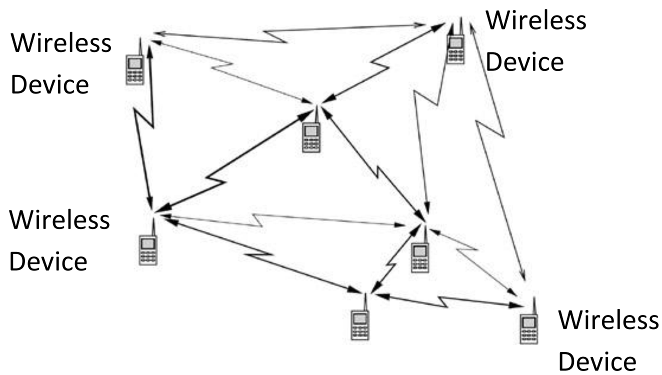

Figure 1: Ad hoc Network

Nodes are divided into two which are transmitter, receivers and can be both. Transmitter emits signals while receiver interprets the signal received. The nodes which are moving are called as blind node. Multiple of nodes can be set up and connected by links made up an ad hoc network. Only two nodes are able to communicate by passing the information through other nodes. Links are influenced by the node’s resources and can be connected or disconnected at any time.

Mostly, the nodes in wireless ad hoc network have access in shared medium and resulting interferences. These interferences can be improved by using cooperative wireless communication which combining the nodes’ interferences in order to improve decoding of the desired signal. Therefore, a functioning network must be able to cope with this dynamic restructuring, preferably in a way that is timely, efficient, reliable, robust and scalable

A local positioning system is a navigation system that allows the network to gather information about its location and update this location to neighbors over a wireless transmission. There are many techniques used by this local positioning system, namely Angle-of-Arrival (AOA), Received-Signal Strength (RSSI), and propagation-time based systems.

Zigbee is a communication protocol based on IEEE 802.15 standard and can be applied in ad hoc wireless network because it does not rely on a central node. The technology of Zigbee has been developed for the last few years and it still on going until now. Zigbee is one of the networking protocols which have channel bandwidth of 1MHz and became another alternative in building a local positioning system. Due to its low-cost, the technology of Zigbee itself can be widely deployed in wireless control and monitoring application. Zigbee also consumes low power due to its frequently sleep time which is provided by small batteries and the mesh networking provides high reliability and larger range due to its ability in having over 6500 nodes in a network. This protocol is suitable in applications which require low data rates and can be used in coordination systems like local positioning system.

1.2. Problem statement

Global positioning system (GPS) is a popular example of local positioning system. Although it provides accurate location information, it is expensive. Therefore, there is a need to build a cheap and reliable local positioning system using low cost microcontroller boards and wireless modules and implement localization technique on this system.

1.3. Objectives

a. To design and build a local positioning system based on Zigbee

b. To test the system taking into account various factors that impact its functional performance such as obstruction and signal strength

1.4. Scope of Study

The scope of the study requires ZigBee module for local positioning system using localization technique. The purpose of using this module must be more efficient and reliable. Arduino Programming is necessary in order to collect the strength of the signal. Gathering data must be done to estimate the distances between the nodes. The data must be repetitive to achieve accurate and precise result. Once the data have been collected, the data must be analyzed to jump into conclusion. In this project, XBee S2 will be used as ZigBee module.

2. LITERATURE REVIEW

Nowadays, people are getting more interested in positioning system technology because it can be very useful to our daily life's activities like hikers can trace back their way back home, track a certain kind species of animal and so on. With the rapid development of wireless technology, localization technology based on Zigbee has been attracted more attentions due to its capability without relying on Global Positioning System devices which are expensive.

2.1 Localization Techniques

In wireless sensor networks (WSNs), the process of finding a sensor node's position in space is called localization and there are two main techniques for computing node position which is trilateration and triangulation [1].

a) Trilateration

Trilateration is the process of finding the position of a node in space based on its distance to three anchors [2]. The location of the remote node is estimated using the area that inhibits errors. The remote node is identified by identifying the center of the intersection point. Multi iteration can be made to determine to exact position. Trilateration usually related to Time of Arrival (TOA) because speed and time will result a distance. Thus, it will determine the position of the blind node.

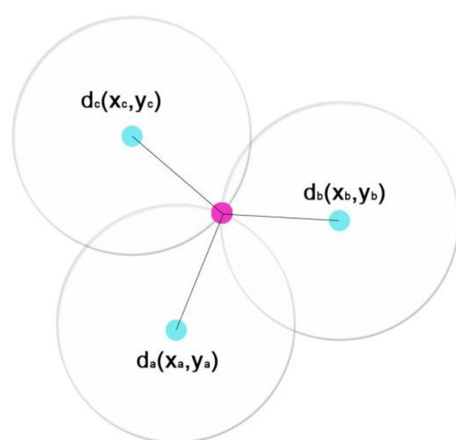

Figure 2: Intersection of three spheres in 2D using Trilateration **[3]**

Each sphere indicates the range of the receiver can cover while the blue node in the middle is the transmitter which is to be localized. The formula for each sphere on one plane is shown below [4] [3]

$$\text{Sphere A; } {d_a}^2 = (x - x_a)^2 + (y - y_a)^2 \tag{1.1}$$

$$\text{Sphere B; } {d_b}^2 = (x - x_b)^2 + (y - y_b)^2 \tag{1.2}$$

$$\text{Sphere C; } {d_c}^2 = (x - x_c)^2 + (y - y_c)^2 \tag{1.3}$$

where d is distance, x is X-coordinate and y is Y-coordinate. These formulas cannot be solved by using simultaneous equation since they are independent and nonlinear. By using Dixon's method [3], the X-coordinate and Y-coordinate can be defined by using equation below

$$y = \frac{v_b(x_c - x_b) - v_a(x_a - x_b)}{(y_a - y_b)(x_c - x_b) - (y_c - y_b)(x_a - x_b)} \tag{1.4}$$

$$x = \frac{v_a - y(y_c - y_b)}{(x_c - x_b)} \tag{1.5}$$

Through this method of calculation, the values of X and Y is the accurate position in two dimension (2D) for the blind node.

b) Triangulation

The position of a node in space is computed based on the angular distance between three different pairs of anchor nodes is called Triangulation [4]. Both trilateration and triangulation are very similar in achieving the same parameters which are distance and direction but in triangulation, angular distance is calculated relative to multiple reference nodes from the angles measured, the distances are computed which are in turn used to calculate coordinates of the nodes.

The collected data must be in average value so that it will become a good sample of data. Thus, more accurate and precise data can be collected.

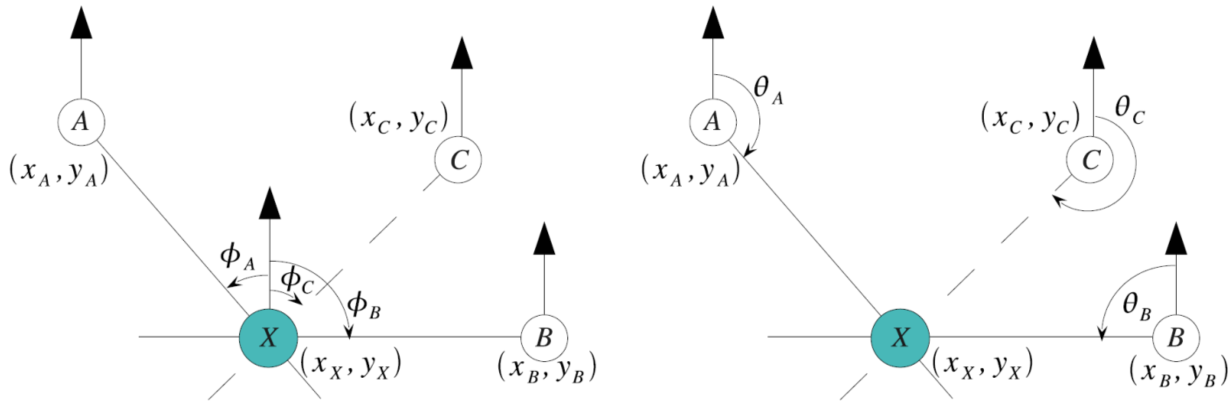

Figure 3: Angle of Arrival and Angle of Transmission **[5]**

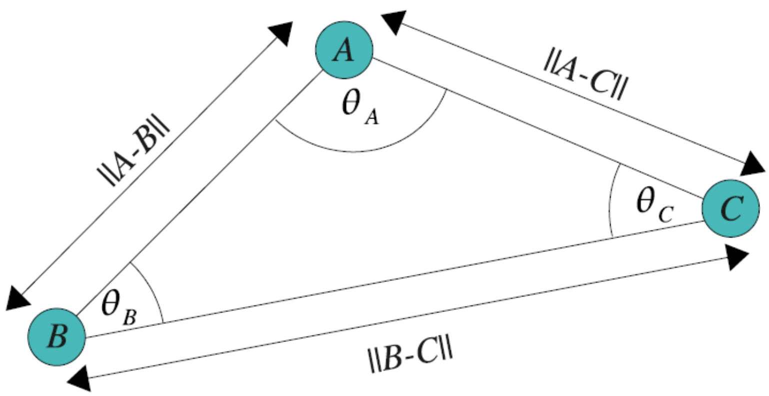

Figure 4: Triangulation deduced to Trilateration **[5]**

Based on Figure 3, the triangulation system can be solved using trilateration technique as shown in Figure 4 as long as the information given or collected is sufficiently enough. The location of the two nodes that are already known can be used to calculate the length between them by using Sine Rule [5]

$$\frac{||A-B||}{\sin \theta_c} = \frac{||A-C||}{\sin \theta_B} = \frac{||B-C||}{\sin \theta_A} \tag{1.6}$$

where $\theta_A, \theta_B, \theta_C$ is the angle between 2 vertices, and $||A - B||, ||A - C||, ||B - C||$ is the lengths of the edges of the triangle.

2.2 Estimating Distances

a) Received Strength Signal (RSS)

The Received Signal Strength Indicator (RSSI)-based localization technique can be applied to both main techniques which are Trilateration and Triangulation. This RSSI technology is based on the intensity and quality of link signal [6]. The more intensity means the closer the distance between transmitter and receiver as the equation below shows [7]:

$$RSSI = -(10n \log_{10} d + A) \qquad (1.7)$$

where n is signal propagation constant, d is distance form sender and A is received signal strength at a distance of one meter. Therefore, these intensities are significant in determining the distances between transmitters and receivers. RSSI is an indicator which indicates a momentary value read at the reception of a data packet [8]. Therefore, repeated RSSI value must be collected in order to get better results. In Triangulation, RSSI signal acts as diagnostic tool that indicate the margin of the received signal compared to the receiver. The name of triangulation is because the object to be located is used as fixed point of a triangle.

b) Time of Arrival (TOA)

This method is based on the measurement of the time of arrival of the signal transmitted by the remote node to different base station [9]. The distance can be identified by translating the propagation time. In order to measure the distance, either measures the time propagation from one node to another or by measure the roundtrip delay of the signal. This method requires high energy and high price of the hardware. Therefore, it is not preferable although it can provide accurate results.

c) Angle of Arrival (AOA)

The Angle of Arrival (AOA) is the measurement of propagation angle between incident wave and another reference wave called as orientation. Orientation wave is the angle measured in degrees which start from the north clockwisely [10].

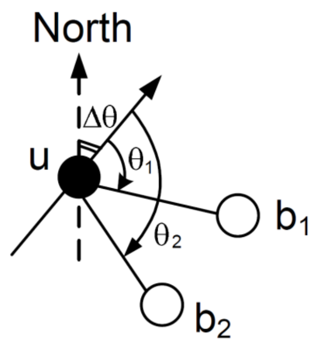

Figure 5: AOA with orientation **[10]**

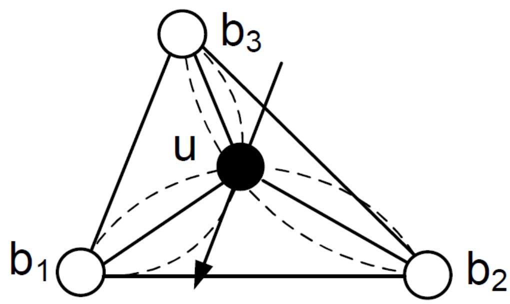

Figure 6: AOA without orientation **[10]**

Based on Figure 5 and Figure 6, localization for Angle of Arrival with and without orientation method can be solved by using triangulation. The Angle of Arrival (AOA) method provides more accurate results than RSSI technique, but the disadvantage of this technique is the requirement of many antennas with anisotropic radiation pattern that will lead to high cost [11] [12]. Therefore, RSSI technique is much more preferable.

Table 1: Techniques that can be used for Localization

	Trilateration	**Triangulation**
Measurement Techniques that can be used	• Received Signal Strength (RSS) • Time of Arrival (TOA) • Time Difference of Arrival (TDOA)	• Received Signal Strength (RSS) • Angle of Arrival (AOA)

3. METHODOLOGY

This chapter will discuss the activities that will be carried out to complete the project's objectives.

3.1 Project Methodology

This section will describe the flow of the project. Figure 7 below provides the flowchart of the methodology of the project. The detailed description of the project is elaborated in this section.

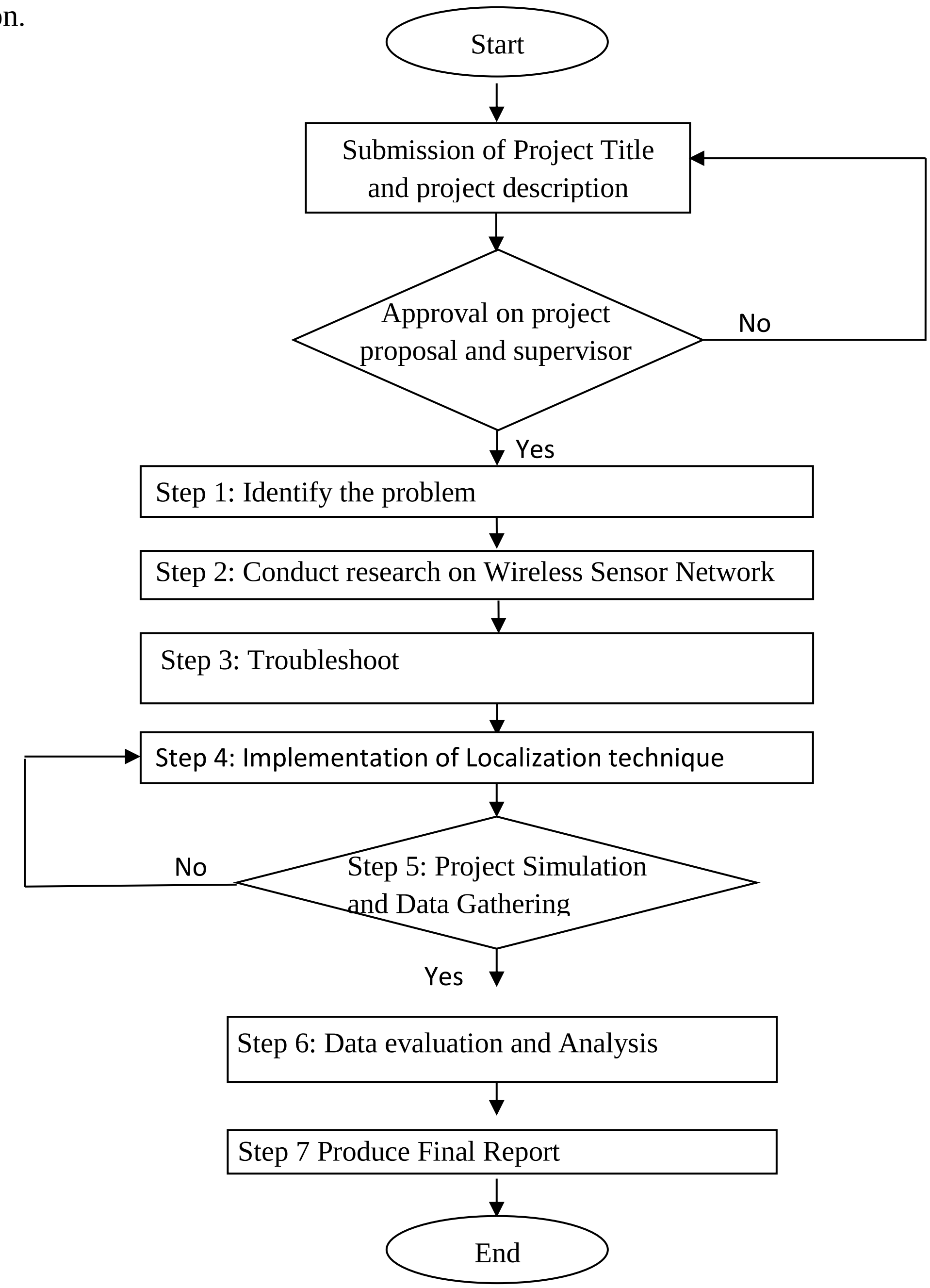

Figure 7: Methodology

Step 1: Identify the Problem

The problem for the project should be identified first which is how to design a local positioning system by using cheaper modules. The technique of localization must be identified first and which technique will be used to increase the efficiency and reliability of the network.

Step 2: Conduct research on localization Techniques

Conduct a research regarding the algorithm for ad hoc localization in ad hoc network. The two main algorithms are called Trilateration and Triangulation. These techniques have several methods which are Time of Arrival (TOA), Angle of Arrival (AOA), Time Difference of Arrival (TDOA) and Received Signal Strength (RSS). Important information regarding those techniques is gathered based on the previous study and experiment of the project is carried out. A literature review based on the information obtained is then produced.

Step 3: Hardware and Software Troubleshooting

The connection of the hardware between Xbees and Arduino board will be tested to ensure no loose connection that will disturb the reading taken. For the software, Arduino programming plays an important role in computing the distances based on the value of the signal strength.

Step 4: Implementation of localization technique using ZigBee

Implementation of localization technique requires programming of Arduino. Trilateration technique is used in this project by solving equation 1.1, 1.2, and 1.3. The ZigBee module will communicate with Arduino to measure the distance based on signal strength of consecutive nodes.

Step 5: Project Experiment and Data Gathering

The experiment is setup for free space modelling and the presence of obstruction. The hardware of Xbees will be tested 3 to 4 times to get the average values using the Arduino software to collect the important data about the strength of a signal.. If the data is failed to gather, step 3 should be repeated.

Step 6: Data evaluation and Analysis

Evaluate and analyze the signal strength by comparing the results of the experiment with the theoretical values. Comparison between the signal strength and measured distance between consecutives Xbees will be made.

Step 7: Produce Final Report

Prepare final report to propose the Zigbee system with the data obtained. Produce some recommendations towards the project so that it can be improves and obtain better result in enhancing the localization technique in ad hoc network using Zigbee.

3.2 Tools Required

Table 3 shows the description about the hardware that used in the project:-

Table 2: Tools required

1	Arduino Uno Board 	i. Microcontroller based on ATmega328 chip to communicate in serial with XBee. ii. An open source computing platform based on a simple input output board. iii. The signal strength measured by XBee will be send in serial to Arduino iv. Implementation of localization technique by using signal strength sent by XBee.
2	XBee Series 2 	i. As ZigBee module ii. Acts as a node in ad hoc network iii. Measure the signal strength iv. Support as Coordinator, Router and End Devices i. Has total of 20 pins
3	XBee Shield 	ii. Designed for Arduino to protect the XBee. iii. Designed to configure the XBee easily iv. Supported all type of XBees v. Provide two switches, first switches for selecting XBee or USB mode while second switch to select run or program mode.

3.3 Project Gantt-Chart

Detail	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
Selection of FYP topics	■	■												
Preparing Extended Proposal			■											
Preparation for Proposal Defense				■										
Gather Literature Review and relating to Localization Techniques				■	■									
Hardware and software configuration					■	■								
Preliminary Simulation Using X-CTU							■	■	■					
Obtain Preliminary Results										■	■	■		
Analysis and Validation of data													■	
Preparing Interim Report												■	■	
Submission of Interim Report														■

Table 3: Gantt Chart for FYP I

Detail	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
Arduino Programming on collecting the value of signal strength														
Data Collections														
Arduino Programming on computing distances														
Submission of Progress Report														
Obtain Final Results														
Pre-SEDEX														
Preparing Final Report and Technical Report														
Submission of Dissertation (Softcopy)														
Submission of Technical Paper														
Oral Presentation														
Submission of Dissertation (Hard Bound)														

Table 4: Gantt chart for FYP II

3.4 Key-Milestone

No.	Milestone	Date
1	Submission of Extended Proposals	February 2014
2	Proposal Defense	April 2014
3	Preliminary Simulation	April 2014
4	Data Collection	May 2014
5	Submission Progress Report	June 2013
6	Final Results of Simulation	June 2014
7	Pre-SEDEX	July 2014
8	Submission of Dissertation (softcopy)	July 2014
9	Submission of Technical Report	August 2014
10	Oral Presentation	August 2014
11	Submission of Dissertation (hardbound)	September 2014

Table 5: Table for Key-milestones

3.5 Experimental Setup

Before data collection is conducted, these XBees must be able to communicate with each other in mesh network. Therefore, configuration of each XBees must be done to allow the XBees to transmit and receive data without any errors.

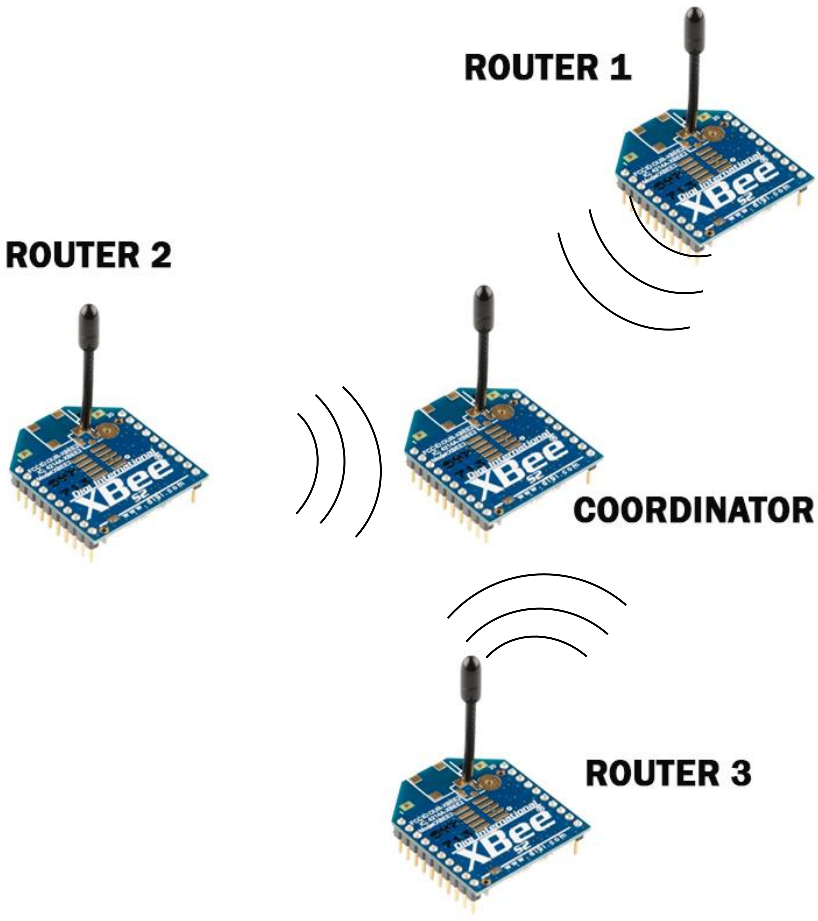

Figure 8: ZigBee Networking

Based on Figure 8, three XBees will be act Router and another one will acts as a Coordinator. These routers will broadcast the signal to the coordinator. Then the coordinator will measure the strength signal and process the signal to determine the location of the coordinator. Each XBee contains an identifier which is referred as PAN id.

In this project, a Zigbee mesh network, two different types of device are used:-

a) **Coordinator :** a node that initiates the communication by broadcasting RF signal to other node. RF data is transmitted and received in transmission and the data is routed through the mesh network
b) **Router :** Receives and transmit RF data transmission and data packets are routed through the network. The receiving nodes will identify the coordinator based on same PAN id.

a) XBee Configuration on XCTU

The XBee modules support both Transparent Mode (AT Mode) and API (Application Programming Interface) Mode. In this project, AT mode will be used because it is easier and simpler to use than API Mode.

When operating in AT mode, the module acts as a serial line replacement. All UART data received through the DIN (Digital Input) pin is queued up for RF transmission. When the data is received, it is sent out through the DOUT (Digital Output) pin. XBees can be configured using AT command mode interface. The Table 6 compares the advantages of these two modes.

Table 6: Comparison AT and API modes

AT Mode	
Simple Interface	All received serial data is transmitted unless in command
Easy to support	Easier for application to support transparent and command mode
API Mode	
Easy to manage data	Transmission to multiple destinations
Indicate the sender's address	All received data API frames indicate the source address
Advanced	Advanced ZigBee addressing support and networking diagnostics
Remote Configuration	Set/read configuration commands can be sent to remote devices to configure them as needed using the API

The XBees is configured as in Figures 9 and 10:-

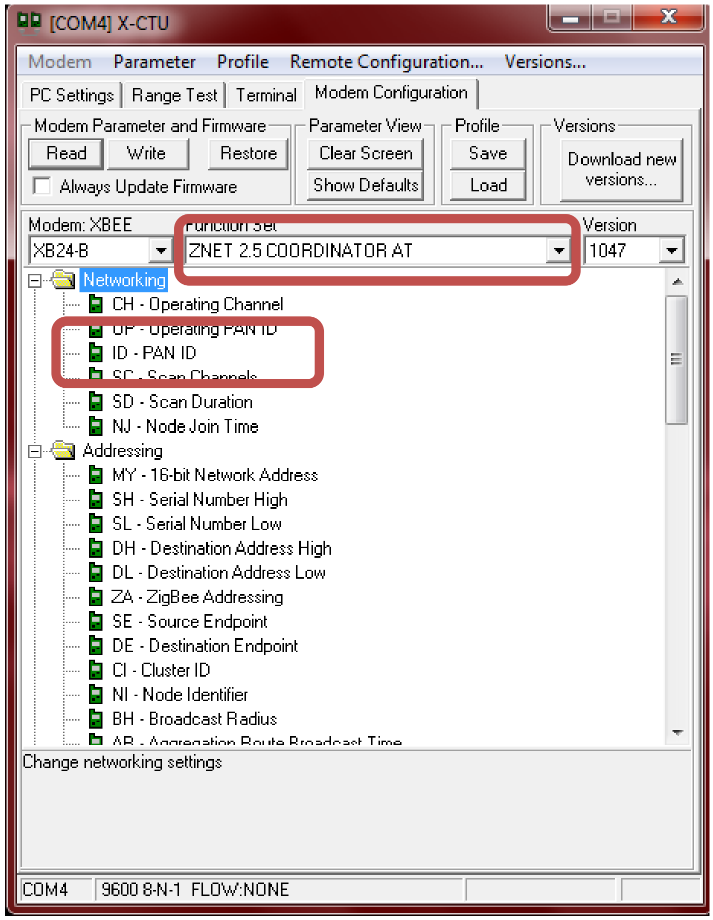

Figure 9: Coordinator AT firmware is loaded

Modem Type : XB-24-B

Function Set : ZNET 2.5 Coordinator AT

Version : 1047

PAN ID : 123

Baud Rate : 9600

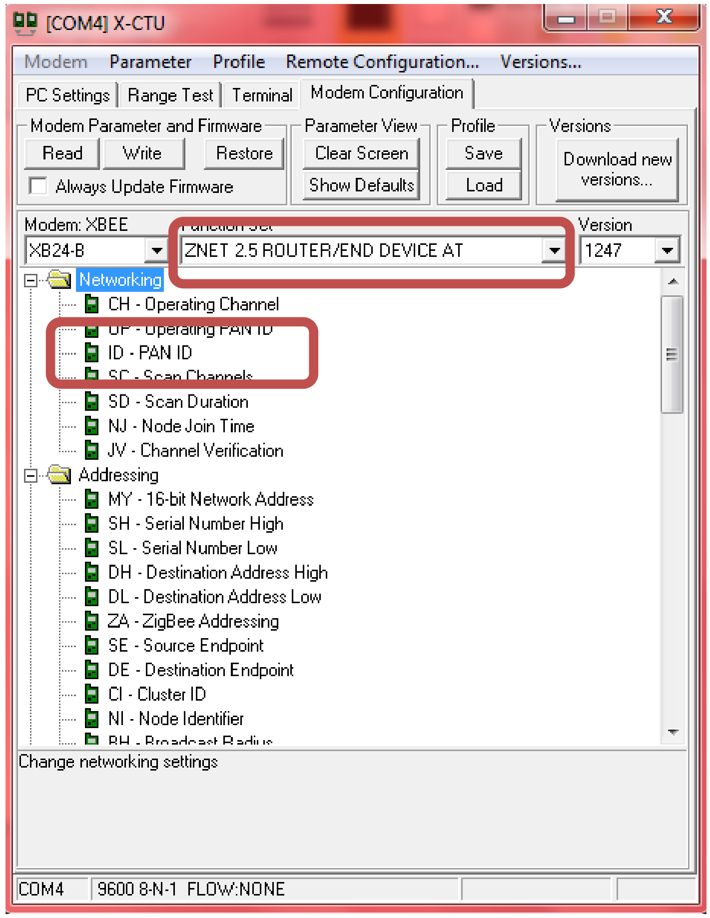

Figure 10: Router AT firmware is loaded

Modem Type	**:**	XB-24-B
Function Set	**:**	ZNET 2.5 Router/End Device AT
Version	**:**	1247
PAN ID	**:**	123
Baud Rate	**:**	9600

b) Calibration of Xbees using XCTU

In order to measure the distance, data collection on RSSI values for 1 meter is important. This step is called as calibration because based on Equation 1.7, the RSSI value for 1 meter must be determined first as a reference. In this progress, there are two steps that have been made to calibrate the XBee.

i) Two Xbees connected via PC USB

These Xbees are serially connected to the PC which has XCTU software installed. Before these Xbees measure the signal strength, it must be configured by using the same software, XCTU. In Modem Configuration, these Xbees are configured as Router and Coordinator respectively. Since these Xbees are connected in serial with PC, there is no need to program it to measure the signal strength. This setup is purposely to check the faulty of the hardware. If there is a fault in hardware, troubleshoot must be made and replacing a new hardware is necessary to reduce errors in collection of data. Then, the signal strength is measured via RSSI interface in XCTU. The signal strength is measured in milidecibels. A part from that, XCTU has the capability to the check the range test between these Xbees. This range test is measured in percentage. The range test and the RSSI value indicate the relationship between the distances between two consecutive Xbees and the signal strength measured. The data transmitted can be sent by using the terminal that is already built in the XCTU. The terminal for the receiver will shows up the data that has been transmitted to the receiver. These are called serial monitoring. This method is limited since the cables that connected to the PC are not long enough to get a greater distance. However, the objectives of this method are to check the RSSI value for 1 meter only for calibration and to configure the Xbees in which mode whether in Coordinator, Router or End Device.

ii) Range Test for greater distances

Based on previous configuration of Xbees on XCTU, these Xbees have been calibrated and configured as Router and Coordinator. Only one Xbee is connected to the PC which is the Coordinator as Serial Monitor and the other Xbee as Router transmitted the data wirelessly. The receiver will not receive any data packet unless the transmitter sends one. Based on previous setup, the data packet is sent via serial monitor in XCTU. However, in this setup, the transmitter can send a data packet through a program compiled in Arduino Board since it is connected to the Xbee via Xbee Shield. With this coding, it enables the transmitter to send the data based on interval time. The strength of the signal will appear as hexadecimal in serial monitor. Although it is in hexadecimal, the unit is still in milidecibel. The strength of the signal is measured with 1metre increment. The data has been collected up until 12metre only and repeated several times to obtain the average value. The distances are measured manually by using measuring tape to validate the data. Multiple of readings of data will be taken to obtain the average value of the RSSI and to minimize the error.

c) Experiment using AT Command to obtain RSSI values

The experiment will be done using AT command to ensure more accurate values and more precise readings. Comparison between the tests taken before must be done to ensure the reading from AT command is usable. The data that have been collected will be used in localization to minimize error. Thus, reliable result can be obtained.

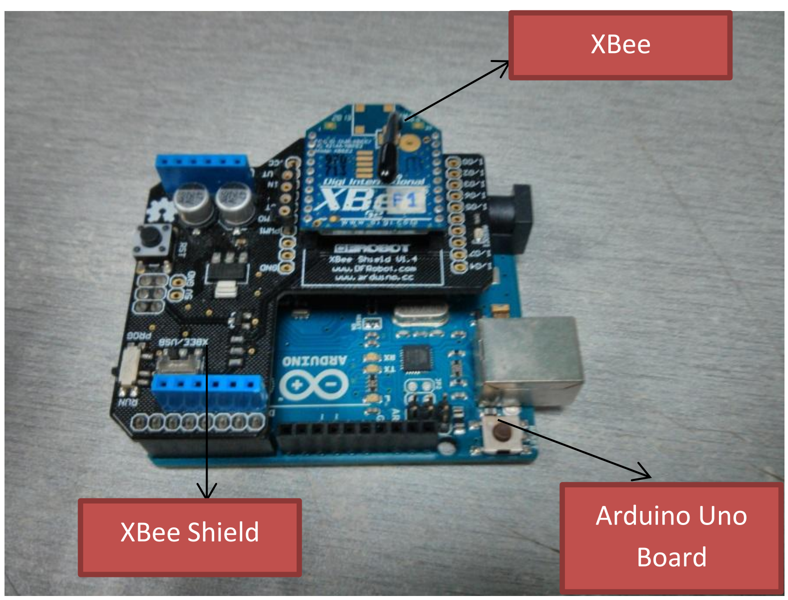

Figure 11: Modem Configuration

In order to obtain the RSSI value in Arduino Serial Monitor, a program based on AT mode must be uploaded into the Arduino Board. The AT Command to measure the signal strength is 'ATDB' command. Before the 'ATDB' is called, the AT mode must be initiated by using '+++' command and this AT mode can be ended by using 'ATCN' command. The Arduino board used is Arduino Uno R3 stacked with XBee shield to connect between the board and XBee as shown in Figure 11.

There are a few requirements to be fulfilled in order to collect the RSSI value in Arduino Serial Monitor. There are:-

i) The Arduino board must at least have two serial port for communication

Serial Port consists of two pins which are RX for receiver and TX for transmitter. Since the program needs at least two serial ports for communication, it means the Arduino board must have at least 4 pins which is RX0, RX1, TX0 and TX1. Based on Figure 12, the Arduino Uno board has only one serial port which is pin 0 and pin 1.

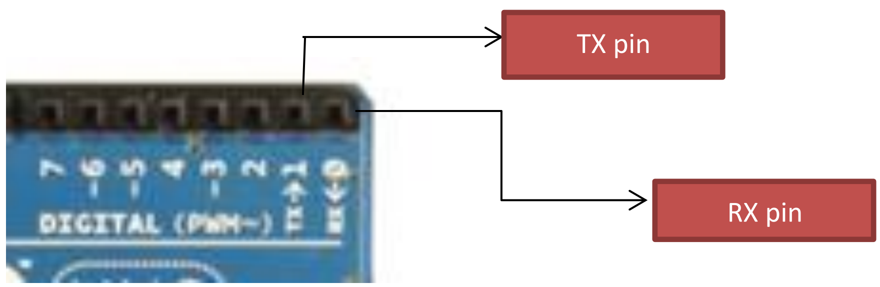

Figure 12: RX and TX pins on Arduino board

Another Arduino board like Arduino Mega board provides 4 serial port of communication is needed for this project. However, the Arduino software has a SoftwareSerial library which has been developed to allow serial communication on the other digital pins of the Arduino. The function of the serial port is replicated by using the software. It is advantage to have multiple serial ports with speeds up to 115200 bps.

ii) There must be a connection between XBee and Arduino board

Based on Figure 13, the schematic of XBee shield shows that when the shield is stacked to the Arduino board, the pin of Digital Ouput and Digital Input of Xbee is connected to RX and TX pin of Arduino board.

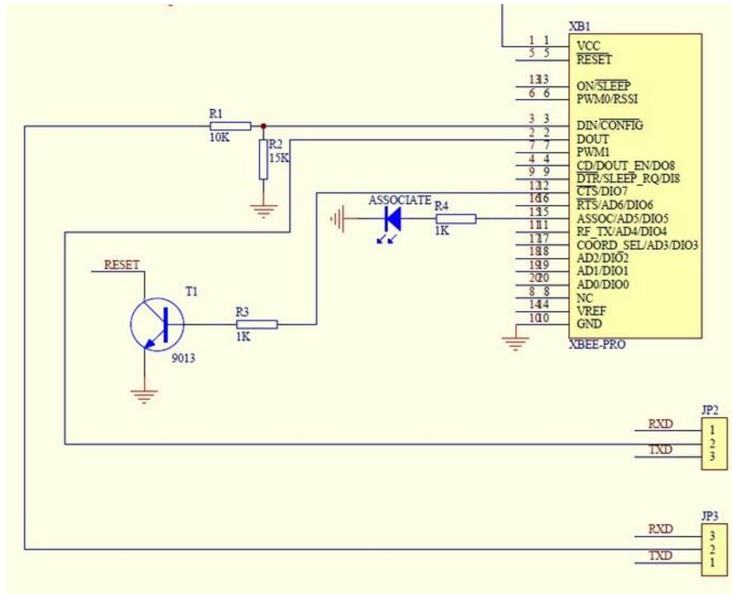

Figure 13: Schematic of XBee Shield

iii) **Connection between Arduino board and PC**

In order to read the value of signal strength, the Arduino board must send the data collected into the PC. In this concept, the second serial port for communication is needed. The values of the signal strength will vary with distances.

3.6 Implementation of Trilateration in Arduino

Figure 15 provides the coding flowchart of the Trilateration on Arduino. From the literature review, Equations 1.1 to Equation 1.5 are coded in Arduino in C language to implement Trilateration. Equation 1.6 is used to measure the distance.

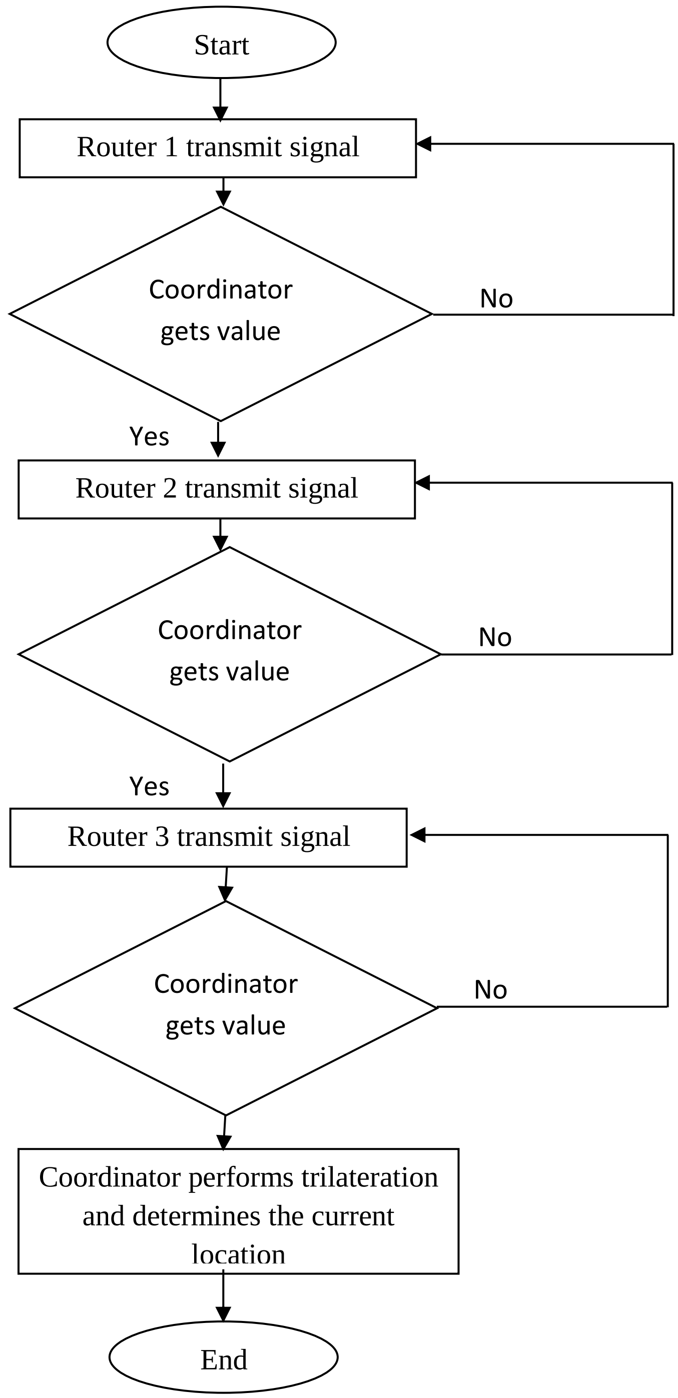

Figure 14: Coding Flowchart

For the start, these routers will transmit data to the coordinator accordingly. These routers must be triggered by a signal by the coordinator to start the transmission. Router 1 will transmit data first and the coordinator will measure the signal strength. After getting value of this signal strength, the coordinator will convert it into distance and store the value. The same process happens when Router 2 and Router 3 start to transmit.

As soon as the coordinator receives these three values, the coordinator will start to calculate and determine the position or location of the nodes in the network. This position will be displayed in terms of X and Y coordinates.

After the RSSI values have been collected on Arduino, these values must be compared to the values that obtained during the range test on XCTU. If both values have minimum error of offset value, then the data obtained in Arduino is valid. The factors that affect the signal attenuation must be taking into account.

4. RESULTS AND DISCUSSIONS

4.1 RESULTS

a) Calibration of XBee and Range Test for greater distances.

The RSSI value for 1 meter must be collected as references for any distance. Then, the RSSI values for greater distance are collected and are compared to actual value. The Equation 1.7 is used to obtain the actual value of RSSI.

$$RSSI = -(10n\log_{10} d + A) \ , \qquad (1.7)$$

where d is the distance from sender, n is the signal propagation constant and A is the received signal strength of one meter.

Table 7: Result Range Test on XCTU

Distance, m	RSSI, dBm (measured)	RSSI, dBm (predicted),n=1	RSSI, dBm (predicted),n=1.5	RSSI, dBm (predicted),n=2	RSSI, dBm (predicted),n=3
1	-36.3	-36.3	-36.3	-36.3	-36.3
2	-45.3	-39.3	-41.1	-42.3	-45.3
3	-52.6	-41.1	-43.5	-45.8	-50.6
4	-52	-42.3	-45.3	-48.3	-54.4
5	-50.6	-43.2	-46.7	-50.3	-57.3
6	-52.3	-44.1	-47.9	-51.8	-59.6
7	-52.6	-44.7	-48.3	-53.2	-61.6
8	-58.6	-45.3	-49.4	-54.3	-63.3
9	-56.6	-45.8	-50.1	-55.4	-64.9
10	-61.3	-46.3	-50.7	-56.3	-66.3
11	-62.3	-46.7	-51.8	-57.1	-67.5
12	-68	-47.1	-52.4	-58	-68.6

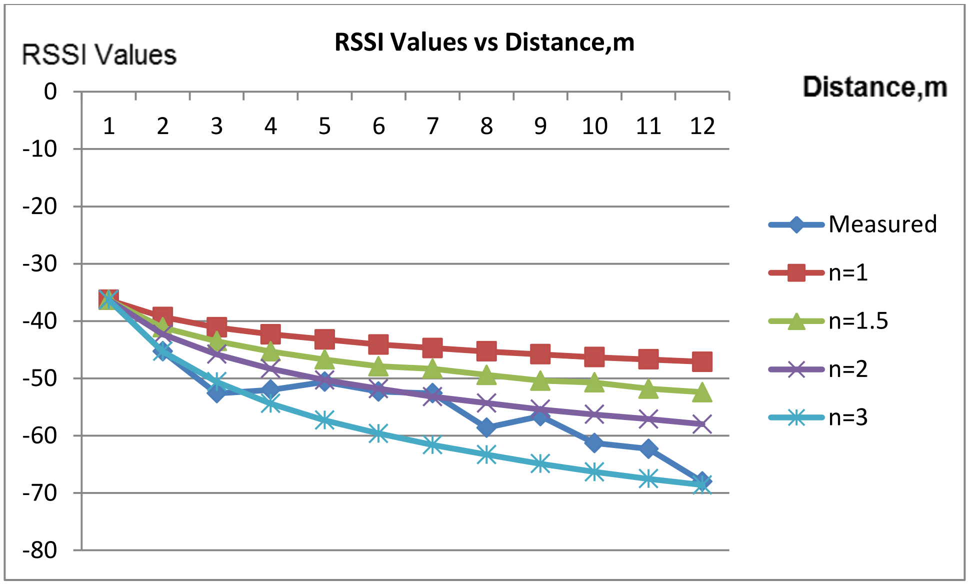

Figure 15: RSSI vs Distances graph

Table 8: Average Percentage of Error

Propagation Constant, *n*	Average Percentage Error
1	17.6%
1.5	8.902%
2	1.12%
3	14.6%

The gathered of the data is tabulated in the Table 7, Table 8 and Figure 16. Based on the signal strength collected, the value of signal strength for 1 meter of -36.3 dBm is used as a reference for another distance.

After obtain the value for 1 meter, the experiment is conducted to test the range up to 12 meters with different value of propagation constant, *n*. The values of *n* tested are 1, 1.5, 2, and 3. Comparison is done between the actual and measured values and propagation constant of 2 is selected because it has the least of error of 1.12% as shown in Table 8 and closest to actual values.. In free space, propagation constant of 2 is used usually.

Table 7 is the result of the range test on XCTU. The RSSI values for distance ranging from 1 meter to 12 meter are recorded.

Based on the data collected, the values of RSSI are decreased when the distances increases. This is due to the path loss cause by obstruction or power lost during transmission. The signal will be attenuated due to these factors..

b) Trilateration Implementation using AT command

From the calibration step**,** each router will have be the same value for the same distance but each router must be tested first to ensure the accuracy during Trilateration experiment.

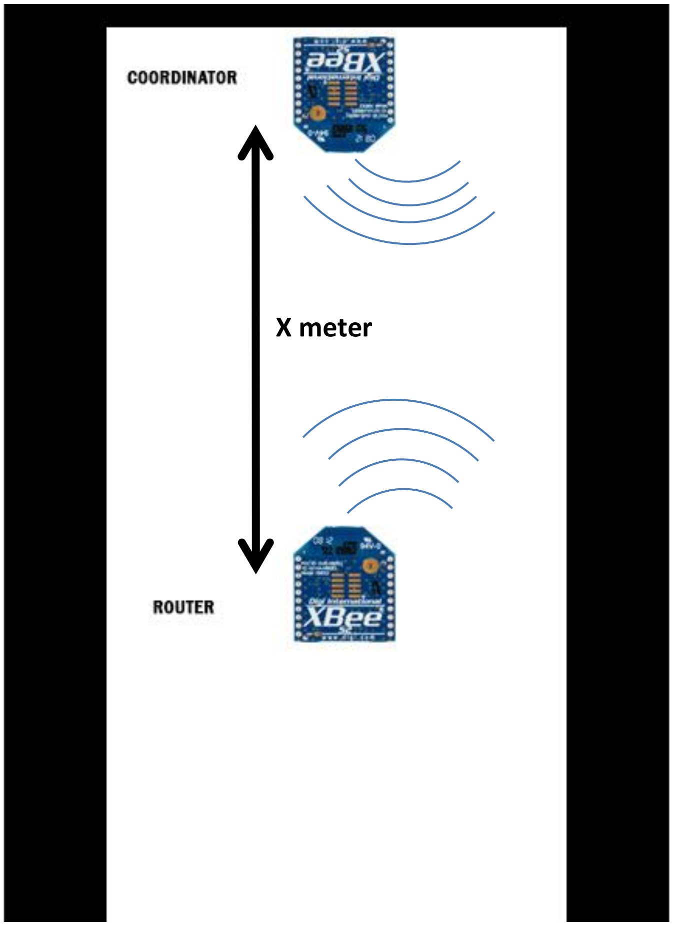

Figure 16: Range test Experiment Setup

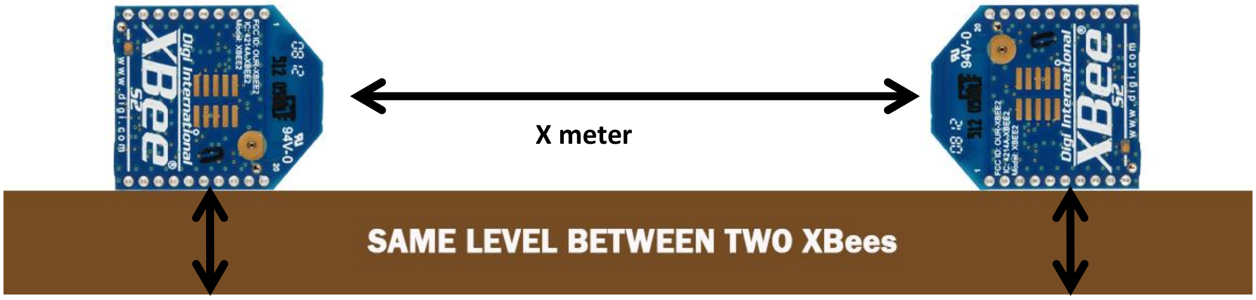

Figure 17: the XBees must be in the same level from the ground

Based on Figures 17 and 18, the XBees must be positioned in the same level from the ground. This is because to ensure that the signal can transfer to receiver efficiently. Furthermore, this same level is to make as fixed variables. If the positions of the XBees are not the same, the data collected will be totally different.

This testing is conducted for indoor and outdoor localization with less obstruction or anything that might interfere the transmission. Thus, through this testing, the signal strength can be measured accurately and Arduino can compute the distance and perform Trilateration algrotihm correctly.

This testing is based on programming Arduino which AT command is used. In order to collect the RSSI value, ATDB command is used. The value will be return as Hexadecimal in milidecibel. Each router must be tested for it range and signal strength between the Coordinator. The result for each router is tabulated on the table below.

Table 9: Range test for each Router (Free Space)

Distance, x	**RSSI value(dBm)**			
	Router 1	**Router 2**	**Router 3**	**Actual**
1m	-33	-31	-33	-32
2m	-34	-34	-35	-38
3m	-37	-37	-38	-41
4m	-40	-40	-39	-44
5m	-43	-43	-44	-45
6m	-47	-46	-46	-47
7m	-54	-54	-54	-48
8m	-58	-57	-59	-50
9m	-61	-60	-61	-51
10m	-66	-66	-65	-52
11m	-69	-69	-69	-54
12m	-73	-72	-72	-55

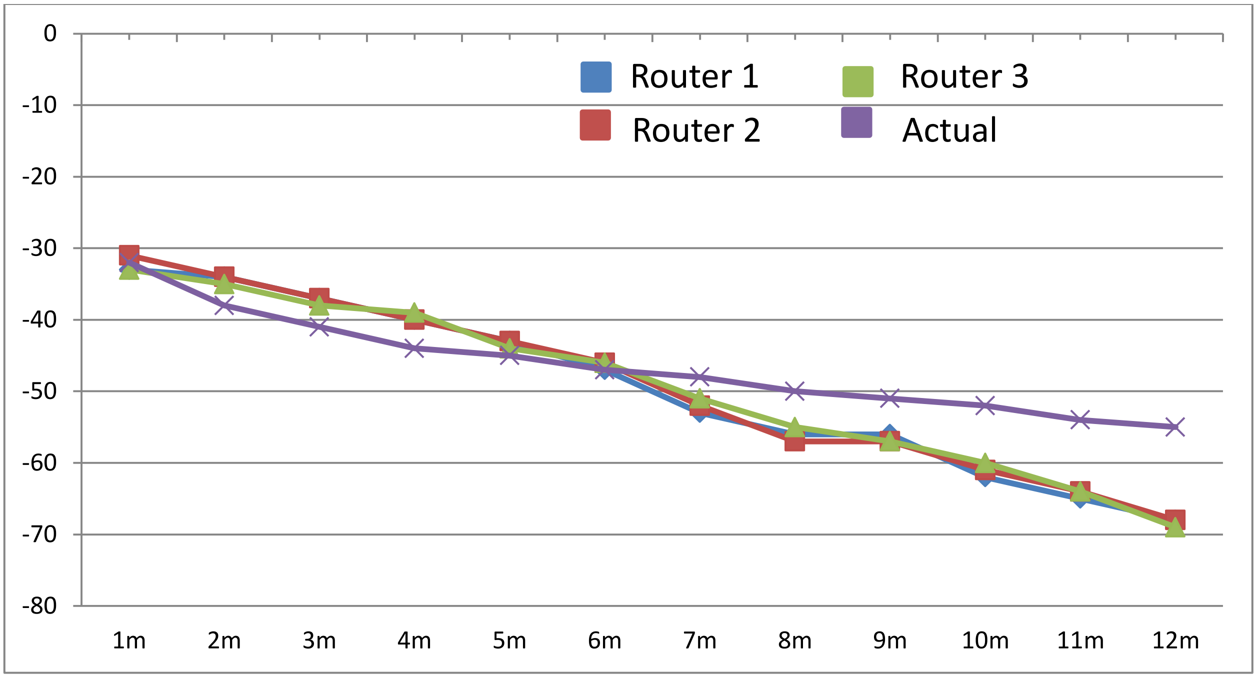

Figure 18: Relationship between Strength Signal and Distance

Table 9 indicates the value of the RSSI of each router. Figure 19 indicates the relationship between the strength signal and distances. The data collected is 81.33% accurate. A slightly error must be occurred during the transmission which is the signal loss.

Thus, each router can compute the distance very well based on the signal strength measured. From this result, the data collected can be used in 2D- Trilateration for ad hoc Localization.

c) Implementation of Trilateration algorithm in Localization

After a few range tests had done, the Trilateration algorithm will be implemented as shown in Figure 20 in Arduino programming using AT command. The experiment is setup to determine the accuracy of this technique.

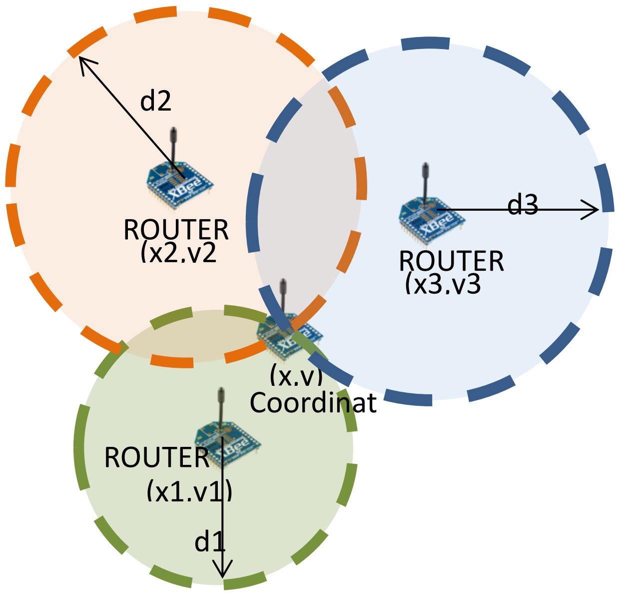

Figure 19: 2D Trilateration

I. <u>Free Space Propagation Model with Line of Sight case</u>

The experiment is set up as shown in Figure 21 without any obstruction or any obstacles that may increase the power loss during transmission of the signal.

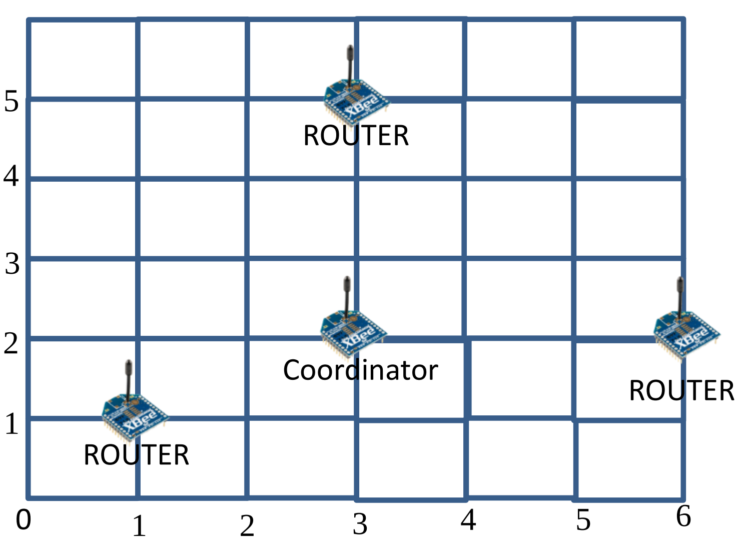

Figure 20: Real Setup

Table 10: Results Trilateration for Free space with LOS

Actual coordinate	**Coordinate (x,y)**			**Measured distance from Coordinator, meter**			**Measured coordinate**
Coordinator	Router 1	Router 2	Router 3	Router 1	Router 2	Router 3	Coordinator
(3,2)	(1,1)	(6,2)	(3,5)	2.24	3.16	3.16	(2.26,3.25)
(3,2)	(1,1)	(6,2)	(3,5)	2.00	3.16	2.82	(2.28,3.22)
(3,2)	(1,1)	(6,2)	(3,5)	2.51	2.82	2.82	(2.31,3.3)

II. Non Line of Sight (NLOS) case

The experiment is set up as shown in Figure 22 with a few obstruction or obstacles that may increase the power loss during transmission of the signal. The data collected will be analyzed for its reliability.

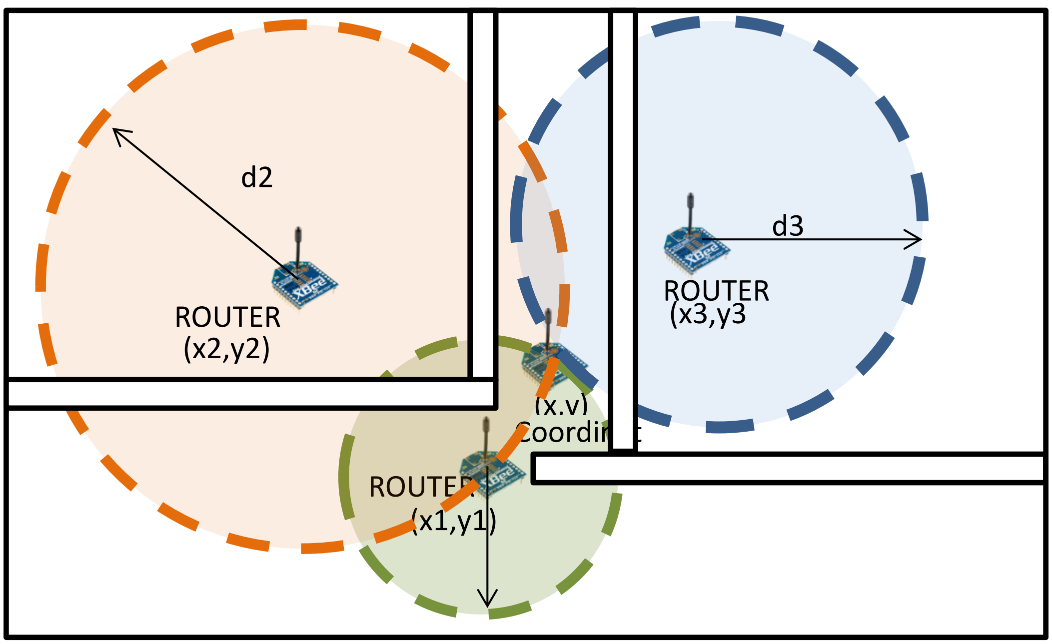

Figure 21: General Layout Experiment Setup for NLOS case

Table 11: Results Trilateration for NLOS case

Actual coordinate	**Coordinate (x,y)**			**Measured distance from Coordinator, meter**			**Measured coordinate**
Coordinator	Router 1	Router 2	Router 3	Router 1	Router 2	Router 3	Coordinator
(3,2)	(1,1)	(6,2)	(3,5)	2.82	3.55	3.98	(2.20,3.28)
(3,2)	(1,1)	(6,2)	(3,5)	3.16	3.98	4.47	(2.20,3.27)
(3,2)	(1,1)	(6,2)	(3,5)	2.82	3.55	3.98	(2.20,3.28)

From the data tabulated on Tables 10 and 11, for Free space with line of sight, the coordinate calculated is quite accurate with minimal error of 22%. For NLOS case, the coordinate calculated has slightly higher error than Free Space case but it still acceptable with 72% of accuracy since there is obstruction during the transmission. The power received by XBee may not be sufficient enough to measure the signal strength. Due to this reason, the measured signal strength will be low. Even though, each router has obstruction to communicate with the coordinator, these XBees are able to send signal efficiently. Based on the table above, the measured coordinate is not exactly the same as the coordinate of the actual one but the percentage error obtained from the experiment is quite low which is 22% to 28%. Thus, the data collected are reliable and precise. For Free Space case, the experiment is setup to gain the power received without any obstruction that might interrupted the transmission.

4.2 FUTURE WORKS

a) Computing distances without connected to the PC

As far as it is concern, due to practicability of the application, the serial monitoring on Arduino must be changed into LCD panel to show the distance measured. There will be a lot of Xbees that will be used. Thus, each Xbee must have its own LCD display panel to show its distances between those anchor nodes. Based on theory, the virtual serial port is not needed because there will be no connection to the PC. Thus, the computing algorithm just take place in Arduino Board and the distances computed will be shown on the LCD display panel.

Testing will be conducted to ensure the validation of data. The data will be analyzed and if the error is not susceptible, changes in coding will be made to get more precise and reliable data.

b) Computing distances using multiple of nodes

The next progress should be applying multiple of XBees as nodes. this is essential in order to implemented Trilateration method. The Trilateration method requires at least three anchor nodes. Each of the nodes will be put the same program as Coordinator. These Coordinators will evaluate the signal strength and compute the distances based on the algorithm that had been put in the program.

5. CONCLUSION AND RECCOMENDATION

This project is proposed to develop a new design of localization technique in local positioning system. The design is purposely made to replace Global Positioning System (GPS) in ad hoc network. Based on previous study and researches, the result using RSS is completely achievable. The system will be tested to take into account various factors that impact its functional performance such as coverage, obstruction and signal strength. A study plan or Gantt chart as well as key milestone have been made to ensure the project can be completed within the time frame. The objectives of this project are achievable due to plans that have been made. To reduce the error, more data will be collected to gain a reliable result.

For the recommendation, it is better to work with multiple nodes to achieve an accurate location. Since the ZigBee used can cover about a certain area, it is better to use a ZigBee which has wider coverage area. The wider area enabled the project to have the least number of ZigBee used for this project. Thus, the data gathering can be made efficiently because the data can be collected based on the area that will cover by the ZigBee.

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