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A ZIGBEE-BASED CONTINUOUS ONLINE VITAL SIGN MONITORING SYSTEM

Hanita D.[1], Nurul Fauzana I.G.[2], Nursyarizal M.N.[2] and Taib I.[2]
[1]Fundamental and Applied Sciences Department, Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia
[2]Electrical and Electronic Engineering, Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia
E-Mail: hanita_daud@petronas.com.my

ABSTRACT

Conventional method carried out by health professionals in measuring vital signs are conducted in every four hours interval in most hospitals in Malaysia. Amongst the wireless technology known to be deployed are Radio Frequency Identification (RFID) and Zigbee technology. They fit the purpose of healthcare application in terms of two ways communication, patient's safety, higher number of nodes and etc. However, the current tag is seen to have setbacks in terms of inefficiency and inaccuracy of data transfer. Zigbee Network on the other hand is able to fulfill the stated criteria with an addition of larger number of nodes and stability during data transmission which is an added advantage to the application. This research is discussing on the development of two different real - time continuous wireless vital sign device which are heart rate and temperature monitoring to be used in hospitals as a medium of patient data transfer and data gathering. Readings obtained were benchmarked with the conventional handheld heart beat reader and a thermometer to fulfill the accuracy and stability criteria. Continuum of the study was multiple tests conducted to ensure stability, transmission range capability and reliability of device for various age groups and gender. Results obtained were impressive and comparable to the miniaturization of device for further testing in the hospital.

Keywords: Zigbee technology, vital sign monitoring, temperature, heart rate.

1. INTRODUCTION

At general medical care site globally, patient's health and safety is the main priority. Malaysia is one of the countries around the globe that is recognized by the World Health Organization (WHO) where according to the statistical information provided by the organization, by the year 2012, from 57 countries listed including Malaysia, 55% of these countries are facing health workforce crisis due to the implementation of the national plan. Meanwhile, according to Ministry of Health (MOH), Malaysia does hold an issue of insufficient medical professionals in hospitals that are under the supervision of MOH [1, 2]. Thus, the criterion's of introducing appropriate technologies such as wired or wireless devices or systems for the purpose of patient monitoring is fitting. According to WHO, health technology is the application of organized knowledge and skills in forms of devices, medicines, vaccines, procedures and systems that has been developed to solve a health problem and improve the quality of life [3].

The system that is practiced in Malaysia is where patients are only monitored in every 4 hours interval. On each visit, certain health parameters, known as vital signs (heart rate, human body temperature, blood pressure, oxygen saturation and respiratory rate) are taken from a patient. For general warded patients, temperature, heart rate and blood pressure are the most frequent bio signals monitored. Medical accidents in terms of patient safety, reliability on bio signal readings, efficiency and also quality of service due to increment in number of patients which leads to decrement of staff often became the top reasoning of the stated criteria [4, 5].

In the development of a proper medical technology, three interrelated aspects which are patient care, monitoring and safety needs to be taken into consideration. By definition, patient monitoring defined by Hudson (1985) as a repeated or continuous observations or measurement of the patient, his or her physiological function, and the function of life to support equipment, for the purpose of guiding management decisions, including when to make therapeutic interventions, and assessment of those interventions [6]. In recent years, the wireless telemedicine has been in line with the current mobile communication system especially for conventional civilian use. However, current mobile telemedicine systems boundaries are characterized as lack of a flexible and integrated tele-medical linkage of different mobile telecommunication options, high cost in communication links, limited data transfer rate of the current mobile telephonic systems, limited availability of mobile internet connectivity and information access, healthcare is a very complex industry and difficult to change, organizational changes are very often required, lack of integration between mobile telemedicine system and other information systems and lack in numbers of demonstration projects to show mobile telemedicine real savings potential [7]. Although some of the drawbacks have been solved throughout the years, the bandwidth, data transfer, limited availability of mobile internet connectivity and cost is still a current drawback towards the emerging of telemedicine system.

Many researchers have conducted studies in monitoring human vital signs. Vital signs is the ability to provide different types of information's on patient's condition and is considered as an important health parameter and known to be important to be monitored during hospitalization period [8]. This study only focuses

on the study of two (2) parameters which are temperature and heart rate [4].

2. SYSTEM OVERVIEW

The system consists of combinations of several aspects as shown in Figure-1. The hardware of the system has been made individual sensing to take inputs from different sensor separately to measure the physiological parameters of human which are temperature and heart rate. The inputs from the sensors will be integrated and processed by the microcontroller and will be sent through the Xbee Module (Zigbee) to a host computer which acts as a Database for the system. The values of the detected readings are displayed in a graphical form in the Graphical User Interface (GUI) that is running in a computer. The interface designed not only is user friendly but is also a web-based interface where the user can monitor and access the interface at any day and anytime as required in a continuous monitoring system. If the person with the tag is medically distressed, the system will automatically generate an alarm alerting the medical professionals on duty. The hardware blocks are explained in full details in a later section.

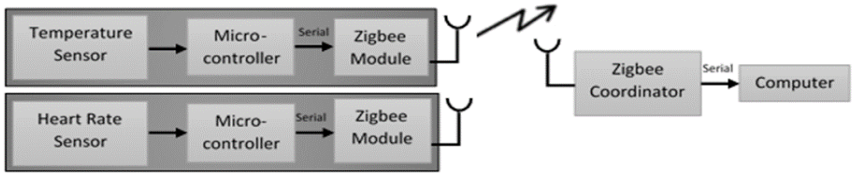


Figure-1. Block diagram of system hardware.

3. DETAILS ON SENSING AND INTERFACING

The proposed system consists of 2 sensors which are temperature sensor and a heart rate sensor. Both of the sensors generate analogue signals which are then fed to the inputs on the microcontroller to be sampled and converted into required readings.

3.1. Temperature sensor

The measurement of body temperature is taken on the skin by using the Negative Temperature Coefficient (NTC) thermistor as a sensor. The NTC sensor is chosen due to its sensitivity, cost, fast response time and accuracy. Moreover, the disadvantage of limited temperature range and self-heating will not be significant due to the temperature that will be measured is in a small range and will be using low power devices as power source. Thermistor is a passive transducer where its resistance depends on supplied heat [9, 10]. The sensor is mounted on a strap which is placed at the armpit of the patient where the accuracy of body temperature is higher compared to others.

3.2. Heart rate sensor

A well designed pulse sensor is used for the heart rate detection. The concept of the heart rate sensor is where it uses the LED and ambient light sensor for detection. The LED shines the light into the fingertip and the sensor will read the light that bounces back. The back of the sensor consists of the rests of the mounted components. Figure-2 shows the circuit diagram of the designed circuit. Note that the designed circuit for both of the monitoring device are basically the same but only uses a different sensor.

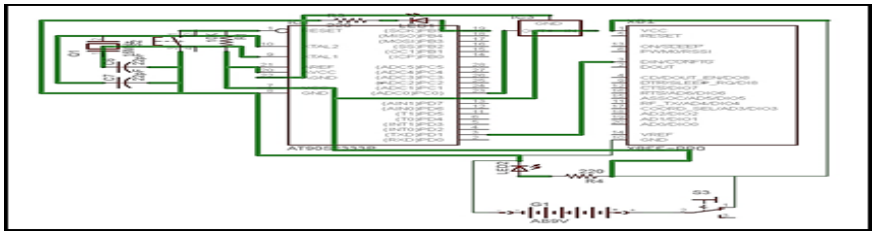


Figure-2. Proposed monitoring hardware circuit diagram design.

3.3. System interface

A graphical user interface (GUI) system has been designed specifically for the wireless monitoring application. This system is designed to ensure that all the data's received are kept in the database and also to enable the user's to monitoring the current situation of particular patient. The system that is designed is web - based where the system can be accessed anywhere and anytime as long as the user has internet connection. This is seen as an added advantage to a continuous and reliable wireless monitoring system. The medical professionals will be able to update the patient's details and conditions via online. Figure-3 shows the system architecture of the monitoring system while Figure-4 (a) to (e) shows the GUI interface for the wireless monitoring application.

The system hardware architecture shown in Figure-3 begins from few subjects placed at a remote location where each subject is embedded with a Zigbee Xbee transceiver module with heart beat sensor. The data collected by the transceiver microcontroller will then be transmitted to the Zigbee receiver. From the receiver, the transmitted data will go through the Ethernet system route that developer uses. One route is through the Wireless Area Network (WAN) which will be connected to the computer that can send the trigger to the mobile nurse available. The other route is where all the collected data will be kept in the system database.

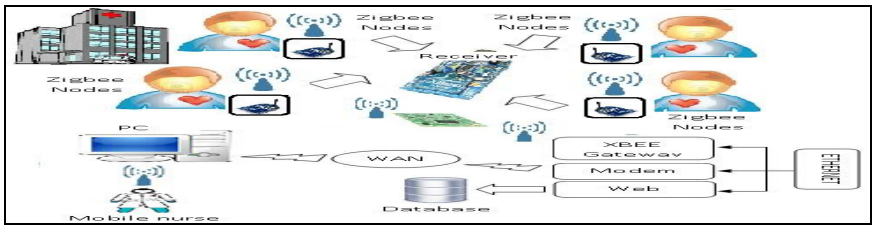


Figure-3. Overall system architechture.

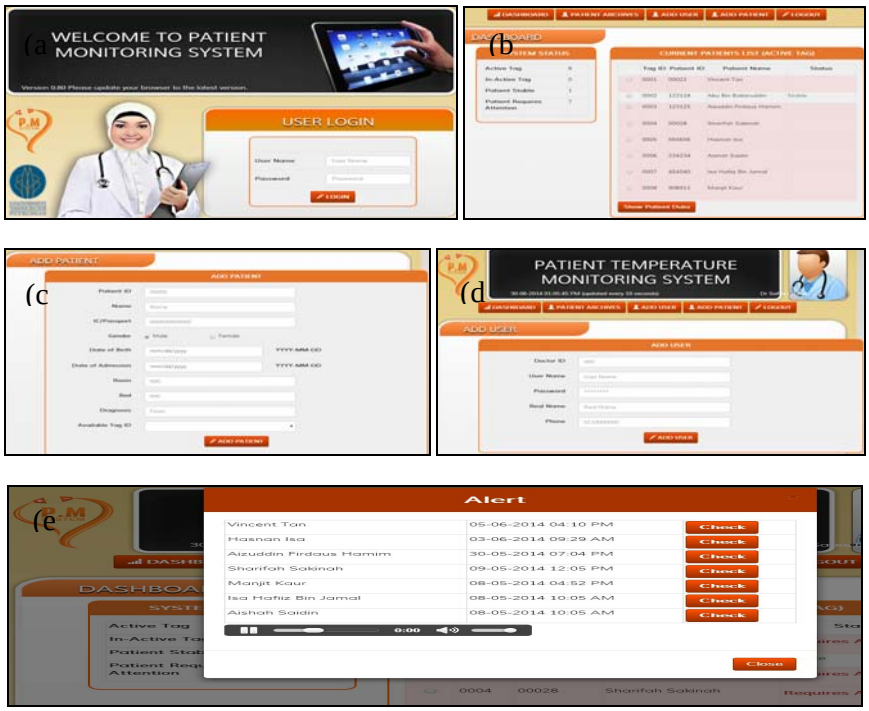


Figure-4. (a) Login Page, (b) Dashboard showing current active patients, (c) Patient data update, (d) User (medical professional) login info details for access, (e) Alert of patient when in abnormalities (With Sound).

4. PROTOTYPE AND EXPERIMENTAL RESULTS

The wireless monitoring system has undergone development stages with testing verifications of reliability, accuracy and sustainability. The hardware of the device has been designed and modelled to ensure high reliability and accuracy of reading from sensors at all stage. Figure-5 shows the development stage of the heart rate monitoring module while Figure-6 (a) and (b) show the reading obtained from the interface.

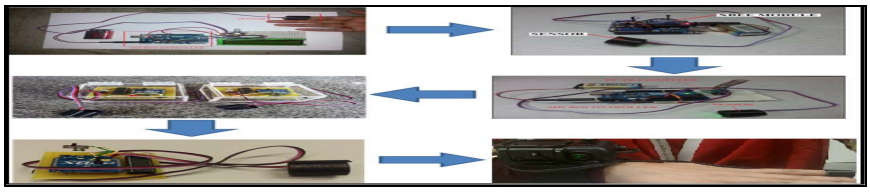


Figure-5. Development stage of the heart rate monitoring module.

The circuit or hardware development begins with the testing conducted on a breadboard form where the readings are displayed on a LCD (wired method). Then the device is tested using 2 different wireless technology (RF and Zigbee) based on conducted literature where based on tests procedure on through transmission range, data stability and power consumption the suitable wireless technology which is Zigbee is selected. From there the PCB layout design of the circuit was designed and printed to its maximum scale and further test based on sensor stability, accuracy, accurate body posture transmission distance, data stability and power consumption criteria was conducted. Next, the circuit undergoes another PCB design with minimum scale and undergoes the similar test as stated earlier. Finally, the circuit is sent for miniaturization and casing process. The final product also undergoes the similar test procedure as previously stated.

(a) (b

Figure-6. (a) Patient archived heart rate reading, (b) Patient current heart rate reading.

Figure-6 (a) shows the archived patient data from the beginning of the stage that the patient was admitted. This enables the user to determine and analyze the patient's heart rate conditions accurately. Previously as discussed in previous research paper written, the results obtained have been verified by comparing the obtained readings wirelessly with the current wired heart rate detection. Thus, the current reading that is shown through the interface is reliable with an error of ± 2bpm. Figure-6 (b) shows the current reading of the patient.

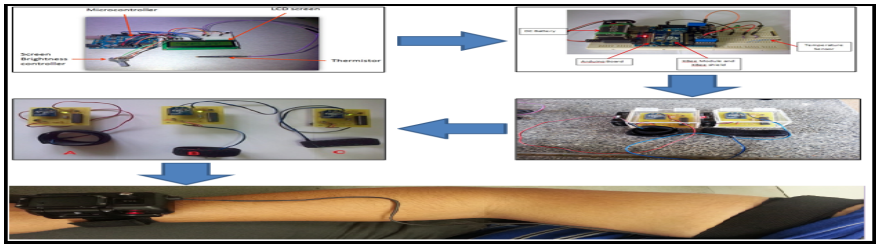
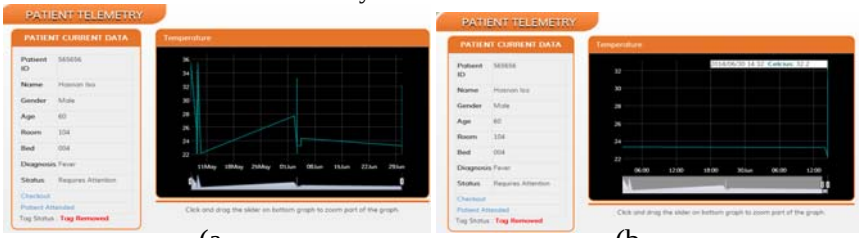


Figure-7. Development stage of the heart rate monitoring module.

Figure-7 shows the development stage of the heart rate monitoring module while Figure-8 (a) and (b) shows the reading obtained from the interface. The circuit or hardware development begins with the testing conducted on a breadboard form where the readings are displayed on a LCD (wired method). Then the device is tested based on conducted literature where based on tests procedure on through transmission range, data stability and power consumption the suitable wireless technology which is Zigbee is selected. From there the PCB layout design of the circuit was designed and printed to its maximum scale and further test based on sensor stability, accuracy, transmission distance, data stability and power consumption criteria was conducted. Next, the circuit undergoes another PCB design with minimum scale and undergoes the similar test as stated earlier. Finally, the circuit is sent for miniaturization and casing process. The final product also undergoes the similar test procedure as previously stated.



(a (b

Figure-8. (a) Patient archived temperature reading, (b) Patient current temperature reading.

Figure-8 (a) shows the archived patient data from the beginning of the stage that the patient was admitted. This enables the user to determine and analyze the patient's heart rate conditions accurately. Previously as discussed in published research papers, the results obtained have been verified by comparing the obtained readings wirelessly with thermometer. Thus, the current reading that is shown through the interface is reliable with an error of ± 0.3°C. Figure-8 (b) shows the current reading of the patient.

5. CONCLUSIONS

The objective of the research is to design and develop a continuous remote wireless monitoring system that enables the medical professional to monitor the patient's conditions more accurately and in vast response time. This system itself enables the medical professional to assists the staffs in charge at that particular time while being away by monitoring the vital signs online and provide fast advice in medical attention required. An added advantage also provided to the patients where the patient will have a comfortable medical environment and as well as fast and accurate treatment for them. Furthermore, this system would help to lessen the burden of medical workforce all together.

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