Data Exchange among Multiple Robots

by

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16322

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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Approved by,

_____
(Abu Bakar Sayuti b. Mohd Saman)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2016

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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NURFARAH HANIM BINTI ABDULLAH

ABSTRACT

Communication subsystem in robotics is one of the important parts of a system, often being used before going to larger communication system. Communication subsystem is essential for one device to communicate with other devices in terms of movement and also location. In this project, data exchange between multiple robots need to be accurate, fast and yet reliable in term of movement and direction. Therefore, by designing a hardware-software, communication between three robots is being established pertaining their movement and direction. Communications between master and slave has been established where the slaves are able to receive the data pertaining to the master.

ACKNOWLEDGEMENT

First and foremost I would like to thank the Electrical and Electronic Department of University Technology Petronas (UTP) for giving me the opportunity to learn and explore EE world. Besides that, I would like to thank them for giving me the opportunity to undergo my final year project (FYP) for two semesters. It is indeed for all the final year students to do their own project to shows their capability and understanding from what they have learnt throughout 4 years of undergraduate studies.

I would like to show my greatest gratitude towards my FYP supervisor, Mr. Abu Bakar Sayuti for helping me throughout this whole semester. Being proficient in his scope of studies, his continuous guidance has assisted me in every major technical difficulty I stumble along the way for completing my FYP. He has guided me all the way and makes me more understand on how the project supposed to works and how to make it work.

Next, I would like to thank my family members for all the support they've given. Especially to my mother who lends me her credit card for purchasing the hardware that I've needed to use for my FYP. Thanks also to my brother who lend me his laptop so that I can test my project as the project that I done required the used of two laptops.

Last but not least, thanks to my friends who spend their precious time accompanying me to buy the hardware needed for my project. Without them, it is hard for me to complete my FYP in time. Thank you for all the cooperation that they've given.

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CHAPTER 1

INTRODUCTION

This chapter will discuss about the communication between three robots. The robots must be able to send and receive data in form of movements, location and direction. This report will explain different protocols that can be used for the communications between three robots. The protocols used falls under short range communication where there available and widely used. Each of the networks has their own capabilities for data transmission and how they are benefit towards users. By choosing the suitable wireless communication, data can easily be transmitted and received according to user input.

1.1 BACKGROUND

Mobile robot is widely used in manufacturing and industrial area, security system, and planet exploration. The usage of mobile robot makes production easier and lessens the usage of man power. In this project, it is required for the robot to exchange data among each other in the form of movement, coordination and orientation. In order for the robot to achieve reliable and accurate data exchange, programming has to be done to the robots to communicate with each other using communication protocol which will be discuss further in next chapter.

Communication has been used widely in this era of technology. Communication is very essential nowadays as it has been a form of message or data that can be received or delivered by one device to another or from another person to another person either short or long distance. However, with widely growth of technology, wireless communication is preferable as one of way for communication. Wireless communication can be divided into three types; short-range wireless communication, medium-range wireless communication and wide-range wireless communication.

Short-range communication used for sending data or signal for short distances where the range is from few centimeters up to hundreds meter. Technologies that use short-range communication are Bluetooth, Wireless Personal Area Network (WPAN), Zigbee, Infrared, ultraband and near field communication [1].

Bluetooth is a device that used radio frequency to transmit voice and data signal from one device to another device up to 10m range. Bluetooth falls under IEEE 802.11 that operate at 2.4GHz frequency band. Bluetooth uses the concept of master and slave where one device/sending device will act as the master and the other device/receiving device will act as the slaves. In order for Bluetooth to communicate with each other software called link manager is used [1].

Zigbee is a device that is user friendly where it can be operated by using control and sensor network. Zigbee can be operated to the distance that up to 70m[2]. Zigbee falls under IEEE 802.15.4 that operates at unlicensed band of 2.4 GHz, 900 MHz and 868 MHz frequency band. Zigbee are able to control the electrical devices in the house, for example, lights, air conditioner, switches and thermostat[3][4][5].

Wireless network can be divided into four categories which are Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), and Wireless Wide Area Network (WWAN) [11]. WLAN falls in short-range communication categories. The range cover for WLAN is from few meters up to hundreds meter. WLAN has been widely used in all places including cafes, public transports, and all over the places due to its easy access.

1.2 PROBLEM STATEMENT

Data exchange among the three robots need to be accurate where the robot able to read data transfer from robot A to robot B correctly. Besides that, the data exchange must be fast yet reliable. There is a need to study the selection of data that need to be shared, pack it in the right format and the most suitable communication protocol, to ensure effective data exchange.

1.3 OJECTIVES AND SCOPE OF STUDY

- To design a hardware-software that effectively exchange key information among three mobile robots pertaining to their dmovement, location and orientation.
- To apply the design of a hardware-software system that effectively exchange key information among the three robots pertaining to their movement, location and orientation.

In this project, the focus will be more on to the communication subsystem between the three robots where one robot will act as a master and the other two robots will act as slaves. Using a microcontroller to program the robot and Zigbee which is a communication protocol, the three robots will be able to exchange data from each other. The robots must be able to communicate with each other in form of movement, location and orientation.

CHAPTER 2

LITERATURE REVIEW

2.1 SHORT DISTANCE COMMUNICATION PROTOCOL

2.1.1 BLUETOOTH

Bluetooth usually installed in a mobile phone for faster and secured data exchanged. Data transfer can be up to 100m long in distance provided there is no interference between while the data transfer takes place [6]. Bluetooth can connect up to seven nodes simultaneously where one network will act as the base network or the master. This type of network uses star network topology [7]. Besides that, it is also called piconet [8]. Diagram below shows star network topology.

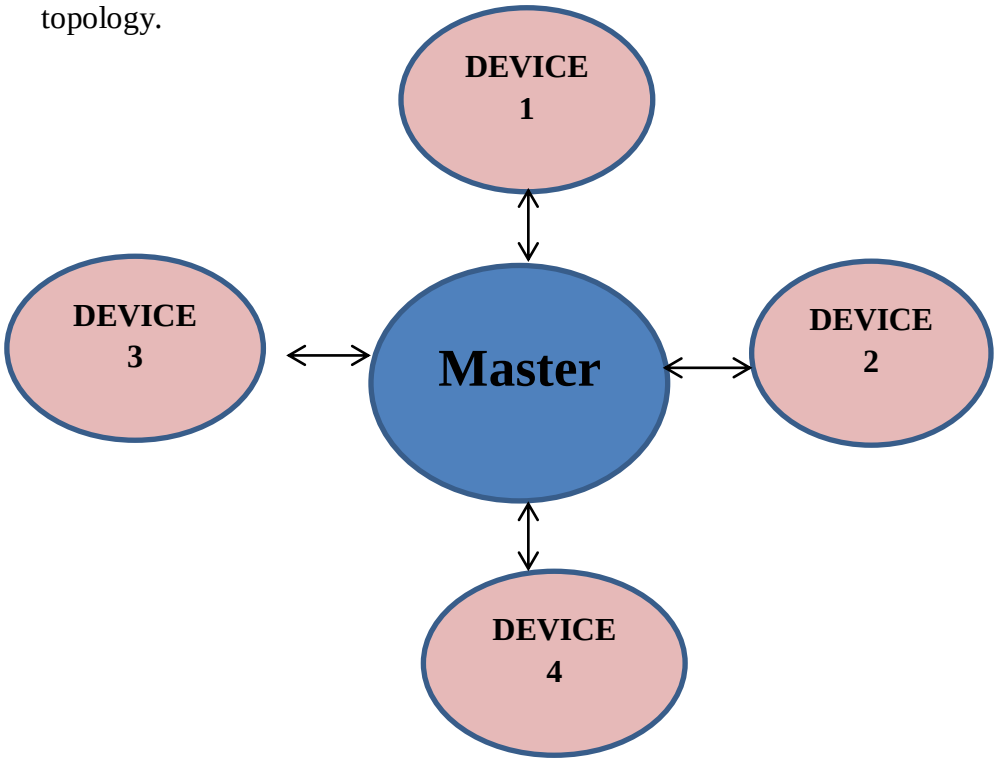

Figure 2.1.1: Star Network Topology [8]

Bluetooth works under standard of IEEE 802.15 where it is operated under unlicensed band of 2.4GHz. Unlicensed band does not require the user to pay the license fee where user can use the device freely. But, even though it is free the user must need to comply with the rules, terms and condition provided. However, there is an outback of using unlicensed band where there will be interference along the data transfer.

Bluetooth can be classified into three classes [8]:

Class 1: +20dBm

Class 2: +4dBm

Class 3: +0dBm

These three classes are to monitor the power output and range. The power output is proportional to the range of the system. Each of the classes except for class 3 required power control output so that the system operated at required output only. The power can be control using received signal strength indication (RSSI) [8]. The transmitter of RSSI will adjust the output power accordingly when it received data from the receiver.

Bluetooth modulate through frequency hopping spread spectrum (FHSS) where the signal will be spread to the transmitter using packet. All data information from the user is stored in the packet in the form of binary where the information can be connected to the computer network [10]. The frequency hop rate for each of the packet is 1600 hops/sec providing that the size of the packet is less than the slot size. Frequency hopping depends on the size of the packet where each time slot is equal to 625μs. When a signal is transmit, it is send through a channel and this signal is then received. After the signal is received, it will recover and demodulate the signal [8][9]. The process will be repeated again and

the data bits can be recovered if the receiver can read the hopping sequence and only a few a bit of frequency taken by the FHSS for hopping [9].

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Bluetooth can support synchronous and asynchronous data, channel and links. The required range for Bluetooth needs to be operated at minimum range of 90dB. In order for the receiver to receive the data effectively, the signal needs to operate at +20dBm and minimum sensitivity of -70dBm [9].

2.1.1.1 BLUETOOTH PROTOCOL

Bluetooth protocol has four categories which are Bluetooth core protocol, telephony control protocols, cable replacement protocol and adopted protocol. Each of the protocol has their designated task. In a Bluetooth core protocol consists of baseband, Link Manager Protocol (LMP), Logical Link Control and Adaptation (L2CAP) and Service Discovery Protocol (SDP). Baseband allows transfer of radio frequency between the Bluetooth to form a piconet and data transfer will be carried in the form of packet. LMP is responsible to set up a security link for the Bluetooth device which includes data encryption, authentication and keys exchange. L2CAP are responsible for high level communication. SDP are most likely involved in all services regarding the Bluetooth devices.

2.1.2 WIRELESS LOCAL AREA NETWORK

Wireless Local Area Network (WLAN) is one of short-range communication that does not require cable or wire for electronic devices to connect to the internet. WLAN is design for easy access anytime and anywhere we are. WLAN falls under IEEE 802.11 where it is operated under unlicensed band of 2.4GHz and 900MHz. WLAN can be operated in two modes which are infrastructure and ad-hoc network. Infrastructure WLAN is connected to the Internet through an Access Point (AP) to the client's network which known as basic service set (BSS) [11]. In a certain range of distance up to hundreds meter, AP can connected to several devices at one time either Wired Lan or wireless. AP will relay data to each of WLAN using unique Service Set Identifier (SSID). Device 1 and 2 can connect to each other using AP as the point of connection.

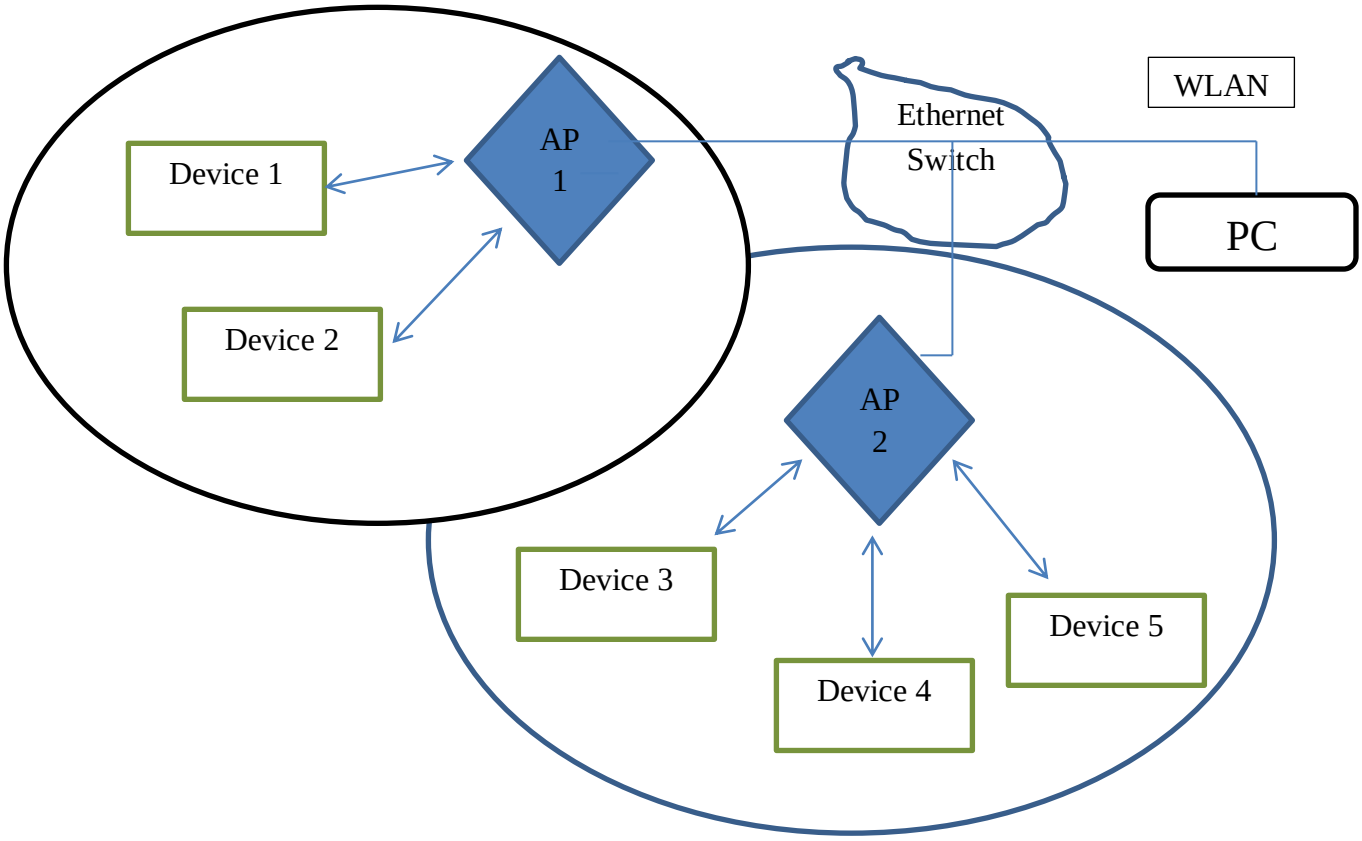


Figure 2.1.2: WLAN Infrastructure [11]

Ad-hoc network is where the unit can communicate with each other without the need of AP. Besides that, this unit can jump from one unit to the other unit. For example, unit 1 to unit 3 instead of from unit 1 to unit 2 to unit 3. This form of network is called mesh network.

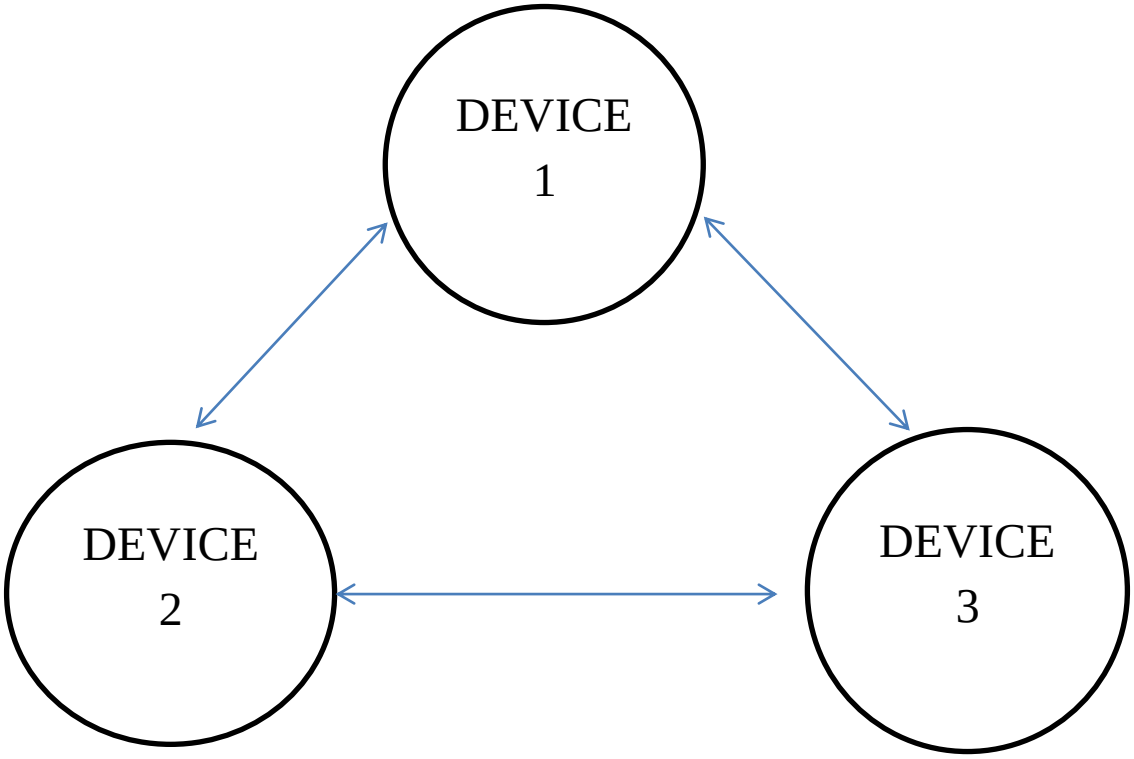


Figure 2.1.3: Ad-hoc network [12]

Diagram below shows the Internet Protocol for IEEE 802 standard. The layer is standardized for all IEEE 802 standards.

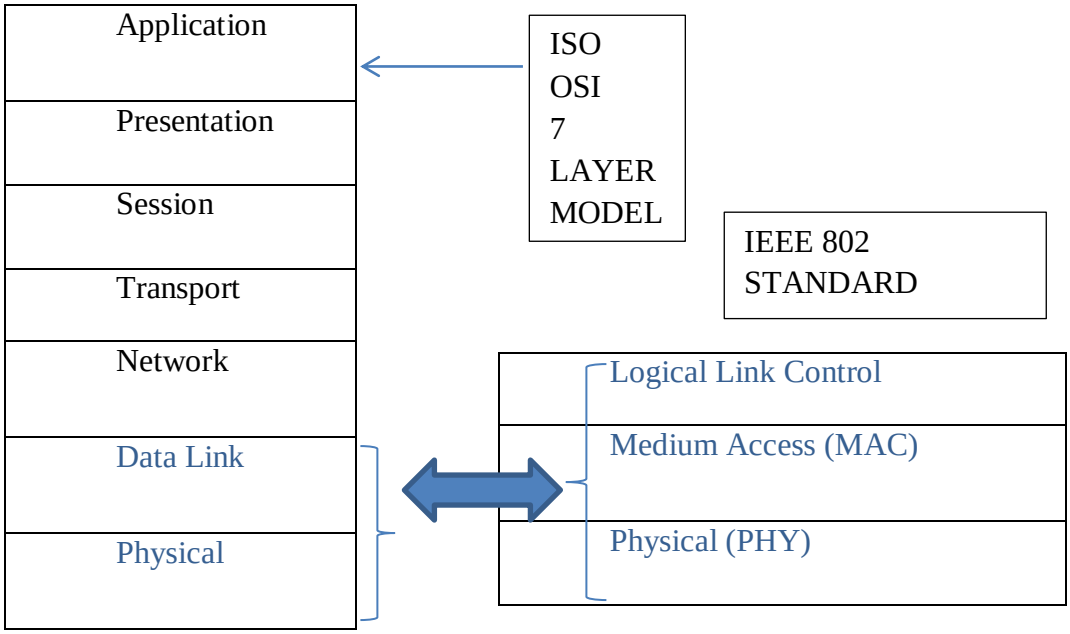


Figure 2.1.4: ISO OSI 7 Layer Model [13]

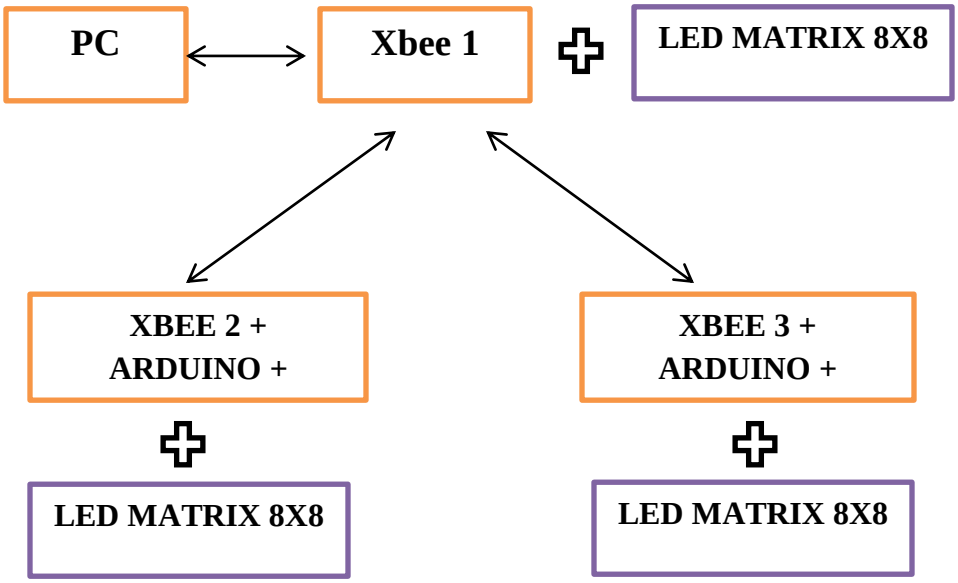
2.1.3 ZIGBEE

Zigbee is designed for low power control devices. Zigbee can operate for a long time without the need of frequently recharging the battery. Zigbee can last long without battery because they can turn to sleep mode and only awake when communication is needed. Zigbee used standard from Zigbee Alliance which operated under three difference unlicensed band depending on where the system deployed. Showed below are three types of band depending on the area;

- 868MHz band ranging from 868.0MHz to 868.8MHz that available in Europe
- 915MHz band ranging from 902MHz and 908MHz that available in North America
- 2.4GHz that is available worldwide

In IEEE 802.15.4 two devices known as full function device (FFD) and reduced function device (RFD) are used to overcome the limitation of range available. FFD is a complete set of MAC where it operates as nodes whereas RFD is the reduce set of MAC where it works as network node[12]. There are two network topologies for Zigbee which are star topology and ad-hoc topology. In star topology only a node are able to connect with more than one device, unlike ad-hoc topology where each of the nodes are able to connect with each other in the system.

In this project, Zigbee is chosen to be the wireless network communication. Three Zigbee devices will be used in this project.



2.1.3.1 STAR TOPOLOGY

Star topology used for small area coverage. Personal Area Network (PAN) will act as the master and the network device only able to communicate with the master. FFD can create its own network by becoming PAN coordinator. In order for other network to join the start topology, it needs to receive message from the packet and send an association request back to the master [12].

2.1.3.2 AD-HOC TOPOLOGY

Ad-hoc network are used for large area coverage. Each of the nodes in the network can communicate with each other within the transmission using multihop communication [12].

2.2 LED MATRIX

Led matrix is arranged in column and row. Diagram below show a 4x4 led matrix representation where rows are represent with letter A to D and column with numbers 1 to 4.

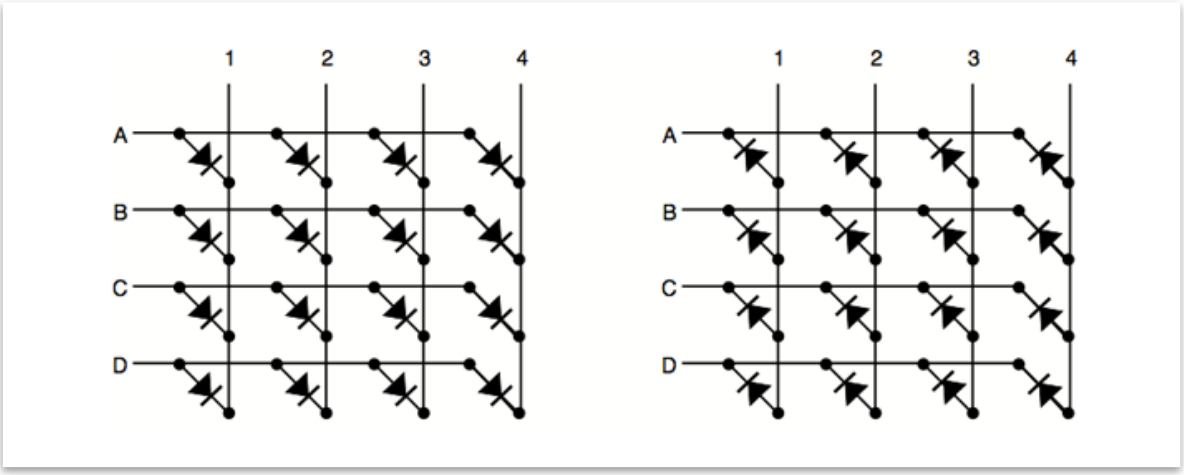
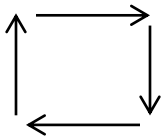


Figure 2.2 : Illustration of Led Matrix 4x4 [14]

Led matrix used in this project is 8x8 matrix. Here, it will display the arrow of direction. For example;



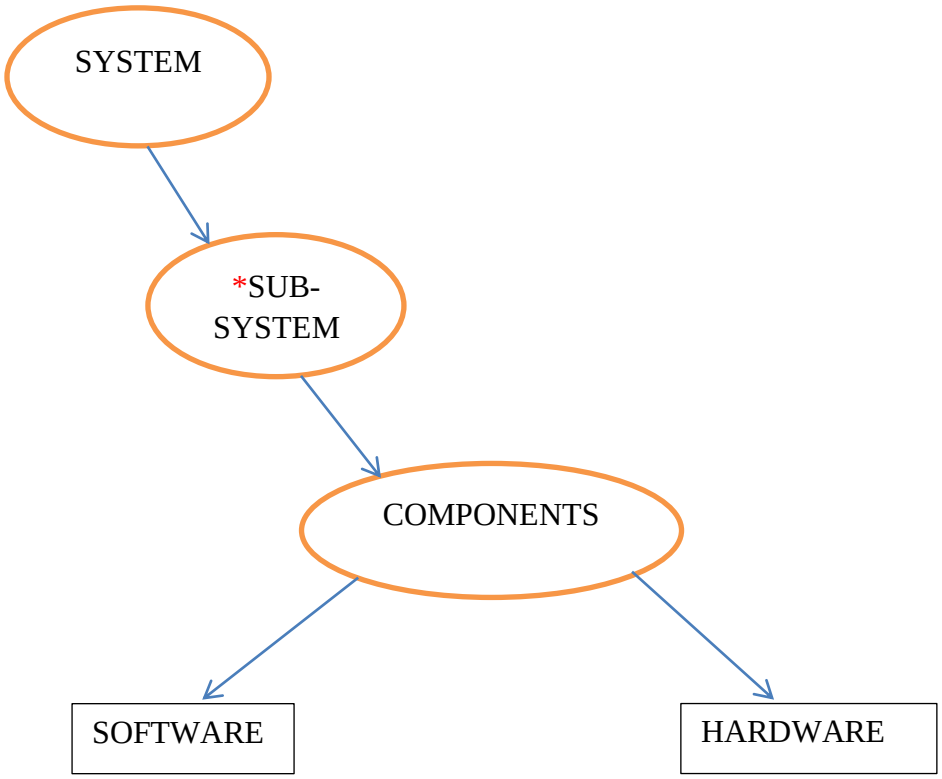
The led matrix will show the direction of forward, reverse, left and right.

CHAPTER 3

METHODOLOGY

3.1 DESIGN BASIS

The fundamental approach on this project starts with be based on V-model methodology which helps to visualize the structure of the project systematically. It also helps to simplify complex activities involves in the project for easy execution process. Each of the phase of the model need to be execute first before moving to the next phase. Figure 3.1 below shows the V-model method in this project.



*NOTE: Major subsystems are communication, navigation, locomotion and localization. This project will focus on the communication subsystem

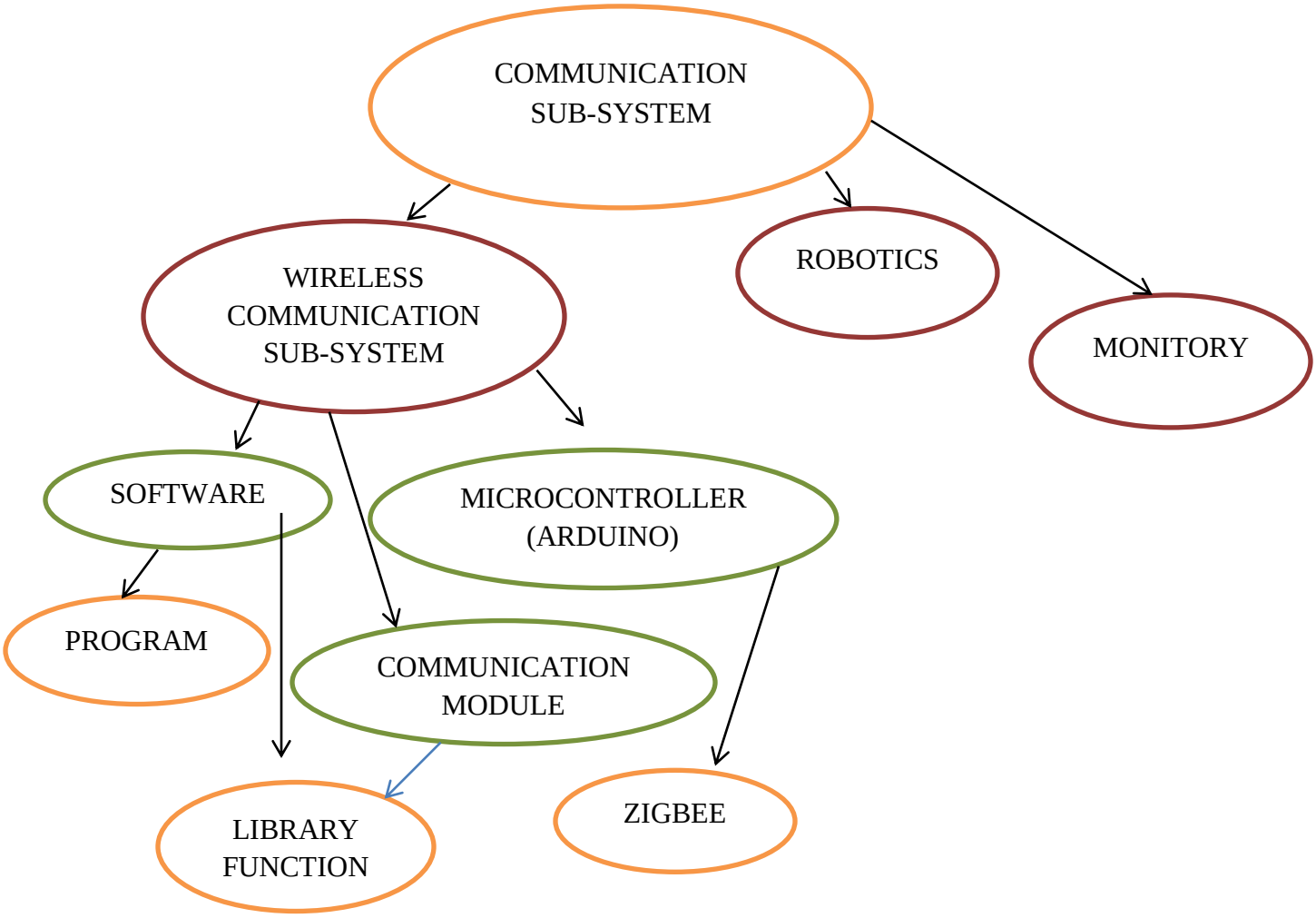


Figure 3.1: V-model methodology

In the first part of the project will be focus on the wireless communication sub-system. Firstly, it is important to identify the suitable wireless communication that need to be used in this project to enable data communication in form of direction and movements. After choosing the most suitable wireless communication devices, a one to one communication is establish where the data is send from one master to one slaves. Later on when one to one communication has been successfully establish, a one to many communication will be establish. After communication between the 3-robot is successfully executed; the next stage will be focus on robotics part. In the wireless communication sub-system, the software used will be determined by the microcontroller that will be used throughout this project which is Arduino Uno since it is easy to interface and be programmed. Programming will be involved in order for the three communications to take place.

3.2 GANTT CHART

3.2.1 GANTT CHART FOR FYP 1

Workflow/task	WEEK													
	SEPT		OCT					NOV				DEC		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title selection	■	■												
Research Work begin		■	■	■	■									
Submission of extended Proposol						●								
Proposal Defence								■	■					
Continuation of Project										■	■	■		
Submission of Interim Draft Report													●	
Submission of Interim Report														●

Table 3.2.1: Gantt chart for FYP 1

Table above shows the Gantt chart of the project throughout the 14 week of the semester.

● Represents the dateline for report to be submitted

3.2.2 GANTT CHART FOR FYP 2

Workflow/Task	WEEK														
	JAN		FEB				MAC					APRIL			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Continuation of project	■	■	■	■	■	■	■								
Submission of Progress Report								●							
Final result/ Findings									■	■					
Electrex											●				
Draft Report												■	●		
Final Report														●	
Viva															●

Table 3.2.2: Gantt chart for FYP 2

● Represents the dateline for report to be submitted

3.3 PROJECT MILESTONE

3.3.1 PROJECT MILESTONE FOR FYP 1

Workflow/task	WEEK													
	SEPT		OCT					NOV				DEC		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research of project														
Design V-model methodology														
Writing for extended proposal														
Survey for microcontroller														
Survey for Zigbee and shield price														
Design of sub-system														
Detailed design of sub-system using Fritzing														
Skeleton coding for arduino														
Purchase of hardware														
1-1 communication of the subsystem														
Successfully 1-1 communication of the subsystem														
1-many communication of the subsystem														
Successfully 1-many communication of the subsystem														
Testing subsystem and handling error														
Writing interim report														

Table 3.3.1: Project milestone for FYP 1

3.3.2 PROJECT MILESTONE FOR FYP 2

Workflow/task	WEEK														
	JAN		FEB				MAC					APR			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Purchase of led matrix															
Purchase of xbee shield															
1-1 communication of the subsystem															
Successfully 1-1 communication of the subsystem															
1-many communication of the subsystem															
Successfully 1-many communication of the subsystem															
Testing subsystem and handling error															
Installation of led matrix to xbee 1															
Installation of led matrix to xbee 2															
Installation of led matrix to xbee 2															
Design of poster															
Preparation for Electrex															
Writing final report															
Preparation for Viva															

Table 3.3.2: Project milestone for FYP 2

3.4 TOOLS

3.4.1 HARDWARE

1. Arduino Uno: Based on ATmega328P where it has 14 input/output pin. It is powered up using a USB cable connected directly to the laptop or can be powered up using battery.

2. Zigbee with shield: The shield allowed Arduino to communicate with Zigbee wirelessly. It is used for mesh network and broadcast network.

3. LED Matrix: Used to display the direction of the subsystem.

3.4.2 SOFTWARE

1. Arduino Software: Since Arduino microcontroller is used, the software will be used since it is open source and compatible with the board.

2. XCTU Software : Programmed the Xbee to see the communication between xctu terminal and serial monitor in arduino

CHAPTER 4

RESULTS AND DISCUSSION

Figures below shows the communication between two Xbee using the Xbee Explorer with XCTU software.

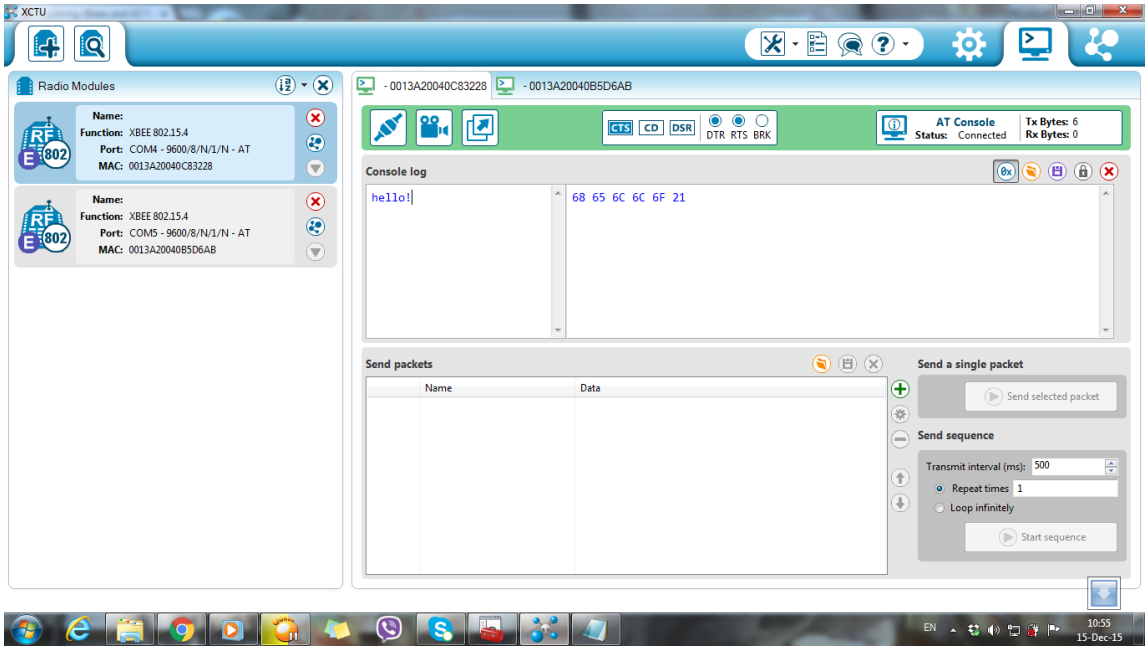


Figure 4.0.1: Data send from one xbee module

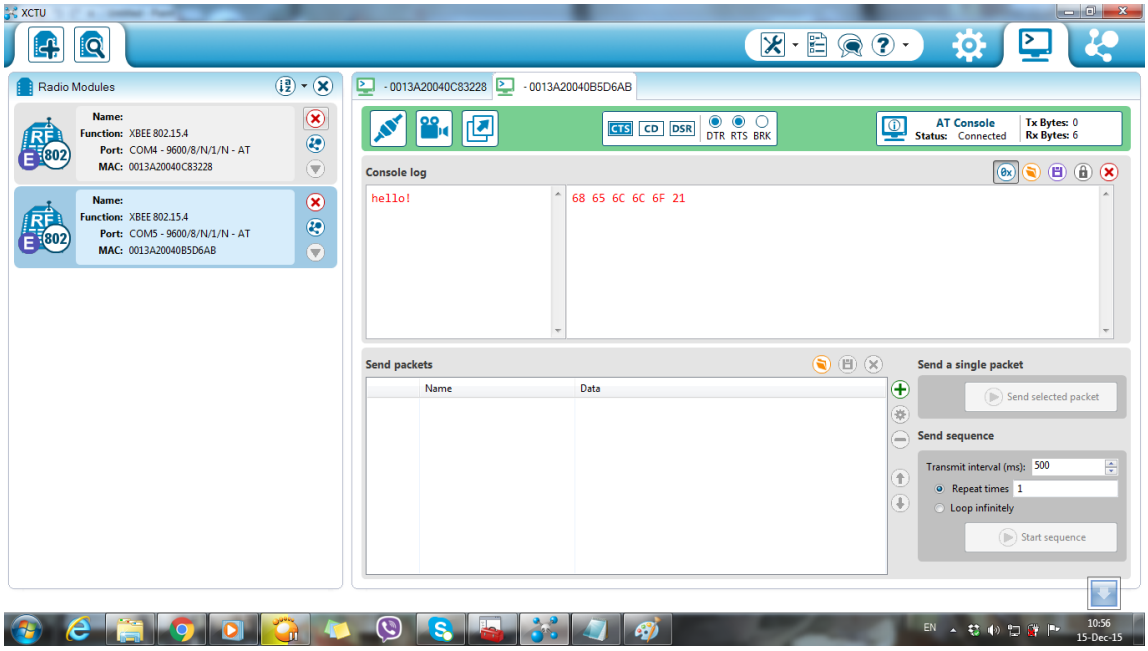


Figure 4.0.2 : Data receive from second Xbee module

The baud rate has been set to 9600 for both Xbee. Before the communication is being establish a few configuration need to be done.

Channel : C

Pan ID: 3333

Destination Address High: 0

Destination Address Low: 0

Source Address: 0

The same configuration is being done to the second Xbee module. The source address for both Xbee module need to be the same so that both of them can send and receive the same data. Words in blue represent data is being send and words in red represent data is received by the second module.

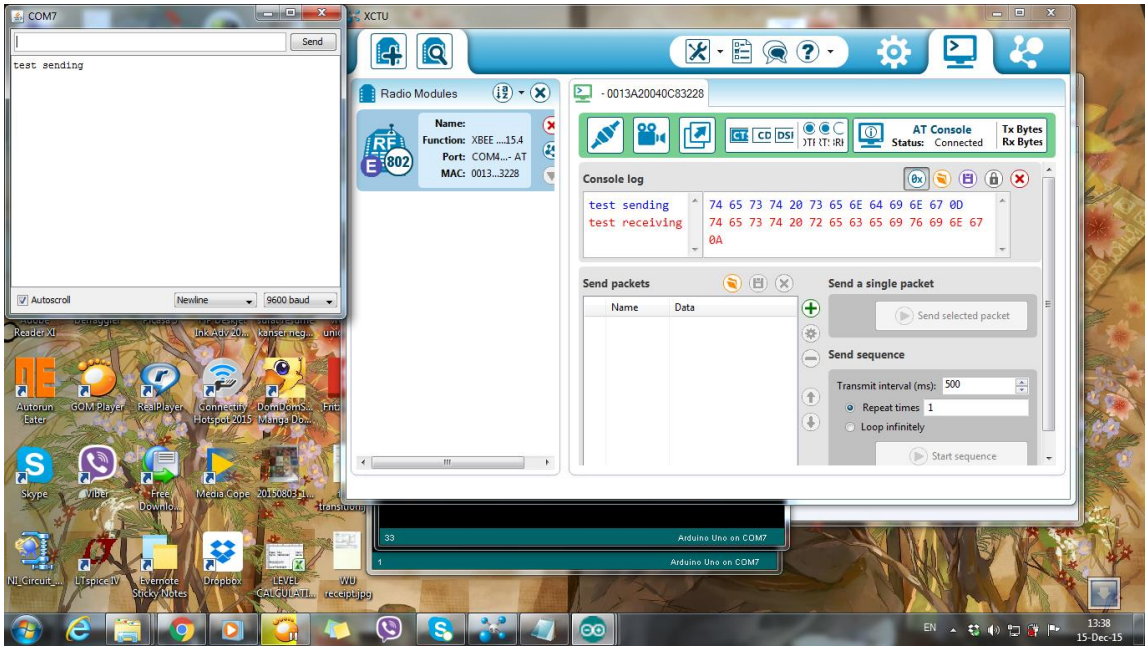


Figure 4.0.3: Communication between xbee module with explorer and arduino board

Using Xbee shield and also Arduino Uno the system is communicating with one another through one to one communication. The blue words represents data is being sent from XCTU or from Xbee with explorer to the Serial port of Arduino software. While, the red words represent data is being received from Arduino software to XCTU.

4.1 Communication between master and PC

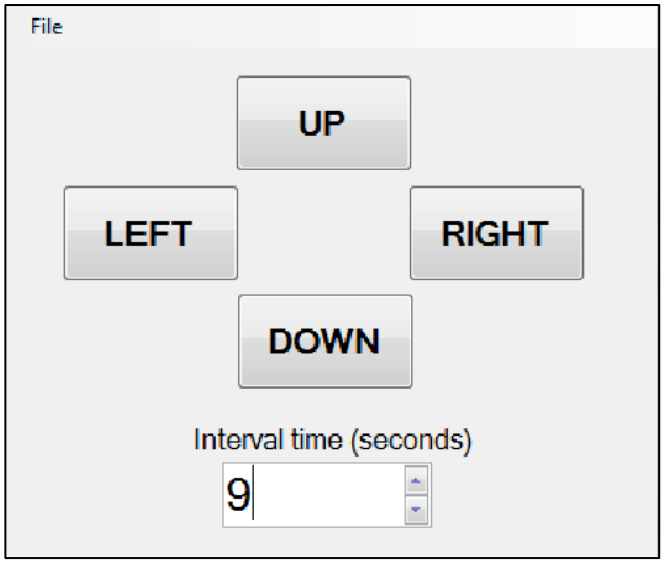


Figure 4.1.1: key operator

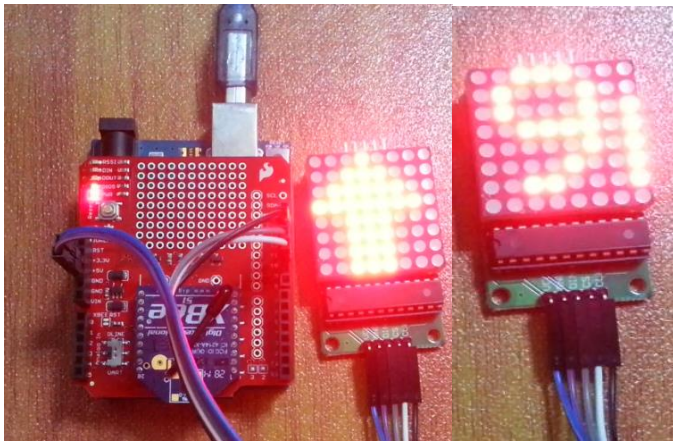


Figure 4.1.2: UP direction with 9meter movement

Figure above shows that the operator of the direction done using Microsoft visual studio. By entering the value of the movement required which is minimum=0 and maximum=100 together with the direction. The data will be displayed on the LED Matrix.

4.2 One to One communication

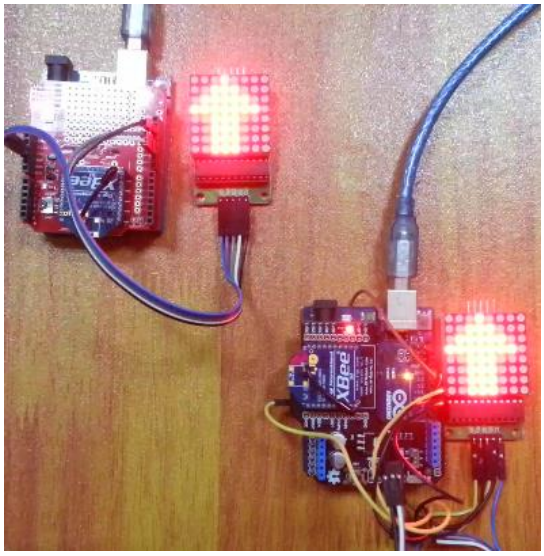


Figure 4.2.1: UP direction with master and a slave

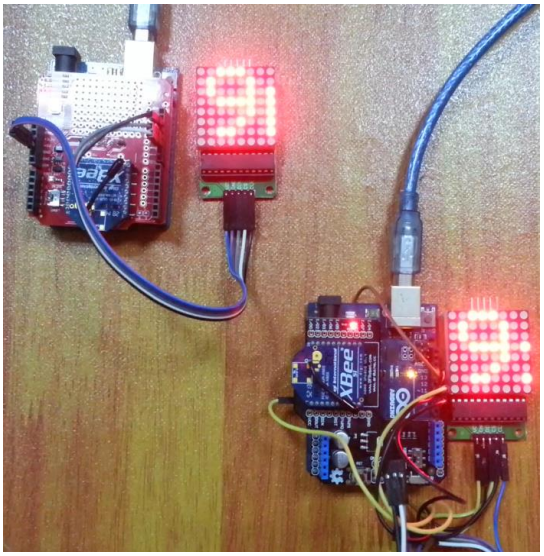


Figure 4.2.2: 9meter movement with master and a slave

Figure above shows that the communication between a master and a slaves. The master will receive the data from the key in required data from the operator and the data will be send to the slave.

4.3 One to Many Communication

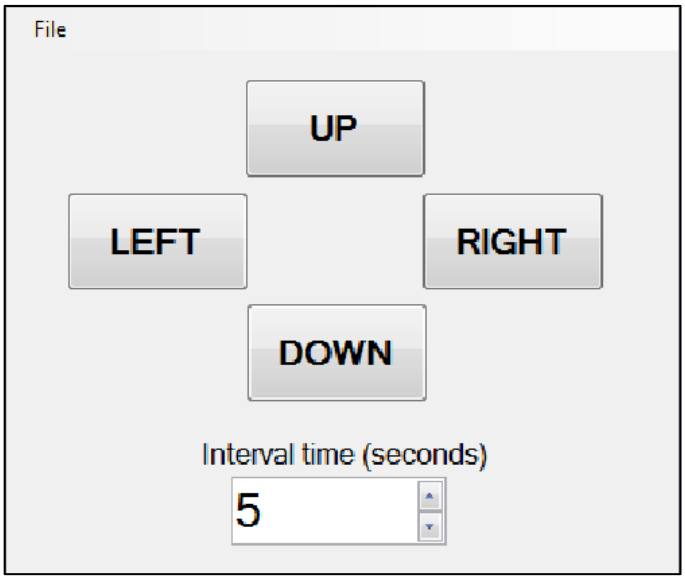


Figure 4.3.1: key operator

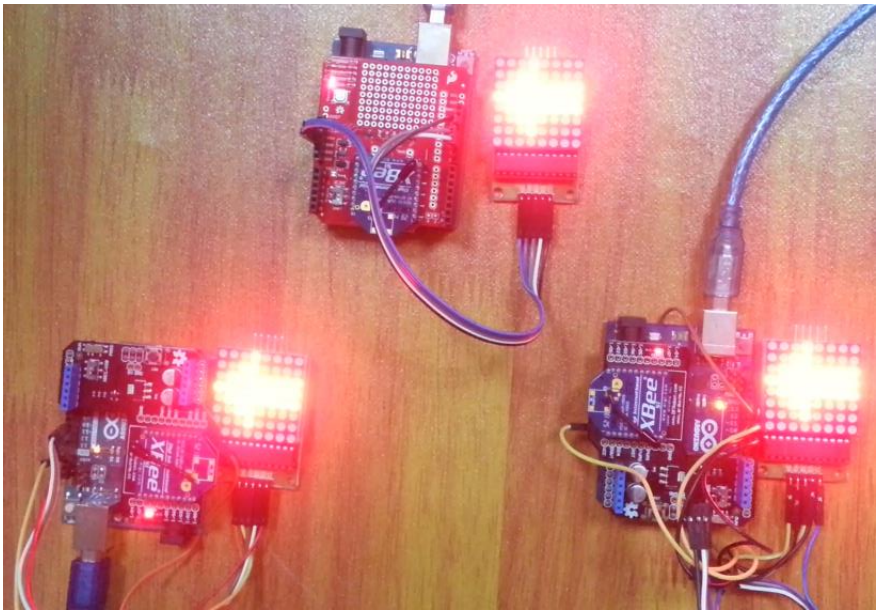


Figure 4.3.2: LEFT direction

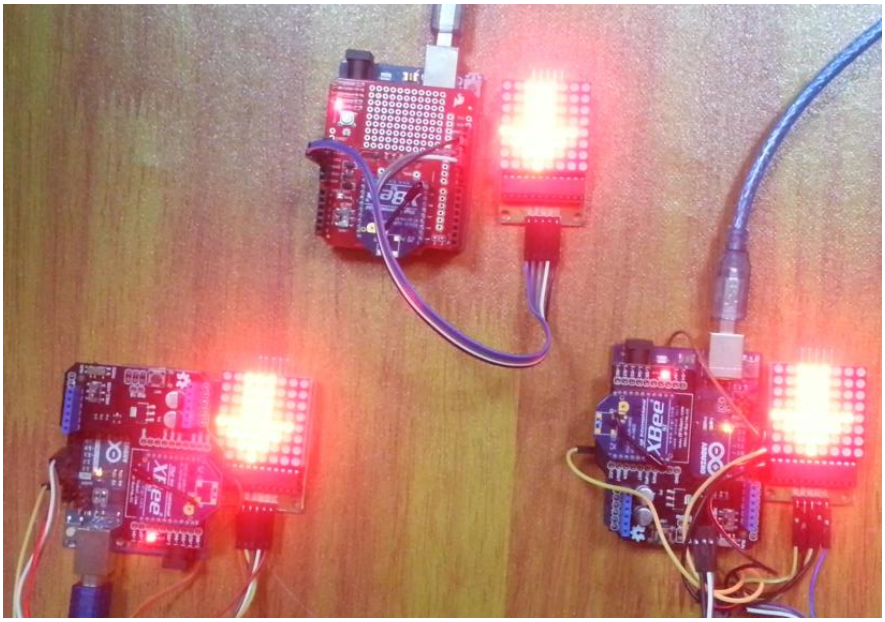


Figure 4.3.3: DOWN direction

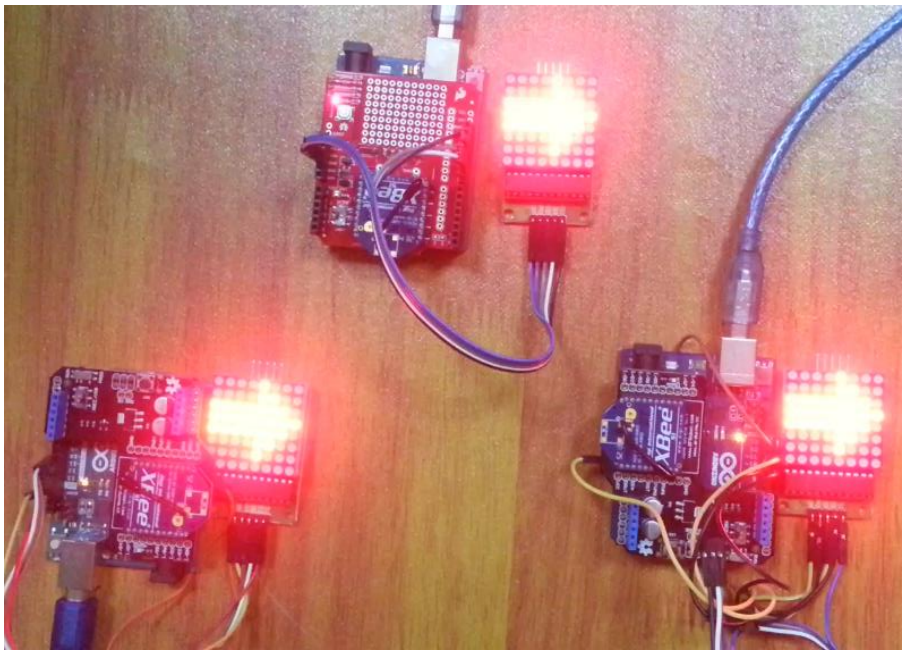


Figure 4.3.4: RIGHT direction

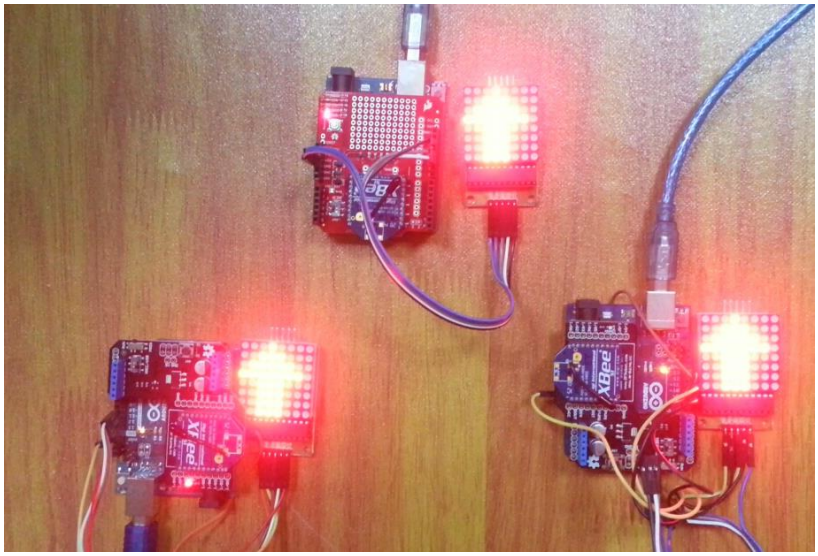


Figure 4.3.5: UP direction

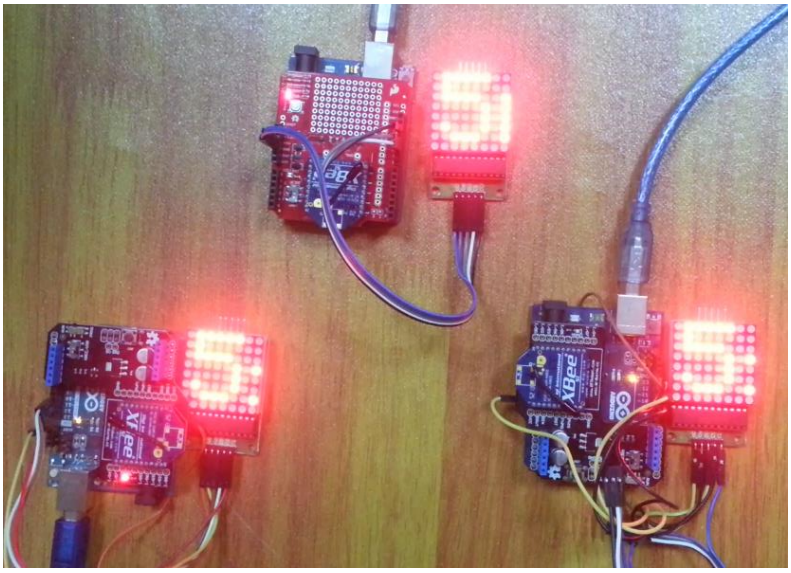


Figure 4.3.6: 5meter movement

All of the figure shown above indicates the direction for all which are Up, Down, Left and Right together with 5meter movement. The data key in from the operator will be send to the master and the master will broadcast the data to both of the slave.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

At the end of this semester it is hope that the 3 communication subsystem are able to communicate with each other accurately, reliable and fast. Attached to the arduino is Led Matrix that will help to display the direction required by the master. As far, the subsystem are able to communicate from one to many. Besides that, the milestone provided must be achieved according to the week stated. Zigbee is choosen to be the communication devices for the subsystem as it is widely used nowadays. Arduino will be used as the microcontrollers as the program are openly available and easy to retrieve. The purchase of all the hardware must be within the budget given which is RM 500. Therefore, items that can get from Electrical Electronic store will not be purchased for cost saving. This project will be further work on for the acknowledgement from slave to the master indicate that the slave already received the data from master. Besides that, the project can be further work for the master to send different data to slave 1 and slave.

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APPENDICES

```
/*
Project: Wireless communication using Xbee and LED Matrix
Programmer: NurFarah Hanim Binti Abdullah
Last Modified: 11 March 2016
Purpose: Final Year Project
*/

#include <SoftwareSerial.h>
#include <SPI.h>
#include <LibraryChar.h>
#include <LibraryChipSPI.h>

SoftwareSerial xbee(2,3);        //RX,TX
MAX7219  max7219(13,11,10);      //clock, data, cs

boolean stringComplete = false;
String inputString = "";
char array[8];

void setup()
{
  Serial.begin(9600);
```

```
  xbee.begin(9600);
  max7219.init(1,0x08,0x07);    //module, intensity, digit
}

void loop()
{
  int i,j,k;
  while(Serial.available())
  {
    char inChar = (char)Serial.read();
    xbee.print(inChar);
    inputString += inChar;
    if(inChar=='B') stringComplete=true;
  }

  if(stringComplete)
  {
    if(inputString[0]=='A')
    {
      inputString[5]='s';
      switch(inputString[1]){
      case 'U':{
        array[0]=0b00001000;
        array[1]=0b00001100;
```

```
    array[2]=0b11111110;
    array[3]=0b11111111;
    array[4]=0b11111110;
    array[5]=0b00001100;
    array[6]=0b00001000;
    array[7]=0b00000000;
    break;}
  case 'D':{
    array[0]=0b00010000;
    array[1]=0b00110000;
    array[2]=0b01111111;
    array[3]=0b11111111;
    array[4]=0b01111111;
    array[5]=0b00110000;
    array[6]=0b00010000;
    array[7]=0b00000000;
    break;}
  case 'L':{
    array[0]=0b00001000;
    array[1]=0b00011100;
    array[2]=0b00111110;
    array[3]=0b01111111;
    array[4]=0b00011100;
    array[5]=0b00011100;
```

```
    array[6]=0b00011100;
    array[7]=0b00011100;
    break;}
  case 'R':{
    array[0]=0b00011100;
    array[1]=0b00011100;
    array[2]=0b00011100;
    array[3]=0b00011100;
    array[4]=0b01111111;
    array[5]=0b00111110;
    array[6]=0b00011100;
    array[7]=0b00001000;
    break;}
  default:{
    array[0]=0b01010101;
    array[1]=0b10101010;
    array[2]=0b01010101;
    array[3]=0b10101010;
    array[4]=0b01010101;
    array[5]=0b10101010;
    array[6]=0b01010101;
    array[7]=0b10101010;
    break;}
  }
```

```
for(i=0;i<8;i++) max7219.send(1,i+1,array[i]);
delay(1000);
for(i=0;i<7;i++) array[i]=array[i+1];
array[7]=0;
for(i=0;i<8;i++) max7219.send(1,i+1,array[i]);
delay(200);
for(k=0;k<4;k++)
{
  for(j=0;j<6;j++)
  {
    for(i=0;i<7;i++) array[i]=array[i+1];
    if(j<5) array[7]=Font7x5[inputString[k+2]-32][j];
    else array[7]=0;
    for(i=0;i<8;i++) max7219.send(1,i+1,array[i]);
    delay(200);
  }
}
for(j=0;j<7;j++)
{
  for(i=0;i<7;i++) array[i]=array[i+1];
  array[7]=0;
  for(i=0;i<8;i++) max7219.send(1,i+1,array[i]);
  delay(200);
}
```

```
    }
    inputString="";
    stringComplete=false;
  }
}
```