

Implementation of Wireless Body Area Network Based Patient Monitoring System

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Abstract

WBAN has gained considerable attention and became an emerging technology at health services due to its wide range of utilities and important role to improve the human health. The proposed system consists of different components, Pulse rate sensor which uses the optical technology to detect the flow of blood. Temperature sensor is used to measure the temperature from the body. Peripheral hemoglobin oxygen saturation (SpO2), blood pressure and electrocardiogram (ECG) are measured by the nurses. Radio Frequency Identification (RFID) reader with passive tags is used to identify the patient. Arduino UNO microcontroller is used for data processing. The patient parameters are transmitted via Bluetooth technology to the base station. The base station which is Raspberry Pi (RPi) B model 3 used to receive the collected data and acts as the web server, so the physician accesses RPi to display different information. The obtained results from different cases prove the high performance of the system and sensor nodes that are designed. The overall system operates within different environments conditions. If one sensor node is fall down, the other nodes are still operate and do not affect. Also we improve the speed of the system response. The usage of wireless communication to send the data instead of the wired one as it provides a greater mobility to the device. The cost is also minimized by utilizing the feature of sending multiple parameters via a single node.

Keywords: Wireless Sensor Network (WSN), Patient Monitoring, Biomedical, sensors, Microcontroller, Arduino, Raspberry Pi.

1. Introduction

Usually, people suffer from many diseases, e.g. heart disorders, diabetes mellitus which are inherited and disorders that are due to inappropriate diet … etc. Different health responsibilities are increasing the cost of health care system. In order to get benefits from wireless technologies in health monitoring system many researchers have made various researches with Wireless Sensor Networks (WSNs) to improve the medical field [1].

WSNs are mainly composed of sensor nodes that are characterized by their tiny size, portability, capability of data sensing, processing, storing and transmitting. These characteristics enable them to be involved in many fields (security, military, etc.). Other features like mobility, tracking, monitoring, and timely delivering of data has made this type of networks very important in the medical field [2]. So a new framework has been brought into medical devices; expanded their capabilities as well as developed certain opportunities that revolutionize healthcare systems. Briefly, patient health monitoring systems have been improved by using this technology [3].

Biomedical sensors (which are used in patient monitoring systems) have the capability of measuring, processing, communicating and storing physiological vital parameters (e.g. heart rate, blood pressure etc.). These sensors are characterized by being small in size, wearable and light in weight [4].

Biomedical sensor nodes form the basic unit of WBAN. WBAN is a special type (a distinct form) of WSN. Both have the same challenges with certain differences [5] as explain in Table (1).

Table (1): Comparison between WSN and WBAN [6].

Challenges	WSN	WBAN
Scale	Monitored environment (meters / kilometer).	Human body (Centimeters /meters).
Node Number	Many redundant nodes for wide coverage.	Fewer, limited in space.
Node Size	Small is preferred but not important.	Small size is essential.
Node Replacement	Performed easily.	Replacement of implanted node is performed difficulty.
Node Lifetime	Several years / months.	Several years / months, smaller battery capacity.
Power Supply	Accessible and likely to be replaced more easily and frequently.	Inaccessible and difficult to replace in an implantable.
Data Rate	Homogeneous	Heterogeneous
Networking	Large scale hierarchical network.	Small scale (Star network).
Biocompatibility	Not a consideration in most applications	A must for implants and some external sensors
Security level Lower	Lower	Higher, to protect patient information
Power demand	Likely to be large, energy supply easier	Likely to be lower, energy supply more difficult
Node tasks	Node performs a dedicated task	Node performs multiple task

2. Related Work

Alumona T. L. et al., (2014) [7] described monitoring system based on WBAN to monitor patient's parameters. This research based on lightly sensors which are put on human body. The researchers designed this system for patients and elderly people for remotely monitoring, therefore reducing their visits to the hospital. The collected data are transmitted to Intelligent Personal Digital Assistance (IPDA) device using ZigBee technology.
Alisinanoğlu F. et al., (2015) [8] designed and implemented a system that based on measuring body temperature and heart rate. All these signals were displayed through Liquid Crystal Display (LCD) in real time manner. Bluetooth module was used to transmit data after processing to the base station.
Miah A. et al., (2015) [9] introduced monitoring system. The proposed system based on continuously collecting patient health information. Wireless data transmitting unit was used to transmit heart rate and body temperature to the medical staff. The collected parameters are displayed to the physician using Android device based application.
Yuvaradni B. et al., (2016) [10] also proposed a system for patient monitoring. In this system the heart rate and body temperature parameters were collected and transmitted through internet to physician in hospital. Therefore physicians could monitor their patients remotely at any time.

Some summary points can be concluded from the above researches as follows: Most of researches are based on using Personal Computers (PCs) or Laptops to display patients' vital parameters; this feature restricts the access to the system. Many designed prototypes are based on android applications to display parameters to physicians. This is not a satisfied feature since not all physicians use android devices. One of the researchers use Apache Tomcat server which is not suitable for huge database.

3. Proposed System Architecture

The architecture of the patient monitoring system (in hospital or at home) depends on the system design requirements. The proposed architecture, which is designed to monitor patient health in hospital, is based on three-tiers, as explained in Figure (1).

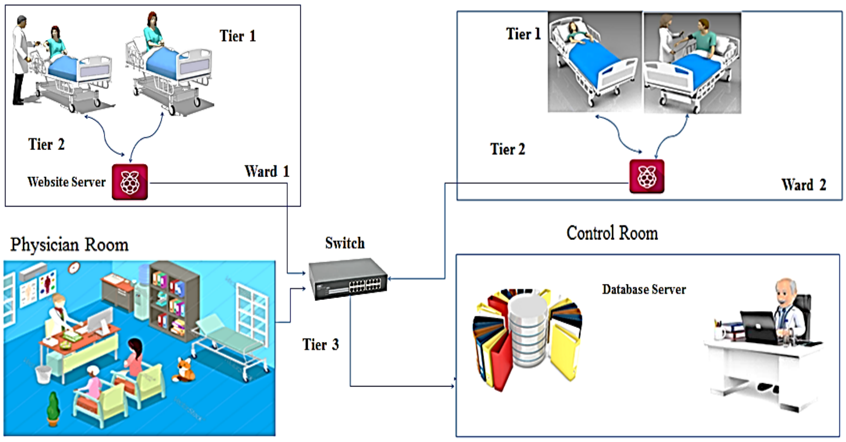


Figure (1): Three-tier architecture of the proposed system

The first tier is represented by WBAN each patient has his/her own sensor node as explained before. The proposed system supposes that there are many patients in the same ward, and each ward contains one RPi device. The communication between the nodes and the RPi represents the second tier in the architecture. RPi device in each ward represents the base station, which receives messages from the sensor nodes continuously through Bluetooth communication technology. Each message is composed of sensory data, date, time, sensor code (Sensor code is used by RPi to recognize the received message, for example, for pulse rate message it is "PR" and "T" for temperature) and ID number. And by separating this information, RPi processes the message and then stores this information in suitable tables.

In order to establish the connection between RPi devices and the main server, Ethernet cables are used for this purpose. Eventually, the third tier is represented by the control room which contains the main and/or backup server that contains the database of the system. System database is composed of tables that are used to store the patients' personal information (full name, age, gender, address etc.), vital parameters and medical history. They also include information about the medical staff (physician specialty, phone number, address etc.), that is discussed in details later. The admin is responsible for control room, he/she has the right to manage and update patients and medical staff information.

4. Proposed Algorithm

a. Sensor Node Flowchart

As demonstrated in Figure (2), when the power of the sensor node is on; Arduino prepares the sensor node for checking whether the Bluetooth port is available or not. If Bluetooth is not available, Arduino continues checking until connection is done. When it is, then Arduino checks whether the RFID reader is available or not. If RFID reader is available, it reads patient's tag; otherwise, it will continue checking.
After node preparation, it should receive a request from the base station (RPi). If the received request is not correct, the node does not send a message. But if it is, pulse rate sensor (TMP36 and Pulse Rate sensors measure vital sign continuously to be available at any time.) measures the heart rate and the real time clock determines the date and time of this measurement. Arduino constructs the message (that will be transmitted) which is

composed of date, time, ID number, and pulse rate and sensor code. Sensor node then waits for interval of time (e.g. five minutes) before sending the next messages.

Then Arduino processes the temperature data that is measured by TMP36 sensor. Temperature message (which is composed of date, time, ID number, temperature degree, and sensor code) together with the pulse rate message are sent to RPi at the same time. After messages transmitting, sensor node wait for an interval (e.g. for five minutes); therefore pulse rate is transmitted and stored every five minutes and temperature every ten minutes. In the previous procedure, sensor node checks whether the processed parameters are valid or not. If they are invalid, sensor node does not send messages. This results in economizing more space for system database. And when the vital sign is cross the normal thresholds, actuator is enabled to get the attention of the physician.

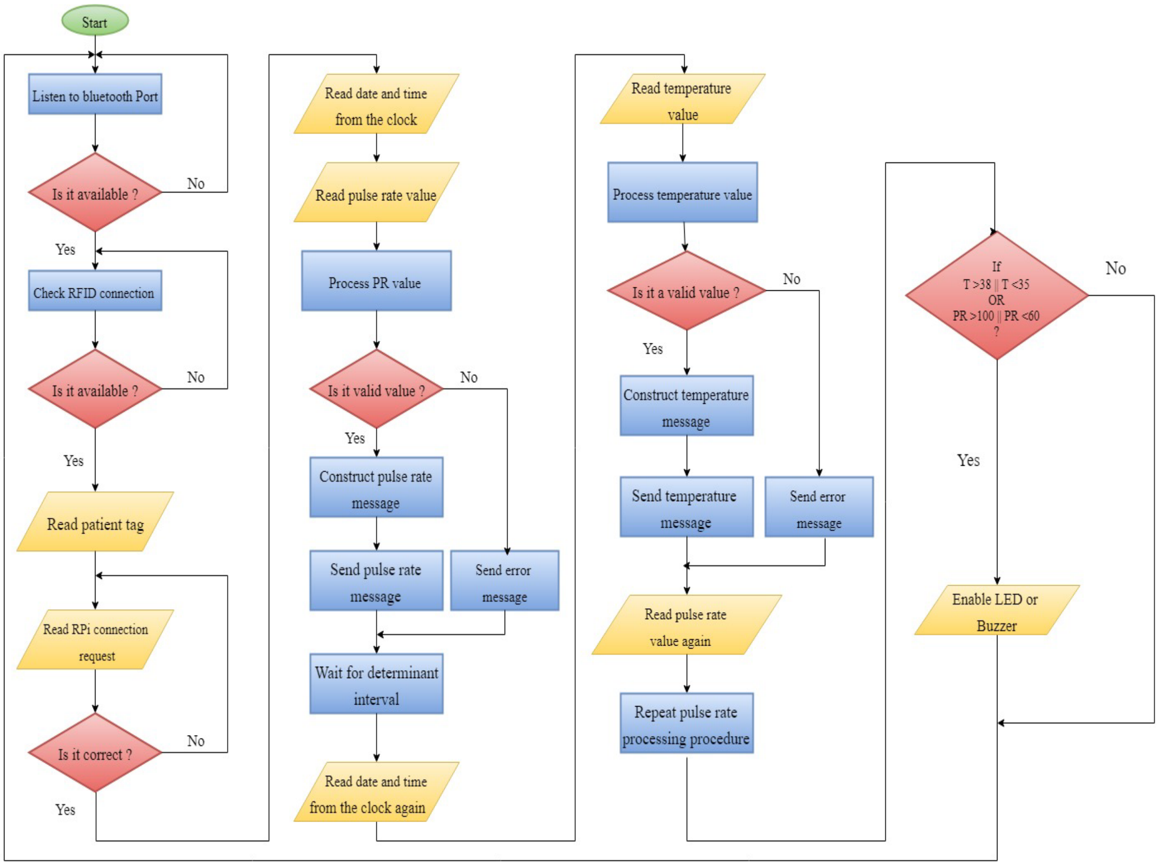


Figure (2): Sensor Node Flowchart

b. Base Station Flowchart

In the other side as explained in Figure (3), RPi start a connection with the medical server. In order to communicate with the nodes, RPi establishes Bluetooth connection, sends them a request and then receives a message. If the message is correctly received, RPi separates its contents and checks whether the sensor code is "PR" or "T". If it is "PR", then RPi stores messages data into pulse rate table, and if it is "T", it is stored in temperature table. In order to store this information correctly, this depends on the tag ID number.

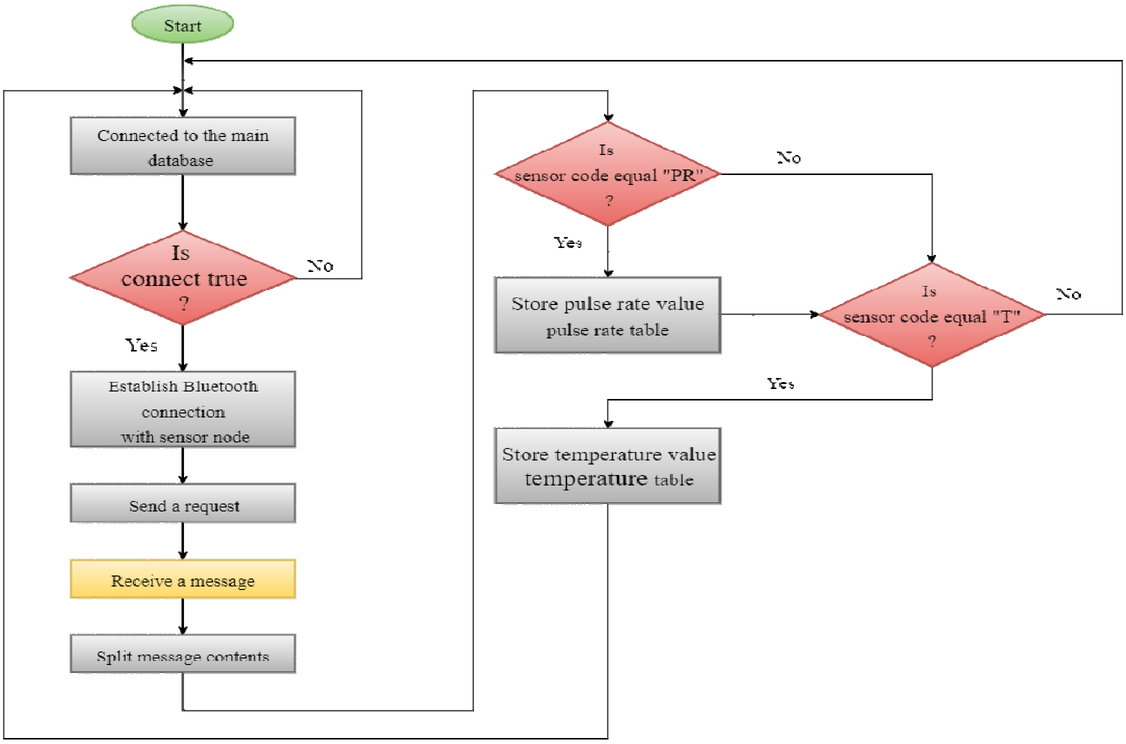


Figure (3): Base station Flowchart

5. Database Design

Database structure was explained and discussed in chapter two, and as mentioned before, three tiers database structure is useful and more suitable for website system. Database structure is represented by user, application and database tiers. Also we mentioned that database is composed of many tables that are connected to each other by using primary keys, therefore this leads to RDBMS.

RDBMS is more suitable for the proposed system. The relationships between the physician, patient, drug, and prescription tables etc. are explained in Figure (4). For example, the relationship between the patient, physician and notes tables as the following: Notes table contains ID (primary key), patient ID (foreign key), physician ID (foreign key), notes, time and date of the notes. Patient and physician tables are joined to the notes table through ID field.

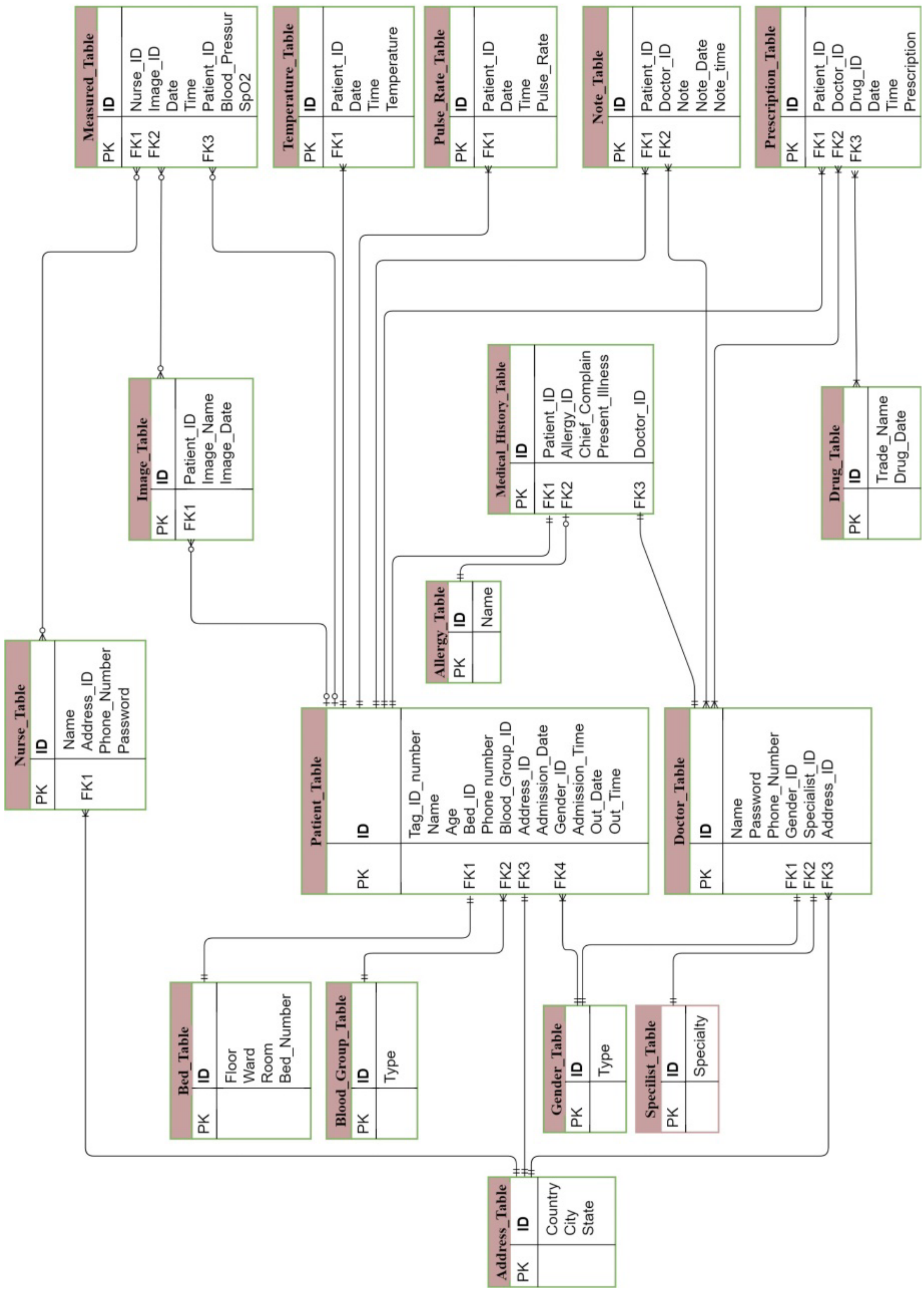


Figure (4): Relational database diagram

6. System Implementation

In order to implement the proposed system all hardware components that comprise the sensor node are connected together. In this system, two sensor nodes were employed; the first contains both pulse rate and body temperature sensors, while in the second only TMP36 sensor is used. See Figure (5).

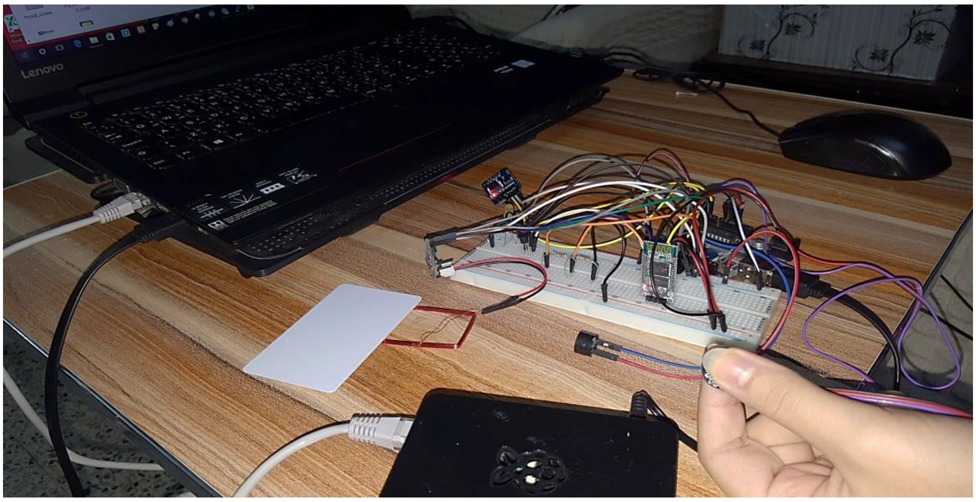


Figure (5): Sensor node implementation

Figure (6) shows how the RPi device (which contains website) is connected to the main server (which contains database) via switch device. This connection is established via Ethernet cables.

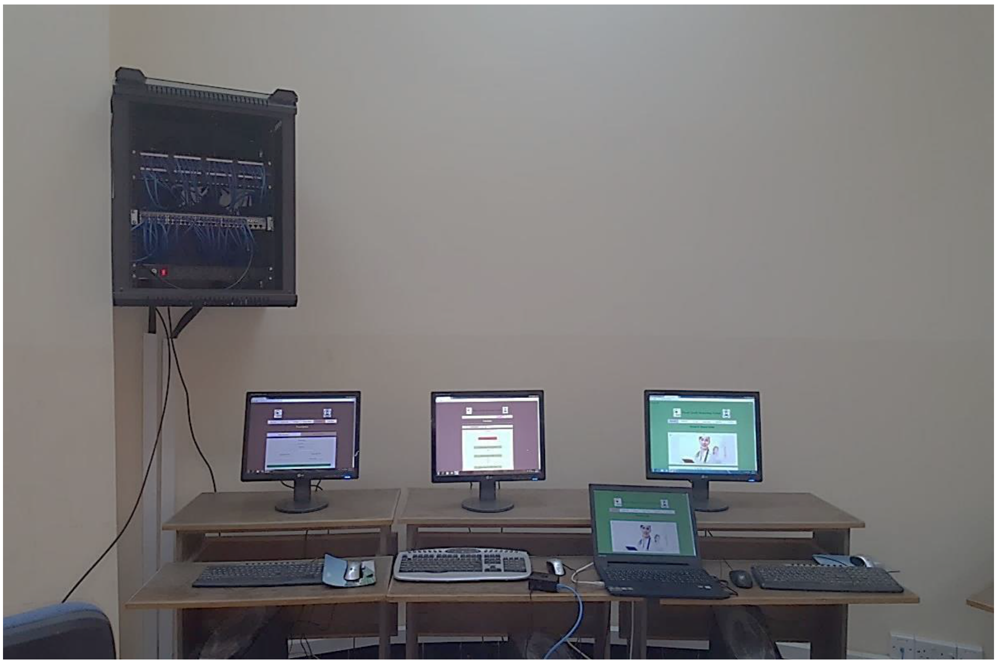


Figure (6): Overall system implementation

7. GUI Design

This system is based on using website to allow the physicians to access the patient case wherever and whenever they want.

Patient Personal information tab as explain in Figure (7), when the physician selects patient name, all information that is related are displayed.

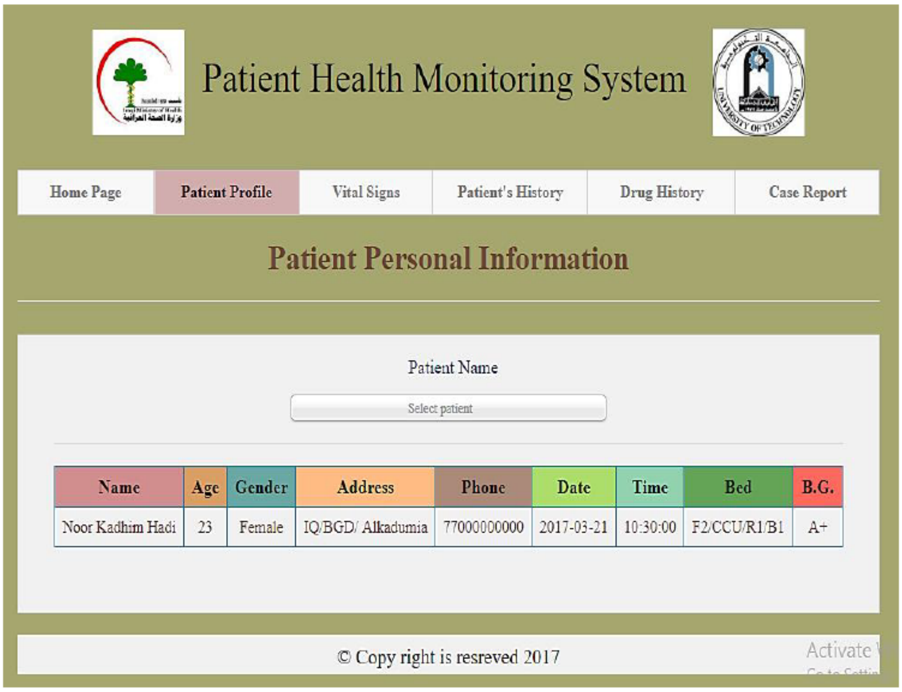


Figure (7): Patient personal information

While vital sign tab displays the parameters that are measured by the sensor nodes and the nurses.
Patient history tab displays both patient case history and all follow up notes. The notes are displayed in separate panels that include the name of the physician who has written the notes, the date and the time at which they were written, see Figure (8). In order to add new note, the physician has to choose the patient name, the date and time of the note and select "follow up note" choice. Then write it in its specified. This information is added into note table in database system by pressing "Insert Information" button.

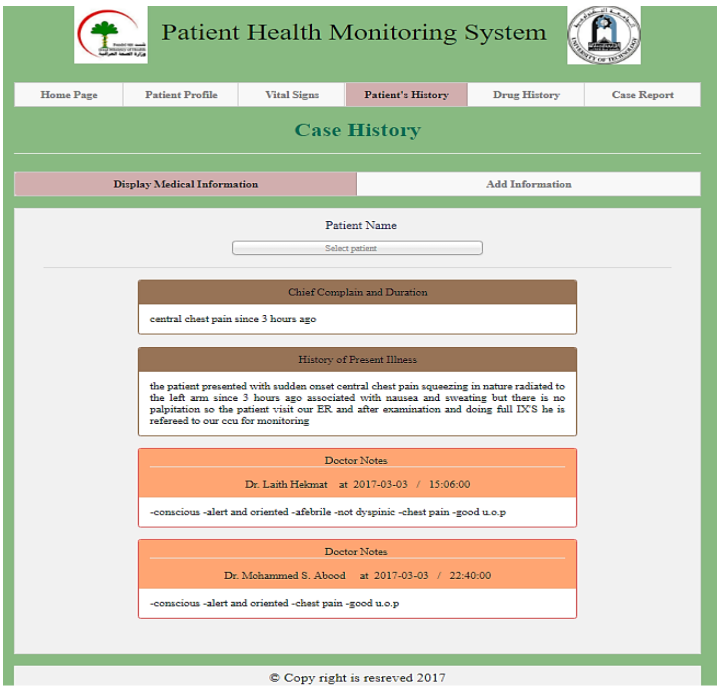


Figure (8): Medical information in patient history tab

Physician can display drug history as shown in Figure (9). After selecting patient name, allergy type and all the drugs that were prescribed to the patient will be displayed in separate panels according to the date and the name of the physician who had prescribed them.

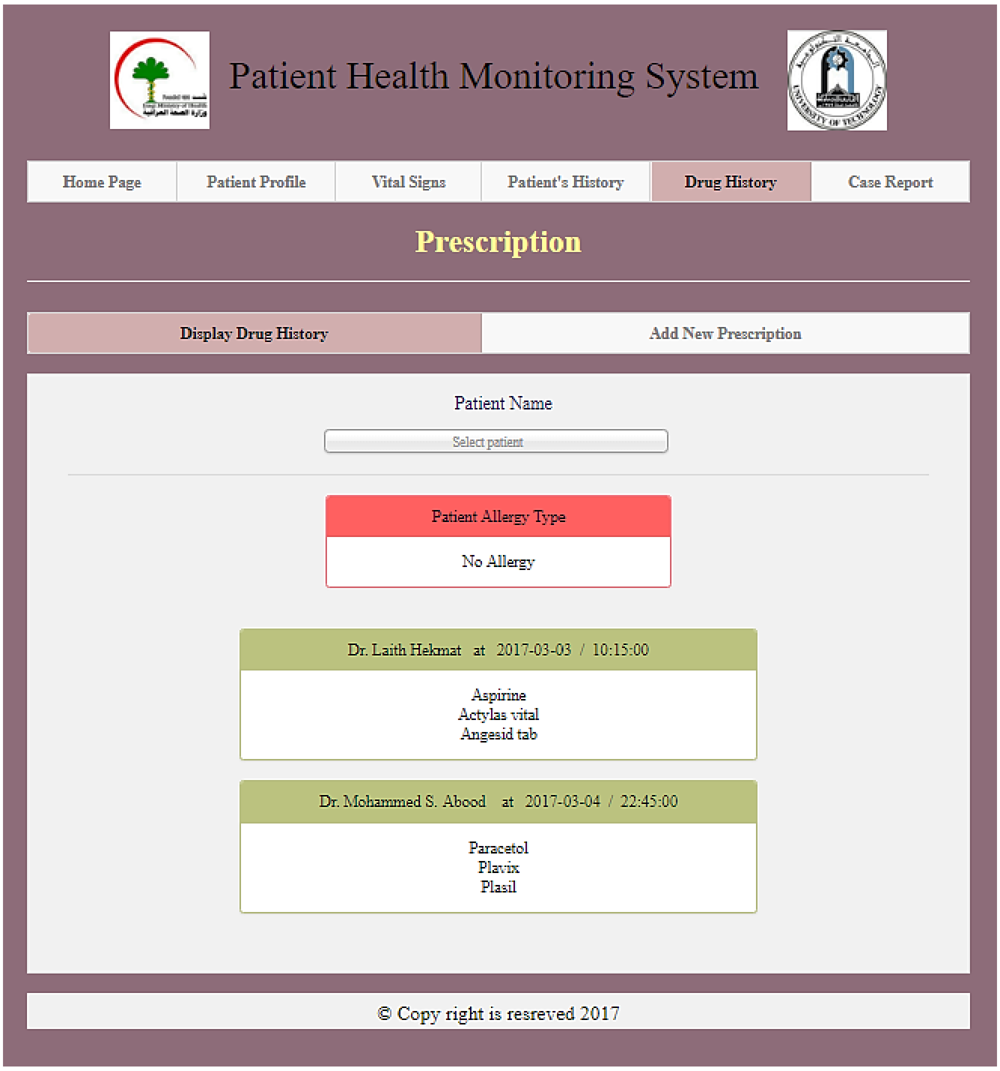


Figure (9): Drug history page

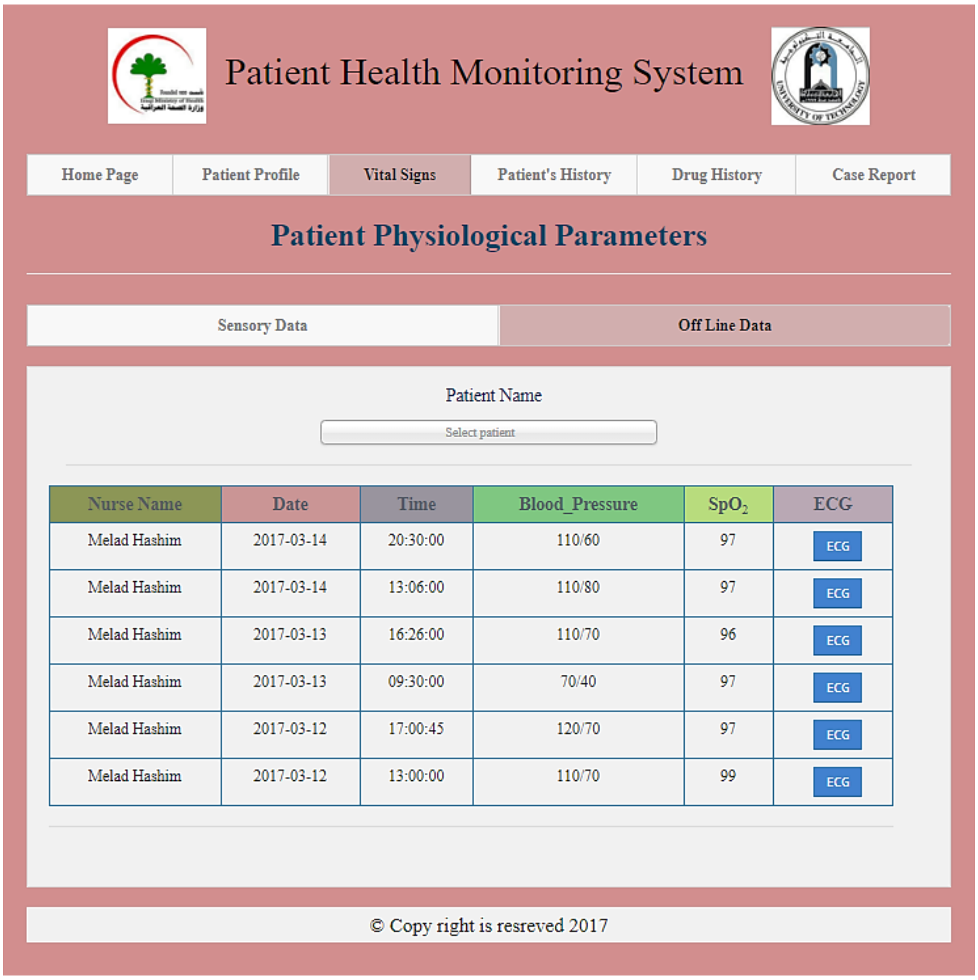
8. Results

Vital parameters that are measured by the sensors are displayed in data sensor tab. See Figure (10). Temperature and pulse rate parameters along with the date and time at which they were collected, are displayed in two separate tables. While the parameters that were measured by the nurse are displayed in offline data tab as shown in Figure (11).

Date	Time	Temprature
2017-07-24	14:00:05	37.04
2017-07-24	14:30:01	37
2017-07-24	15:00:01	37.1
2017-07-24	15:30:04	37.2

Date	Time	Pulse _ Rate
2017-07-24	12:45:02	88
2017-07-24	13:00:06	87
2017-07-24	13:15:01	88
2017-07-24	13:30:00	86
2017-07-24	13:45:03	90
2017-07-24	14:00:01	89
2017-07-24	14:15:02	91
2017-07-24	14:30:04	87

Figure (10): Parameters that are measured by the sensors



Nurse Name	Date	Time	Blood_Pressure	SpO_2	ECG
Melad Hashim	2017-03-14	20:30:00	110/60	97	ECG
Melad Hashim	2017-03-14	13:06:00	110/80	97	ECG
Melad Hashim	2017-03-13	16:26:00	110/70	96	ECG
Melad Hashim	2017-03-13	09:30:00	70/40	97	ECG
Melad Hashim	2017-03-12	17:00:45	120/70	97	ECG
Melad Hashim	2017-03-12	13:00:00	110/70	99	ECG

Figure (11): Parameters that are measured by the nurse

In Figure (12), the statistical analysis of temperature values is explained. The chart is represented by “X”-axis and “Y”-axis, which represent the time of measurement and temperature value respectively. The label includes the chart name like “Pulse Rate”, “Temperature”, etc.

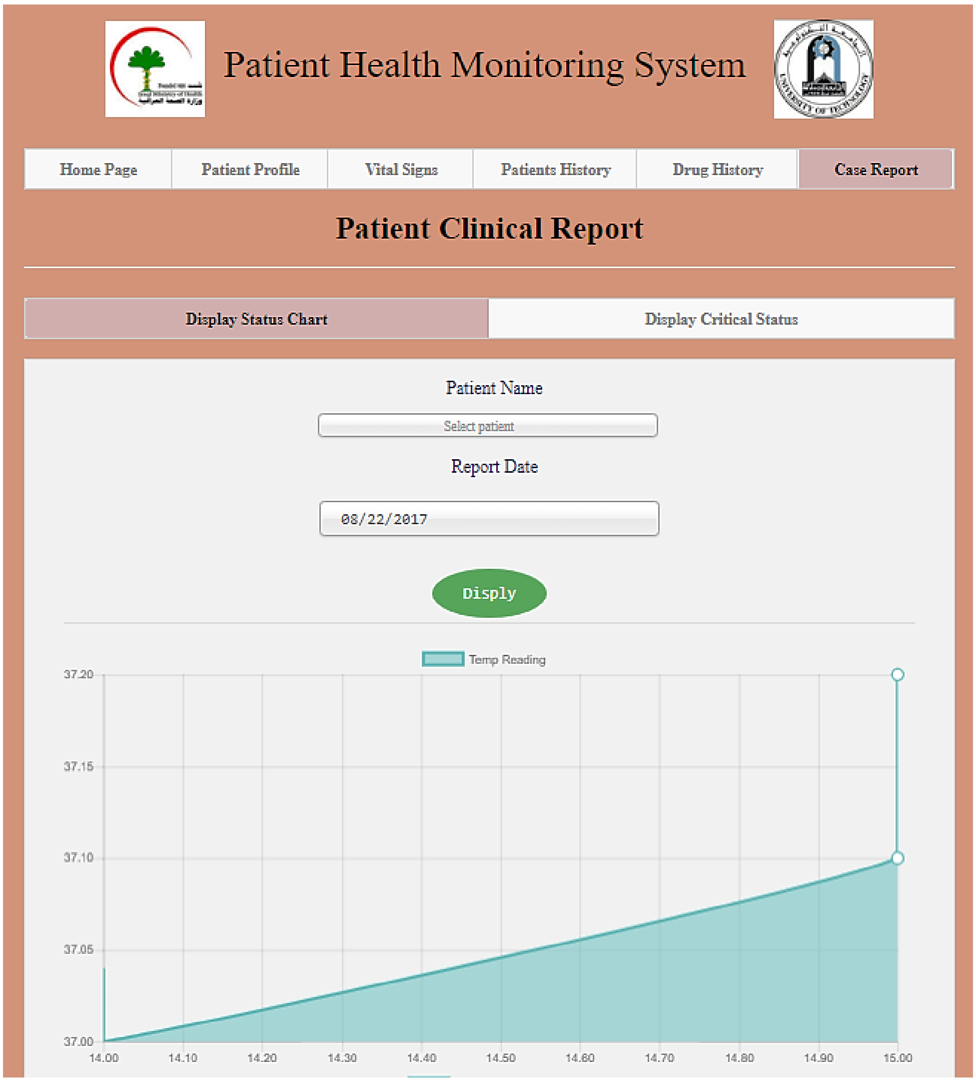


Figure (12): Temperature values report chart

Figure (13) shows the heart rate values chart at (24/7/2017). This explains that when pointing on the white circle, the chart displays the value of pulse rate and the date of measuring. SpO2 and blood pressure reports are explained in Figure (14). After selecting the patient name and date of measuring, and when press “Display” button, the date field shows the current date.

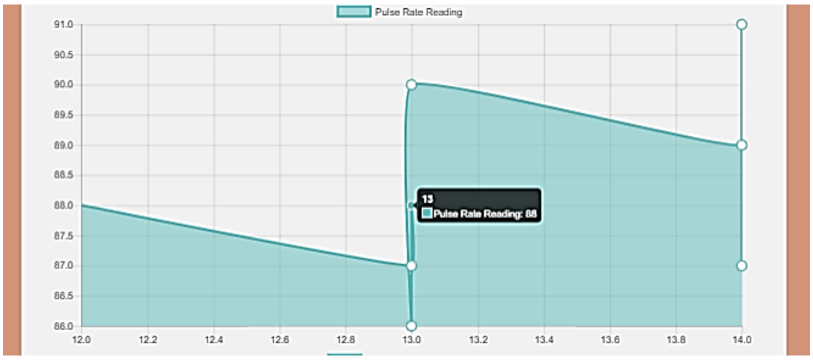


Figure (13): Pulse rate report chart

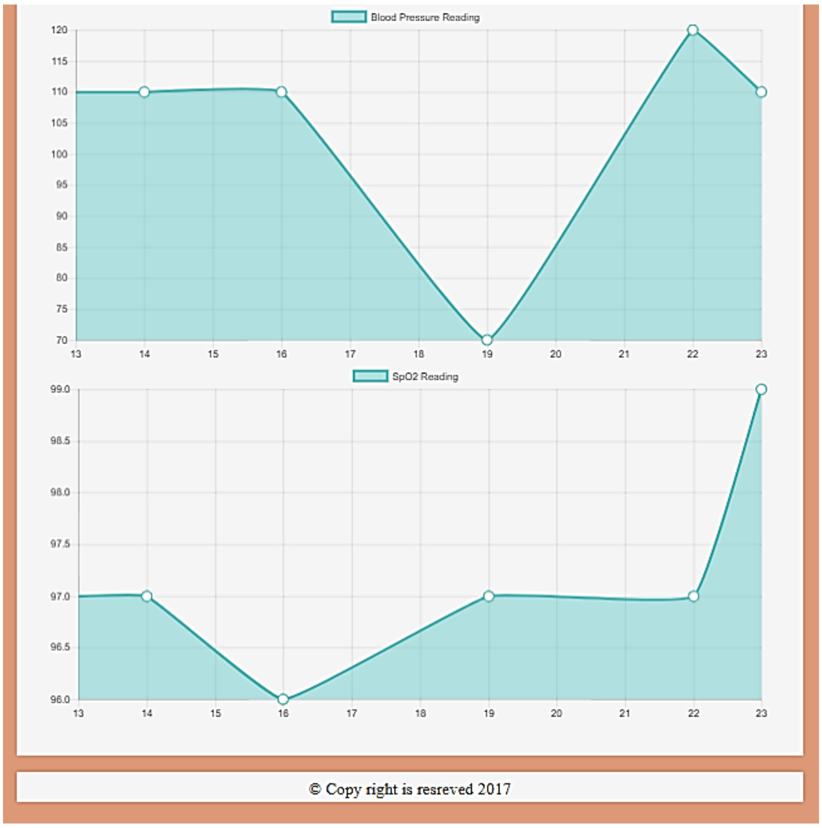


Figure (14): Blood pressure and SpO2 values reports chart

9. Conclusion

Monitoring patient's parameters continuously is important, and when the number of the patients in the hospital is huge, this process will be tedious, time and effort consuming for the physicians, therefore:

1- One of its benefits is to reduce stress and workload that the medical staff suffers from.

2- By using the system the healthcare professionals can monitor, diagnose, and advice their patients all the time.

3- System which measured heartbeat and temperature of a patient and sent it to a remote end by the use of a microcontroller at a reasonable cost with great effect.

4- The system is reliable, economical and user-friendly.

5- It is easy to use, fast, high efficiency, and safe.

6- The implementation of the proposed system support the results obtained, we shows that this system is the most suitable for monitoring the patients in hospitals.

7- In contrast to other conventional medical equipment the system has the ability to save data for future reference.

8- The results show that this system monitors patient health state continuously in real time and with different conditions.

9- This system provides the physicians with useful feedback about the patient health case.

10- It reduces time consuming in touring for following up patients cases and in collecting patient parameters. Therefore, provide more time to the physician to follow more important cases in the hospital.

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