Implementation of Wireless Area Network for Patient Monitoring System

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Abstract– *There are many critical cases in which the patients need continuous monitoring by the medical staff. Implementing wireless sensor network in medical field helps the medical staff to monitor the patients remotely. This system is designed to collect the patient's physiological parameters, and store them in the database. The doctor monitors the patient continuously in real time. In this project the biomedical sensor nodes used are temperature and heart rate sensors; Arduino UNO is used as a microcontroller for data processing, and then the messages are transmitted to the base station via Bluetooth wireless technology. The Raspberry Pi is used as a system personal server. The results, reports and other information related to the patients are displayed in website pages which are suitable for the desktop, Personal Digital Assistance (PDA) and mobile devices.*

Index Terms— *Patient Monitoring, Biomedical sensors, Microcontroller, Bluetooth, Arduino, Raspberry Pi.*

I. INTRODUCTION

The recent developments in sensor nodes and wireless technologies have enabled Wireless Sensor Networks (WSNs) to be available in many fields such as in Intelligent Buildings, military applications, medical applications, etc... One of the medical applications is the patient health monitoring, in which many sensors are attached to the body or be implanted, a sensor nodes should be low power consuming, miniature, and detect medical signal such as EEC, ECG, blood pressure, heart rate, PPE etc. [1]. This type of network is called Wireless Body Area Network (WBAN). WBAN is an emerging technology which uses wearable sensors for continuously patient health monitoring in real time manner to enhance individual living [2]. The sensors that are applied for each patient depend on the cases and type of the parameters. Wireless body sensor network is suitable to be used in hospital environments to constantly monitor the patients, in addition, it provides more time to the medical staff to treat more important issues [3]. The advantages of such networks for patient are to reduce the risk of infection, offer flexibility for them and in order to make the patients feel more comfortable. Furthermore, implementation of patient monitoring in hospitals might reduce the costs in terms of installation and maintenance of wiring [4]. The proposed system is used for patient monitoring in hospitals. The patient is provided with two biomedical sensors (temperature and pulse rate) and coordinator node. The Raspberry PI has been used as a system server, where the patient information is stored.

This paper is organized as follows: Section 2 provides related work; in Section 3 the proposed system is described. Section 4, a description for the hardware and the software components that are used in this project is discussed. Section 5 details the system implementation and results. Finally, the conclusion and the future work are given in Sections 6 and 7, respectively.

II. RELATED WORK

The small size of the sensor nodes and its ability to sensing, processing and transmitting the data make it available in medical applications; therefore, there are many applications and scientific researches in this field, especially in health monitoring. Reference [5] developed a system based on

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microcontroller for wireless heart beat and temperature surveillance using ZigBee technology, this system is developed for the patients that are at home and need for continuous monitoring. When the patient becomes in a critical condition, an SMS is sent to his/her family as well as to the specialist doctor. In reference [6], a patient monitoring system is designed. The proposed system was based on measuring the saturation of blood oxygen, blood pressure, pulse rate, and the patient breathing rate. The sensors used are SpO2, blood pressure and heart rate. The sensors are activated according to the patient state. This system was based on the GSM modem to send SMS messages to the doctor to give reports about the patient state. In reference [7], a system based on data sensing, processing and data transmitting was designed. The system is used for warning the clinicians about the patient critical conditions. When the doctors are at the hospital, they could remotely monitor the patients through the internet. The sensor unit used in this system is based on three biosensors blood pressure, temperature and heart rate. Wireless body area sensor network system is designed in Reference [8] for monitoring both heart rate and blood pressure. This system is used to monitor different patients at the same time. The sensors measure the patients' physiological parameters and transmit them to the base station which is represented by a personal computer. In reference [9], an integrated portable device was developed for continuously monitoring the heart rate and body temperature. This device is useful in rural areas when there are no doctors or hospitals available or near to the patients. The developed system is based on microcontroller and android application to give real time information about patient's health. Reference [10] also proposed a system based on wireless sensor network and mobile platform for patient care and monitoring in hospital for twenty-four hours a day, and it was used to follow the patient state if there is a medical side effect occurred after the treatment or surgery. The data are collected when the sensors are touching the finger of the patient; the collected data are then sent to the patient's mobile device, the patient's medical records then transmitted to the hospital database as well as to the doctor.

III. SYSTEM DESIGN

The architecture of the proposed system is a multi-tiers system; the first tier is the WBAN, as explained in Fig. 1 [16]. The WBAN actually is represented by body sensors and controller device. Temperature and heart rate sensors are used for patient's health monitoring in this project, while Arduino Uno is used as a microcontroller device. The number and the type of the sensor nodes that are used to monitor the patient depend on his/her state.

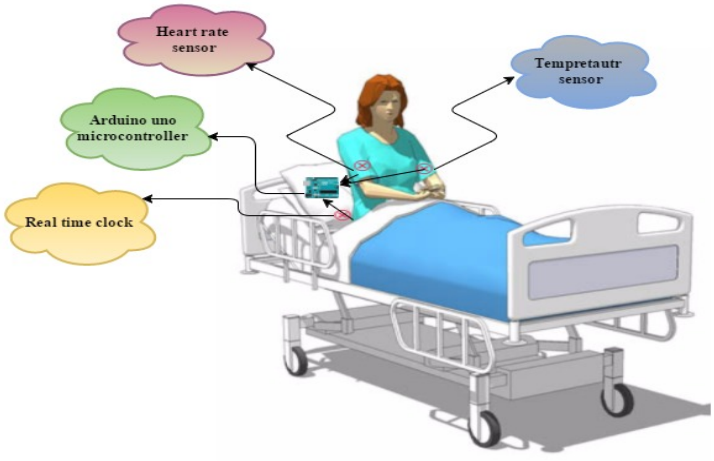

FIG. 1. WIRELESS BODY AREA NETWORK. [16]

The patients' body parameters are measured by the sensors. Arduino processes the vital signs captured by the sensors, if the sensory data are greater or less than the threshold which is assigned

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previously, the actuator (e.g. buzzer or LED) will be indicated, the arduino works flow chart is explained in Fig. 2-a. After signal processing, the arduino sends the message by Bluetooth wireless technology to the Raspberry PI where the database is used for data storage, this scenario represents the first tier of the system.

The second tier is represented by personal server (Raspberry Pi device) which stores the processed sensory data that are transmitted from Arduino, the flow chart of Raspberry Pi work is explained in Fig. 2-b. The RPI devices in the hospital are connected together through the switch by using the Ethernet cables, and then this switch device connects to the control room. The medical server in the control room has the information about the patients in the hospital stored in system database, so it represents a backup server. The medical server acts as the third tier in the system. See Fig. 3, which explains the overall system architecture.

It is important to mention that the number of the tiers for any system depends on the architecture and the application that are required to be implemented.

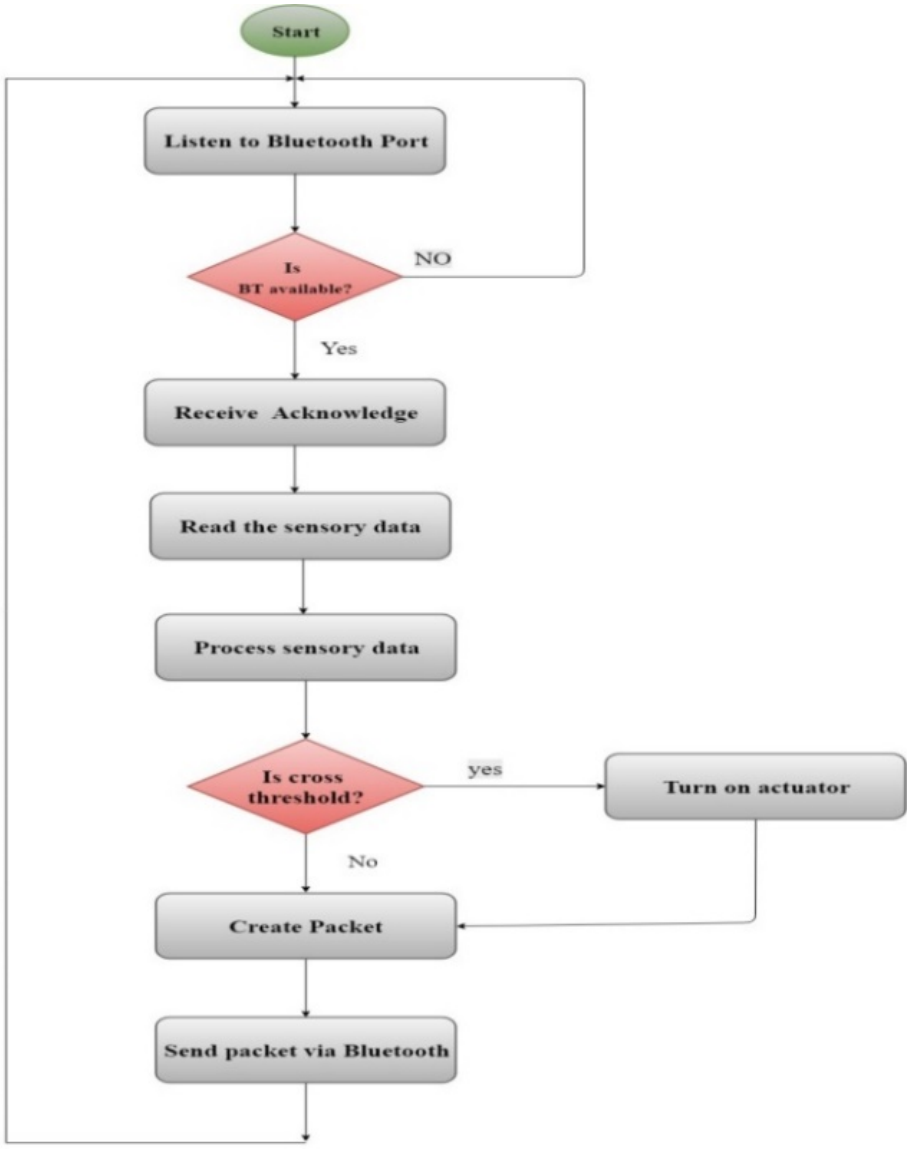

FIG. 2. SYSTEM FLOWCHART, A : ARDUINO WORK FLOW CHART.

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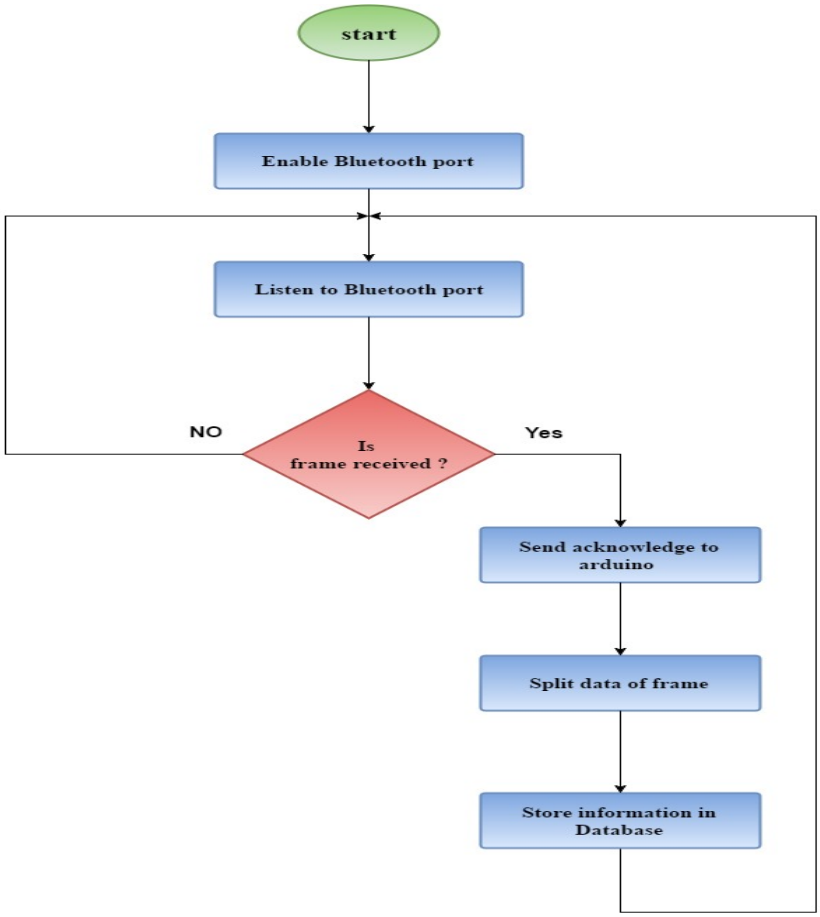

FIG. 2. SYSTEM FLOWCHART, B: RASPBERRY PI WORK FLOW CHART.

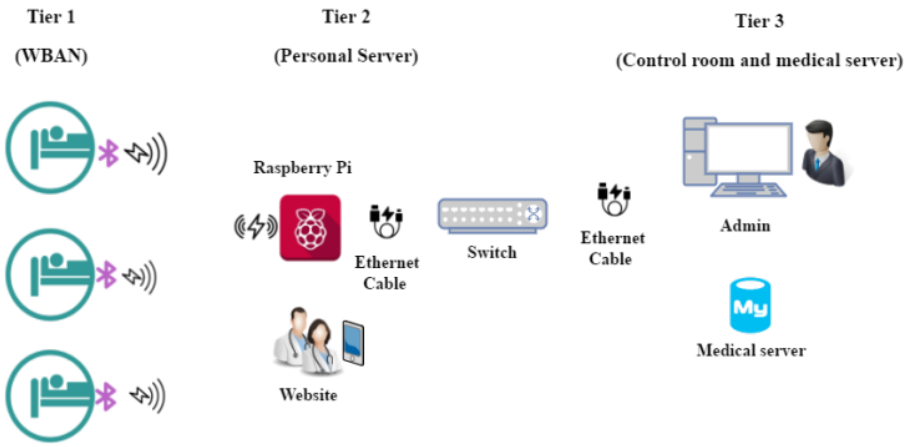

FIG. 3. SYSTEM ARCHITECTURE.

IV. HARDWAR AND SOFTWARE

In this section, the devices that are used in this proposed system and related software tools will be explained.

A. Hardware components

The devices that are used in this system will be discussed here.

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1. The temperature sensor (TMP 36)

The temperature sensor (TMP 36) [11] is low voltage, precision centigrade temperature sensor, see Fig. 4. It provides a voltage output that is linearly proportional to Celsius temperature. As well as it doesn't require any external calibration to provide typical accuracies of ± 1°C at +25°C and ±2°C over the −40°C to +125°C temperature range. It is so easy to use just connect the device to ground and 2.7 to 5.5 VDC and from the Vout pin the data can be captured.

FIG. 4. TEMPERATURE SENSOR TMP36.

2. Heart rate sensor

Heart rate could be defined as the speed of people's emotional state, intensity of exercises and objective indicator of cardiac function. In other words, it could be defined as cardiac frequency. Heart rate is expressed in beat per minute (bpm). Therefor heart beat sensor, see Fig. 5 [12]; has been designed to give the digital output of the heart beat when the patient finger is placed on it [4] [7]. In the following is the classification of ideal human heart rate at rest, all defined as beat per minute [13].

- Newborn baby: 120-160.
- Baby aged from 1-12 months: 80-140.
- Baby/ toddler aged from 1-2 years: 80-130.
- Toddler /young child aged 2 1o 6 years 75- 120.
- Child aged 7 to 12 years: 75-10.
- Adult age 18+ years: 60-100.
- Adult athlete: 40-60.

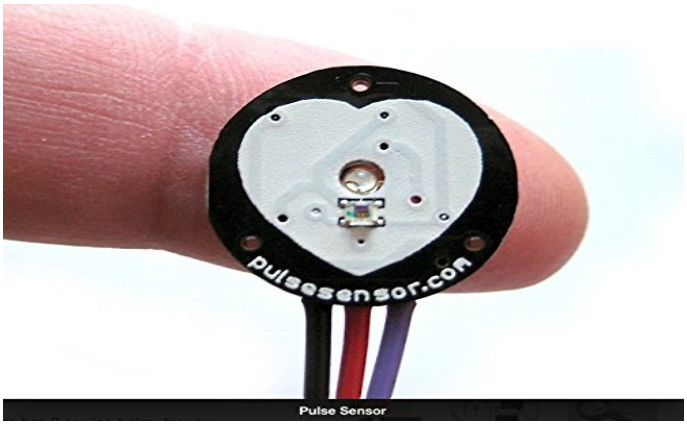

FIG. 5. HEART RATE SENSOR

In this proposed system the temperature and pulse rate sensors that are used are wired sensors; we used them because the wireless sensor nodes are not available. And therefore we use Bluetooth module with microcontroller for data transmission to the base station.

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3. Arduino UNO

Arduino is an open source microcontroller board based on the Atmega328, designed to make experiments with electronic devices and it can be programmed easily and intuitively. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, 16 MHZ ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to computer with a USB cable or power it with AC-to-DC adapter or battery to get started, see Fig. 6 [14].

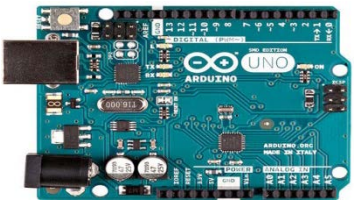

FIG. 6. ARDUINO UNO PLATFORM

4. Raspberry Pi

Raspberry Pi 3 is a tiny credit card size computer; see Fig. 7 [15]. It is the latest version of the Raspberry Pi. Keyboard, mouse, display, power supply, micro SD with installed Linux Distribution are added to this version. Also it supports the HD video. For these reasons it is recommended for use in schools or any general use that runs media center, applications from word processors and spreadsheets to games [15].

FIG. 7. RASPBERRY PI 3

B. Software Tools

At first we start with arduino software, integrated development environment (IDE). IDE contains a text editor for code writing, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects with arduino hardware to upload the programs and for communication.

MySQL database is also used to create all the tables, we based on relational database model to connect tables together, the relations among the tables are explaining in Fig. 8.

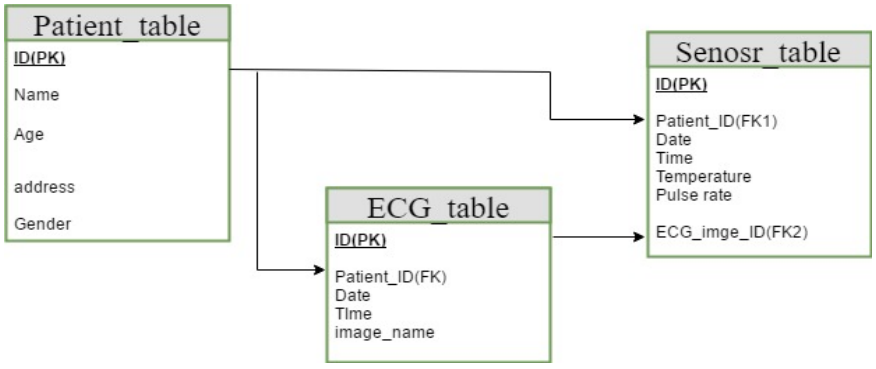

FIG. 8. TABLES' RELATIONSHIP.

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V. SYSTEM IMPLEMENTATION AND RESULTS ANALYSIS

A. System Implementation

The system components are connected together; see Fig. 9 [17]. Biomedical sensors measured the body vital sing. The Sensory data are processed by the microcontroller, then the date and time are added to the sensory data to produce the message. The message is transmitted continuously in real time via Bluetooth module to the Raspberry PI. Raspberry Pi represents the system base station; it's containing the database where the data are stored.

The web pages that are designed for this system are in Fig. 10. When the doctor selects the patient name, see Fig. 11, the time, date, previous, and current sensory data will be displayed, see Fig. 12.

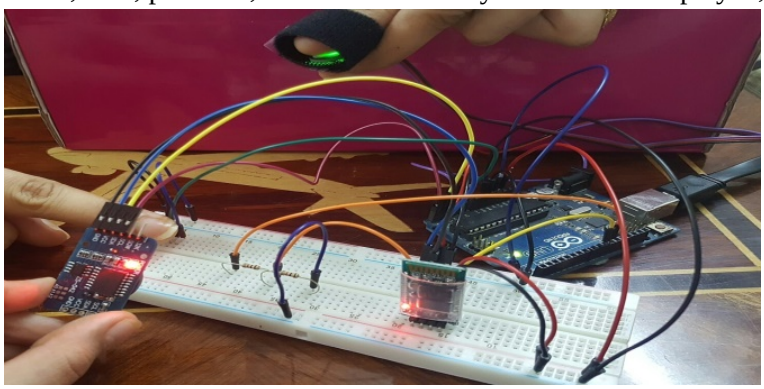

FIG. 9. SYSTEM IMPLEMENTATION.

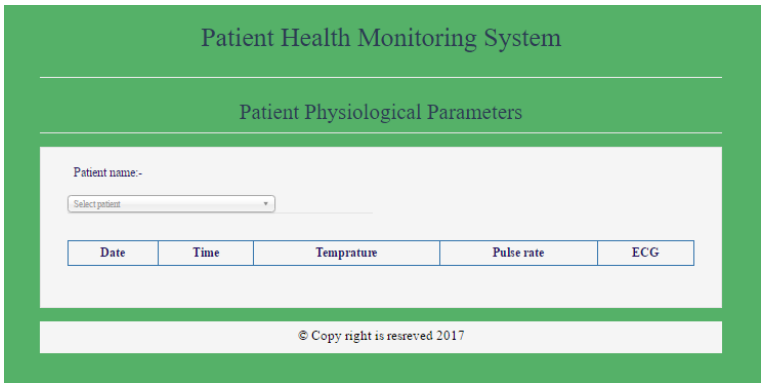

FIG.10. WEB PAGE OF PATIENT HEALTH MONITORING SYSTEM.

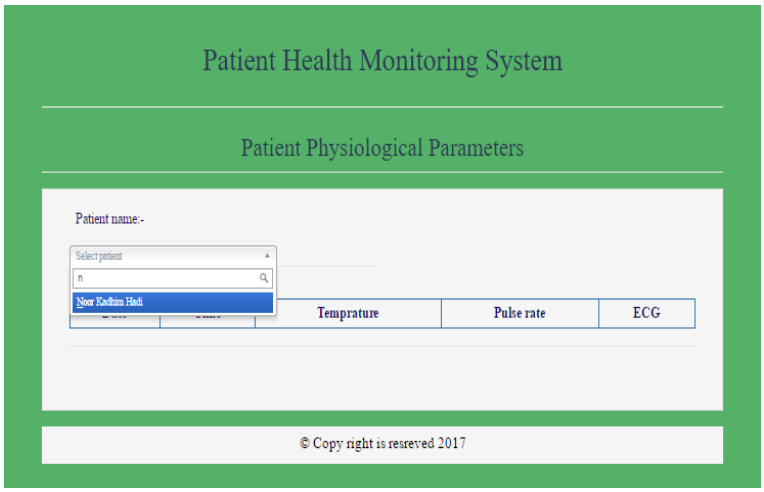

FIG. 11. PATIENT NAME SELECTION

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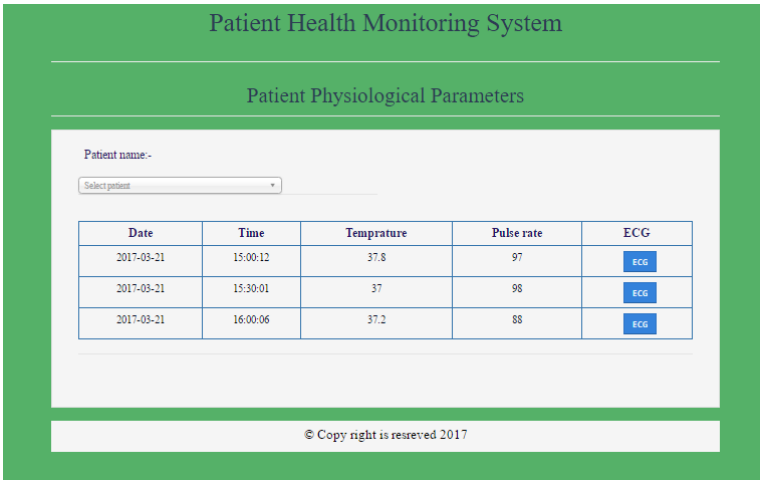
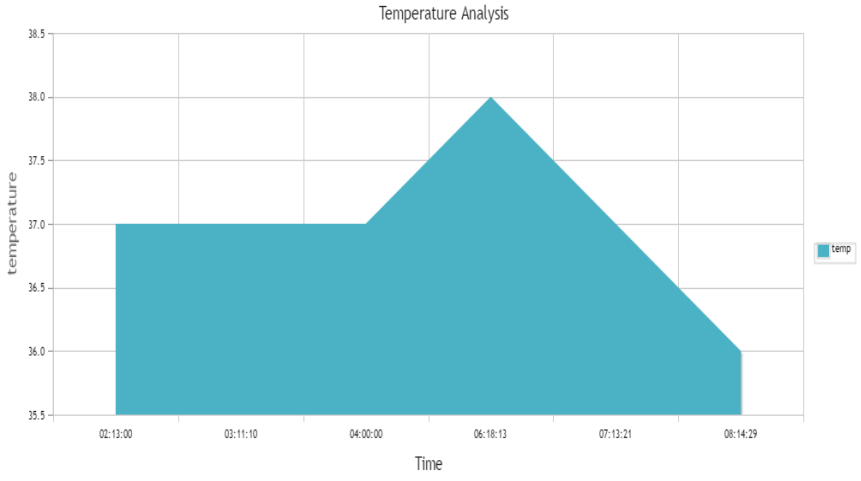


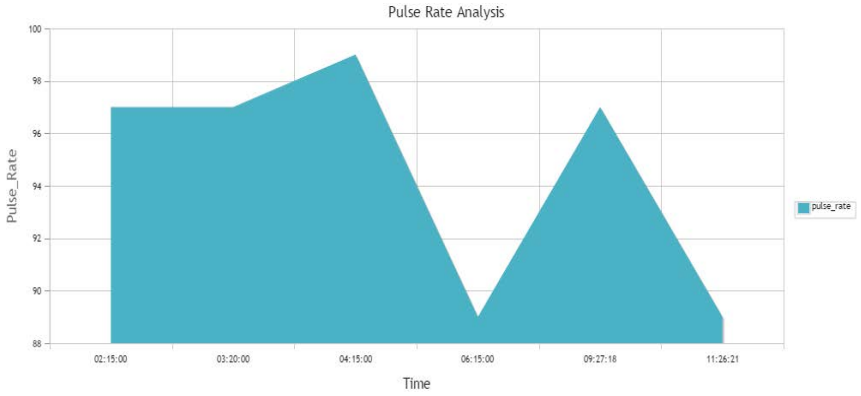
FIG. 12. PATIENT'S VITAL PARAMETERS MEASURED BY BIOMEDICAL SENSORS.

B. Result Analysis

The results after implementation to the system show that the sensory data are transmitted in real time, with high accuracy. The previous stored data are also displayed when the doctor selects the patient, so this helps the doctor to follow patient's state, see Fig. 13(a, b) which shows the analysis of temperature and pulse rate data, respectively.



(a)



(b)

FIG. 13(A, B). TEMPERATURE AND PULSE RATE DATA ANALYSIS

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6. CONCLUSION

This system offers the doctors and the rest medical staff the possibility to access any patient at any time and at any place. The medical staff could see the last updating of the patient state, so they monitor the patients continuously without the need to be represented physically beside them.

7. FUTURE WORK

In the future, we could implement the GSM system to give daily reports for the patient family as well as to give an indication or alarm in critical situations via SMS. Also, we could implement the cloud computing for data storage. And the system can be connected to the internet to enable the doctors to access the patient from outside the hospital.

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