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Heart Rate Analysis and Monitoring of Patients from Offsite through Wireless Sensor Network

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ABSTRACT: Researchers throughout the years have been searching for methods to improve the available technologies to ease the users worldwide. In medical industries, researchers have made many improvements and development in medical equipment's to ease the medical professionals in serving patients. This work is the continuation of the previous research work in providing complete set of data for analysis on human behavior to set an accurate threshold for device detection. In this work, heart rate is monitored to all age groups for both genders wirelessly from remote locations. Results shown that these various age group is giving average reading that complies to the benchmark reading and is able to provide the necessary threshold value for future device improvement and enhancement.

KEYWORDS: Heart rate; Patient monitoring; Wireless monitoring; Wireless protocol zigbee.

I. INTRODUCTION

Medical professionals are currently evolving with the current technologies that are being developed. With wireless technology evolving with time, it is essential that the medical equipment's in the hospitals synchronize with the technology in order to provide better quality services to patients. The numbers of patients are increasing while the current medical professional's number is decreasing gradually due to retirement or etc. and upcoming graduates still in training. The conventional method (wired and manual data retrieve) only provides certain amount of data which enables the medical professional to identify and detect the level of sickness and seriousness of the patients conditions [1].

The continuous wireless monitoring system introduces enables the medical professionals to have sufficient data and monitoring time of the patient in order to recognize and detect the level of patients sickness. This will enable the patient to be monitored closely for any sudden irregular physiological signs. Many researchers have developed wireless handheld devices in this field area. This work introduces a wireless body worn heart rate monitoring device using Zigbee module to be used by general ward in hospitals.

II. BACKGROUND STUDY

Many researchers have implemented numerous types of wireless modules to be implemented in the handheld or body worn devices. After consideration taken in comparing the wireless technologies such as Bluetooth, Zigbee or Wi-Fi, Zigbee has been chosen as the wireless technology method in transmitting the subject's physiological signs detected from the sensor. The Bluetooth technology provides better transmission rate, but the startup time is low and can only supports up to several meters in range thus, making the IEEE 802.15.4/Zigbee the best transmission method with low power consumption and suitable for continuously monitoring in hospitals. Meanwhile, 802.11b (Wi-Fi) has limited standards that is not suited for low power consumption. Other than stated the above, the Infrared technology only provides line of sight transmission and also angle limit problem, it has not been used in the physiological signal transmission [1-4].

From earlier research phase conducted in [4] comparison between RF and Zigbee Xbee module has been made and it is seen that the data from Zigbee Xbee module produces stable reading, low power consumption and fast response. Thus the work is continued using the Zigbee Xbee module as the transmitter for the body worn device.

There are studies in applying Zigbee to be integrated in medical devices as in [5], where the paper introduces one part of a larger project to provide complete patient monitoring system that which features such as Electrocardiogram (ECG) and Pulse - Oximetry data. The analysis of the work starts from wireless technology comparison where Zigbee is chosen due to its low cost, low power consumption and the capability to communicate with each other and other

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devices also relates on mobility if the Zigbee where it supports sleep mode (for lesser power consumption), co-existence of two same bandwidth technology Zigbee and Wi-Fi so that the signal does not collide by implementing simple site survey, the device parameters that sense vital signs such as respiratory rate, non-invasive blood pressure, SPO2 and temperature, bandwidth using Maquet Servo-I which supports all ventilator parameters and lastly scalability which is experimentation on obtaining parameters scale for device design. The system architecture consists of the Wireless Personal Area Network (WPAN) implemented for Zigbee network communications with Local Area Network (LAN) via gateway. The Medical Device Interface (MDI) also consists of Zigbee module, a microcontroller and RS232 [5-6].

Physiological signs are, according to Merriam - Webster online dictionary a characteristic of or appropriate to an organism's healthy or normal functioning, which by means the signs of a human that is in normal condition [7]. Signs that are referred here is the vital signs of a human body, specifically the heart rate condition. A heart rate is defined as the total of heart beats (frequency cycle) per minute or bpm and is caused by the flow of the blood through the body which supplies an amount of oxygen in the body depending on the body's condition.

The heart rate normal range readings for both men and women have been tabulated in previous research conducted in [8]. The table only provides the benchmark of reading range for an individual in an age group. It does not specify the health condition of the individual. Thus in this work, the continuum of the experimentation is to discuss on the heart rate reading for certain age group and also to discuss on the comparison between the obtained reading referring to the benchmarked readings from the provided table below [4],[8]. The age groups discussed in the table are from the range of 18-25, 2635, 36-45, 46-55, 56-65 and 65 above for both genders with level heart beat categories from athlete, excellent, good, above average, average, below average and poor.

An abnormal heart rhythm can happen at anytime and anywhere without prior notice which provides an effect such as heart "racing", lightheadedness or dizziness. In some cases, if the abnormal heart rhythm last for a long time this may affect one heart's function and can lead to fatality. Symptoms of irregular heart rhythm are classified as palpitation (skipped beat), Bradycardia (slow heartbeat), Tachycardia (rapidheartbeat), Chaotic, Quivering or Irregular Rhythm, Presyncope (almost fainting) and Syncope (fainting) [8].

III. METHODS AND MATERIALS

This section discusses on the methods of implementation of the experiment work and the materials that are used to design the hardware and architecture. Continuation of this research is specifically on only implementing Zigbee Xbee module as the main wireless transmitter as results from the conducted research from [4].

3.1. System Architecture

The complete system architecture is designed as in Figure 1. The architecture design is based on implementing the networking protocol of a Zigbee network. A certain amount of subjects will be embedded with the body worn device that has been embedded with an individual sensor. By implementing a route of wireless networking protocol, the data from the sensor on the body worn device is able to be transmitted in wide range of communication area. However, networking protocol is not discussed in this work. All collected data will be kept in a database system and any unwanted detection (exceeds the threshold/predefined limit) from the transmitted data will send a trigger to the computer host notifying person in charge for immediate response [4].

3.2. Microcontroller

Microcontroller is implemented to change the data input from analogue to digital signal and also to control the amount of data transmitted. This would help in controlling the amount of power consumption in the body worn sensor circuit. For this pre - designed circuitry, a microcontroller IC ATMEL328P is used. The Atmega328P is an Atmel Pico-Power 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM and 23 general purpose I/O lines [8].

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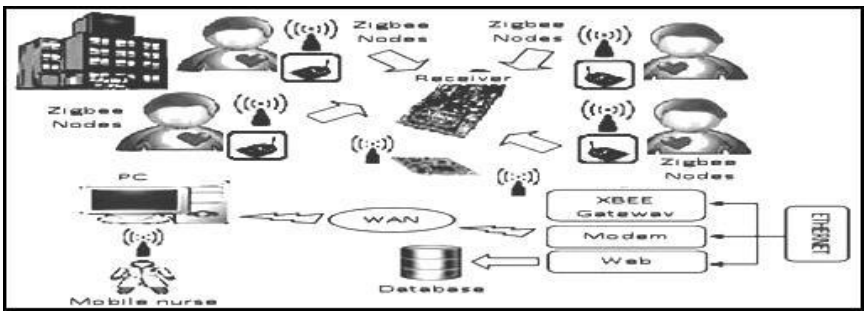

Figure 1: The complete system architecture of monitoring system [4].

3.3. Zigbee Module

In this research, the Zigbee Xbee-Pro OEM RF Module was chosen as the transceiver module at the body worn device for data transmitting. The Xbee - Pro OEM RF Module, is a Zigbee - based wireless device that helps to reduce the implementation cost by simplifying the communication protocols and reducing the data rate. The module uses RF transceivers frequency for communication transmission but uses the Zigbee standard protocol for networking, application and security layers [8].

3.4. Heart Rate Sensor

A basic heart rate sensor is made of an LED and a photodiode. The sensor used detects the level of blood color volume to determine the intensity of the reflected light, providing an analogue signal that can be fed into the microprocessor. The amount of blood at fingertip varies in each reading. For each heartbeat, the signal will increase in amplitude and heartbeat rate level is to be determined by using microprocessor [8].

3.5. Developed Prototype

The preliminary phase prototype consists of a heart rate sensor on strip, microcontroller, battery and transceiver module where reading was captured every 60 seconds on two different posture positions. Heart beat reading is transmitted to a computer by using two (2) types of transmitter and receiver, RF and Zigbee. Figure 2 (a) shows the RF transceiver part with heartbeat sensor strip while and (b) RF receiver that will be connected to the computer. On the other hand, Figure 3 (a) and (b) shows the Zigbee (Xbee) transceiver attached to heartbeat sensor strip and Zigbee (Xbee) receiver that is connected to the computer respectively.

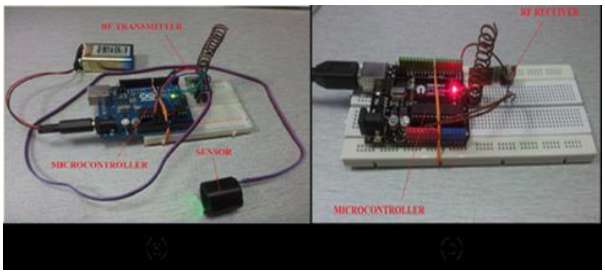

Figure 2: RF Tranceiver with Heartbeat.

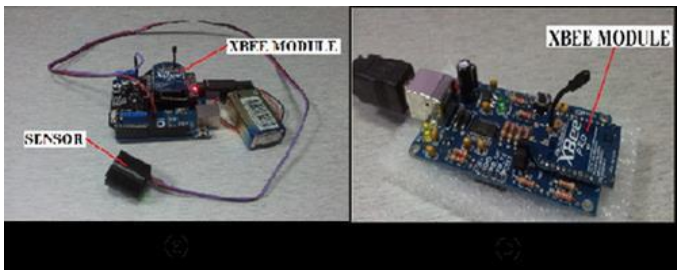

Figure 3: Preliminary Prototype Zigbee (Xbee) Transceiver.

The prototypes shown in Figure 2 and Figure 3 have been transferred to PCB form in order to utilize the size and applicability on subjects. The prototypes are tested again to ensure that the readings are as stable as our preliminary findings as shown in Figure 4 [8].

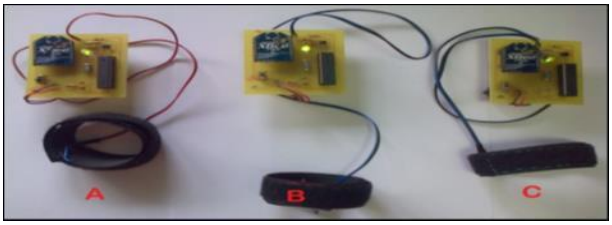

Figure 4: Heartbeat Monitoring Device using Zigbee [8].

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IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The current research discussed here is determining the stability and accuracy of the data provided by the sensor through the circuit that has been designed. The readings taken from multiple subjects from different gender are compared and analyses through the benchmarking discussed in Section II. However, if a reading obtained is abnormal, the results will be referred and discussed with a proper source to determine the proper explanation of the behavior.

4.1. Body Posture Comparison

Previous procedure conducted in Reference [4] is regarding the wireless technologies comparison on stability and accuracy of transferred data in different age groups. The body posture positions were also compared in order to obtain the reliable heart rate reading for 3 different male subjects labeled as Subject A, B and C at the age of 18 - 25. Figure 8 shows the comparison of reading between lying and sitting positions where Condition A is lying and Condition B is sitting. The straight line indicates Condition A while dashed line indicates Condition B. Figure 8 (a) is Subject A, Figure 8 (b) is Subject B and Figure 8 (c) is Subject C.

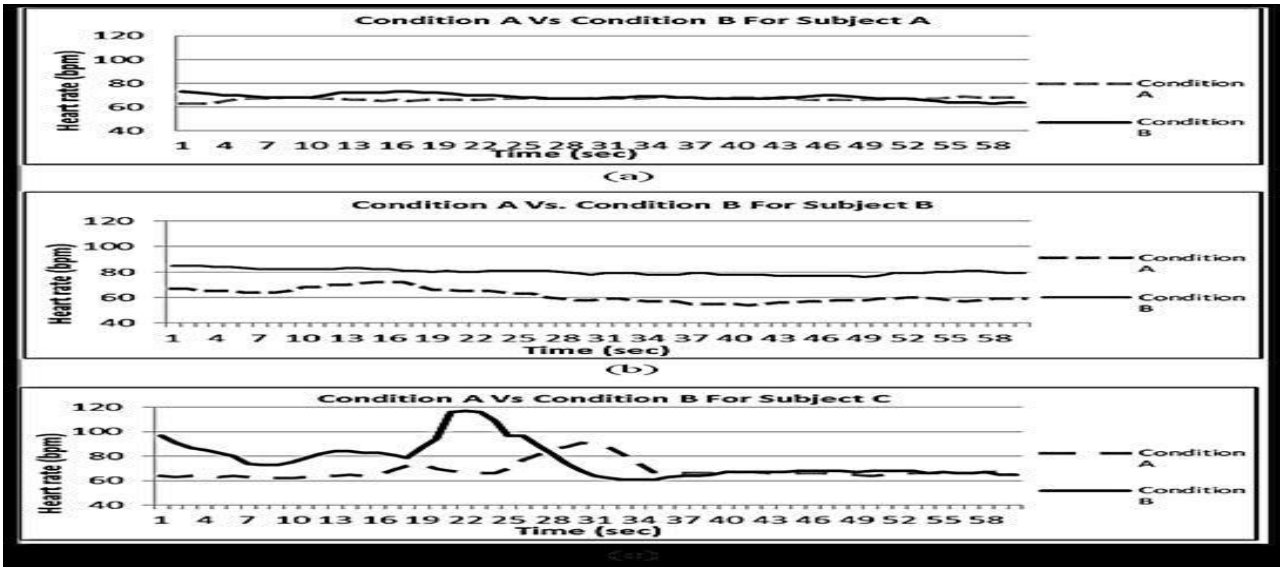

Figure 5: Condition A Vs. Condition B for (a) Subject A, (b) Subject B and (c) Subject C [4] SOURCE from Escorts and Fortis Hospitals.

The lying down position provides reliable and stable reading due to the blood can flow smoothly throughout the body thus provide sufficient oxygen in the blood. This helps the heart to settle (rest) thus providing a more excellent range of heart rate reading [4].

4.2. Preliminary Experiment on Comparison of Wireless Technology

The next experiment is to identify between RF (conventional method) and Zigbee Xbee technology (proposed design) transmission of the three subjects heart rate reading. The readings were taken using a direct method as benchmark device, two sensors connected with RF transmitter and another with Xbee transmitter respectively [4]. Figure 6 until Figure 8 shows the results of wireless comparison. The straight line indicates direct method transmission, dotted line indicates RF transmission method and dash dotted line indicates Zigbee transmission method.

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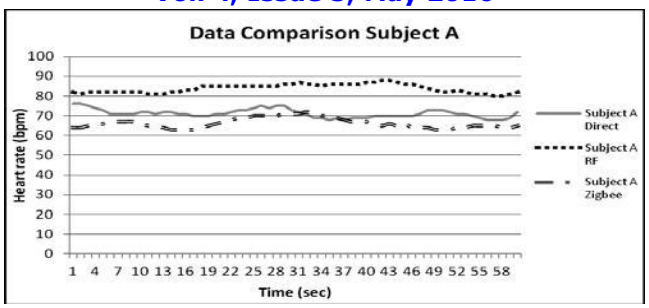

Figure 6: Data Comparison Subject A On Direct Method, RF And Zigbee [4].

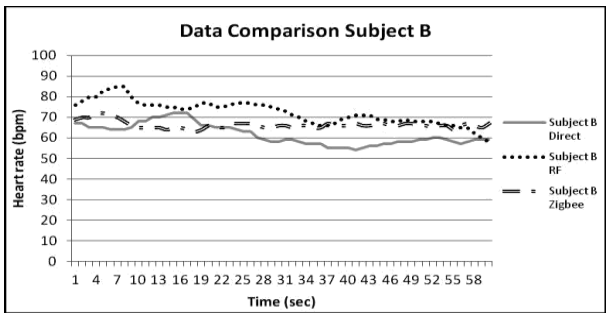

Figure 7: Data Comparison Subject B Direct Method, RF And Zigbee [4].

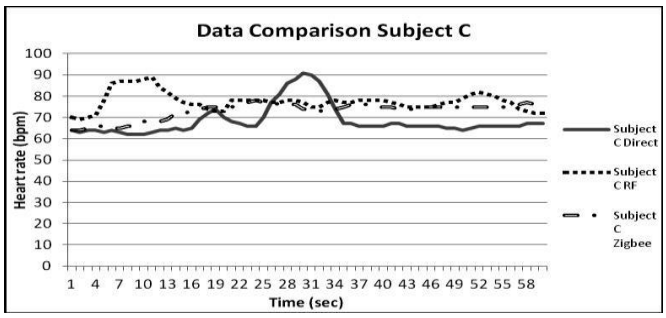

Figure 8: Data Comparison Subject C On Direct Method, RF And Zigbee [4].

From the above figures and if referred to [8], subject B provides excellent and stable reading while subject A is an average, and subject C is unstable in the beginning then bstabilizes and reaches excellent reading. The differences may be due to internal factors such as stress, tired or food consumption of each individual [4].
From the figures also shown that the Zigbee approach provides stable reading in terms of heart rate where the value is nearing the direct approach. The RF approach on the other hand, took some moment of time interval for it to stabilize to provide better reading of the subject. However, the data from RF produces sudden peaks in graph during time reading was taken [4].

4.3. Preliminary Experiment for Multiple Age Groups for Male:

Comparisons conducted by obtaining data from multiple age groups for male gender according to [8] and being analyzed as shown in Figure 9 to Figure 13.

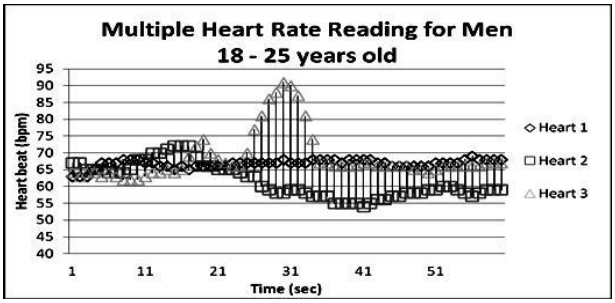

Figure 9: Multiple heart rate reading of men for age group 18 to 25 [4].

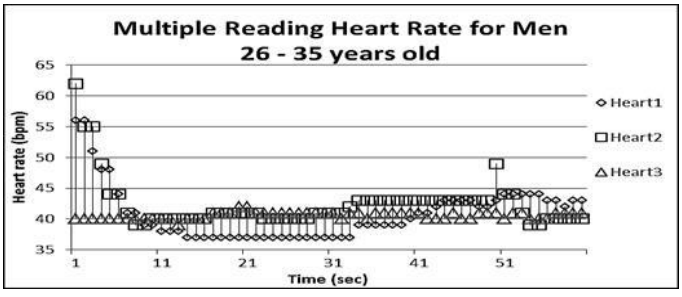

Figure 10: Multiple heart rate reading of men for age group 26 to 35 [8].

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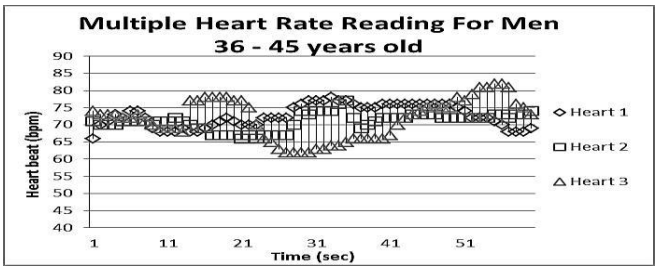

Figure 11: Multiple heart rate reading of men for age group 36 to 45.

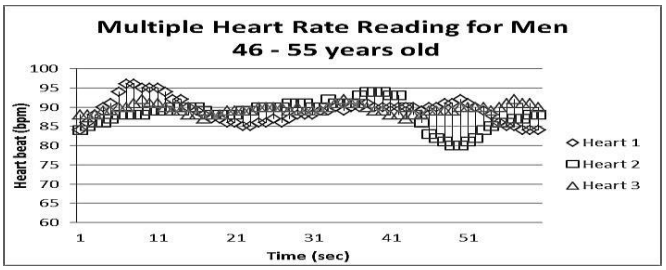

Figure 12: Multiple heart rate reading of men for age group 46 to 55.

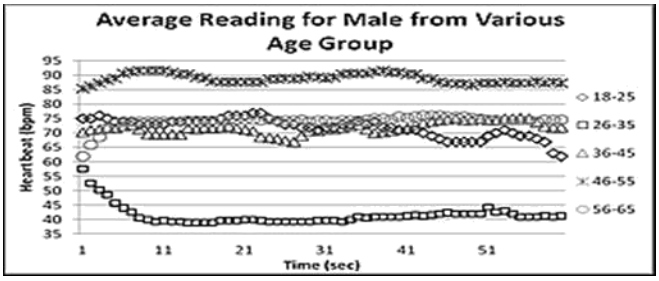

Figure 13: Multiple heart rate reading of men for age group 56 to 65 [8].

Readings from Figure 9 until Figure 13 are taken 3 times to ensure the stability of sensor and range of reading detection and respect to varies age group as tabulated in [8]. The higher an age group is, the higher the possibility of unstable heart rate reading. The reading of heart rate varies in terms of one's living lifestyle where taking into consideration their daily activities, food consumptions and health conditions.

Aim of the proposed From the average value of an individual man for all groups of ages as benchmarked in [8], the average reading heart rate may determine the suitable value of threshold, minimum and maximum scale value to be used in the sensoring program. This is shown in Figure 14.

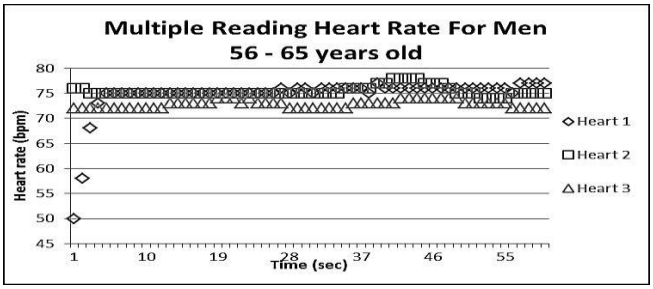

Figure 14: Combination reading of average reading for all age group for men.

Figure 14 it shows that the average reading for age group 46 - 55 shows a very high reading. To analyse this reading, the individual lifestyle is investigated. The individual is a high risk patient due to unhealthy lifestyle, overweight and has high blood pressure. Another reading that needs to take into notice is the low reading range for 26 - 35 years old where the reading is below than athlete range which is the minimum. The lifestyle of this individual is healthy and is an athlete. Due to this factor the individual has a controlled heart beat even during exercise. The figure also provides the average threshold value that can be used to detect the heart rate of a male. The threshold value is set at a minimum value of 40 (too low) until 75 (too high).These values are important in alerting the medical assistants in charge in case of emergency.

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4.4. Preliminary Experiment for Multiple Age Groups for Female

Comparisons were done by taking data's from multiple age groups for male gender according to [8] and being analyzed as shown in Figure 15 to Figure 19.

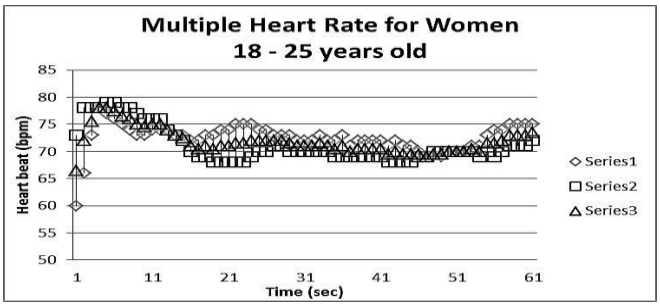

Figure 15: Multiple heart rate reading of female for age group 18 to 25 [4].

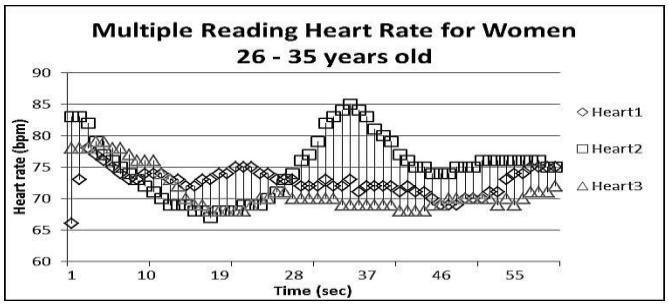

Figure 16: Multiple heart rate reading of female for age group 26 to 36 [8].

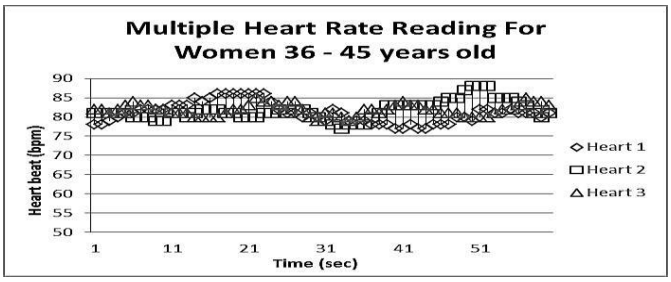

Figure 17: Multiple heart rate reading of women for age group 36 to 45.

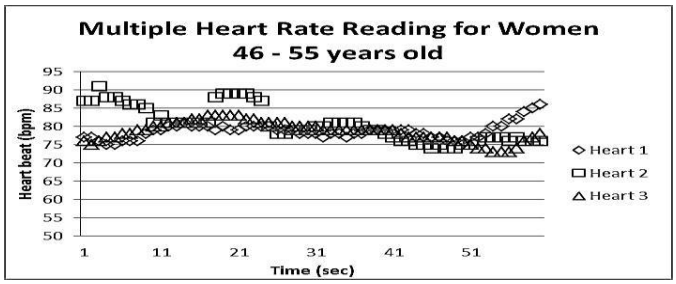

Figure 18: Multiple heart rate reading of women for age group 46 to 55.

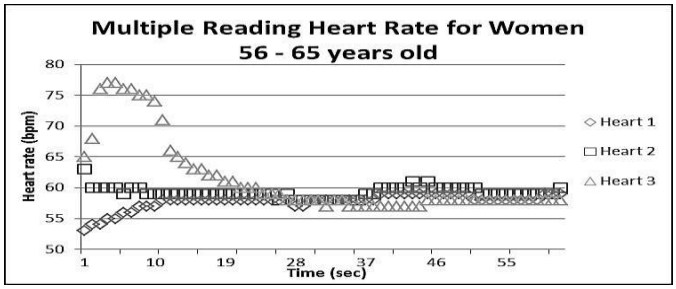

Figure 19: Multiple heart rate reading of women for age group 56 to 65[8].

Readings from Figure 15 until Figure 19 are taken 3 times to ensure the stability of sensor and range of reading detection and respect to varies age group tabulated in [8]. The higher an age group is, the higher the possibility of unstable heart rate reading. The reading of heart rate varies in terms of one's living lifestyle where taking into consideration their daily activities, food consumptions and health conditions. However, women has a different living style where they are most likely to be involved in stress either occupation or at home. This situation must also be taken into consideration whereby when starting a monitoring test, the first 30 seconds are the time that the patient or person takes to stabilize their heart rate reading.

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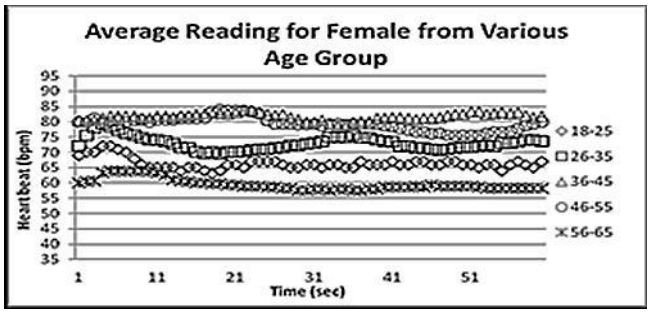

Figure 20: Combination reading of average reading for all age group for women.

The Figure 20 it shows that the average reading for age group 36 - 45 and 46 - 55 shows high reading. To analyse this reading, the individual lifestyle is investigated. The individual is a low risk individual living in normal lifestyle. Thus the assumption in this situation is maybe the individuals have the stress and anxiety feeling during monitoring.

From the average value of an individual woman for all groups of ages as bench marked, the average reading heart rate may determine the suitable value that can be used to detect the heart rate of a female. The threshold value is set at a minimum value of 50 (too low) until 80 (too high). These values are important in alerting the medical assistants in charge in case of emergency. From the Figure 14 and Figure 20 it is seen that the heart rate of an individual will be at rest after 30 seconds of transmitting. Thus it is suggested that the reading is suitable to be taken after 3 - 5 minutes of the individual check - in in a hospital ward.

The maximum heart rate value of a man is lower than women. Thus, taking this into consideration, the threshold value must be considered as an average in order to allow the same device to be used for both genders. The maximum range of reading will alert the medical staff in charge. This sample has provided the researcher a maximum value threshold of heart rate for a men and women at multiple age groups.

V. CONCLUSION

From the experiment in comparison of wireless technology in wireless monitoring system, it shows that RF technology is capable in transmitting efficient data. However, RF needs a certain time interval for it to provide the stable and accurate reading. Meanwhile, Zigbee provides the stable and accurate reading from start for both condition positions. It is also seen that a patient needs to be in a lying position in order to provide a better and stable reading due to sufficient blood flow of the body. The sensors obtain heart rate reading from the thickness of blood under the skin.

From the figures, improvements must be made in terms of delay in data transmission. The delay of minimum of 11 seconds after the first transmission would be able to provide the medical professionals the right data which is when the heart is at rest. Another assumption for to obtain a better data set is by delay of 30 seconds to 5 minutes from the first transmission.

Different age groups and gender provides different sets of heart beat data. This heart beats differ due to a person's condition. The experiments were done in a quiet location (room) to calm the subjects. However, some of the individuals are easily developed with anxiety and stress leading to higher heart beat values. The advantage of this situation is that the reading provides a certain interval that can be used as a threshold upon improving the body worn prototype.

From the series of tests conducted using the wireless Zigbee technology, results have shown the stability and improved reading range when the power supply or battery is in full capacity. The sensors that were embedded in the devices also showed reliable readings for long term use as the devices were tested on multiple times in one experiment procedure.

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