School of Engineering & Design

Electronic & Computer Engineering

MSc *Advanced Electronics & Electrical Engineering*

Brunel University

Using zigbee to monitor patients around their homes

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September/2014

A Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science

School of Engineering & Design
Electronic & Computer Engineering

MSc Advanced Electronics & Electrical Engineering

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Using zigbee to monitor patients around their homes

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Declaration: *I have read and I understand the MSc dissertation guidelines on plagiarism and cheating, and I certify that this submission fully complies with these guidelines.*

ACKNOWLEDGEMENT

I would like to express my appreciation to everyone who has helped me complete this dissertation.

Many thanks to my dear supervisor Dr. Kostantinos Banitsas for his incomparable guidance and encouragement.

I would like to express my sincere and emotional appreciation to my beloved family members for their genuine and continuous support.

Special thanks to Dr Maysam Abbod, Prof Dr Bala and University’s technicians for their help and support.

Many thanks to Brunel University Electronic Engineering department for providing the facilities and equipment for this research process.

ABSTRACT

Patient health monitoring systems based on wireless communication has recently been drawing the attention, on the electronic industry. This project researches on the use of zig bee wireless communication for the use in patient monitoring. The zig bee standards are superior to Bluetooth as it has reduced power consumption, wider communication range and a reduced cost in long term. This wireless method in particular supports a communications standard that provides a short range of cost effective networking capability.

The dissertation aims to measure patients' body temperature signal using a LM35 temperature sensor and obtains the heart rate signal using a pulse oximeter sensor from the patient unit. The sensor signal received by the zig bee RF module is then transmitted to receiver via zig bee RF module in a form of a medical signal. Meanwhile, Arduino UNO microcontroller processes the patient signals and displays the results on the remote units (checked by the doctors or caregivers). The device assists continuous monitoring of the patients' signals and transmission to the doctors or caregivers in real time. So the doctors are able to evaluate the medical signals measured by sensors and take necessary action.

In a nutshell, by using the zigbee monitoring system patients are free to leave the hospital, carry on daily activities and still be safely monitored. This saves time for patients, space for hospital and minimises cost.

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LIST OF ABBREVIATIONS

IEEE	Institute of Electrical and Electronics Engineers
PC	Personal computer
WLAN	Wireless Local Area Network
RF	Radio frequency
ECG	Electrocardiogram
PDA	Personal Digital Assist
(WSN)	Wireless sensor network
ICSP	In Circuit Serial Programming
DC	Direct current
AC	Alternative current
LED	Light Emitting Diode
USB	Universal Serial Bus
SRAM	Static Random Access Memory
EEPROM	Electrically Erasable Programmable Read Only Memory
PWM	Pulse Width Modulation
KB	Kilo Byte
CMOS	Complementary Metal –Oxide Semiconductor
RISC	Reduced Instruction Set Computer
MIPS	Million Instruction per Second

WPAN	Wireless Personal Area Network
PAN	Personal Area Network
MAC	Medium Access Control
PHY	Physical
RFD	Reduced Function Device
FFD	Full Function Device
TX	Transmitter
RX	Receiver
Bpm	Beat per Minute
IDE	Integrated Development Environment
GUI	Graphical User Interface
IR	Infra-Red
µF	Micro-Farad
Hz	Hertz
HR	Heart Rate
LabView	Laboratory Virtual Instrumentation Engineering

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Telemedicine is one of the newest technologies which studies the medical information exchanged (transmits information from one side to another by electronic communication). This new technology is combines telecommunication and information technology for medical purposes; such as patient monitoring. There are many advantages of a patient monitoring system. To name but a few, reducing the risk of infection and other complications in order to ensure safety in working environment. In addition, implementation of patient monitoring system in hospitals might reduce the costs in long term, as regards to installation and also maintenance of wiring. In short, the main function of telemedicine is to improve, maintain and assist patients' health status. In addition, it is aimed to provide cost effective alternative for information transfer, hence reduce costs for rural patients and to improve professional isolation of the rural doctors. Patient monitoring is vital for home-care systems, therefore is one of the most popular topics of telemedicine that is developing continuously. [12]

In the recent years, wireless sensor networks are applied to many home-care system researches. Many Wireless Technologies like RF, Wi-Fi, Bluetooth and Zigbee have been developed and remote monitoring systems using these technologies are popular due to flexibility, low operating charges, etc. Today Wireless Sensor Networks are used in increasing number of commercial solutions, aimed at implementing distributed monitoring and control system in a great number of different application areas. [1, 2, 5, 8]

In the current project, we will investigate the Design and Development of a Wireless Remote Patient Monitoring System using Zigbee. ZigBee has got its' name from the way bees zig and zag, while tracking between flowers and relaying information to other bees about where to find resources. ZigBee has been introduced by IEEE with IEEE 802.15.4 standard and the ZigBee Alliance is to provide the first general standard for these applications. It is a new global standard for wireless connectivity, focusing on standardizing and enabling interoperability of products. This wireless method is a communications standard that provides a short range cost effective networking capability. It has been developed with the emphasis on low-cost battery powered applications. To find out more information about zig bee refer to chapter 3.2.2. [7, 9]

In many cases, the patients in the hospital do not need active medical care. Mostly, the principal reason for a lengthy stay in the hospital is simply continual observation. Hence, efforts have been made to avoid acute admissions and long lengths of stay in the hospital. Recently, emergency admissions and long-time of stay have become extremely costly especially for age-related chronic diseases such as stroke, heart disease and high blood pressure. As well as improving the distance monitoring of the patients, usage of wireless equipment will reduce space required at the hospital environment and the number of staff needed for information transfer. Furthermore, patients under monitoring need to revisit the hospital for health examinations frequently. This is unfavourable way of tracing the health condition of patients, because it is inconvenient and not time effective for the patient. Therefore, Using zig bee to monitor patients around their homes is currently the best option to resolve the problems mentioned above. [2, 3, 6, 7]

1.2 Project Units

This current study consists of two main units. The first one is home unit which includes a patient monitoring for medical signals. The measured medical signals or parameters data will be transferred to the central receiving unit through wireless communication. For transferring data through wireless is being going to use zig bee technology .The second one is remote section, in this section all related measured signals and parameters will be seen on the laptop or PC. As a result the doctor can evaluate the medical signal measured by sensors and according to patients' condition, it would need to give some recommendations or if it is an emergency the doctor can take the necessary action.

1.3 Aim and Objectives

Aims

The aim is to design a system based on Zigbee that will be capable of communicating information between local patients and doctors (wireless monitoring). According to measured medical signals via zig bee communications, the Doctor will have the opportunity to evaluate results and give necessary recommendations to patients. If a patient in unable to overcome the problem as an individual, the Doctor could visit local patient or can call emergency service to take immediate action.

In addition, an implementation to low cost and power consumptions will be discussed. It would be valuable to extend the research about how the battery life could be improved.

Objectives

- Primarily looking at the existing status of research in remote monitoring.
- To design low cost intelligent embedded system based remote monitoring system.
- The major aspect of the research had been to work out strategies to keep operational cost of the system minimum to emphasize its utility to automate simple systems with remote monitoring capabilities.
- Develop wireless sensor networks, radio transceivers, etc. spread over a local area.
- Study the zig bee technology in depth and understand if it is possible to develop these technology specifications.
- Collect all equipment which is needed for the best monitoring communication.
- Look in to research about this topic, focus on solutions and observe advantages and disadvantages of this system.
- Go through laboratory tools to implement all needed tests and develop codes in order to communicate between zig bee and monitoring.
- Research to find out the best requirements for implementing zig bee monitoring communications.

1.4 THESIS OUTLINES

This thesis contains five chapters, namely; introduction, literature review, methodology, results and discussion and the last one is conclusion and future work.

In the introduction section it generally talks about the use of telemedicine on patient monitoring (with wireless network) and the benefits for the health care system.

Additionally it gives a deep explanation to why the zig bee standards should be preferred. This chapter also consists of background, project unit, aim and objective for the project.

In the chapter literature review, different methods of related researches regarding patient monitoring wireless network applications are discussed. In addition, the projects aim and methodology is summarised and the details about devices which are used during designing the related work is given. Hence, these academic studies' designing schemes have been given figures.

Following chapter is methodology. This chapter studied on hardware and software methods. Thus, prototype design of the patient monitoring system based on the zig bee is described in the block diagrams and figures. The chapter discusses the type of devices and materials used in the current study. Hence, detailed theory and information is given about the temperature sensor (LM35) and pulse oximeter as regards of measuring body temperature and measuring heart rate, respectively. As well as, detailed principles and specifications of Arduino UNO software, microcontroller, and X-CTU software are provided. Furthermore, Zig bee specification and features are analysed. Especially, transmitter and receiver module configured to obtain patient information from one side to another side.

The result and discussion chapter proves that the results are taken from the proposed system. Hence, the signals and data are analysed and compared. In the meantime, the results are displayed with figures, photos and block diagrams. Also, some requirements to obtain results from the project are given.

Last but not least is the conclusion and future work chapter. In this chapter, final outcome is reached about the success of the project and the need for further work related to the current topic.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This project idea is coming from the problems that are encountered by the health staffs to monitor the patient properly because of the problem of lack of space (in wards) within the hospital and also the high cost needed to install and ensure maintenance of wiring for the patient monitor.[2, 3, 6]

This chapter also give details about the theory and basic concepts of electronic components that have been used in the project such as Arduino Uno board, zigbee (xbee pro series 1), pulse sensor, temperature sensor (LM 35), XCTU software, Arduino UNO software.

2.2 RELATED RESEARCH

Tagad et al. implemented a wireless medical interface based on ZigBee. Home section unit composed of patient monitoring with parameters such as ECG, movement sensing and body temperature. The measured parameter data from home unit transferred to the central receiving unit through Zigbee communication. The purpose is to acquire, process, and transfer raw data from medical devices to zig bee network. The zig bee network connects to PC or PDA for further processing.

The measured parameter data transferred to the central receiving unit through Bluetooth communication or Zigbee Technology. In Remote section, RS232 acquires data from zig bee and measured parameter data, which is displayed with the help of Ethernet communication. To support this, SMS could be sent to Doctor's mobile. If a problem occurs, the alarm will process. According to patients' health situation and Doctors' decision necessary action could be taken. e.g., contact the patient to give some advice or send an ambulance to their home. [1]

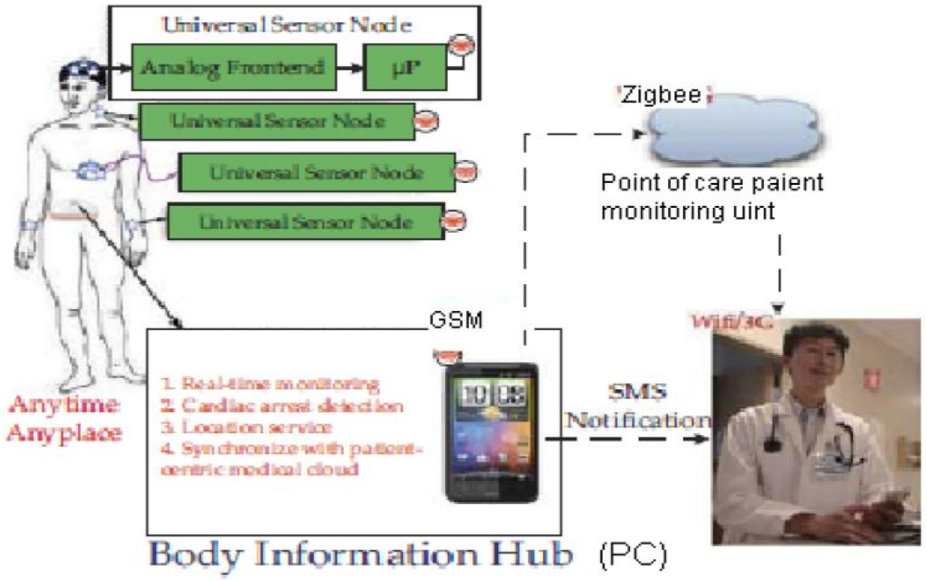

Figure 2. 1 the proposed care patient monitoring system [1]

Navyal et al. studied on wireless sensor network (WSN) for monitoring patient's physiological conditions continuously using Zigbee. Patient's physiological conditions are monitored by sensors. The output of these sensors (Heart rate signal, temperature, saline level) is connected to microprocessor and then transmitted by Zigbee. At the remote wireless monitor, measured signals are received by Zigbee and then the signal is sent to the PC (personal computer) via the RS-232 serial port communication interface. Although Bluetooth is better than Zigbee for transmission rate, ZigBee is preferred because of lower power consumption. [2]

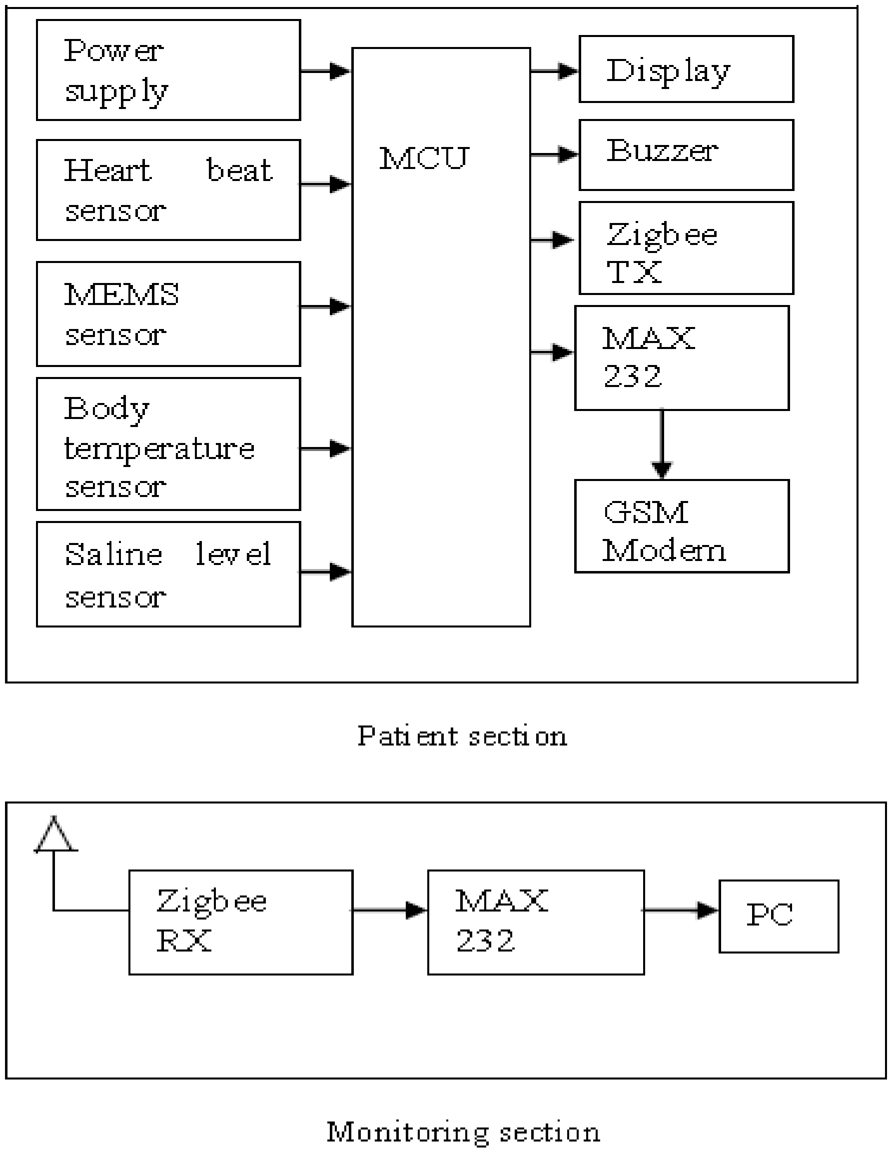

Figure 2. 2 Functional block diagram of the system hardware [2]

Arun et al. study focus on remote patient monitoring using Bluetooth and enabled mobile of the Doctor. In this project, each patient is connected to a temperature sensor. Measured data are interfaced with the system at the patient end. At the patient end system data is received by server and Doctor mobile via Bluetooth. The central database of all the patients is stored by the server system. If the situation is abnormal, then the parameter is immediately intimated to the Doctor. The negative sides of this project are the Bluetooth has a short-range communications where the range is limited, high current consumption and expensive compared to zigbee. [11]

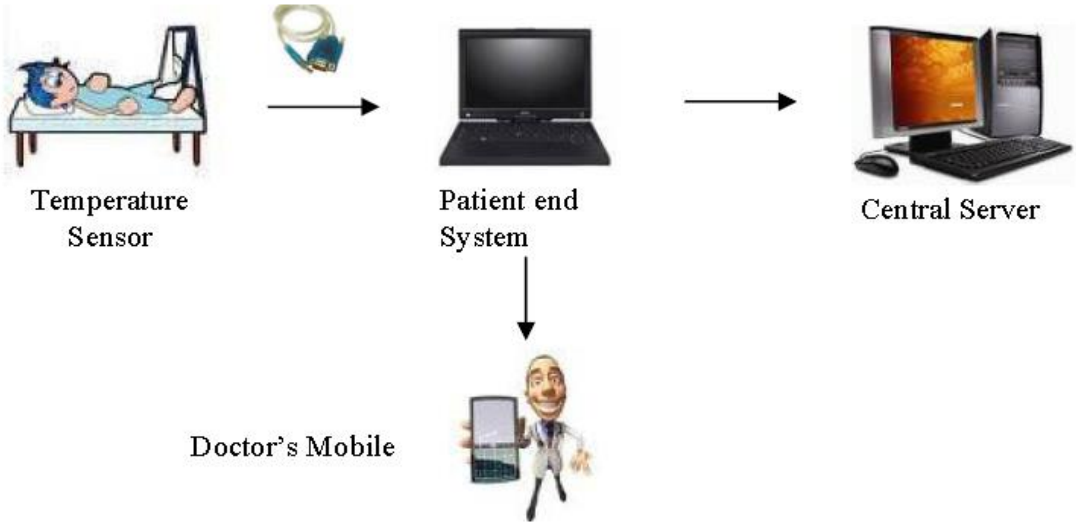

Figure 2. 3 System working model [11]

A. Sagahyroon et al. researched on monitoring the patients' signs wirelessly. This study implemented the monitoring system to patients on the hospital floor. The system consisted of end units carried by the patients which collected the sense data (health sign readings) and this is transmitted to the coordinator unit to the floor nurse.

One of the advantages of using zigbee-based network is to make the patients feels comfortable and allows them to move freely. Furthermore, it also contributes to the cost reduction efforts in health care. This project proposed prototype was tested in the laboratory setting by monitoring the heartbeat, temperature and acceleration of few subjects. The patient data received using the zigbee wireless network were compared against data obtained using regular static devices such as a thermostat placed under the patient's tongue or by using the stethoscope to measure the beat for calibration process. The challenge in this research is the limitation of zigbee transmission and reception range, which needs a further development.

The results are displayed as shown in Figure 2.4. [13]

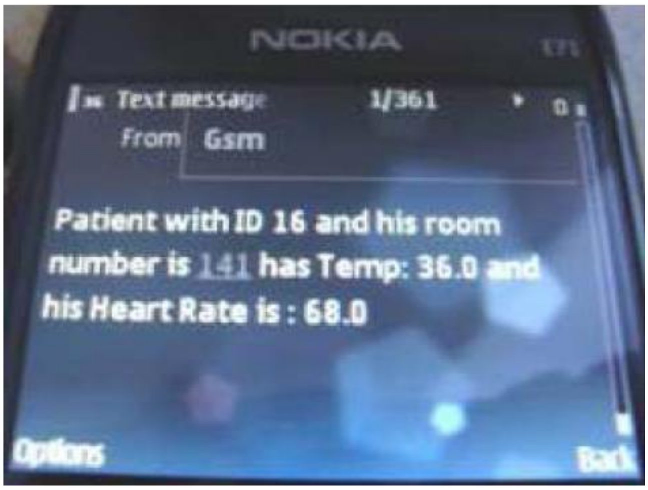

Figure 2. 4 Screen Shots from the Physician's Mobile Phone [13]

K.AlSharqi et al. studied on the system which consists of a set of biomedical sensors attached to the body of a patient and the patient signal coordinated through the microcontroller unit (in current project they used Arduino) and transmitted wirelessly. The patients' data is received by the receiver module and is transferred to local monitoring unit. In this work, four biomedical sensors were used to monitor changes in; heart beat rate, temperature, muscles power, and ECG signals from patients. These sensors transform the physiological changes of the patient's body into biomedical signals. The Arduino microcontroller reads analog data from the sensors and controls the transmission of data to the patient monitoring unit. The physicians have a chance to evaluate the readings and if the medical signals are abnormal, they can give recommendations according to data monitoring unit displays.

The wireless receiver unit consists of Xbee that receives data and sends it to the local monitoring unit. The monitoring unit can display, record, and analyse the data. It can send reports as well as alarming messages to the healthcare professionals. The system block diagram of the proposed system is shown in Figure 2.5. [14]

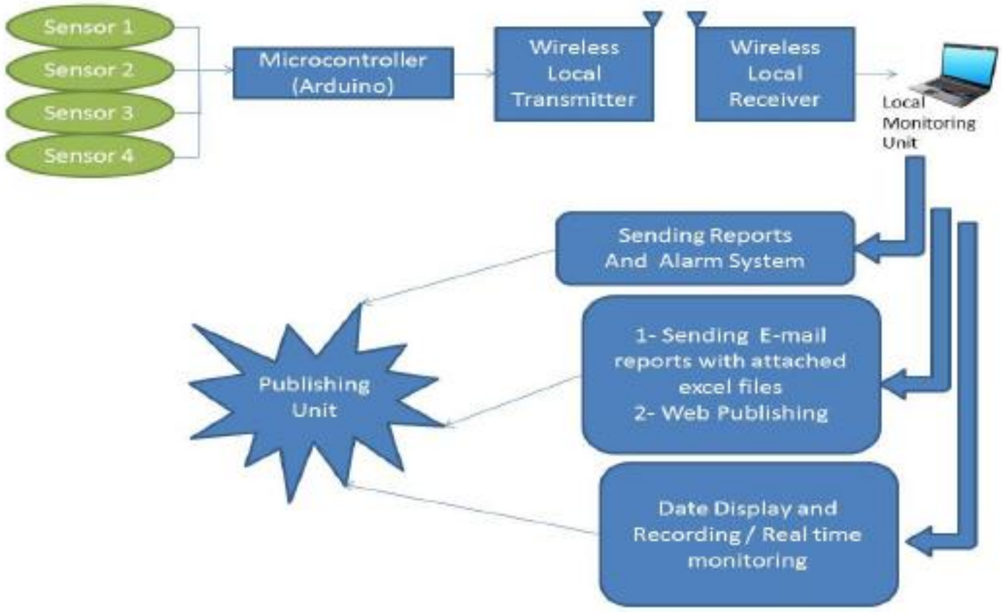

Figure 2. 5 The system block diagram [14]

N.S.A.Zulkifli et al. study's system proposed of pulse oximeter (non-invasive medical equipment), Xbee modules and Arduino-Nano. Two units of pulse oximeter are attached to the XBee via Arduino-Nano as the brain of the system. Pulse Oximeter were used to get the heart rate data of a patient. Then, these patients data are transferred to the Arduino to be processed before transmit wireless through XBee. Arduino is one of the microcontrollers that can transmit data widely. This step helps to miniaturize the system created. Each pulse Oximeter is symbolized as node A (Patient 1) and node B (Patient 2). Each set consisted of Arduino-Nano, XBee and Pulse Oximeter. This combination of units is acknowledged as transmitter part.

Each node is responsible to read the data in real time (continuously) and need to be reprocessed by the Arduino-Nano in order to give a unique ID address to each of them. Fortunately this way, overlapping of data can be avoided.

On the other side, in the receiver part, Xbee was connected to CP2102 serial port and interfaced with PC unit. The main function of CP2102 in this project is to power up the XBee. Xbee modules obtain data from node A and node B (from pulse oximeter). Latter to the collection of data, the information is transferred to the nearest XBee or is directly transmitted to the Coordinator.

All patients' multiple data is identified at the receiver side and is displayed on a single monitor. Thus, it might be easier for the medical practitioner to monitor many patients simultaneously. The weakness point of this project is the data which is obtained from the pulse oximeter is locked by its own unique ID that leads to nonuniform data transmission at real time. [15]

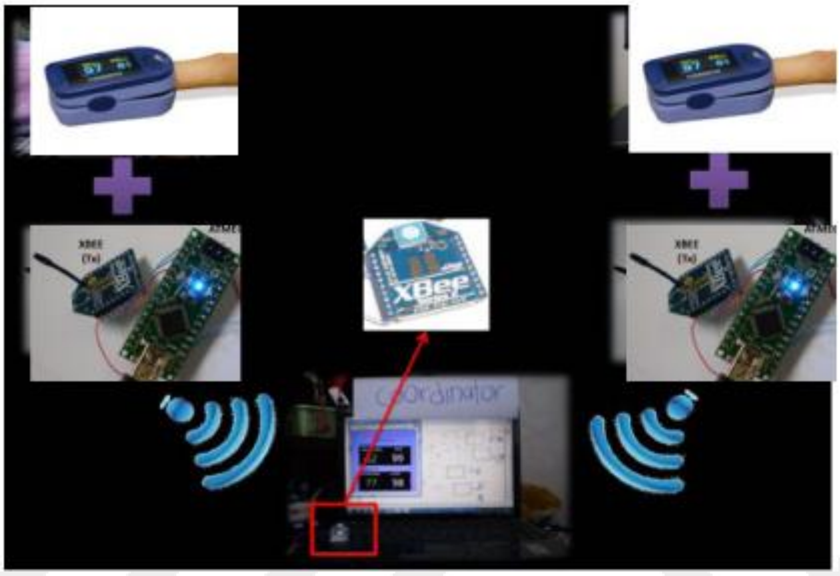

Figure 2. 6 Setup for ZigBee Wireless Mesh Networking [15]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will concentrate on the methods implemented on the current project. The project consists of hardware software design. The hardware design section focuses on the Arduino UNO microcontroller unit which obtains patients signals from pulse oximeter sensor, Xbee modules and temperature sensor (LM35). In the meantime, software design part includes Arduino software that processes patient data and X-CTU software which is used for Xbee configuration.

3.2 HARDWARE DESIGN

In this section, design, data-acquisition and implementation of the project system is discussed. The discussion includes Arduino UNO microcontroller unit, pulse oximeter sensor, Xbee modules and temperature sensor (LM35) as mentioned just above. The design of hardware is shown in the figure below.

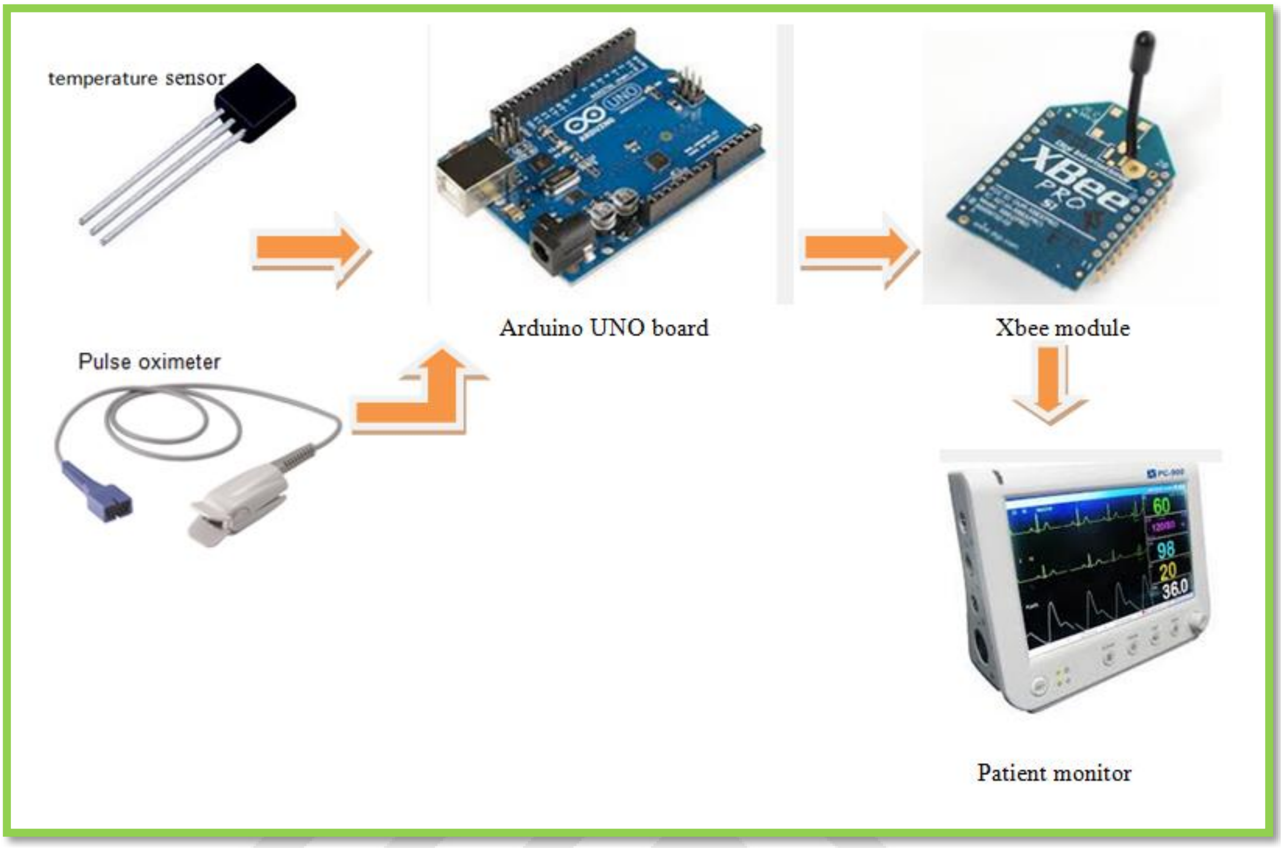

Figure 3. 1 Design of patient monitoring system

As shown in figure 3.2, temperature sensor will measure the temperature of the patient from their fingertip. This date is then interfaced with Arduino to be processed before transmitting wireless information through XBee. Meanwhile, Pulse Oximeter could be used to read the heart rate data of a patient from the patient's finger. Whereas the Arduino Uno board, reads and processes the data which has been transferred by Xbee transmitter module. All the data received by the receiver Xbee module will be sent to patient monitor.

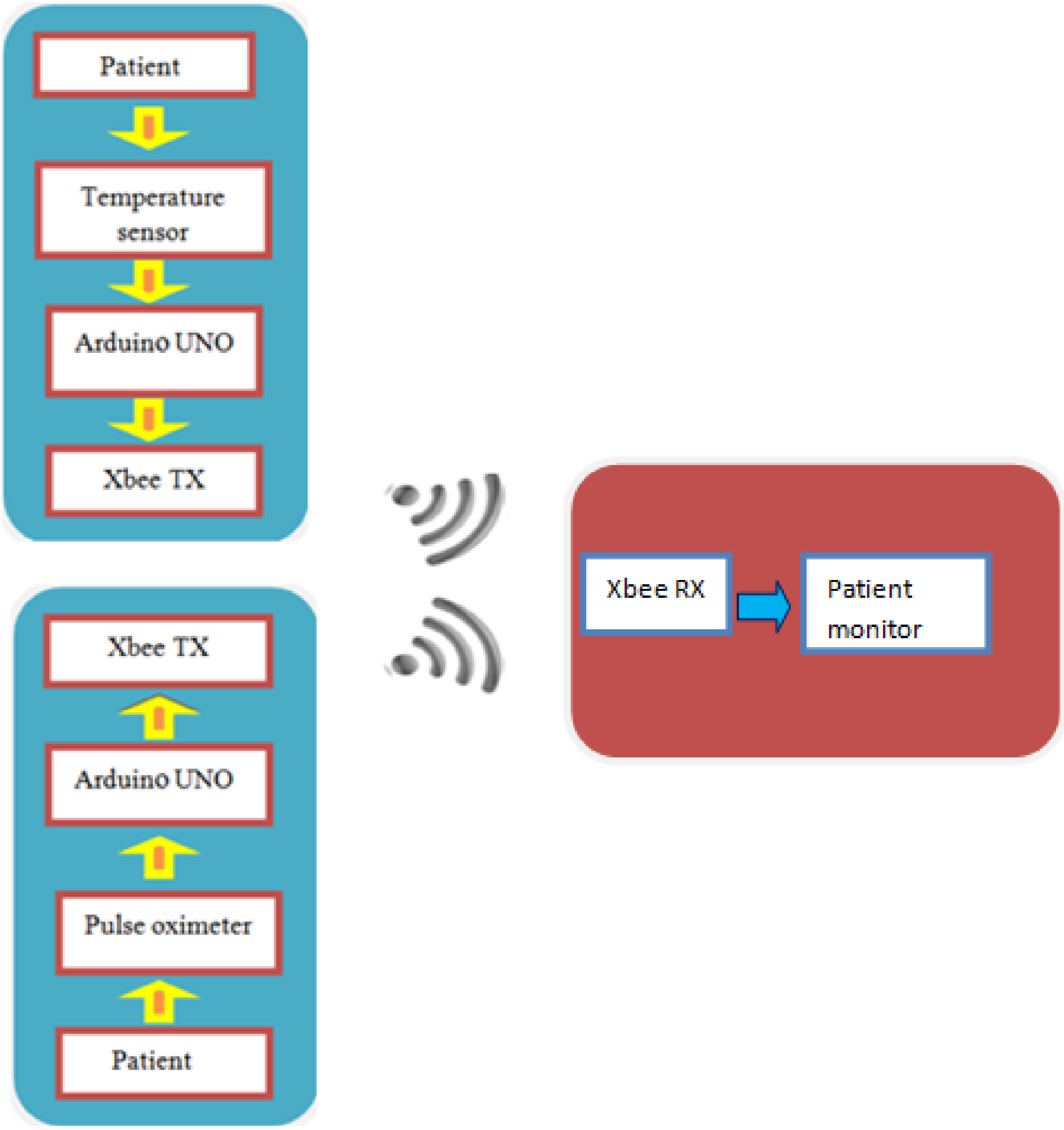

Figure 3. 2 Block diagram for whole system

3.2.1 ARDUINO UNO

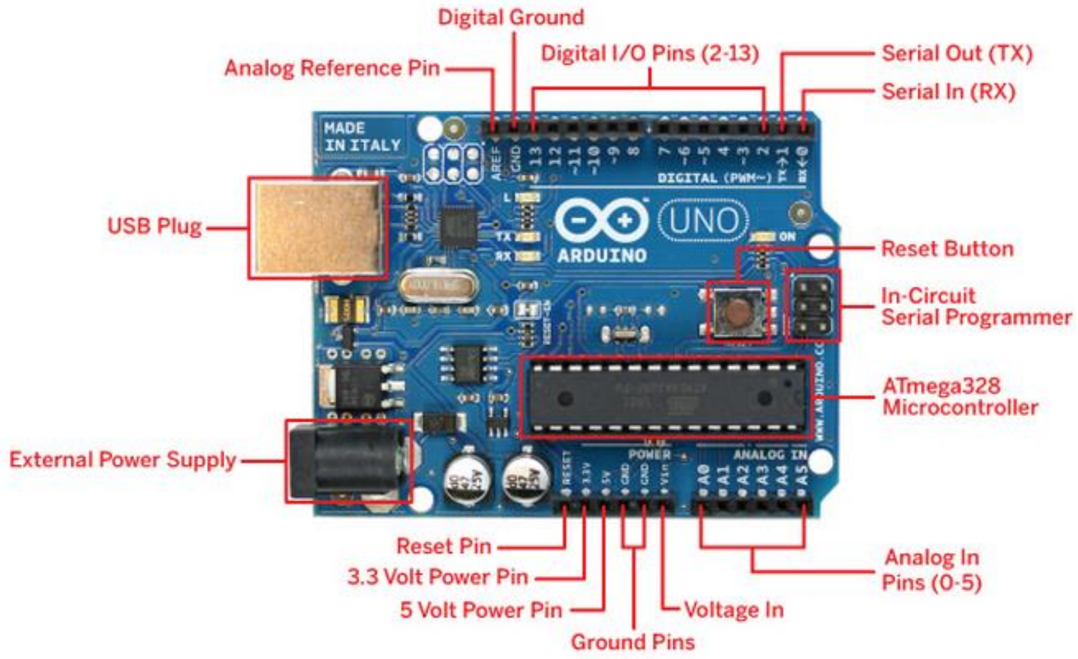

Figure 3. 3 Arduino UNO board [16]

The Arduino Uno board is based on the ATmega328 microcontroller. It has 14 digital pins which can be used as input or output. Meanwhile, it consists of a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button as illustrated in figure 3.3. Therefore it is well designed to work as a microcontroller. The Arduino UNO board can be operated by simply connecting it to a computer through a USB cable or it could be powered with an AC-to-DC adapter or a battery. [17, 20]

The board can only control and respond to electrical data, so specific components are interfaced to it, in order to assist the interaction with the real world. These components can be sensors that change other signal types (i.e.: mechanical or temperature) to electrical signals so that the board can recognise it. Whereas actuators read the electrical data from the board directly and convert it into whatever is required. The sensors consist of switches, accelerometers, and ultrasound distance sensors. Examples of actuators include lights and LEDs, speakers, motors, and displays. There are a lot of official boards that can be used with Arduino software and a wide range of Arduino-compatible boards. [19]

The main function of the Arduino Uno board in the system is to read and interpret the data from the temperature sensor output and the pulse oximeter sensor output. [19]

The Arduino microcontroller needs a USB cable to power up the board in 5V. If more power is given, the board can be damaged and cannot be reused anymore. In order to prevent this, technical specifications as mentioned below should be followed. [17]

Technical specification

- Microcontroller ATmega328
- Operating Voltage 5V
- Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA
- Flash Memory 32 KB of which 0.5 KB used by boot loader
- SRAM 2 KB
- EEPROM 1 KB
- Clock Speed 16 MHz [17, 20]

3.2.2 ATMEGA328 MICROCONTROLLER

ATmega328 Microcontroller is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. The ATMEGA328-PU comes in a PDIP 28 pin package (Pin mapping indicated in figure 4.4). [18, 21]

“By executing powerful instructions in a single clock cycle, the ATmega328 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. Besides, memory Includes 32KB of programmable FLASH, 1KB of EEPROM and 2KB SRAM.The operating voltage interval is 1.8V to 5.5V. Furthermore, the microcontroller can be work with temperature range between 40°C to 85°C. The microcontroller lower power consumption mode is 1.8V, 1 MHz and 25°C.” [18, 21]

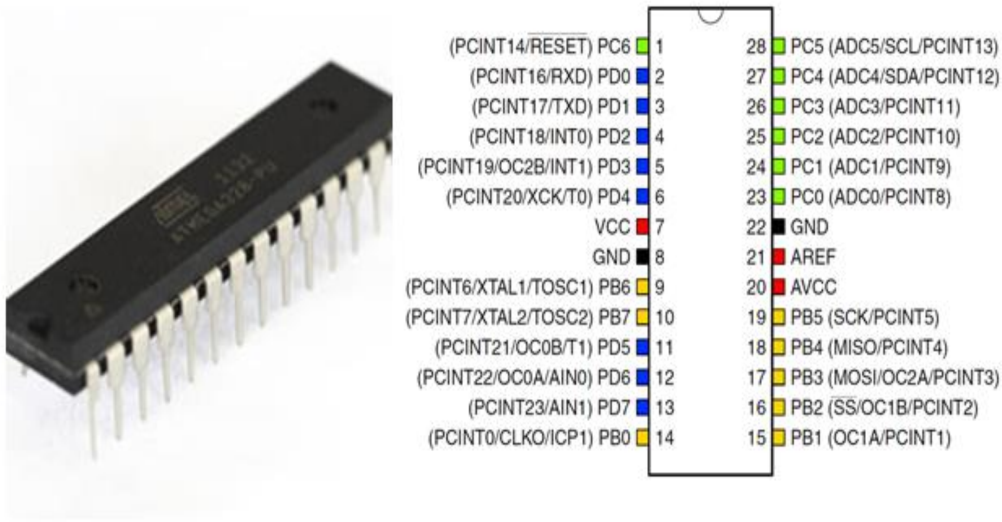

Figure 3. 4 ATmega328 Pin Mapping [18, 21]

3.2.2 ZIGBEE

ZigBee is a set of specifications for a suite of high level communication protocols jthat use small, low-power digital radios, hence are characterized by long battery life. The Zigbee technology specification is intended to be simpler and cheaper than other WPANs, compared to Bluetooth. In other words, Zigbee allows the usage of a low data rate, therefore provides a long battery life, and secure wireless mesh networking standard at radio-frequency (RF) applications. As a result, the low cost allows the technology to be consumed extensively in wireless control and monitoring applications and the usage of low power allows longer life with smaller batteries. In addition to this, the mesh networking provides high reliability and wider range of working distance. [3, 22, 23]

Standard	Bandwidth	Power Consumption	Protocol Stack Size	Stronghold	Applications
Wi-Fi	Up to 54Mbps	400+mA TX, standby 20mA	100+KB	High data rate	Internet browsing, PC networking, file transfers
Bluetooth	1Mbps	40mA TX, standby 0.2mA	~100+KB	Interoperability, cable replacement	Wireless USB, handset, headset
ZigBee	250kbps	30mA TX, standby 3#&956;A	4"32KB	Long battery life, low cost	Remote control, battery-operated products, sensors

Table 3. 1 Wireless technology comparison chart [13]

This project is based on zig bee IEEE 802.15.4 standard which defines the protocol and interconnection of devices via radio communication in a personal area network (PAN). This zig bee standard contains two layers. First layer is MAC layer (Medium Access Control) which provides all access to the physical radio channel and targets supporting PAN association and disassociation, providing device security and a reliable link between two peer MAC entities. Whereas the second layer PHY (Physical) layer is responsible for activation and deactivation of the radio transceiver, channel frequency selection and data transmission and reception. [24]

Zig bee network uses three types of devices (figure 3.5) which are coordinator, full function device (FFD) and reduced function device (RFD). The Network coordinator arranges the network and sends network beacons to related network devices. Furthermore, the network coordinator manages network nodes and stores network node information. Besides, it routes messages between paired nodes which is able to function in any topology. In short, the zig bee network coordinator is the most sophisticated of the three types and necessitates the most memory and computing power. Secondly, full function device (FFD) supports all 802.15.4 functions and features, identified by the standard. It can act as the network coordinator but generally, its' main function is a network router or network end device. Finally, reduced function device (RFD) is generally used for network end device. It consumes less power than other network devices as it can go on sleep mode. [3, 22, 23]

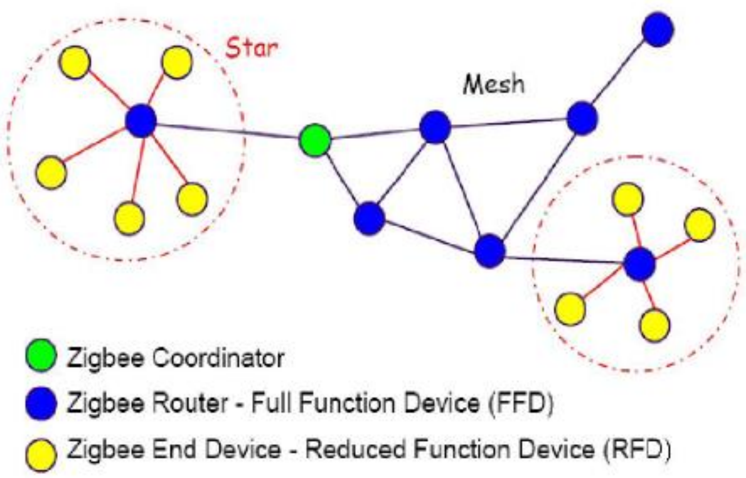

Figure 3. 5 Zig bee network module [3]

3.2.3 XBEE PRO RF MODULE

In this study the XBee Pro series1 RF module is used. Xbee Pro has better specifications compared to other Xbee modules, in ways which it transfers more power and is capable of receiving weaker signals (hence this means the XBee Pro has better receiver sensitivity). Therefore, the XBee Pro has higher sensitivity in recognising signals and is able to transmit more power. [25, 26]

In addition to this, it is able to send and receive data over longer distances in contrast to XBee. Xbee Pro RF Module operate in the 2.4 GHz ISM band and series 1 are used for point to point serial communication. One of them operates as transmitter and the other as the receiver as indicated in figure 3.6. [25, 26]

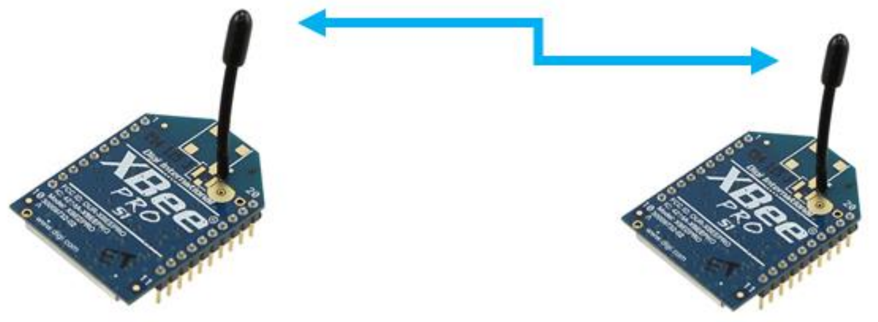

Figure 3. 6 Xbee Pro series 1 RF module [24]

3.2.4 ZIGBEE TRANSMITTER

To design xbee pro and LM35 certain requirements should be followed, where both xbee pro and LM 35 should operate with 5V and they should be grounded as drawn on the following figure in red and black lines, respectively. Next, to receive information from temperature sensor, Xbee module pin (AD3) is connected to LM35 pin out, which can be observed in following figure in light blue line. These stages mentioned have been implemented practically in laboratory therefore has been proved in figure 3.6 second schema. [25, 26, 27]

As mentioned before, both zigbee systems are the same but how it is programmed (whether as a receiver or transmitter) depends on the configuration with X-CTU software. This will be discussed extensively in future sections. Once, transmitter module obtains skin temperature, it processes the information and then transmits this to receiver module wirelessly. The receiver module will evaluate the data and will interface with the microcontroller unit. [25, 26, 27]

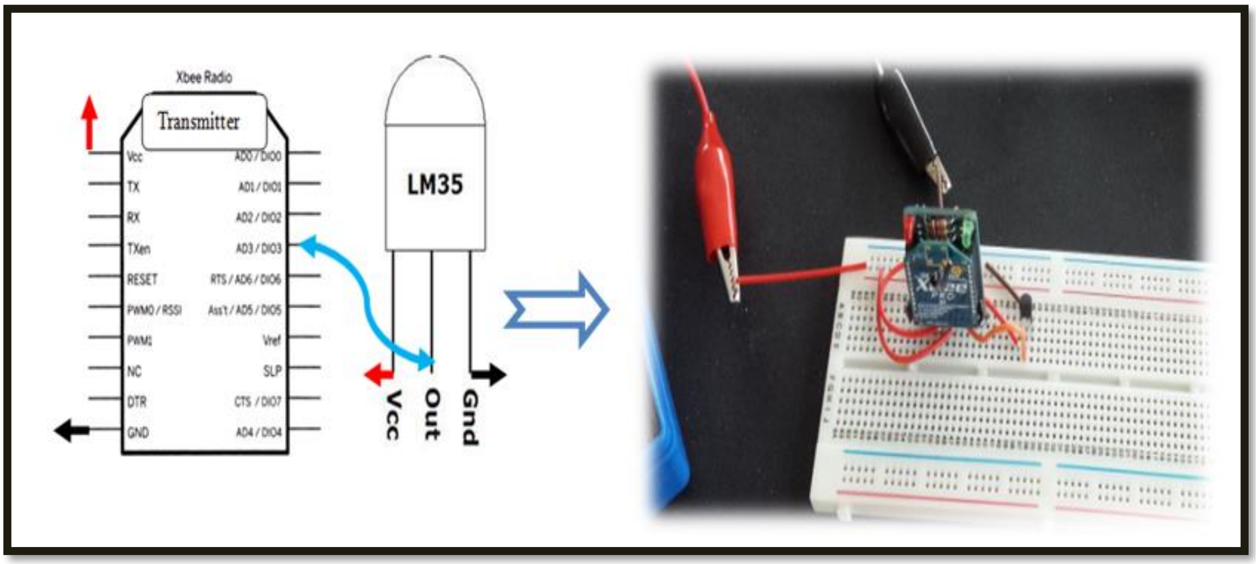

Figure 3. 7 Transmitter and temperature sensor connection (transmitter side)

3.2.5 ZIGBEE RECEIVER

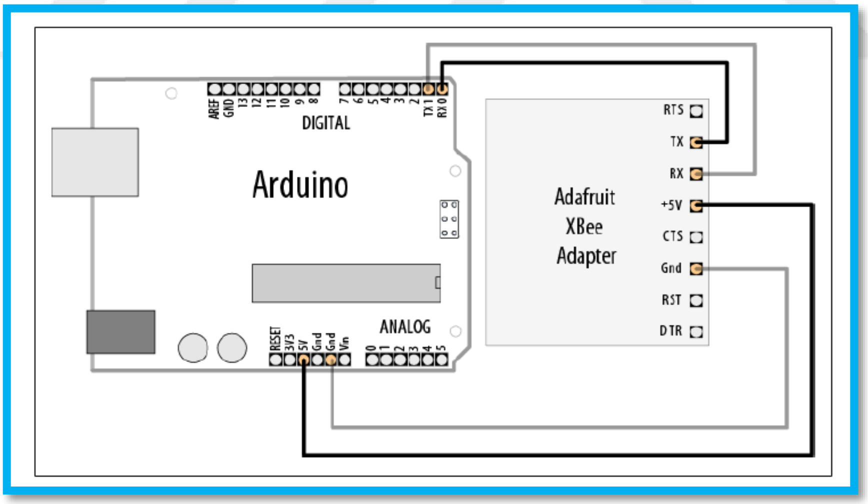

Figure 3. 8 Arduino UNO board and receiver module connection [19]

The zig bee receiver is put on the adafruit Xbee adaptor and then connected with Arduino UNO microcontroller as seen in the above picture. Both zig bee module and microcontroller operate with 5V which is generally taken from laptops or PCs via USB cable to Arduino UNO board. Whereas the receiver module gets 5V through arduino

Uno board as illustrated in figure 3.8. The receiver module gets information from the tranmitter module. In the meantime, this information is processed and later sent to Arduino UNO microcontroller according to programming data (sent wirelessly). The results are then displayed on Arduino UNO microcontroller serial monitor section (more detail is present in the result chapter). [19,25,26]

Once the zig be modules are configured as tarnsmitter and reciever, receiver part is connected to the Arduino UNO. Receiver Rx should be matched with arduino UNO board Tx and receiver Tx leg should be matched with Rx board. As mentioned before Xbee pro receiver module is powered up via Arduino UNO which has 5V leg as displayed in the actual work in figure 3.9. [15, 19]

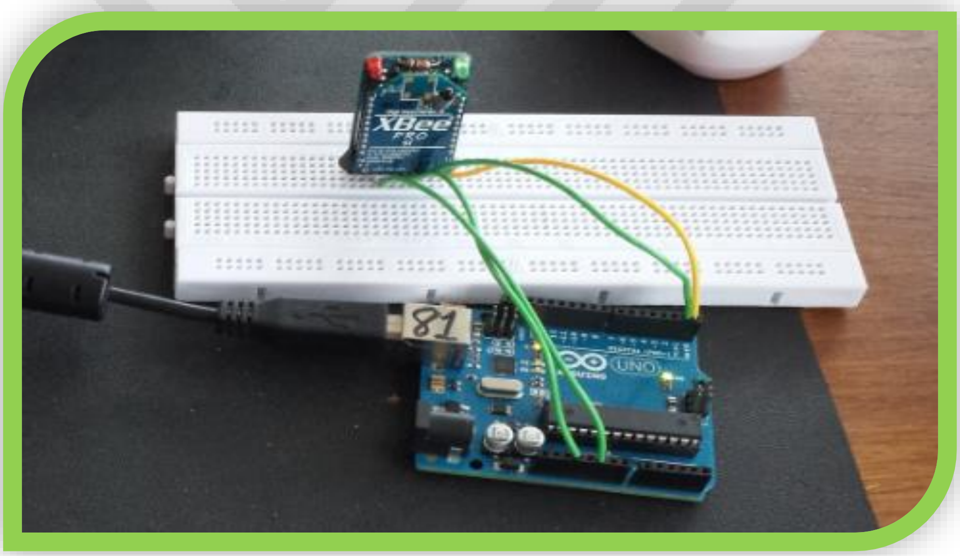

Figure 3. 9 Implementation of Arduino UNO board and receiver module (receiver side)

3.2.3 Temperature sensor (LM35)

Although there are big differences in temperature of the surroundings and also in physical activity, in a healthy individual, body temperature remains constant and only varies in a small range. In general human body temperature depends on individual condition and metabolism rate, especially within inner and outer parts of the body. For example, temperature measured in anus is about 37.1ºC, in mouth – 36.7ºC, in armpit – 36.5ºC. [29]

Telemetric measurements of human body temperature usually employ electronic temperature sensors. LM 35 which is produced by National Semiconductor Corporation is used as a body temperature measurement because it is linear temperature sensor which based on the semiconductor and offers a functional range from -40 degree Celsius to 150 degree Celsius. It can detect the ambient air temperature. The sensitivity of the temperature sensor is 10mV per degree Celsius. The output voltage is proportional to the temperature. Temperature measurement sensors include thermocouple, platinum resistance, thermal resistance and temperature semiconductor chips. It has 3 pins which are; ground, voltage input (operates with 5V) and output pins (transmitter module receive data from this pin). Temperature sensor and transmitter connection is studied in Zig bee Transmitter section and LM35 and Arduino UNO board connection indicated in following figure [28, 29, and 30]

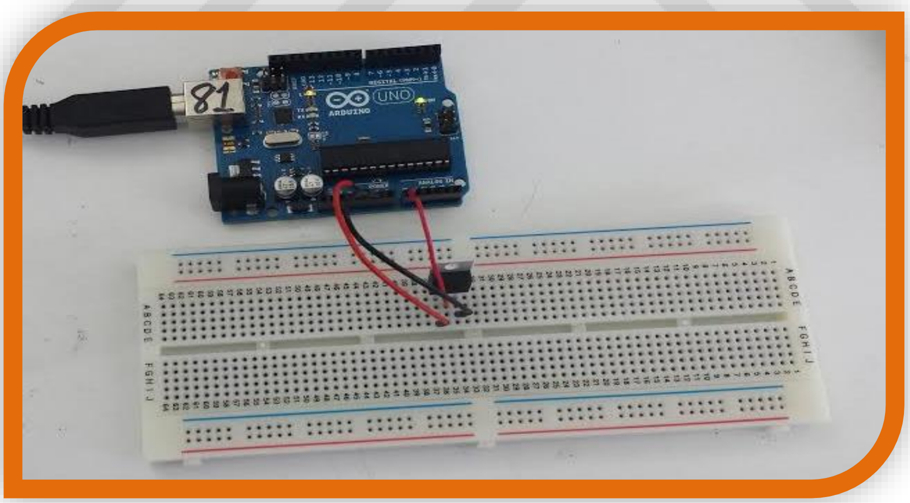

Figure 3. 10 LM35 and Arduino UNO board connection

3.2.4 PULSE OXIMETER

Within the pulse oximeter sensor, light emitting diodes shine red and infrared light through the skin tissue. The patients' information can be obtained from the finger, toe or ear. Although, most of the light passes through the blood, tissue and bone at the application site, some of the light is absorbed by the extremities. A light-sensitive detector opposite the light source receives it. After that, data is sent to microprocessor which is charted below. [31, 32]

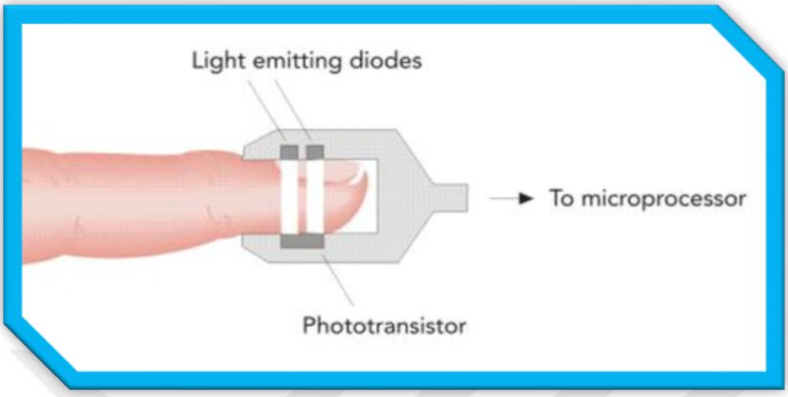

Figure 3. 11 Pulse oximeter [33]

Pulse Oximeter sensor is used to get the heart rate data of the patient in this project. This date is then transferred to Arduino for a processing before it is transmitted as wireless information through Xbee pro RF module. The amplifiers are used to monitor the heart rate. Whereas capacitors in the circuit are designed to reduce excess noise and harmonics. [15]

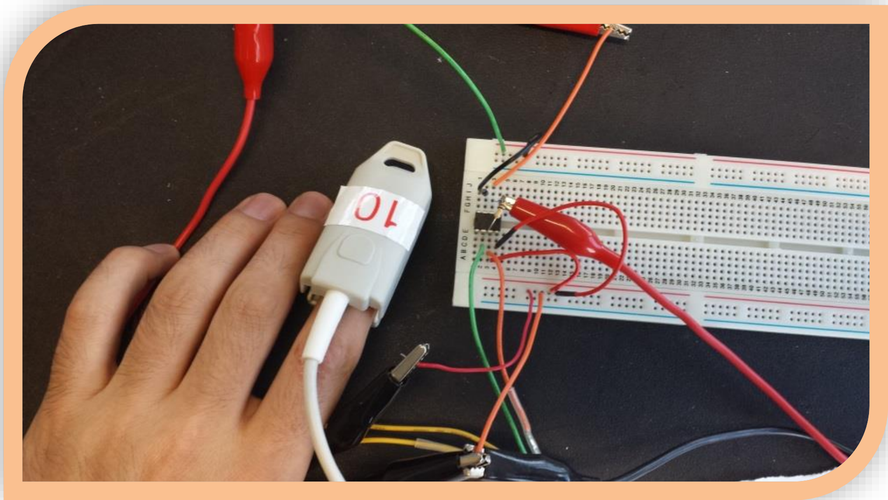

Figure 3. 12 Implementation of pulse oximeter

3.2.5 Heart Rate

The number of heartbeats per unit of time is called heart rate, normally stated as beats per minute (bpm). The heart rate can oscillate according to the body's physical needs and oxygen requirements. In addition, the body activities such as physical exercise, sleep, anxiety, stress, illness, ingesting, and drugs can change the heart rate .The heart rate is used by medical professionals to assist in reaching a diagnosis and in tracking the state of medical conditions. [40, 41]

A more accurate method of measuring heart rate is the use of an electrocardiograph, or ECG (also abbreviated EKG). The principle of ECG is that it generates a visual pattern based on electrical activity of the heart. Continuous ECG monitoring is routinely done in many clinical settings, especially in critical care medicine. On the ECG, instantaneous heart rate is calculated using the R wave-to-R wave (RR) interval and multiplying/dividing in order to derive heart rate in heartbeats per minute. (as indicated in figure 3.13) [40]

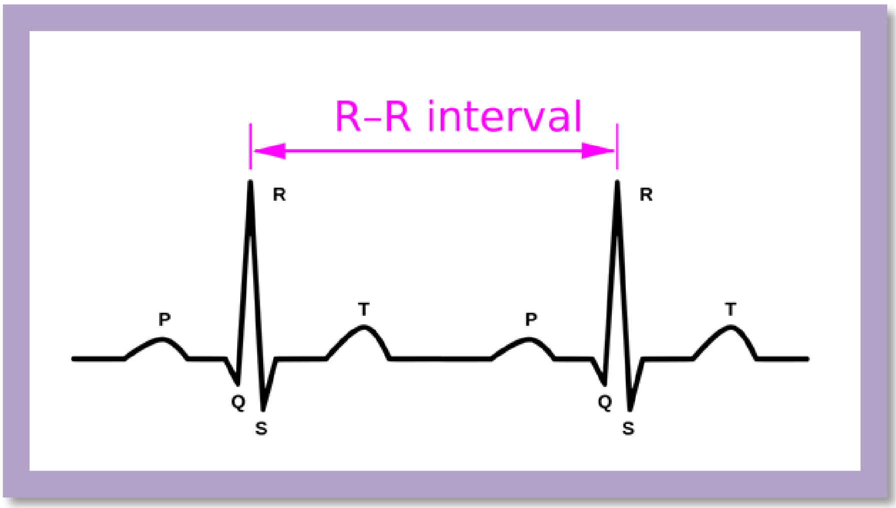

Figure 3. 13 ECG- RR Interval [40]

One of the vital parameters of cardiovascular system is heartbeat rate. At the normal resting condition, a healthy adult heart rate is around 72 bpm. Meanwhile, Babies' heart rate is around 120 bpm. This figure is higher compared to the heart rate of mature adults. Whereas older children heart rate is around 90 bpm. The heart rate goes up increasingly during exercises and returns slowly to the rest value after exercise. [41]

3.3 SOFTWARE DESIGN

Arduino and X-CTU software will be discussed in this part of the current study. Shortly, Arduino UNO software is used to process patient data and display. Meanwhile, XCTU software is targeted to program the zigbee to transfer data from the transmitter side to the receiver side. [19]

3.3.1 ARDUINO UNO SOFTWARE

Software programs include sketches created on a computer using the Arduino integrated development environment (IDE). The IDE allows user to write and edit code and convert this code into instructions that Arduino hardware understands. In addition, uploading process takes place where the IDE also transmits instructions to the Arduino board. This is illustrated in figure 3.14. [19]

As mentioned, Arduino Uno microcontroller has its own open license software that assists users to code the microcontroller as needed. In this work, this software is used with the xbee pro RF transceivers and receiver network for coding purposes. The Arduino Uno can easily communicate with a computer, another Arduino, or other microcontrollers. For instance, the ATmega328 provides serial communication, which is available on digital pins 0 (RX) and 1 (TX). Besides, the Arduino software contains a serial monitor that enables simple textual data to be sent to and received from the Arduino board which is implemented in this study. [19, 34]

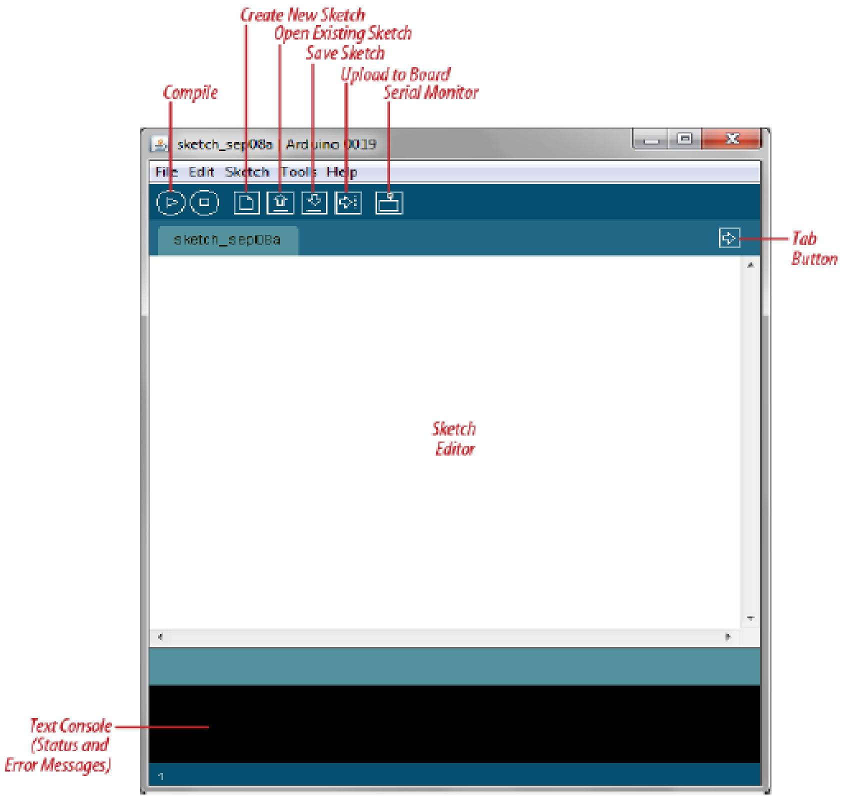

Figure 3. 14 Arduino IDE [19]

3.3.2 X-CTU SOFTWARE

X-CTU software is provided by Digi international based on Windows applications. It is designed to enable a simple and user friendly GUI as well as to cooperate with the firmware files found on Digi international RF products. The new version software is able to; automatically detect RF modules which are directly connected to laptop or PC and allows read and write device settings. This software has the necessary tools to get Xbee working. The XBee network and the signal strength of each connection are displayed on the graphical network view. [35, 36, 37]

In addition, the software can discover, manage and configure multiple RF remote devices which physically connects to the computer. [35, 36, 37]

As illustrated on the below X-CTU software radio configuration page, program can automatically detect radio modules, read firmware information and display module settings. [37]

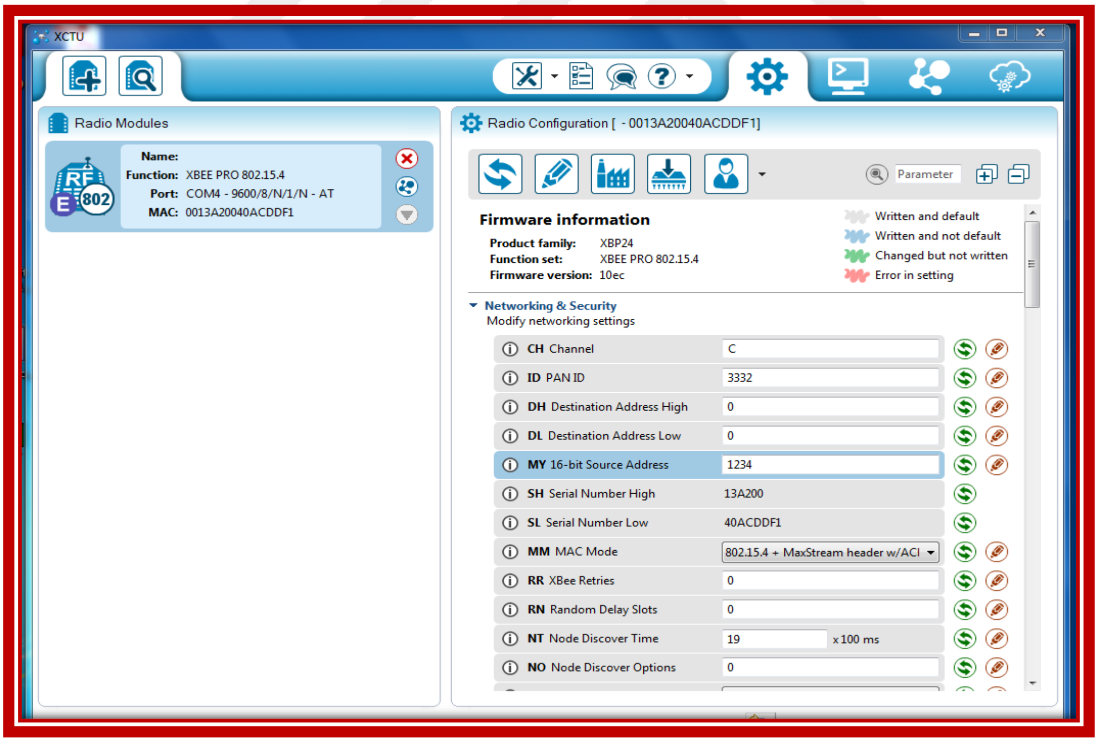

Figure 3. 15 X-CTU software

3.3.3 XBEE CONFIGURATION

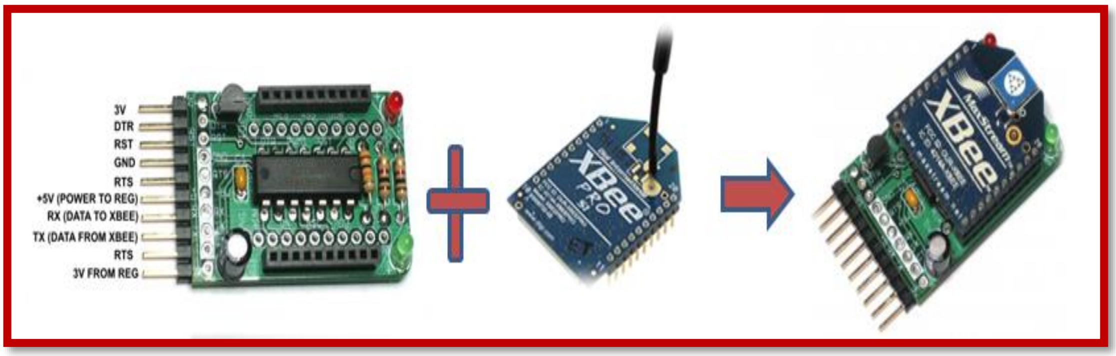

Figure 3. 16 Xbee configurations [38]

To configure Xbee setting, xbee adaptor board is required and xbee module should be connected to the computer. There is a couple of ways to that. One of the methods is using FTDI cable where on one side exists a USB port, which allows the connection to the computer and other side has six pins for xbee adaptor connection. The other method used in this project is the Arduino UNO board. In order to ensure necessary connection, xbee adaptor's RX, TX pins is connected with Arduino board's RX, TX board, respectively. Meanwhile, Xbee is wired from the Arduino's 5V line (5V board goes to 5V pins), grounds are all connected and reset board linked with ground board in order to protect microprocessor as seen in figure 3.17. Then, Arduino board allows serial communication between xbee and computer. As a result, the xbee module can easily configure as receiver or transmitter with using X-CTU software. [35, 36, 37, 38]

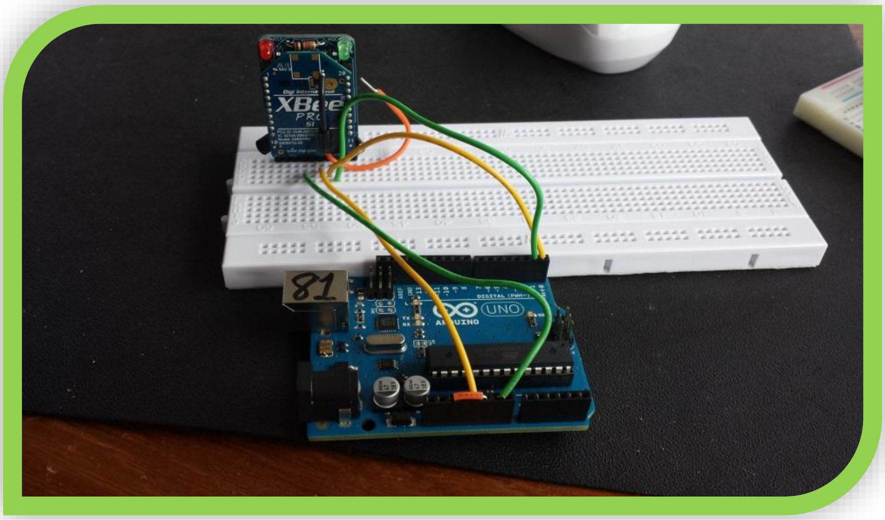

Figure 3. 17 Arduino board used for confirugation

To configure transmitter, once the serial cable is connected and tested that it can communicate with the modem, go on the configure icon and read the current setup as shown in figure 3.18. Then some important following steps should be changed;

- New version of X-CTU software can automatically detect the PAN ID which every modem has. For further privacy the PAN ID should be changed in some digit hex number. The changed of the digit hex number will mean that the device can only between two modems- in order to prevent confusion.
  - Ensure the baud rate is 9600. In order to figure out which baud rate is used for related modem check from Arduino documentation.
  - Next change the Packetization Timeout. This is what determines how long to wait before sending the characters over. This number should be set as high.
  - Enable pin D3 to be a digital input (this pin connected to temperature sensor output).
  - Lastly set the Digital IO change detect to digit hex FF that the mask to listen for only D3. [19, 38, 39]

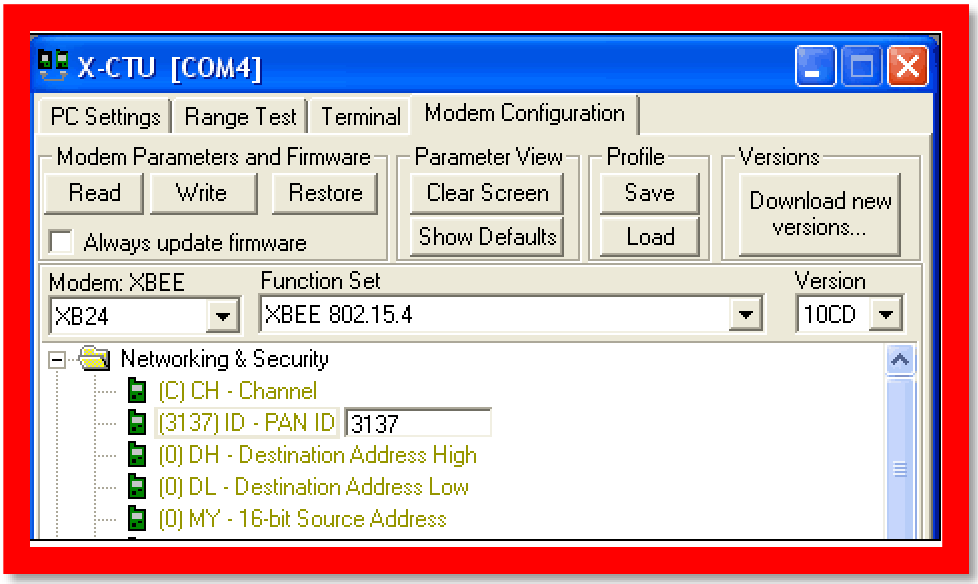

Figure 3. 18 Xbee settings [39]

To configure receiver;

Now, the other Xbee will listen to changes on pin .Connect serial cable and read the current configuration just like transmitter.

- The PAN ID, Packetization Timeout and baud rate should be the same as transmitter's
- Set pin D3 to be a digital output, enabled to high.
- Choose the I/O Output to Disabled. This will prevent the receiver from displaying the status update in the serial line and instead just toggle the matching pin.
- Finally, change I/O line passing input address to FFFF as indicated in figure 3.19. If it is set up to unique addresses for the receiver and transmitter xbees, settings should be changed to match this (but FFFF will match all addresses). At the end, to save the changes, should be pressed write icon. [19, 38, 39]

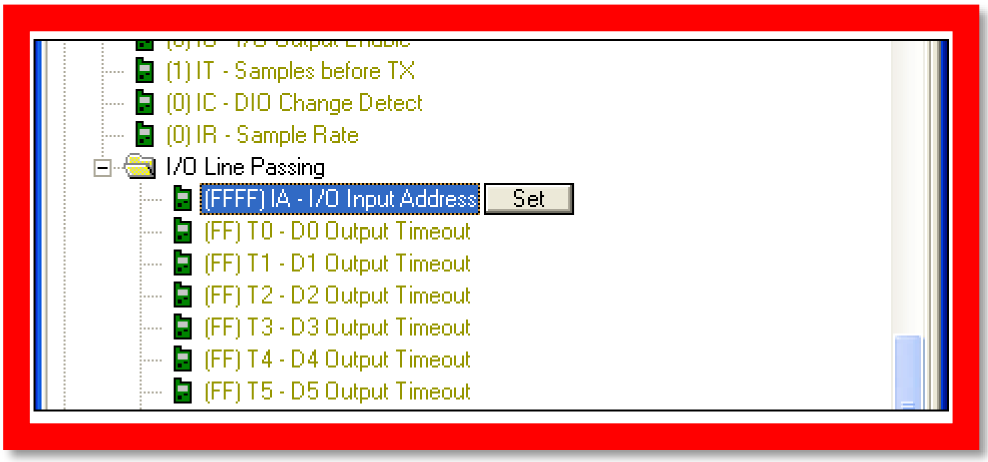

Figure 3. 19 Xbee settings [39]

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will be divided in to two main headlines, namely; results and discussion. The project results will be displayed in the form of figures and diagrams and it will be discussed and compared to other studies. Overall evaluation of the results will help recognise the weak and positive points of this project.

4.2 RESULTS

Body temperature measurement is displayed on the Arduino UNO board serial monitor. Before sending temperature data wirelessly, the data is observed on the serial monitor with wired temperature sensor and Arduino UNO board. Meanwhile, pulse sensor signal waveform is displayed on the oscilloscope.

4.2.1 SYSTEM TESTING

First of all wireless system is set up to send and receive data remotely. Xbee adaptor consists of two LEDs (red and green). The green LED's blink proves that the xbee RF module is working properly. Meanwhile, the red LED is used for data exchange. If it is red, it shows that there is information exchange present. However, there is a possibility that these LEDs may not work. To make sure that the transmitter side transmits data and receiver side receives the data, xbee adaptor pin (AD3) is wired with red LED as indicated just below. If the LED turns to red, it indicates that information exchange is present.

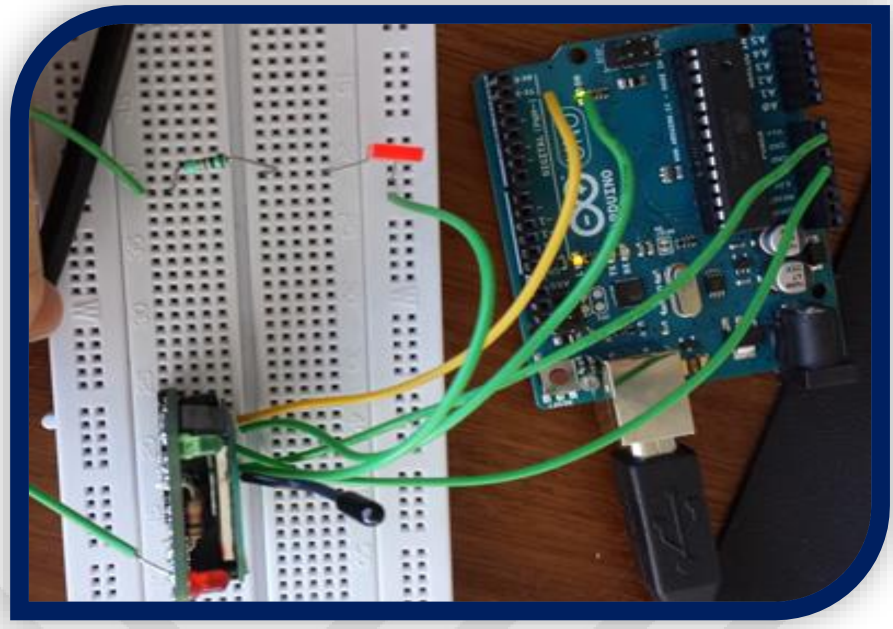

Figure 4. 1 System testing

4.2.2 Body Temperature Result

Body temperature measurement results are displayed in Arduino UNO software's serial monitor according to the code (refer to appendix A for further detail). Arduino UNO software will read the temperature sensor information and send the values to the serial monitor on the computer. Firstly, LM35 sensor has been used to detect ambient temperature (results are shown in figure 4.2). In order to make sure temperature sensor works properly, sensor is programmed to measure in Celsius and Fahrenheit. This allows an easy conversion between units based on specific formula (mentioned in the program code).

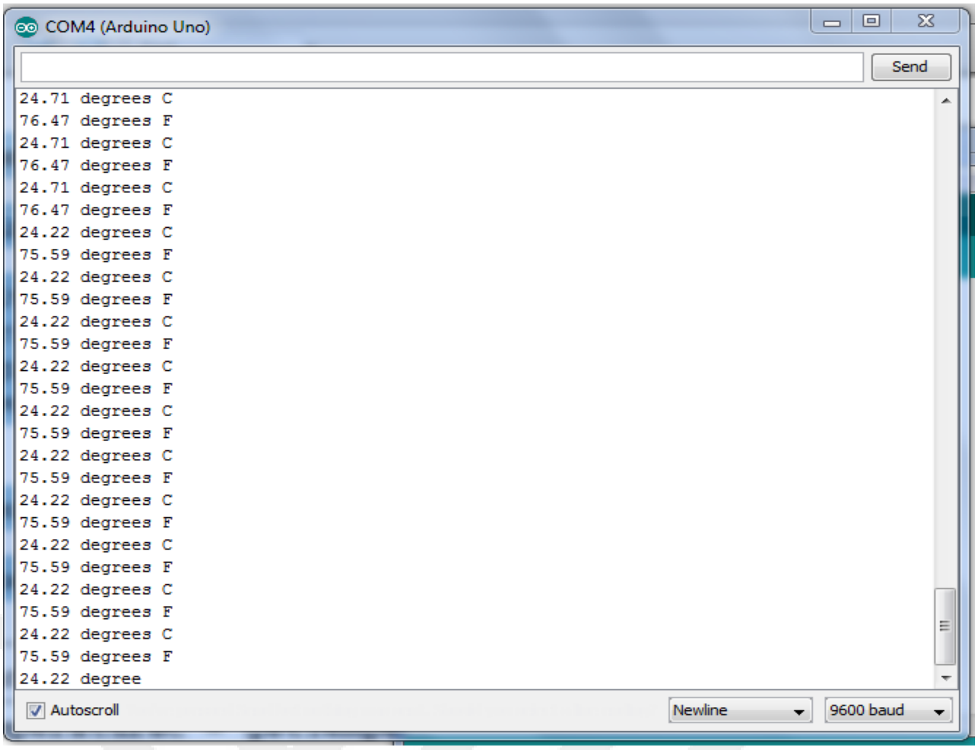

Figure 4. 2 Ambient temperature measurement displayed on the serial monitor

There is a slight fluctuation in the results. Yet overall the results are very close to normal ambient temperature.

Following the setup, the system remote section is activated. Then the Arduino UNO is connected to the laptop and the software program begins to run (see the system's visual figure in appendix B). The following temperature results are then displayed on the serial monitor. In short, although transmission delay was observed, the ambient temperature is transmitted and received successfully.

As it can be distinguished from the wireless and non-wireless temperature monitor results, there is a small difference. The wireless system has a higher temperature measurement compared to non-wireless. This is due to extra heating of the sensor as a result of the continuous power supply

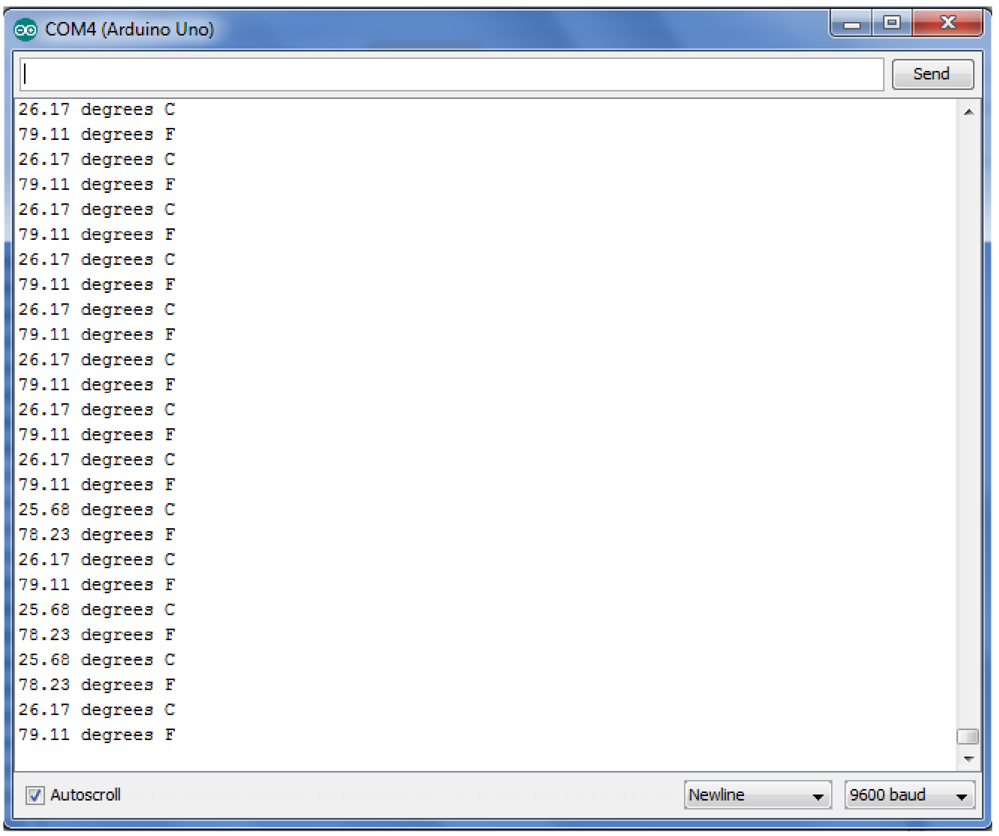

Figure 4. 3 Ambient temperature measurements displayed in the serial monitor wirelessly

The temperature sensor is covered with the fingertip to get the body temperature and then the code is uploaded to the microcontroller from the Arduino IDE. After a while the xbee receiver LED blinks by turning green. This indicates the finger's temperature is obtained. Next, the information is displayed via serial monitor. This is shown in figure 4.4. However, as discussed in the past sections, the body temperature measurement varies between individuals. This is because activities, metabolism rate, age, gender are all different factors which affect the body temperature. Therefore, the finger's temperature (measured about 35 degrees) does not directly match the body temperature (approximately 36.5 degrees).

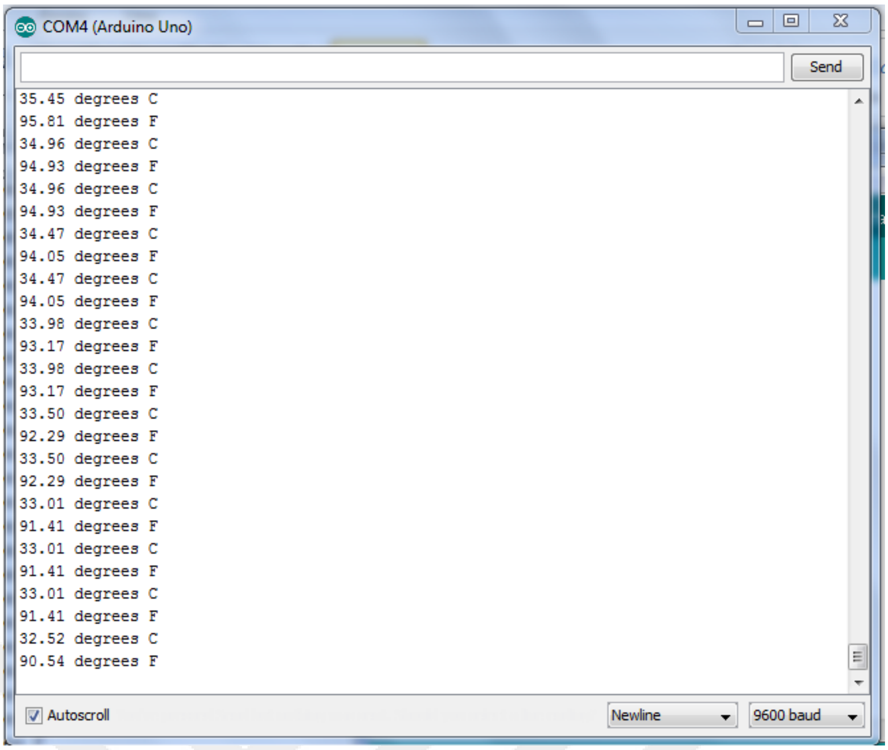

Figure 4. 4 Body Temperature Displayed in Serial Monitor of Arduino Uno Board

4.2.3 HEART RATE

The pulse sensor contains an IR light emitting diode transmitter and an IR photo detector acting as the receiver. The skin tissue allows the IR light to pass through. Variations in the amount of blood within the finger control the volume of light incident on the IR detector. In the practical configurations, the finger placed between the transmitter and the receiver is as shown in Fig. 3.10. [41]

The amplifier circuit is a standard design and is documented in many sources. The IR sensor signal is very weak where the voltage is just around 50µV. So it contains a significant noise level as measured and displayed in oscilloscope in Fig.4.5. [41] The signal is affected from the interference caused by movement of artefacts such as rings and mains 50Hz.

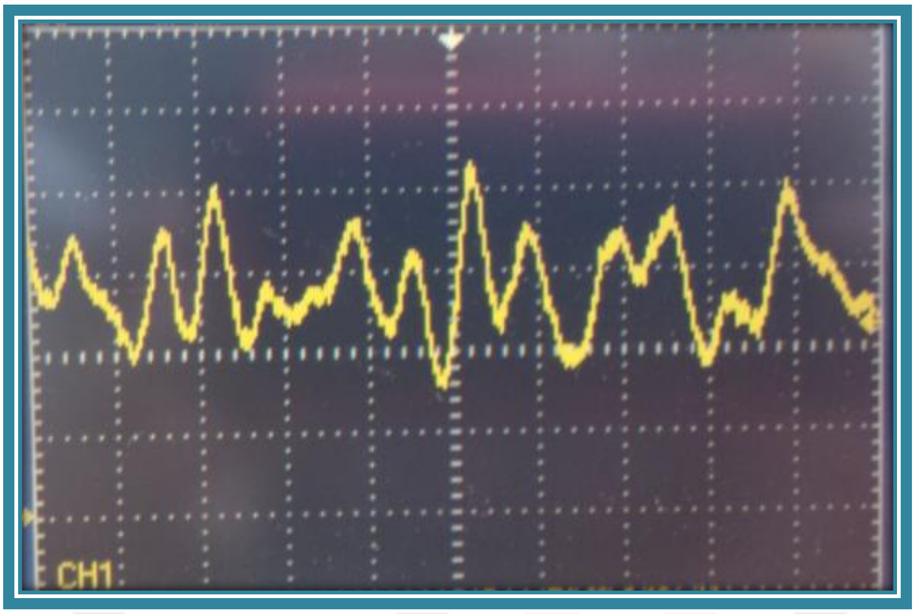

Figure 4. 5 Pulse sensor's output signal with harmonics

To get pure heart waveform, the filtering process should be applied to the related circuit. Therefore, a capacitor of 1µF value at the input of each stage is required to block the dc component (in the heart waveform signal). The standard ECG signal has frequency components in the range 0.05-200Hz. So, the filtering range is chosen from 0-50Hz to block the higher frequency noise components in the signal. [40, 41]

In addition, the pulse sensor is supplied with 5V DC power and pulse sensor analogue output pin is connected to an oscilloscope input. The aim is to find successive moments of instantaneous heart beat from graphical display on oscilloscope (as shown in figure 4.6). To calculate the heart rate the following should be measured:

- Inter Beat Interval (IBI), the time between these moments
- Heart Rate (HR)
- The interval between successive heart beats (I.B.I.)

HR = 60000 / IBI; (as displayed in figure 4.6)

The above equation is used to work out the heart rate of an individual**.** [41, 42]

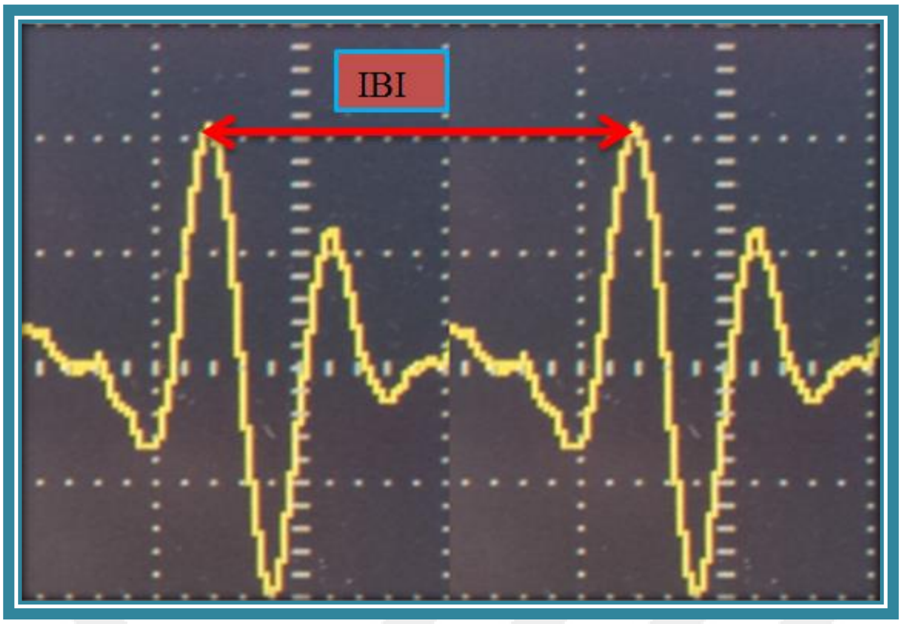

Figure 4. 6 Pulse sensor's output signal

4.2.4 PATIENTS' BODY TEMPERATURE AND HEART RATE

There are many effects on the patients' skin temperature and heart rate (such as age, individual condition, emotions, metabolism rate etc.) as mentioned in the past sections. The patients' age and their body temperature and heart rate are compared in the current project.

Age	Skin temperature	Heart rate	
17	**34- 35 ºC**	**<85 BPM**	
25	**33-34.5 ºC**	**< 75 BPM**	
30	**33-34 ºC**	**< 72 BPM**	
50	**32.5-33 ºC**	**<70 BPM**	

Table 4. 1 Compares human skin temperature and heart rate

Pulse oximeter sensor and LM35 sensor are used to measure the heart rate and human skin temperature, respectively. The system results are gained from four individuals' skin temperature and heart rate.

Table 4.1 shows that as age increases the skin temperature decreases. There could be many influencing factors that may result in this difference. But one clear effect is the reduction in the metabolism rate as age increases. Yet there is need for more data to reach a more reliable conclusion.

The heart rate is varies between 60 and 120 bpm. Infants approximately have a heart rate of 120 bpm. This is because their metabolism rate is the highest compared with other age groups. Thus, the anabolism rate is higher than catabolism rate [31, 41, and 42]. Therefore, it can be concluded that there is an inverse correlation between ages and heart rate.

4.3 DISCUSSION

The use of wireless technologies in medical application is bringing many advantages to the existing healthcare services. Although there are some research challenges such as various types of network communication infrastructure, interference, data integrity, low-power consumption, transmission delay, node failure, etc. One of the most important factors in a successful healthcare system is reliability. To ensure reliablity, system designers should be cautious about node adaptation, when there is a change in location, connection and link quality.[43]

As mentioned in this project, the xbee RF module ID and other software specifications should be rearranged during configuration. In addition to this, transmitter and receiver module could not communicate for some time due to interference (one of the reasons could be because of many electronic equipments in laboratory). This means that there is a transmission delay which has been an issue during the project expremental.

On the other hand, the zig bee xbee pro series 1 module has been used for wireless data transferring. The reason for the choice is because the communication range is longer than other xbee RF modules, that is about 100 meters according to datasheet.[25] Although in practice there is no communication at this range, due to device tolerance and other affects as mentioned above.

In the meanwhile, instead of actual body temperature sensor, temperature sensor (LM 35) is used in the project. Thus, the measurements of the body temperature results (displayed in figure 4.4) are not exactly accurate, compared with real body temperature (which is 36.5 °C). This is because; the measurements are collected by touching the head of LM 35 sensor with the fingertips. Also, the sensor is affected by ambient temperature as well. [28, 29]

In addition, the temperature sensor became warm with the continuous power supply. This may have caused error to the results. Moreover, the body temperature depends on physical activity of the individual and the metabolism rate. To sum up, the measurements of body temperature is not completely precise because of the mentioned reasons.

The choice of the pulse sensor is very important to get accurate heart rate. Hence, there are some important guideline points to choose the right sensor. The ideal sensor should not generate movement artifact, however it should be comfortable for the patient and should allow easy application. [31]

In addition, size of the application site (such as finger, toe etc.) decides the size of the sensor to use. It is not related to age of the patient. If a chosen sensor is too big or too small, the light emitting diode and the light detector would not work properly. This would cause incorrect data reading. [31] Furthermore, heart rate signal is too small to be recognised and amplified as a signal; so an amplifier is used in the circuit to allow the recognition of the heart rate. But, the filtering process is needed to prevent unwanted dc signal to get pure heart rate wave.

Successfully, results have been obtained using the zigbee wireless communication system. This clearly shows the possible use of zigbee in future medical communication environments. Since the main purpose of this dissertation is to prove the value of cost and power saving communication using zigbee monitoring, we have only obtained few results for heart rate and body temperature measurements. The results are only but a small reflection of the norm. These results can be extended on and repeated further to increase reliability and to reach a more firm conclusion on general (body temperature and heart rate) patterns.

CHAPTER 5

CONCLUSION

Telemedicine has the potential to provide a solution for the medical services and to enhance quality and easy access to the health care of patients. The development in information and communication technologies in electronic industry allows continuous monitoring of patient health for long term and in real time with lower power consumption. Although there are many wireless standards in order to implement this study, some important considerations should be taken account (such as communication range, throughput, system security, power consumption, ease of implementation and cost). Therefore, the zig bee standard is more convenient for the local area patient monitoring.

Zig bee wireless communication effectively improves the quality of life and also reduces the burden of cost by allowing usage of less power, particularly in the hospitals. Also, zig bee standards provide 24 hours of continuous communication. Zig bee modules can be easily configured with X-CTU software. This crucial software allows user to change zig bee module settings according to types of communication. The settings differ in different zig bee modules. Whereas, configuration settings depend on the zig bee module types. In the meantime, zig bee modules can easily interface with Arduino Uno software via zig bee board adaptor. Arduino UNO software and microcontroller provides process between patient signal and zig bee.

On the other side, the continuous monitoring of health related parameters with wireless sensors (such as temperature sensor, pulse oximeter and so on) give the doctors the opportunity to monitor and analyse the patient health condition. According to the patients' medical information; doctors, nurses or caregivers can give some recommendations (which patient can do easily) or if it is an emergency case the doctor can take the necessary action.

Patient monitoring system based on zig bee communication has been designed and successfully implemented in this project. The designed system has been tested in the laboratory environment. The proposed system results are observed via used hardware and software in the project. The test results prove that the proposed system is able to monitor the body temperature with combination of: temperature sensor (LM35), xbee pro series 1(transmitter and receiver), Arduino UNO software and ATmega328 microcontroller.

This project is also able to observe the heart rate waveform on the oscilloscope via usage of pulse oximeter sensor and amplifiers. It obtains the heart wave with harmonics and dc system noises during this stage. Then, these unwanted signals are prevented by supplying filtering capacitors.

As the patient monitoring system is based on zig bee, we have reached to a conclusion that it allows users and researchers to transmit and receive data based on wireless monitoring mechanism on real time basis. In addition, we have realised that zig bee is not only capable of providing accurate real-time monitoring data for sensors but also capable of providing power efficiency for longer monitoring usage.

In the meantime, this zigbee module has flexible network topologies (stars mesh and etc.). This allows the users to use and reach different types of wireless zigbee network. Furthermore, it provides data communication security. The wireless license-free bandwidth is publically available everywhere in the world.

Moreover, X-CTU software allows an easy friendly zig bee configuration, which has very important settings. The main role of this software is to provide the privacy settings during zig bee communication. Meanwhile, this is a free software and can be easily downloaded from the Digi international company website.

In conclusion, telemedicine patient monitoring system is an important field in medical electronics. It has the potential to deliver immediate service in crucial life-saving situations and providing continuous monitoring.

FUTURE WORK

Although there are great improvements in telemedicine, especially in the patient monitoring system, there is need for further studies for improvements. Firstly, temperature sensor (LM35) cannot measure accurate body temperature. Therefore, the actual body temperature sensor should be used instead of LM35. On the other hand, pulse oximeter is not only used for measuring heart rate, but also used for measuring patient's SpO_2. These signals can be transmitted from patients unit to remote unit based on zig bee module with Arduino UNO software.

The proposed project could be implemented in using LabView GUI software. Hence, the system may be easily reconfigurable and could be interfaced with the internet easily. In addition to this, Arduino UNO software can interface with this software easily.

Moreover, the zig bee specifications could be improved in a way that, distance for the range of communication and information transfers could be increased from locally to internationally. This will provide patients to be monitored across the continents.

Besides, ID may be provided for each patient for further security and patient side can be interfaced with doctors' or caregivers' mobile phone. Hence, the doctor will have an opportunity to reach each patient's information easily via his/ her mobile phone.

Finally, an alarm system can be implemented to the patient monitor in order to give warning to the caregiver in abnormal situations.

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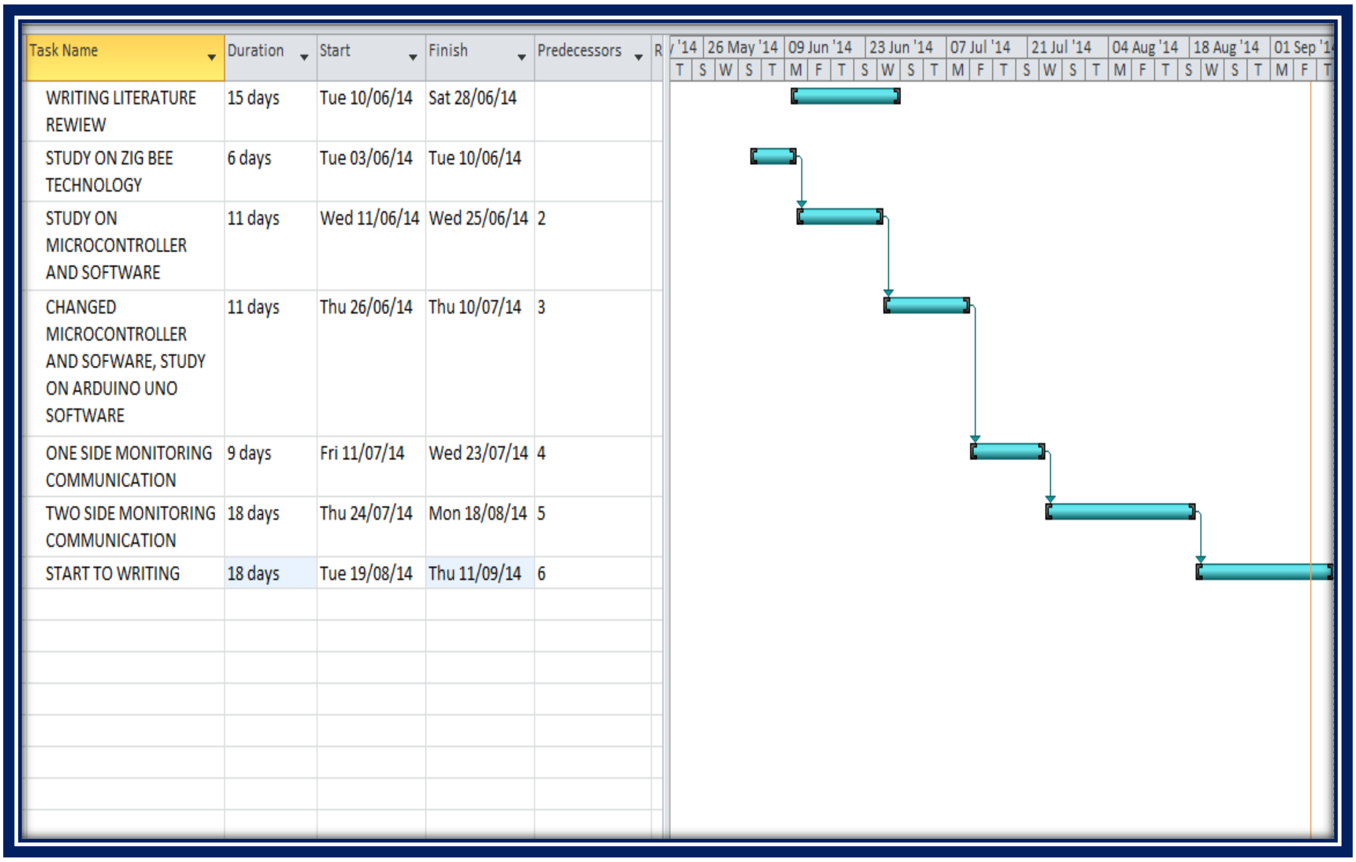
Management Of The Project



Task Name	Duration	Start	Finish	Predecessors
WRITING LITERATURE REWIEW	15 days	Tue 10/06/14	Sat 28/06/14	
STUDY ON ZIG BEE TECHNOLOGY	6 days	Tue 03/06/14	Tue 10/06/14	
STUDY ON MICROCONTROLLER AND SOFTWARE	11 days	Wed 11/06/14	Wed 25/06/14	2
CHANGED MICROCONTROLLER AND SOFWARE, STUDY ON ARDUINO UNO SOFTWARE	11 days	Thu 26/06/14	Thu 10/07/14	3
ONE SIDE MONITORING COMMUNICATION	9 days	Fri 11/07/14	Wed 23/07/14	4
TWO SIDE MONITORING COMMUNICATION	18 days	Thu 24/07/14	Mon 18/08/14	5
START TO WRITING	18 days	Tue 19/08/14	Thu 11/09/14	6

Chart A. Gantt chart for the dissertation

This dissertation has been done according to the plan given in the Chart A and below details give information about how the tasks have been carried out.

- The literature part was completed in shorter time compared with interim report plan
- Zig bee technology part was completed on the time according to plan.
- Microcontroller and software part were taken more times, because the microcontroller and software were changed.
- One side monitoring communication was taken less time, because new microcontroller and software are easier than old ones.
- Two sides monitoring communication were finished due to having needed devices.
- Finally, the dissertation was finished on the time according to interim report plan.

APPENDIX

APPENDIX A

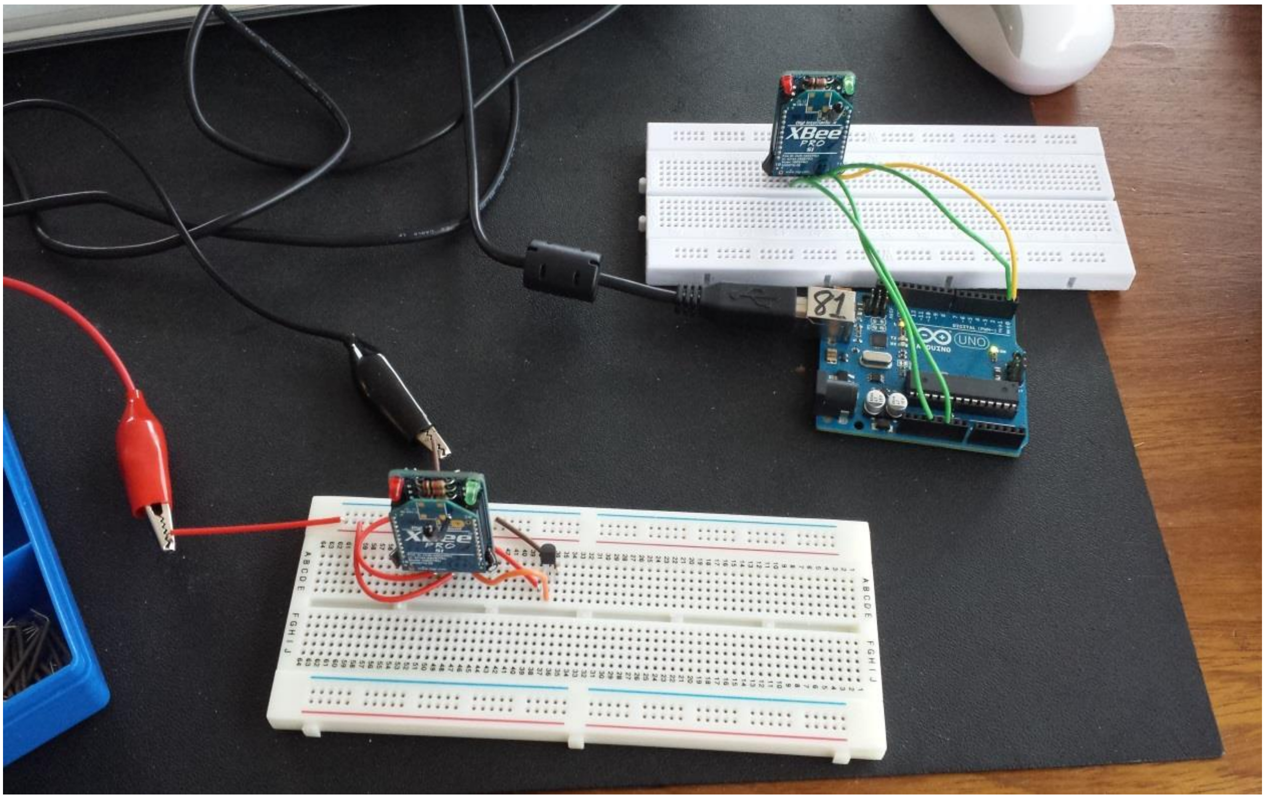


Figure A. Both sides (patient unit- remote unit) of system communication

APPENDIX B

Arduino UNO software code for temperature

```
const int PinTemp = A0;

void setup()

{

  Serial.begin(9600);

  }

void loop()

{

 float tempC = getTempC();

 Serial.print(tempC);

 Serial.println(" degrees C");

 // now convert to Fahrenheit

 float tempF = convertToF(tempC);

 Serial.print(tempF);

 Serial.println(" degrees F");

 delay(400);

 }

float getTempC()

 {

 int reading = analogRead(PinTemp);
```

```
float voltage = (reading * 5.0) / 1024;

// convert from 10 mv per degree with 500mV offset

// to degrees ((voltage - 500mV) * 100)

return (voltage - 0.5) * 100;

}

float convertToF(float tempC)

{

return (tempC * 9.0 / 5.0) + 32.0;

}
```

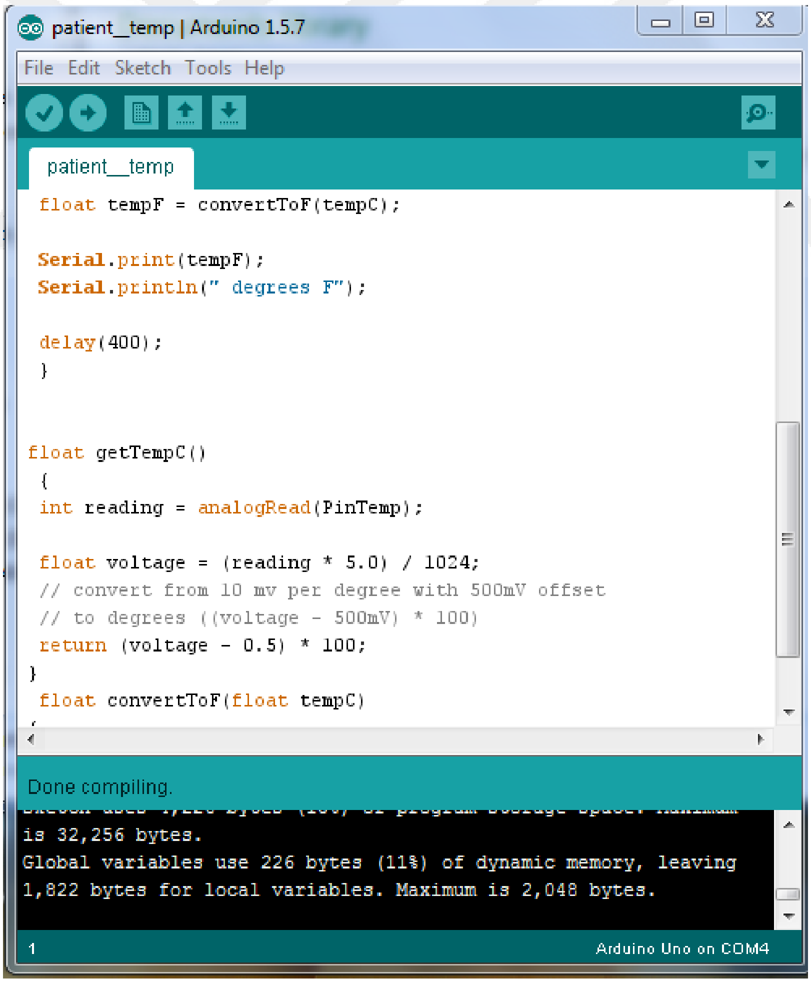


Figure B. temperature code programming