HEMODYNAMIC RESCUE I-MONITORING

By

MOHAMMAD SYAFRIL BAHAR

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

HEMODYNAMIC RESCUE I-MONITORING

by

Mohammad Syafril Bahar

A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved:

_____

Ir. Dr. Nursyarizal Mohd Nor
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2012

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.

_____

Mohammad Syafril Bahar

ABSTRACT

This research is regarding the important of monitoring system for a firefighter while they are doing rescue during fire. Unfortunately, there is no such a system that can help us to monitor their condition while they are in the fire zone/area. The usual system which is using walkie talkie is not practical because it have many disadvantages. It is because during fire, when firefighter going inside the building to safe the victim, there is no system monitor them whether they have enough oxygen, or whether they can find the fire extinguisher in a very smoky room or are they faint because they hardly to breath. In this research, we basically monitor the heart beat of firefighter to avoid any critical heart beat based on predetermined values. Using the most outstanding wireless system nowadays, Zigbee make the process of monitoring the firefighter easier. This research is still at the early stage, but the idea to improvise the usual system used and the responsibility as an engineer to contribute to the society definitely become a great combination to uphold the credibility of this research area.

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to all those who gave me the possibility to complete this project. I want to thank the Department of Electrical & Electronics Engineering, Universiti Teknologi PETRONAS for giving me permission to commence this project.

I am deeply indebted to my supervisor Ir. Dr. Nursyarizal Mohd Nor from the Electrical & Electronic Department, Universiti Teknologi PETRONAS whose help, stimulating suggestions and encouragement, helped me in all the time of research and writing of this thesis.

I would like to express my gratitude to former colleagues for supporting me in my research work. I want to thank them for all their help, support, interest and valuable hints. Especially I am obliged to Mr Mohamad Subakin and Mr Norhusaidil Hussein.

My family for giving me support and financially help me. My research would not be completed successfully without your motivation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, as technology develops; we can see a lot of applications are being use for many type of purpose. Such as sensor, it is a great inspiration toward interest for scientist to do the research. Furthermore it also gives a big impact to scientific and technological community. Although it is still new in technology, the wireless has open up a lot of purpose of sensors. Wireless sensors are different from basic wireless network and pose more challenges to solve such as power consumption, decay of lifetime, etc. [1].

Bluetooth is not an unusual name for community nowadays as we can see it is being use widely such as in mobile phone, laptop, etc. but today, a new radio called ZigBee becomes a new trend. It is not compatible to Bluetooth but in certain way it does have the advantages compare to Bluetooth. In fact, in this research will show why using ZigBee is more feasible compared to Bluetooth and how it can develop a further studies to achieve our goal.

This system definitely will be easier for us to monitor hemodynamic of firefighter during fire due to lower power consumption, different data throughput and update rates, low latency and high reliability.

1.2 Problem Statements

The ZigBee Alliance [2], as the promoting consortium, claims the development of a LLL communication standard: low data rate, low cost, low power. In the aspired markets home, building and industrial automation short control commands are sent from different network nodes – spread over a wide area – are

carried together. In this case all the features of a 3L's system totally fit into the situation.

The problems that we will face are whether this system is applicable for monitoring firefighter during fire. Because my concern is whether the device can handle the high temperature during fire that will disturb the signal or it could melt. Second, how we are able to monitor each firefighter since ZigBee do not used ID to recognize and just show the collective data. For a highly reliable Body Sensor Network used for healthcare monitoring, Bluetooth with its highly synchronized network architecture seems to be the appropriate solution. But can a less power consuming ZigBee based wireless network be an alternative solution?

1.3 Objective and Scope of Study

Objective:

In this research the author wants to find out whether this ZigBee system can send a hemodynamic data of the firefighter during fire to the Personal Computer (PC) so that we can monitor the hemodynamic status of firefighter.

Scope of Study:

1. Study and research on how ZigBee work.
2. Implement the resource to develop hemodynamic monitoring system.
3. Apply the system to the actual condition.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Background

Various wireless network technologies have been used in health monitoring system; however, the purpose of this research is the communication between sensor and other sensors in the group. The author want to develop and implement Wireless Sensor Network (WSNs) for communication in health monitoring system for firefighter during fire, the entire wireless system should be able to re-route and change network architecture when firefighters move to any position immediately. The system is based on ZigBee wireless standard. ZigBee is famous for low cost, low power consumption and flexible network topology.

ZigBee takes its name from the zigzag flying of bees that forms a mesh network among flowers. It is an individually simple organism that works together to tackle complex task [3]. Zigbee is generally consists of 3 layers as shown in Figure 1, IEEE 802.15.4 physical and MAC layer, network layer [4], and application layer. The IEEE 802.15.4 standard [5] [6] is initially developed by the ZigBee alliance [5]. IEEE 802.15.4 defines CSMA-CA protocol that reduces the probability of interfering with other users. Automatic retransmission of data ensures robustness. It is designed to support low data rate, low power consumption, and low cost wireless communications. The PHY layer supports a data rate of 250Kbps using 2.4GHz unlicensed bands within a range of 10 to 75 m. the MAC layer is responsible for acknowledge frame delivery, channel access mechanism, frame validation, guaranteed time slot management and beacon management. The network layer is responsible for delivering the data across the wireless sensor network to the target device. In addition, it controls topology management, routing discovery protocol, and security management. The application layer is responsible for maintaining tables for binding and forwarding message between

devices. It discovers the devices in the local area and defines the role of the devices in the ZigBee network; ZigBee network coordinator, or ZigBee end device.

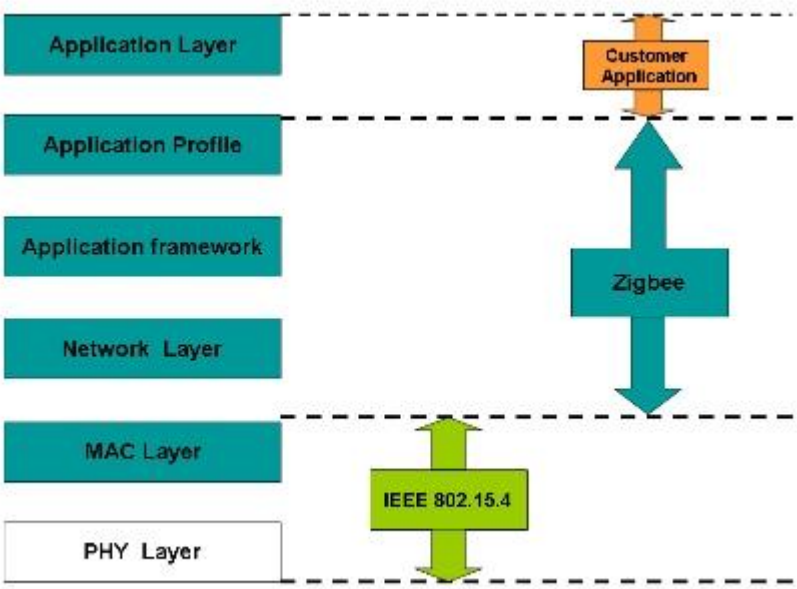
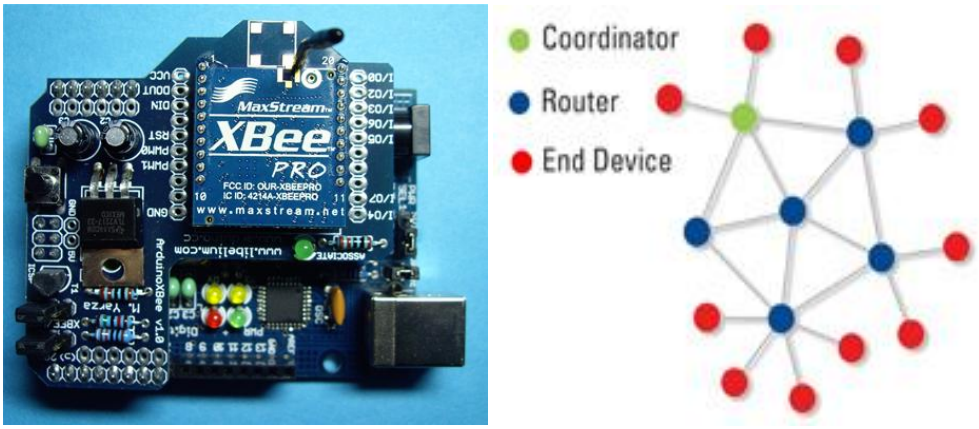


Figure 1 Zigbee Stack

In general, a ZigBee network topology can define in three types of network; star network, tree network and mesh network. In this work, the author wants to adopt mesh topology using in hemodynamic monitoring system. Reasons are as followed. Firstly, the mesh networks can communicate in every pattern of nodes. Secondly, the author will consider on the position of firefighter during fire that moves. The data from every node can repeat in nearest node in the system for reliability. Data in network can be send and repeat to base node in any times. After system started, the base node is finding all nodes in personal area network. After the base node are waiting to receive data in network from each node.



(a) **(b)**

Figure 2 *a)* Prototype of sensor. *(b)* Topology of ZigBee namely mesh network.

2.2 Comparison between Zigbee and Bluetooth

Today two standardized wireless communication technologies – Bluetooth [7] and ZigBee [2] – and a number of specific solutions to build up a wireless sensor network are competitors in the field of medical applications. But as they are mainly deployed in consumer electronics, it has to be checked if they also fit into a medical device for real-time and of course long-term monitoring of vital signs. The requirements for medical healthcare monitoring are:

- Different data throughput and update rates, depending on the sensors to be used
- Low latency
- Low power consumption
- High reliability

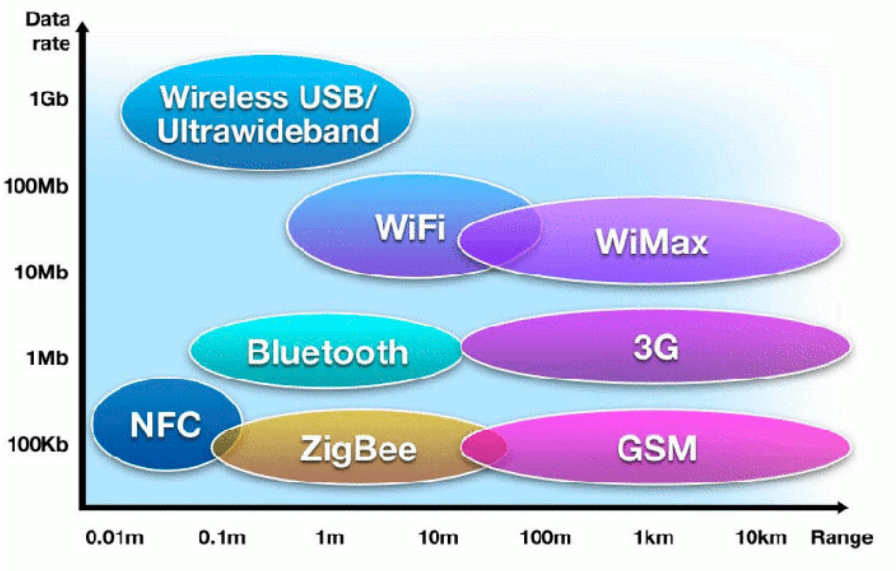


Figure 3 Signal range and data rate of different wireless transmission standards

For these applications (shown in Fig. 3; [8]) high data rates and continuous data transfer in real-time is needed. All of these results in a stack size of more than 250kByte. Comparing ZigBee over Bluetooth the stack size is much smaller (see Table1). This results from focusing on lower data rates, smaller data packages and the need to develop applications directly on the ZigBee protocol stack.

	Bluetooth	**ZigBee**
Stack Size	250 kByte	4.32 kByte
Data Rate	1Mbit/s	250 kbit/s
Information Rate	~720 kbit/s	~128 kbit/s
Packet Size	2870 Byte	127 Byte

Table 1 Comparing Bluetooth and ZigBee protocol

2.3 Wireless technologies in health area

Based on certain research findings, no manufacturer has overcome for 3L data transmission from patient to monitoring person in hospital. Definitely there is type of wireless measurement such as ECG, SpO2 and etc. The maximum data rate is insufficient for multi patient networking systems in the ICU or surgery rooms [9]. In medical diagnostics the most important signals that are measured on a patient are called vital signs. Some of the vital signs are numerical values that slowly change over the time and only once in a while need to be refreshed on a monitoring display. The patient's temperature would be one of those numerical signals. Another type of vitals sign are continuous wave forms. The characteristic run of these curves gives a lot of information to physicians.

Figure 4 ECG-signal (left) and Pulse signal (right)

Due to the frequency components contained in these signals, a certain sampling rate is necessary when converting the analog signal from the primary sensor into digital values for further signal processing in a microcontroller or PC. While the highest frequency component in a pulse wave is lower than 20 Hertz, the distinctive from the QRS-complex in an ECG signal leads to 100 Hertz as the highest frequency component. Typical sampling rates in medical applications are 100 Hertz for a pulse wave signal and 400 Hertz respectively for an ECG. Table 3 shows the needed data rates when digitizing with an 8 up to 16 bit ADC.

Signal	Sampling rate	Bits	Data volume in bits / s
Temperature	1	10	10
Movement	20	10	200
Breathing	20	10	200
Pulse wave	30…100	10	300…3000
One lead ECG	100	10	1000
Three lead ECG	100…400	8….16	800…. 6400

Table 2 Data rates from medical devices

The ZigBee communication protocol allows a general packet size of 127 byte to send data from one node to another. In such a package a payload of 86 byte is provided for user specific data. Due to limited frame size of each data package the user data has to be fragmented into several packages. With the data volumes of different sensors from table 3 the value of required packet range from one packet per second up to 10 packets per second. The resulting data rate from user specific payload and package overhead therefore reaches a maximum of 9.9 kbit/s. Combine several medical devices to a body area network all devices have to share the same medium and therefore the data rate has to be split up among each of them. But counting the data rates of a sensor set a firefighter might wear as a body area network the useable data rate of ZigBee should be sufficient.

2.4 Integrating for firefighter purpose

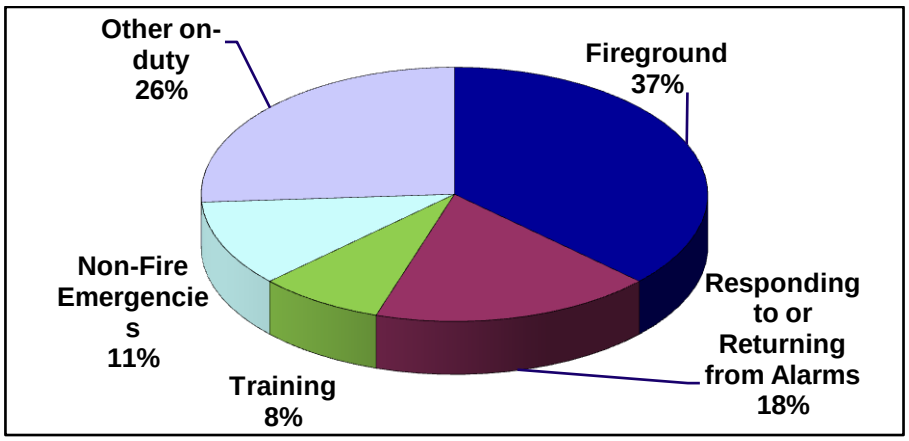


Figure 5 US Firefighter Injuries Cause Death by Type of Duty, 2010

Based on US Firefighter Injuries Cause Death by Type of Duty, 2010 in Figure 5, the major cause of death is during fire. As engineer, how we can help them to reduce the injury cause death during fire? From the previous research we can understand that it is possible to monitor patient in hospital from a big distance. Hence, we can integrate this method to apply to the firefighter to monitor their heart beat from a big distance while they rescue during fire and for any critical heart beat occur we can respond fast to avoid any injury cause death happen.

As Zigbee only require a small data rate, low power consumption and high reliability, hence it is easier to use since to monitor heart beat that does not exceed the amount provided by Zigbee.

CHAPTER 3

METHODOLOGY

3.1 Project Work

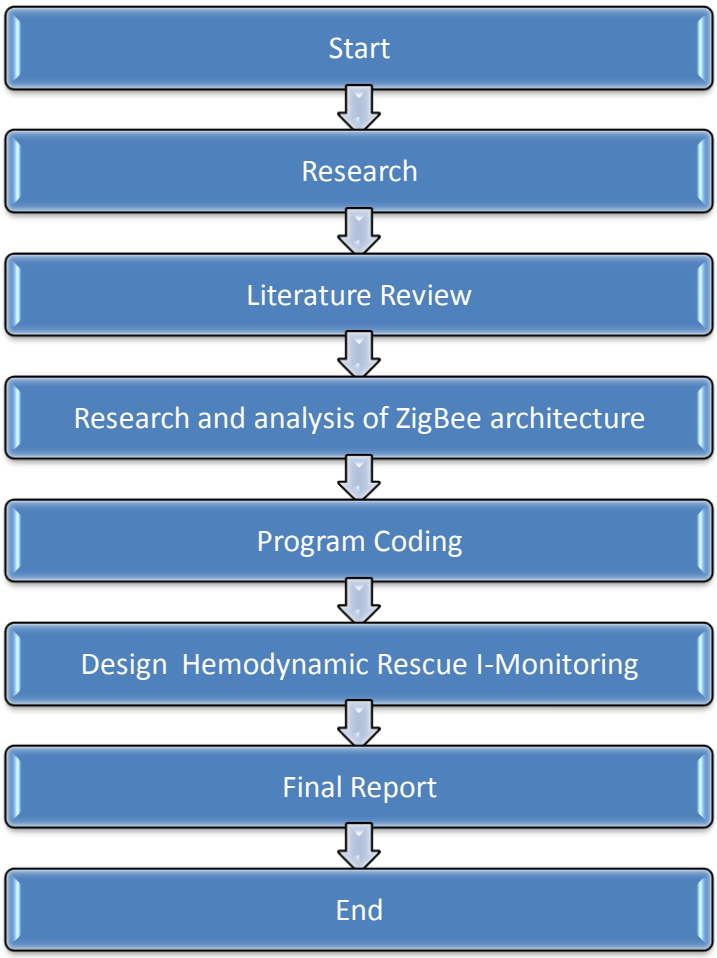


Figure 6 Project Activities Flow

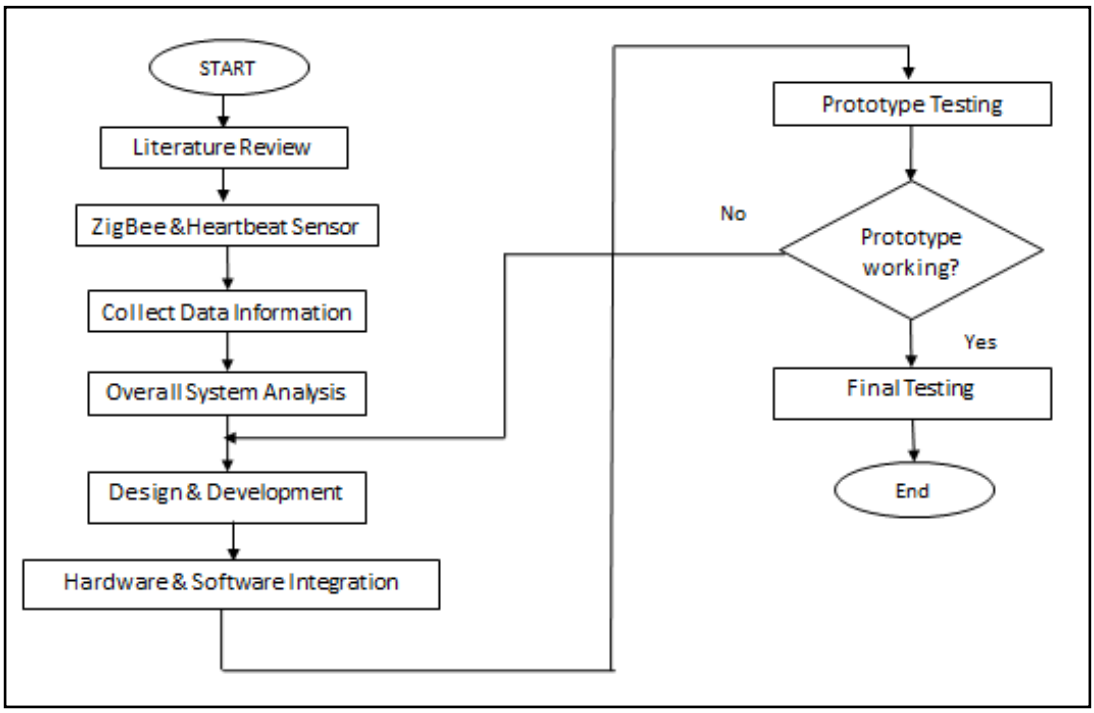


Figure 7 Overall Flow of Project

This project is a study base project. To be specific, it is a study of the application of ZigBee and how it can help to monitor hemodynamic of firefighter during fire. Based on figure 4, first and for most, the project will begin with the research on several issues which had been mention in the research methodology below. Research on ZigBee, the system architecture and comparison between other systems will be done first.

With all the collective and informative information, the project will proceed with the literature review on the application of ZigBee and how it work. All the literature review materials will be downloaded directly from the IEEE store to maintain the source reliability. Materials review may be any journals or conference papers related to the field of this project.

After completing the literature review, the further studies of ZigBee systems architecture and program coding will be done. During this period, analysis will take place and all the characteristics will be noted out. Apart from that, simulations also will be done so that the results can be analyzed for further improvement.

Then, it will come to the hardest part which is designing the product. During this period, results from the analysis part will be compiled and reviewed. Based on that, calculations will be made and the prototype will be designed.

Last but not least, all the studies and discussion will be compiled in the final report.

3.2 Research Methodology

Research is a method taken in order to gain information regarding the major scope of the project. The sources of the research cover the textbook of ZigBee, e-journal, e-thesis and several trusted link.

The steps of research:

1. Gain information about ZigBee.
2. Comparison between ZigBee and other systems.
3. Understand the application of Zigbee.
4. Compile all of the information.
5. Start to do program coding.
6. Apply the system to the actual situation.

Make a conclusion and propose a way to integrate the system.

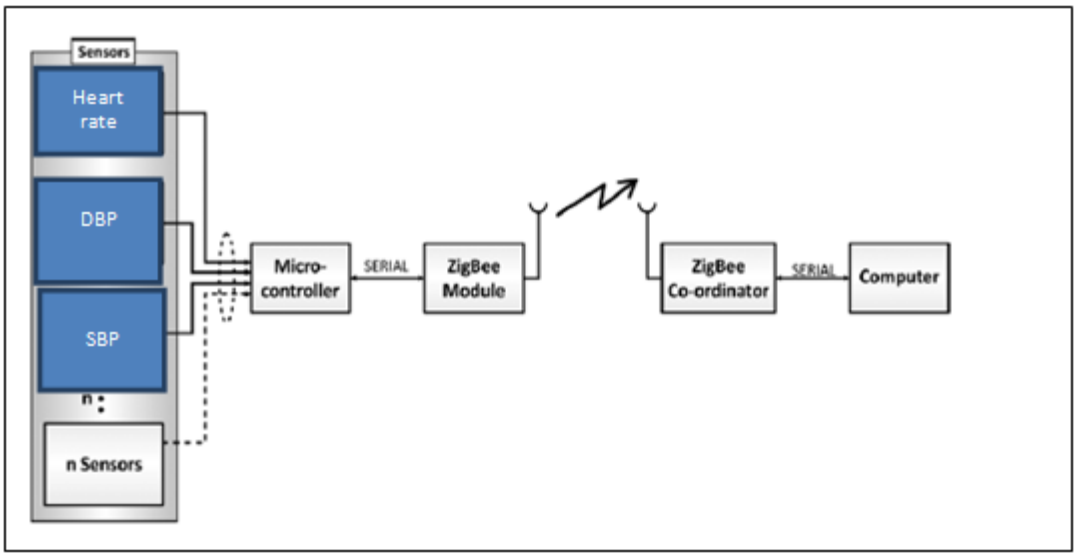


Figure 8 Proposed System Block Diagram

Figure 6 show the functional block diagram of the system hardware. The system has been designed to take several inputs to measure hemodynamic parameters of firefighter such as heart rate, SBP and DBP. The input from the sensors are integrated and processed. The results are sent through the XBee Module to a host computer, which stores the data into an Access Database. The value can then be displayed on the Graphical User Interface (GUI) running on a computer. If it is that firefighter is medically distressed, an alarm may be generated.

The program is a user interface, allowing a report on the current status of the individual. Once the user has connected to the receiver unit, data is automatically updated on the screen. BPM (beat per minute), body temperature and impact (in both axes) are given on the display. The data are also plotted on a time graph which can be customized to show data received from any of the sensors.

3.3 Activities/Gantt Chart and Milestone

No	Detail/Week	1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14
1	Selection of Project Topic: Hemodynamic Rescue I-Monitoring															
2	Preliminary Research Work: Research on literatures related to the topic															
3	Submission of Extended Proposal															
4	Viva : Proposal Defense and Progress Evaluation															
5	Draft Report															
6	Final Report															
7	Project work continues: Further investigation on the project and do modification if necessary															

Table 3 Gantt chart and Key Milestone (FYP I)

No	Detail/Week	1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14	15
1	Develop prototype																
2	Troubleshoot and debug																
3	Finalize prototype																
4	Pre-EDX																
5	Draft Report																
6	Final Report																
7	VIVA																

Table 4 Gantt chart and Key Milestone (FYP II)

3.4 Tools Required

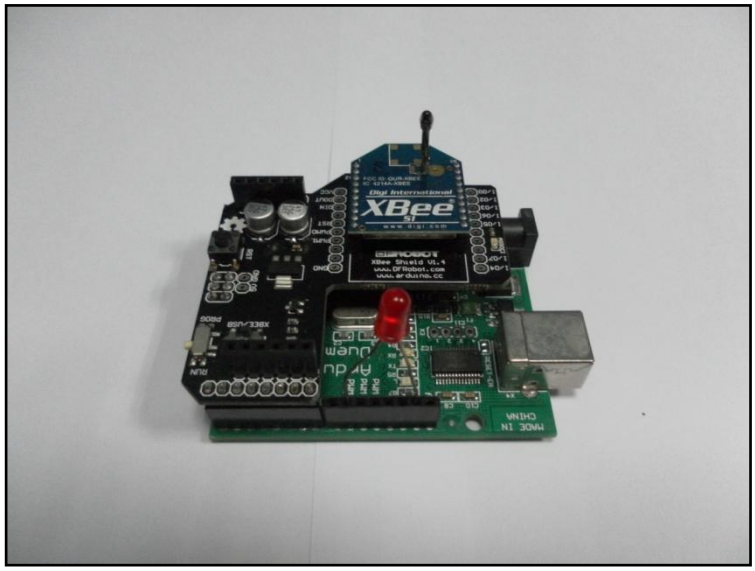


Figure 9 Transceiver

The *Arduino Deumilanove* work as transceiver where the data of heart beat will be determine using arduino coding before it send to the receiver.

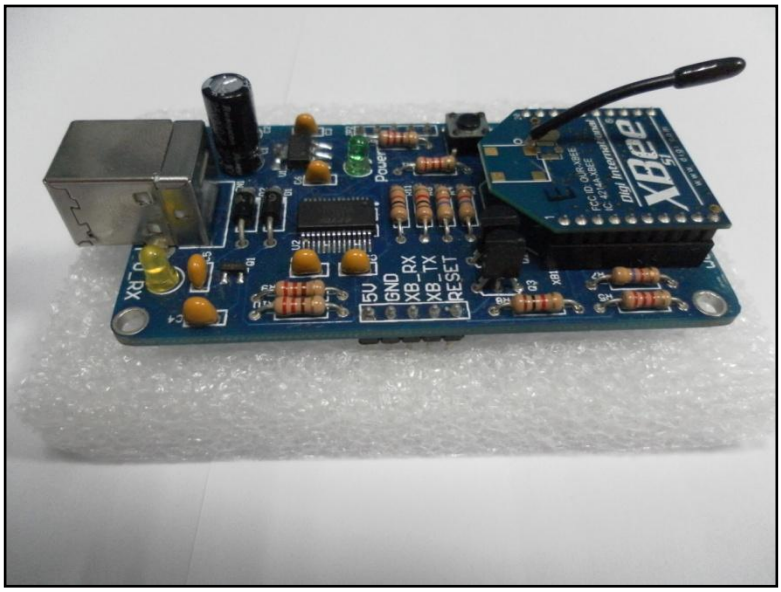


Figure 10 Receiver

The Zigbee series 1 work as receiver to receive the data send by the transceiver. Using the processing coding the data receive will be displayed to the graphical and value of heart beat of firefighter.

Figure 11 Pulse Oximeter

The pulse oximeter will provide the transceiver with the value of heart beat that will be calculate in 60 seconds period. The raw value will be inserting into input analog 0 pin that will be process inside the transceiver before it will be send to the receiver to be shown in graph and value of heart beat per minute.

3.5 Software Required

Figure 12 Arduino Software

This arduino software use to upload coding to the I/O board (transceiver).

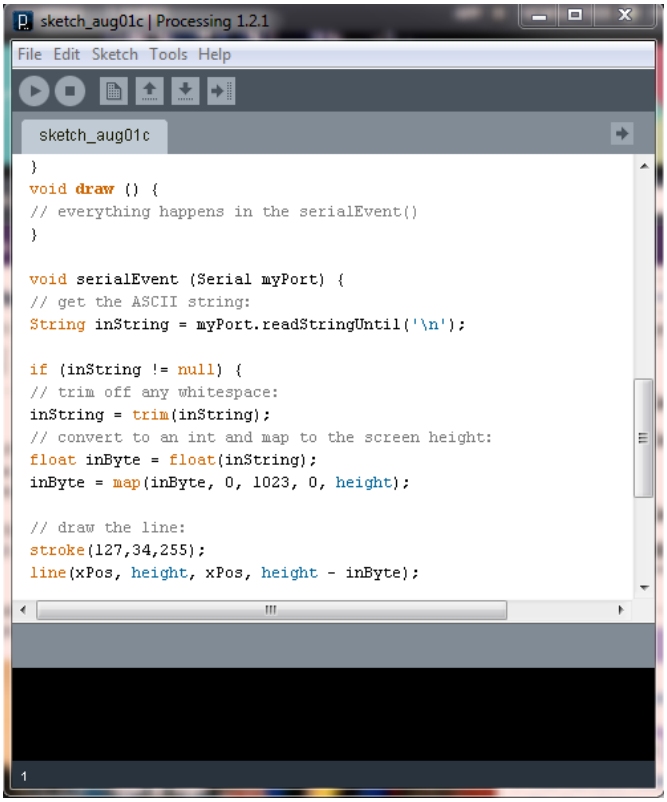


Figure 13 Processing Software

The processing software is use by the receiver. In this software it can show the data in many forms such as graph or value. The coding can just be run when connect the receiver to this software.

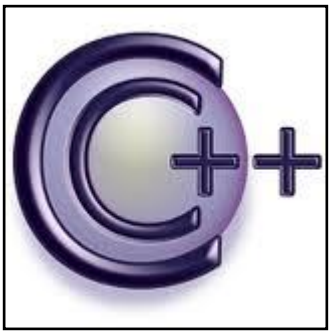


Figure 14 C++ Programming

The expertise using C++ programming is vital at this point since both software (Arduino & Processing) require massive understanding about C++ software to make this research a fully success.

CHAPTER 4

RESULTS & DISCUSSION

Figure 15 Walkie Talkie

Most of firefighter in the world used this type of systems and there is no exceptional in Malaysia too. It is the easiest and the cheapest way for firefighter to communicate. Hence, they are easily can check on each other condition especially during fire.

But there are several disadvantages using this system. As we know, while using walkie talkie we are required to push button for us to talk with others. If the firefighter is lifting someone else and it is hard for them to acknowledge and respond at that time.

Furthermore, while in fire, we can barely heard others talking through walkie talkie and this make the instruction from the leader are hard to understand and could be miscommunication. This can increase the amount of injury and will getting worst if there is no new system to being replaced with the existing one.

It is also not a practical system. For example, during fire for the operator to manage and monitor everyone for every second is impossible. It is because, are they should

talk all the way while in rescuing people? Hence, they will just monitor them in every 5 minutes to make sure all the firefighters in a good condition. Unfortunately, there is a high possibility anything bad can happen in every single minutes and that is why walkie talkie system is not practical anymore.

In this result and discussion, the author will present the experiment and work progress regarding the *Hemodynamic Rescue I-Monitoring System*.

4.1 Temperature Experiment for Electronic Device

Most of electronics devices are made of silicon device that capable to fail catastrophically, but still its can change the characteristics of its electrical and undergo intermittent or any changes. Most devices are not function properly beyond 70oC – 80oc.

During fire the temperature is around 60oC – 70oC only, hence, it is will not change the electrical characteristics or any permanent changes. Furthermore, there should be no problem because the device will be wear under the firefighter's fire proof jacket.

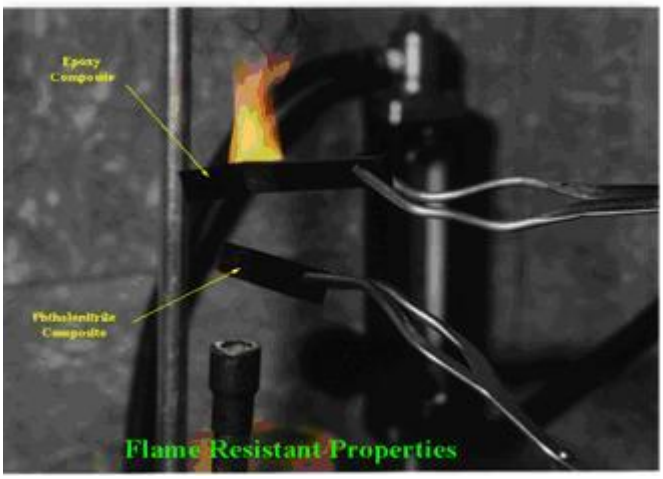


Figure 16 Temperature experiment towards electronic devices

4.2 Distance Experiment in Determine the Signal

Theoretically, Zigbee can send and receive the signal up to 100 meters. Based on this research, the author conducted two types of experiments. First, when there is no obstruction and with obstruction. Without obstruction the distance is longer to receive the signal compare with obstruction and the time Zigbee received the signal is less.

When we moved far from the receiver, the signal was disturbed and need time to recover the signal. With obstruction was conducted with applied the real situation where we send the signal from the top of the building to the ground floor. The space of room, wall and doors became the obstruction and hence disturbed the signal. Table 5 shows the result of the distance experiment.

Obstruction	Distance, m	Time taken to recover the signal, s
Without	93.4	1.45
With	71.5	3.60

Table 5 The Distance Experiment's Result

4.3 Development of the System

Basically, this research/study is more to prototype project and hence it is more to build the hardware and software development. First, we need to develop the coding that will tally with the heart beat monitor. It is vital to translate the raw data by the pulse sensor to be display and easy to monitor. The coding has two parts which are using *Arduino* (transceiver) and *Processing* (receiver).

Figure 17 Coding load into Arduino Software

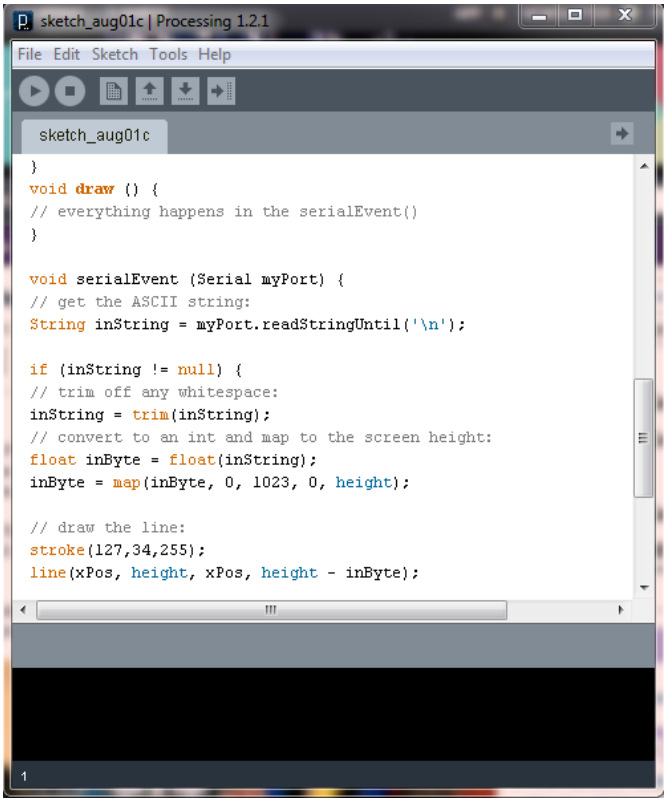


Figure 18 Coding for Processing at the receiver

The coding at the processing (receiver) is to develop a graph and show the value of the heart beat. The outcome of this programming is shown in Figure 19 below.

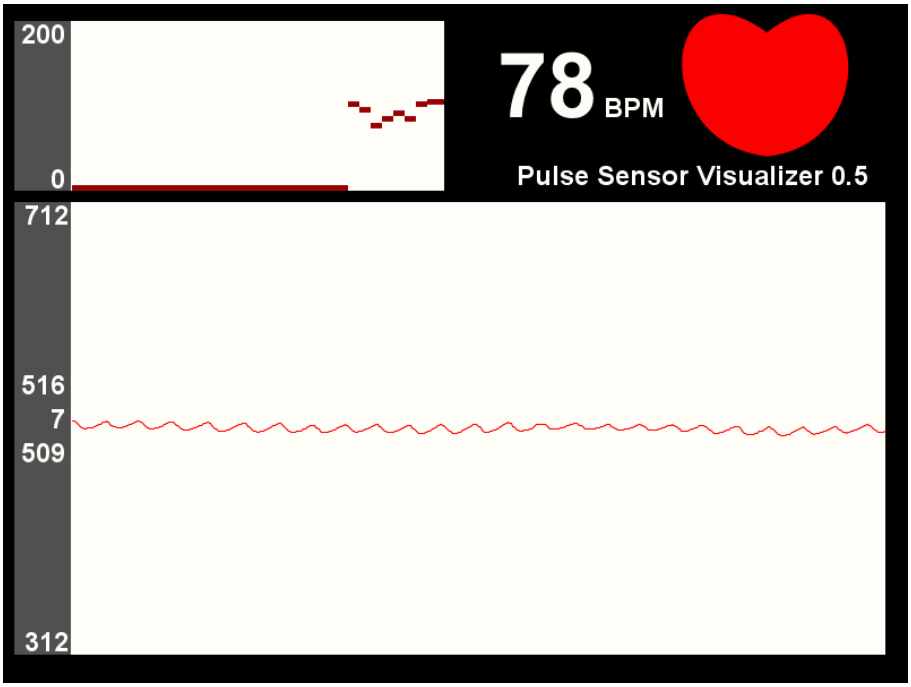


Figure 19 The outcome of the processing coding

4.4 Experiment Using Pulse Oximeter

There is 3 main condition of heart beat that we need to know which is while sitting, walking and running. Since firefighter need to run and do movements, the different heart rate show and we do not want it to be confuse if heart attack happen and we need to know the value of heart beat for this 3 conditions.

The sensor consists of a super bright red LED and light detector. The LED needs to be super bright as the maximum light must pass spread in finger and detected by detector. Now, when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reached the detector. With each heart pulse the detector signal varies. This variation is converted to electrical pulse. This signal is amplified and triggered through an amplifier which outputs +5V logic level signal. The output signal is also indicated by a LED which blinks on each heart beat.

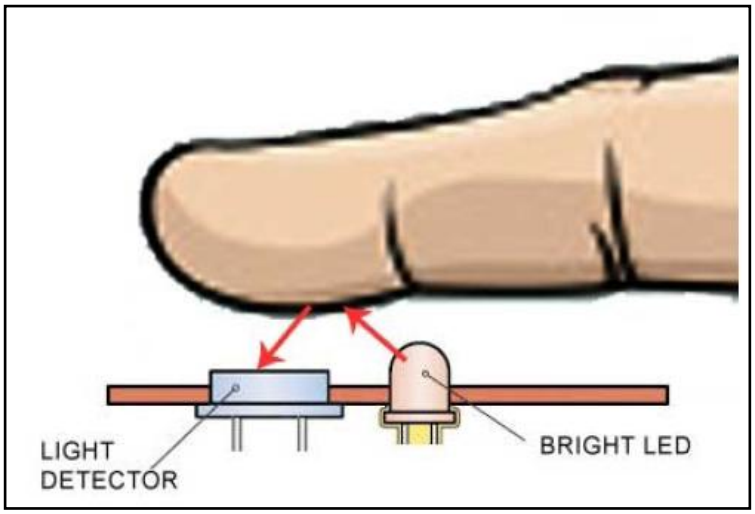


Figure 20 Sensor principle

As the working systems of the sensor shown, we will now see the result of the three main conditions for firefighter during the rescue while in fire.

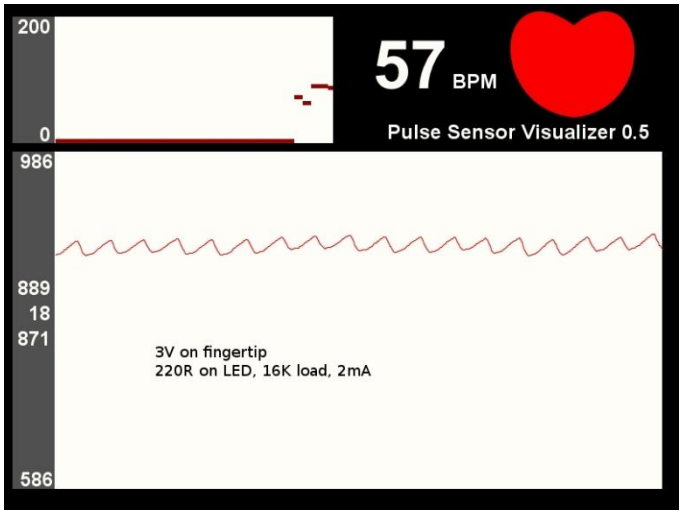


Figure 21 Heart beat during relaxing time (Sitting)

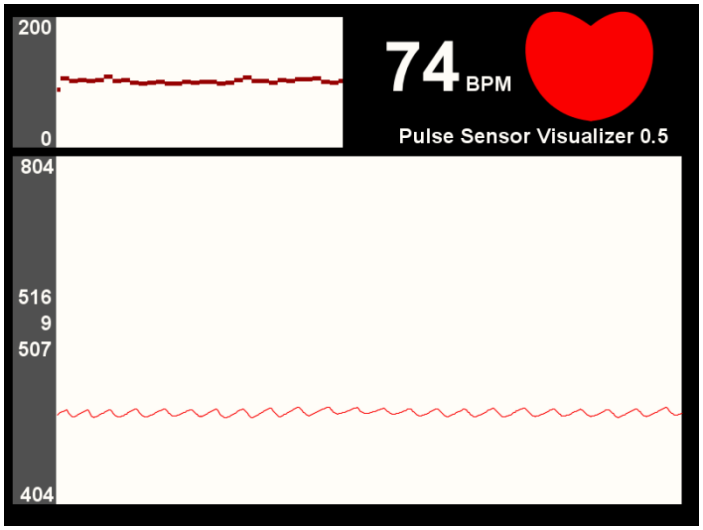


Figure 22 Heart beat while doing slow movement (Walking)

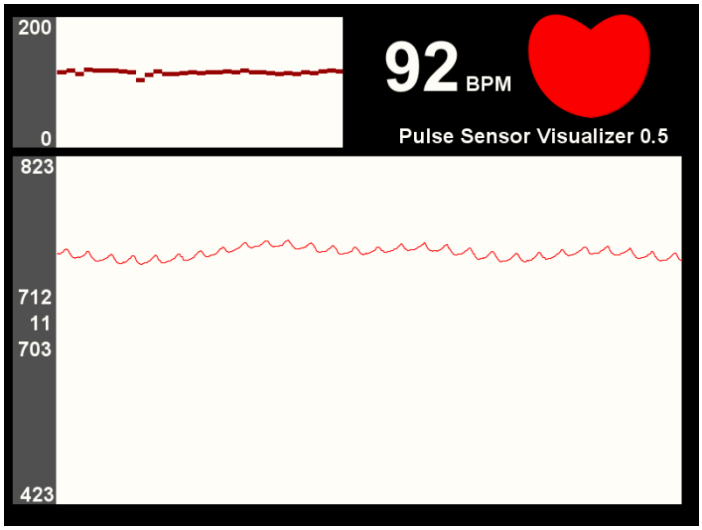


Figure 23 Heart beat while doing fasst mmovement (Running)

4.5 Determine of the Normal Heart Beat

Based on this research, we should know the range of the normal heart beat. The normal heart beat here means that the value of heart beat while we doing any movements. It is important to know the range to avoid any false alarm if anything happen to the firefighter. Figure 24 below show the range of the normal heart beat based on ages while exercise. During rescue, firefighter needs to walk, run and jump that make their heart rate faster than normal and the condition is same while doing exercise.

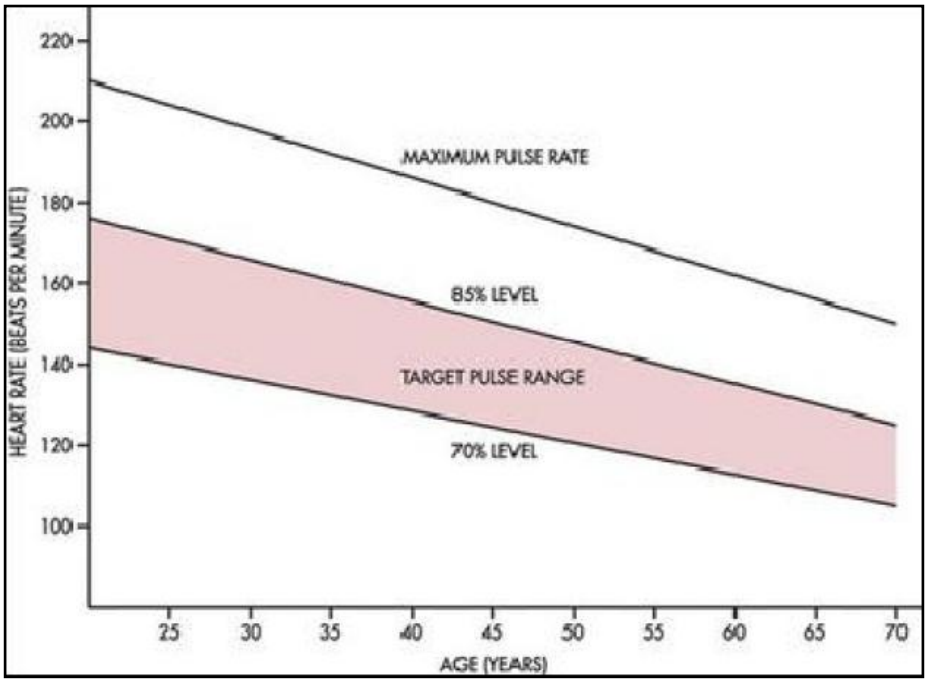


Figure 24 Normal heart rate while exercise

4.6 Design of the prototype

Figure 25 Transceiver wear inside the firefighter's fire proof jacket

Figure 26 The HRIM system jacket

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This paper presents implementation and design of wireless sensor network for real-time health monitoring system for firefighter during fire using ZigBee wireless standard, and demonstration of pulse oximetry data (heart rate and SBP and DBP). The author plan to include other health monitoring module such as; blood pressure measurement, ECG, EKG for completing the system, and the author hope that the system should be adapted for minimizing the device's size and easier to be use by firefighter.

REFERENCES

1. [1] J.L. Weber and F. Porotte, “Medical remote Monitoring with clothes”, PHealth, Luzerne, Vol. 31, pp.246-252, Jan, 2006
2. [2] ZigBee Alliance [www.zigbee.com]
3. [3] Gang Ding, Sahinoglu Z., Orlik P., Jinyun Zhang, Bhargava B., “Tree-Based Data Broadcast in IEEE 802.15.4 and ZigBee Networks”, published by the IEEE transactions on mobile computing, Volume 38, No. 11, Nov. 2006, pp.1561-1574.
4. [4] IEEE standard for part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specification for Low rate Wireless Personal Area Network, 2003
5. [5] http://www.ieee802.org/15/, IEEE 802.15 Working Group for WPAN
6. [6] Patrick Kinney, “ZigBee Technology: Wireless Control that Simply Works” Kinney Consulting LLC, Chair of IEEE 802.15.4 Task Group Secretary of ZigBeeBoD, Chair of ZigBee Building Automation Profile WG.
7. [7] Bluetooth Special Interest Group [www.bluetooth.com]
8. [8] Jon Adams (Motorola), “What you should know about the ZigBee Alliance”, Sensors Expo Workshop, 2003
9. [9] IEEE 802.15.1 WPAN Task Group 1 web site: http://grouper.ieee.org/groups/802/15/pub/TG1.html

APPENDICES