Design and Implementation of a Wireless Patient Health Monitoring System

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Abstract— **This paper presents the design and implementation of an IoT wireless patient's health monitoring system. The system can be used to continuously monitor the body temperature and pulse rate of a patient located in a hospital room using biomedical sensors. The temperature and pulse rate values are taken from the sensors and processed by an Arduino Uno. Furthermore, they are sent wirelessly via RF communication using a 433 MHz transmitter and receiver kit. The readings are encoded and sent to the receiver where they are decoded and displayed on an LCD screen. Finally, the temperature and pulse rate values are also displayed and stored online using an Arduino Ethernet Shield 2 for future analysis.**

Keywords— Arduino Uno; Ethernet Shield; Pulse sensor; Temperature sensor; 433 RF transmitter module; 433 RF receiver module

I. INTRODUCTION

Advancements in electrical engineering technology have become quite remarkable over time in many spheres of life including in medical science. Human vital medical data can now be acquired from patients using electronic devices, such as heart rate monitor, pulse rate and temperature [1],[2],[3],[4]. Currently, people are becoming increasingly health conscious, furthermore, there is also the desire for more preventive health actions as opposed to curative actions [1],[2].

One way to attend to the above-mentioned issues is to develop a wireless monitoring system that can keep track of the biomedical parameters of a certain number of patients [3]. The system has to permanently keep track of the body temperature, blood pressure and pulse rate of a distinct patient. The recorded data must then be sent to the doctor's or nurse's room to be continuously assessed and analysed. In this way monitoring a patient can be done remotely which can then ultimately lead to an increased number of patients being closely followed by a doctor or even a nurse at any given time. Moreover, this could allow a reduction in the number of staff needed for specific monitoring services and permit doctors to better manage their time as well as focus on other tasks [5]. Additionally, if well calibrated, these monitoring systems could lead to a significant decrease in human errors and bias decisions which can then contribute to a more efficient service provided by health care professionals [6].

The proposed system is a wireless patient's health monitoring system that will frequently keep track of the medical parameters mentioned in the above paragraph, hence permanently monitoring the patient. The wireless communication system that is used between the transmitter and receiver device is a RF system making use of 433 MHz transmitter and receiver module. The sensors placed on the patient's body are gathering the data that is sent to the microcontroller unit, Arduino in this instance via a wireless sensor network. The data is then stored in a database so that the received data on the receiver side is always accessible to doctors who may analyse the overall health condition of a particular patient.

The main purpose of the paper is to design and implement a wireless monitoring health patient's system using RF communication technology that would allow doctors to monitor their patients' health parameters and record the data whenever the sensors are placed on the patient's body without having to be in the same room with them. The proposed design should also be able to set an alarm on in case of any kind of irregularities as well as sending readings online every time there is an input. The body temperature and pulse rate are the main parameters that are monitored.

II. DESCRIPTION OF THE PROPOSED SYSTEM

The system proposed is to continuously monitor the body temperature and the pulse rate of a particular patient using temperature and pulse sensors. The data collected in the patient's room which is considered as the transmitter side of the full system, is displayed on the LCD screen and then sent to the doctor's room, considered as the receiver side of the system, using a 433 MHz RF module kit. The data is also sent to one of the "Thingspeak.com" channel created in order to access and store the data so that it can be accessed anytime by the medical staff. A light system composed of LED's is used as an alarm system to indicate whether the temperature or the pulse rate values is higher than normal values.

Figure 1 and Fig. 2 present the block diagrams of the transmitter and receiver portions of the system respectively.

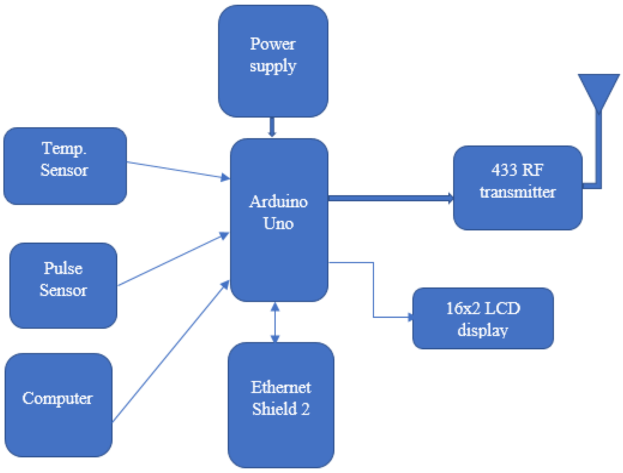

Fig. 1. Block diagram of the transmitter section of the system

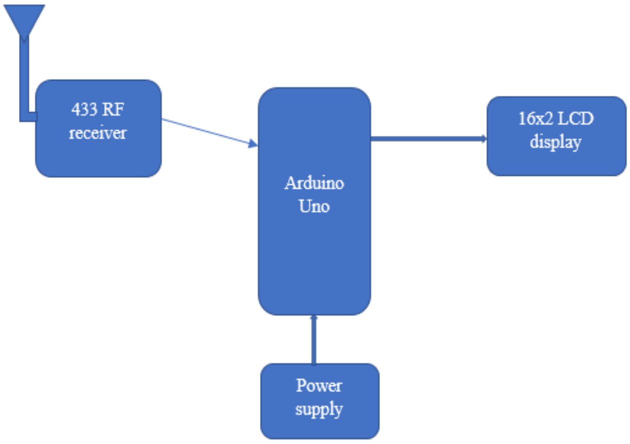

Fig. 2. Block diagram of the receiver of the system

A. Pulse rate sensor

Easy pulse sensor (version 1.1) [7] is used to detect cardio-vascular pulse wave from the fingertip. The device uses an infrared light source to illuminate the finger on one side, and a photodetector placed on the other side to measure the small variations in the transmitted light intensity (Embedded Lab).
The Easy pulse sensor is based on the principle of photo plethysmography (PPG) which is a non-invasive method used to measure the difference in blood volume in tissues making used of a light source and a detector. Because the change of blood volume is synchronous to the heartbeat, the technique can be used to compute the heart rate. The principle of photo plethysmography is divided into two categories: Transmittance and Reflectance. Concerning the transmittance PPG, the light source emits into the tissue and a light detector is placed in the opposite side of the tissue measuring the resultant light. Since the depth of light through the organ tissue is limited, the transmittance PPG is limited to some parts of the body such as the fingertip or ear lobe and that is the reason why the pulse sensor used is placed on the finger.

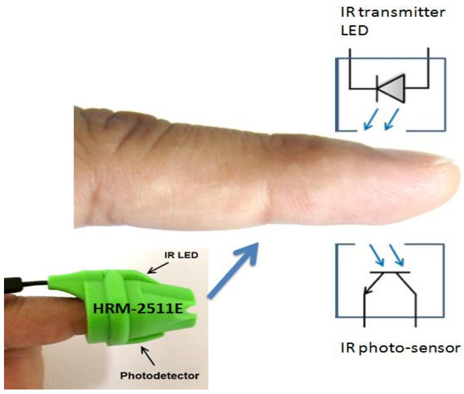

Fig. 3. Working principle of the pulse sensor [6]

B. Temperature sensor

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and it is equipped with an alarm function with non-volatile user-programmable upper and lower trigger points (htt6). The DS18B20 makes use of One-Wire which requires only one data line (and ground) for communication with a central microprocessor. The DS18B20 can also derived power directly from data line (parasite power) eliminating the need of external power supply. The DS18B20 can measure the temperature ranging from -55 degrees Celsius and -125 degrees Celsius (-67 degrees Fahrenheit with an accuracy of $\pm$ 0.5 degrees Celsius from -10 degrees Celsius to +85 degrees Celsius. The unique One-wire interface of the DS18B20 requires only one port pin for communication. The DS18B20 simplifies distributed temperature sensing applications with multidrop capability.

C. 433 MHz RF transmitter module

The 433 RF transmitter module makes use of AM to launch signals at the distance between 20 and 200 meters depending on the voltage applied to it. The operating voltage applied to the device is between 3.5V and 12V. The data travelled at a rate of 4 KB/s and uses a frequency of 433MHz.

D. Arduino Uno

Arduino is an open-source electronics platform based on easy to use hardware and software. Arduino boards have the ability of reading inputs light on a sensor, a finger on a button and a twitter message by converting the signal into an output that can activate a motor, turn an LED on or publish something online. Arduino Uno is a microcontroller board based on the ATmega328. The device has fourteen pins (input/output). The microcontroller contains six of its pins that can be used as PWM outputs and six that can be used as analogue inputs. It also possesses a 16 MHz crystal oscillator, a USB connection, a power jack an ICSP header and a reset button.

E. Arduino Ethernet Shield 2

The Arduino Ethernet Shield give the Arduino board the capability to connect to the internet. It is based on the Wiznet W5100 ethernet chip [8]. The Wiznet W5100 has both TCP and UDP network (IP) stack capacities, with a support of up to four socket connections concurrently. It uses the Ethernet library to write sketches which connect to the internet using the shield. The ethernet shield connects to an Arduino board using long wire-wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top. The version of the shield used has a micro-SD card slot, which can be used for file storage for serving over the network. Arduino communicates with both the W5100 and SD card using the SPI bus (through the ICSP header). This is on digital pins 11, 12, and 13 on the Arduino Uno. Pin 10 is used to select the W5100 and pin 4 for the SD card. These pins cannot be used for general input/output.

F. 433 MHz RF receiver module

The 433 RF transmitter module has a sensitivity f -105dB and operates at 433.92 MHz. The operating voltage of the device is 5VDC and the quiescent current is in the order of 4 MA.

III. METHODOLOGY

The design of the system was divided into two distinct sections namely: transmitter section located at the patient's room and receiver section situated at the doctor's office. The block diagrams of the different sections were shown in Fig. 1 and Fig 2. The system was designed following those block diagrams.

A. Transmitter section

The flow chart of the transmitter section is presented below, and the working principle of the section is demonstrated.

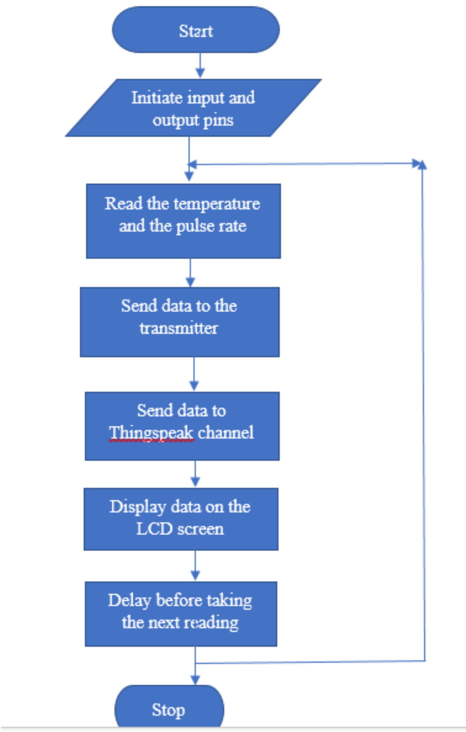

Fig. 4. Flow chart of the transmitter

The transmitter section was composed of the following components: pulse rate sensor, temperature sensor, Arduino Uno, Arduino Ethernet Shield 2. The design of the transmitter section was done following Fig. 1.

The whole circuit was power by the external power cable of the Arduino Uno. The Arduino Ethernet Shield was mounted on top of the Arduino Uno. The signal pin of the pulse sensor rate was connected to the analogue pin A0 of the Arduino. The VCC pin was connected to the 5V pin of the Arduino and the GND pin was connected to the ground of the circuit. The sensors values were read by placing a finger on it. Once a beat was detected by the sensor, the LED situated on the pulse board was indicating that there was a pulse. The pulse rate was computed after counting a certain number of beat and multiplying the number of beats by a certain time interval to get beat per minute.

The data pin (pin 3 on the temperature sensor) of the temperature sensor was connected to the digital pin 7 of the Arduino. The Vcc pin (pin 2) was connected to the 5V pin and the GND pin (pin 1) was connected to the ground of the circuit. The temperature sensor made use of its library in order to compute the body temperature once placed on the body.

The 433 RF transmitter module was placed at digital pin 3 on the Arduino and made use of the Radio Head library and Amplitude Shift Keying method to send the data wirelessly o the receiver side. The data was coded by the transmitter module and sent to the receiver module in form of strings. The LCD screen used was a 16x2 LCD with I2C interface and the I2C interface was connected to pin A4 and A5 to insure communication between the Arduino and the LCD screen. A laptop was used as a router to connect the Ethernet Shield to it via an ethernet cable. The internet connection of the laptop was shared between the laptop and the Ethernet Shield. Once the Ethernet Shield was connected to the laptop, an IP address was automatically allocated to it hence the internet connection was initialized. The data was sent and stored online using *Thingspeak channel*. The data was accessed online using the following URL link: https://thingspeak.com/channels/608077.

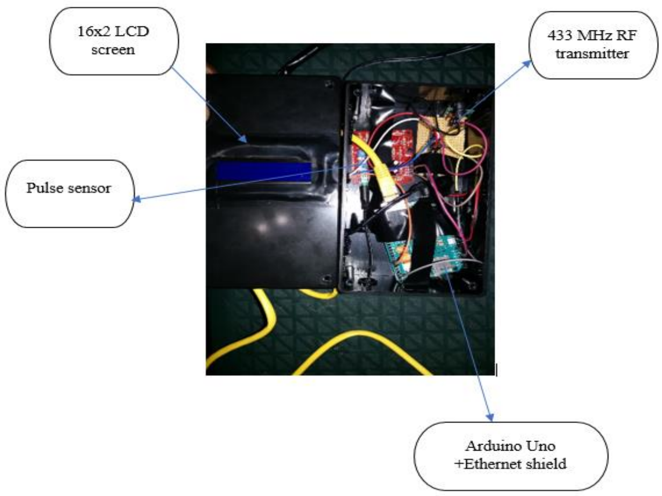

Fig. 5. Implementation of the transmitter section

B. Receiver section

The flow chart of the receiver section is presented below, and the working principle of the section is demonstrated.

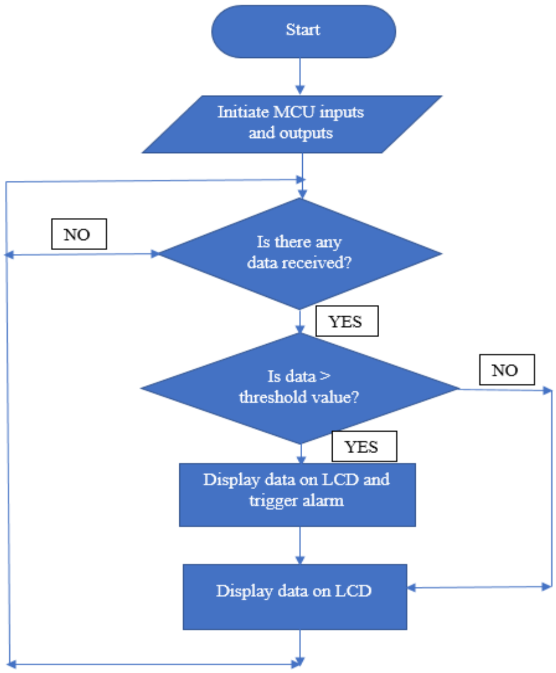

Fig. 6. Flow chart of the receiver section

On the receiver section, an LCD screen with the same characteristics as the one used for the transmitter section was used to display the readings from the transmitter section. The 433 MHz RF module was connected to digital pin 2 of the Arduino. The received readings were decoded and converted back into integers and finally displayed on the LCD screen. New readings were sent to the receivers every 20 seconds. An alarm system consisted of LED's was set to go on every time the temperature or the pulse readings received were higher than the set threshold.

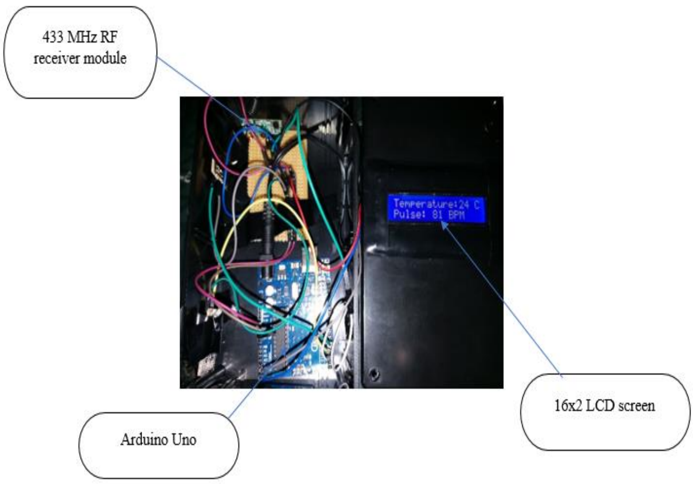

Fig. 7. Implementation of the receiver section

C. Working operation of the entire system

On the transmitter side (patient's room), the temperature sensor was attached to the arm of the patient and the pulse to their finger. The temperature and pulse rate recorded were coded by the RF transmitter module and then sent to the receiver module and online through the Ethernet shield. The readings were updated and saved online every time there was an input. Once the results were received and decoded. The readings were displayed on the LCD screen placed at the receiver side.

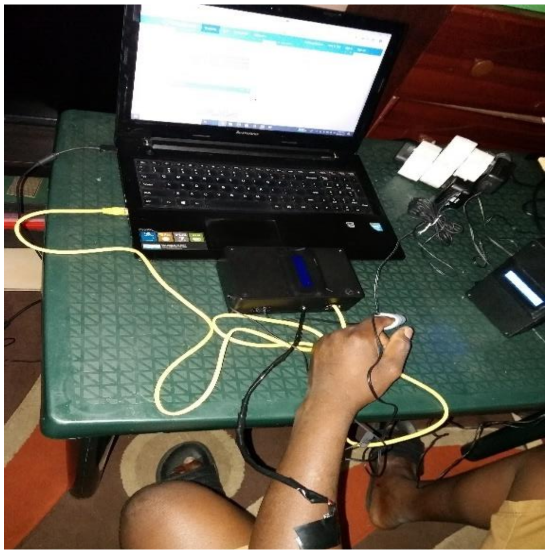

Fig. 8. Recording and sensing readings online

Fig. 9. Readings received on the receiver section

IV. RESULTS AND DISCUSSION

The entire system was tested under the following conditions:

A. Under normal conditions

At normal conditions, the readings observed when testing the device were 66 BPM for the pulse rate and 37 degrees Celsius most of the time. When the body was in motion the pulse rate increased but stayed between the normal ranges (60BPM-100 BPM). The results obtained are presented in Figures 10-14:

Fig. 10. Pulse readings at rest

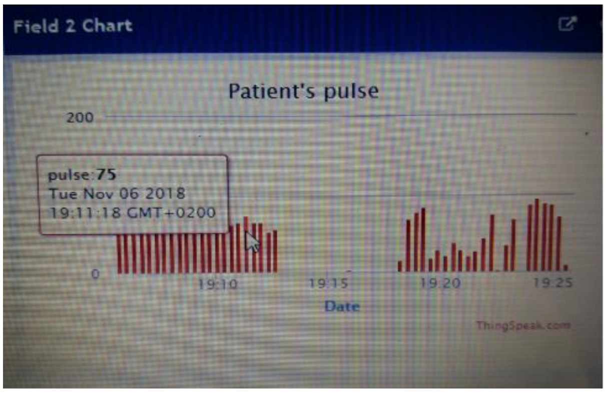

Fig. 11. Pulse readings when moving

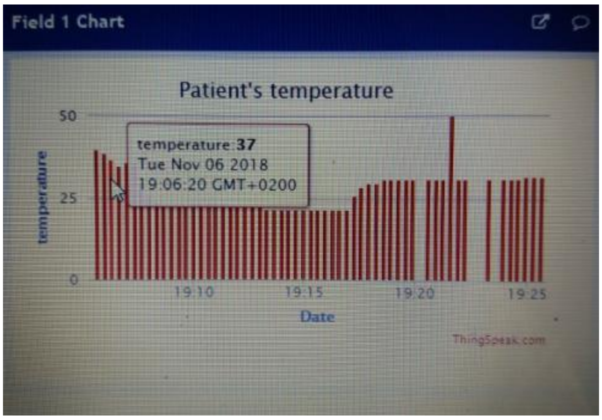

Fig. 12. Temperature readings at normal condition

B. Under high condition

A case of emergency was simulated under this condition to confirm that the device was responding accordingly. When the temperature or the pulse rate reached a value that was higher than the threshold set, a light system that was used as an alarm was switched on to indicated that the values were higher than the normal ones, therefore a doctor needed to go check on the patient.

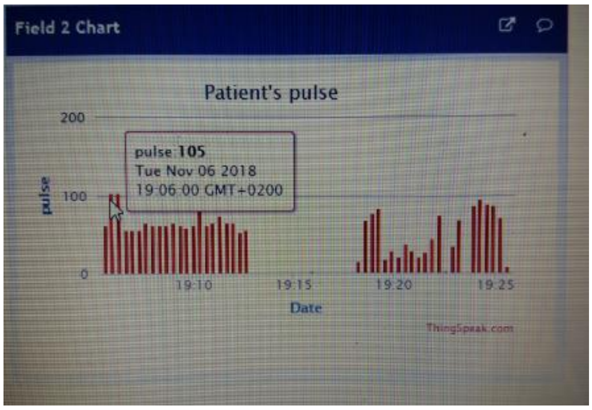

Fig. 13. Pulse readings at high conditions

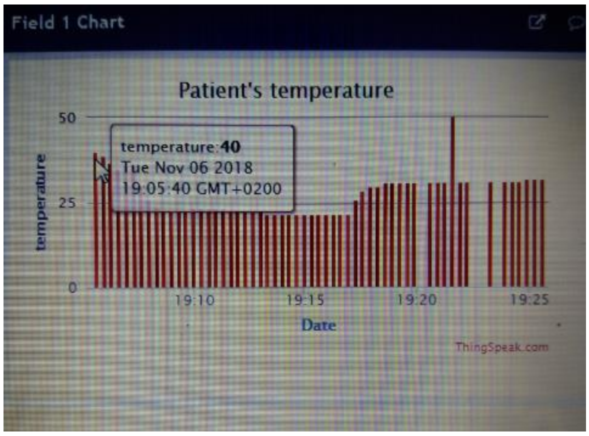

Fig. 14. Temperature readings at high conditions

V. CONCLUSIONS

A wireless health monitoring system that monitors remotely vital signs such as body temperature and pulse rate of patients in real time, displays readings, stores readings and notifies doctors in case of an emergency has been designed and implemented. The body temperature and pulse rate were continuously monitored by means of sensors. The detected readings were processed by a microcontroller and displayed on an LCD screen and then sent to a receiver antenna using a 433 MHz RF transmitter module. The same readings were also sent, displayed and stored online using Ethernet Shield. The readings were decoded by the 433 MHz RF module then displayed on the LCD screen placed on the receiver side. A light system created with LED's was set on every time the readings were above the threshold values that were set. In this work, two sensors were used. Inclusion of more vital sign monitoring sensors in the system is plans for future work.

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