Design and Simulation of Microcontroller Based Wireless Patient Intelligent Health Monitoring System with GSM Alert Technology

Chukwunazo. J. Ezeofor [#1], Remigius. O. Okeke [*2], Ogbuokebe S.K[#3]

[#]Department of Electronic & Computer Engineering, University of Port Harcourt, Rivers State, Nigeria

[*]Department of Electronic & Computer Engineering, University of Port Harcourt, Rivers State, Nigeria

[#] National Space Research and Development agency, Abuja

Abstract*- This paper presents the design and simulation of a wireless patient intelligent health monitoring system with GSM alert Technology. In the hospitals where patient's body temperature needs to be constantly monitored, this is usually done by a doctor or other paramedical staff by constantly observing the temperature, pulse rate and maintaining a record of these parameters. This is a very tedious method and can really be stressful, especially in overcrowded hospitals. The primary function of this system is to monitor the temperature and pulse rate of a patient's body, and send the information wirelessly to the doctor's office on the LCD display unit. In this proposed system, a transmitting unit continuously reads patient's body temperature and heart rate through digital sensors, displays them on the transmitter LCD. At the receiving end, a receiver is used to receive the data, decode it and feed them to another microcontroller which then displays it on the doctor's LCD screen. The receiver unit is kept in the doctor's chamber to continuously display the patient's body temperature and heart rate wirelessly. An alarm is also activated at the receiver end where the doctor will be, and is activated when the patient's temperature or heart rate goes below or above the normal human threshold value, which are 37°C and 70 beats per minute. An SMS will be sent to the doctor, just in case he or she is outside the vicinity and to serve as an avenue for constant update. The proposed system was simulated using Proteus software and programs written in Embedded C language. The result obtained shows an efficient method of relating information to the doctor on duty for urgent attention to patients.*

Keywords*- Arduino Uno, Transmitter, Receiver, LCD, Intel Galileo, GSM technology, Health Pulse rate, WPIHMS*

I. INTRODUCTION

In recent years, great innovations have brought advanced technologies in Medical sector. Most of the Health Centers and Hospitals are trying to make available and uphold the effective enduring treatments, with more alert and preventions [1]. Such an effective treatment requires a professional Patient intelligent Monitoring System. The Patient Monitoring System is a greatly developed technology for controlling and monitoring the situation of various Human-health parameters. Some of our Human-health parameters include temperature, heartbeat, blood pleasure, pulse rate, etc. requires continuous monitoring process and update to doctors on duty.

Mobile computing describes a new class of mobile computing devices which are becoming omnipresent in everyday life. Handheld smart phones and manifold embedded systems make information and internet access easily available to everyone from anywhere at any time [2]. The goal of mobile health care is to provide health care services to anyone anywhere at any time, overcoming the constraints of place, time and money.

Although the prominent present systems available allow continuous monitoring of patient's vital signs, these systems require the sensors to be placed at bedside monitors or PCs, and limit the patient to his or her bed. This proposed system does not require patients to be limited to their beds but allows them to move around, although within a specified distance. This is because outside this range, the possibility of collecting data will be unfeasible.

A combination of wireless sensor networks, existing Radio Frequency Identification (RFID) and Vital Sign Monitoring technology to simultaneously monitor vital signs are used, while keeping track of the users' locations [3]. The use of wireless technology makes it possible to install the system in our homes and link to various hospitals. Radio frequency waves can travel through walls and fabrics, sending the vital signs and locations' information to a central monitoring computer server via a miniature transmitter network at the patients' end. The benefits of wireless technology are already apparent: portability, convenience, ease of installation, and cost effective [4].

II. RELATED WORK

Some of the related researched theses are:

A. *Wireless sensor network for e-health system based on radio-active and radio-passive positioning:* Anliker U., J. A. Ward et.al [5] has developed a wearable medical monitoring and alert system aimed at people who are at risk from heart and respiratory diseases. The system combines multi parameter measurement of vital signs, online analysis and emergency detection, activity analysis, and cellular link to a telemedicine centre in an unobtrusive wrist-worn device.

B. *Model based on a fuzzy regular formal language to describe the current state of health of the wireless health monitoring system*: Alexandros, Pantelopoulos et.al considered symptom ambiguity and causal relationships between various disorders and symptoms to derive a thorough estimation with a certain degree of confidence [6].

C. *Design of a processor that samples signals from sensors on the patient health*: Rasid M. F. A, and Woodward B. et.al [8] focused on the design of a processor which samples signals from sensors on the patient. It then transmits digital data over a Bluetooth link to a mobile telephone that uses the General Packet Radio Service.

D. *A prototype system using open source technologies for centralized medical patient records:* Shihab A. Hameed et al (2008) built a prototype system using open source technologies for centralized medical patient records that can be viewed and updated by physicians using any web browser [9].

E. *A.I, F, & G have proposed a complete real time Electrocardiogram (ECG) acquisition, transmission, storage, and visualization system for nonclinical applications:* Chin-Teng Lin et.al designed a novel for cardiovascular disease. A wireless, ambulatory, real-time, and auto alarm intelligent tele-ardiology system to improve healthcare mobile patient monitoring system was designed, developed, and tested by Yuan-Hasiang Lin, I.-Chien Jan et.al. Authors integrated current personal digital assistant and wireless local area network technology. At the patient's location, a wireless Personal Digital Assistant (PDA) based monitor is used to acquire continuously the patient's vital signs including heartbeat, lead ECG, and Blood Oxygen Level (SpO2). Through the Wireless Land Area Network (WLAN), the patient's bio signals can be transmitted in real time to a remote centre for data storage and management unit. The authorized medical staff can access the data and patient's history via wireless device[13].

III. METHODOLOGY

The System Design of Wireless Patient Intelligent Health Monitoring System (WPIHMS) is designed in two sections namely; the transmitter section at the patient's room and the receiver section at the doctor's office. To actualize these design research objectives, the block diagram of the wireless health intelligent monitoring system used is shown in fig.3.1.

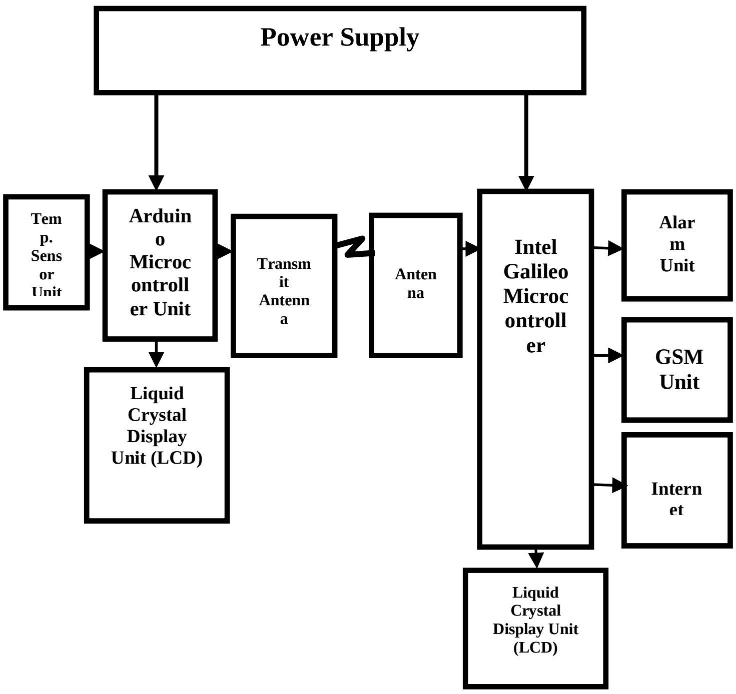

Fig.3.1: Block diagram of Wireless health intelligent monitoring system

A. *Transmitter Section of the WPIHMS*

The proposed transmitter system at the health patient's location is designed following the diagram shown in fig.3.2 below. The transmitting section consists of power supply, temperature sensor, pulse sensor, Arduino uno (microcontroller), LCD and RF antenna, which is the RF link transmitter.

Power Supply is a system that supplies electrical energy to the entire WPIHMS system. In the transmitter, the pulse sensor is designed to give digital output of heart beat when a finger is placed on it. When the heart beat detector is working, the beat LED flashes in unison with each heartbeat. This digital output can be connected to Microcontroller directly to measure the Beats per Minute (BPM) rate through program code. It works on the principle of light modulation on blood flow through finger at each pulse. The temperature sensor is attached to the health patient whose temperature is to be measured. Its values are expressed in millivolts (mV), which is sent to the Arduino uno Microcontroller. This is received as analog signals between 0-1024 and mapped to 5V through written program codes. The value is scaled by the Arduino and converted to a digital value which is sent to the transmitter RF antenna and further displayed on transmitter's Liquid Crystal Display (LCD). These parameters are transmitted by the RF link transmitter antenna to the receiver section in the doctor's office where output will be read by the health worker or doctor in charge.

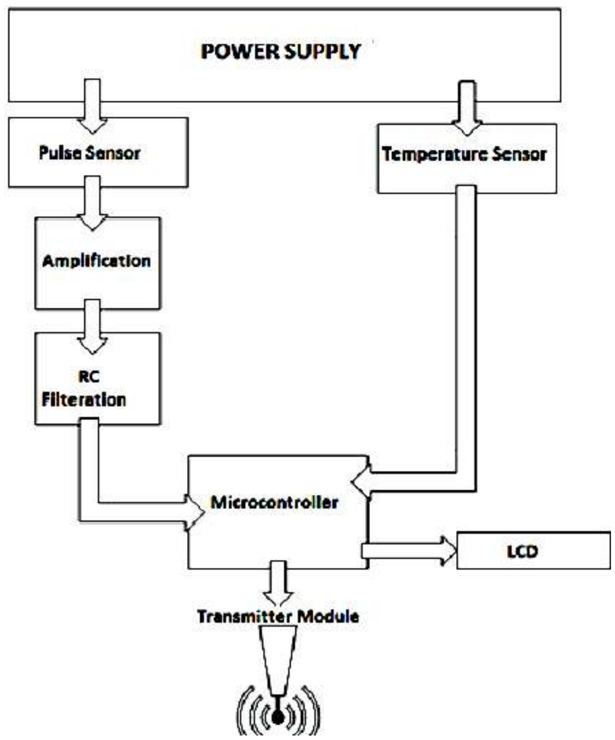

Fig 3.2: Block diagram of Transmitter Section [1]

Also, Fig. 3.3 below shows the connection of the transmitter circuit on an electronic bread board. The pulse sensor and the temperature sensors are connected to the A0 and A1 pins on the Arduino uno board. The LCD pins are connected to the pins 2, 3, 4 and 12, 10, 9, 8 pins on the Arduino board. A rechargeable battery is connected to the power port of the Arduino.

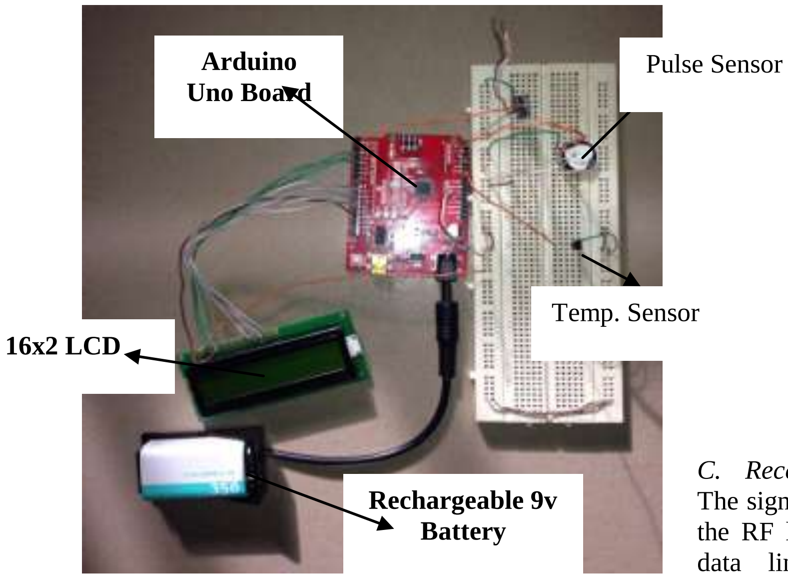

Fig. 3.3: Snapshot of the transmitter section

B. WPIHMS 's Transmitter Flow chart

The flow chart in the fig.3.4 below shows the transmitter section that was used to realize the program part which controls the transmitter section of the system. When properly coded, the microcontroller input and output pins become initiated. The initiation triggers the microcontroller to check input values from the temperature and pulse sensors. Since the microcontroller has been programmed in such a way that it can map out the voltage values from the sensors, and convert to digital form, it further sends this converted values to the transmitter. The transmitter on receiving these values sends output results to the LCD for display. There will exist a delay time in pre-defined seconds, before another reading will be taken, after which one cycle of the program is ended. This process continues checking for temperature and pulse rate and relating the value to the Microcontroller for further processing.

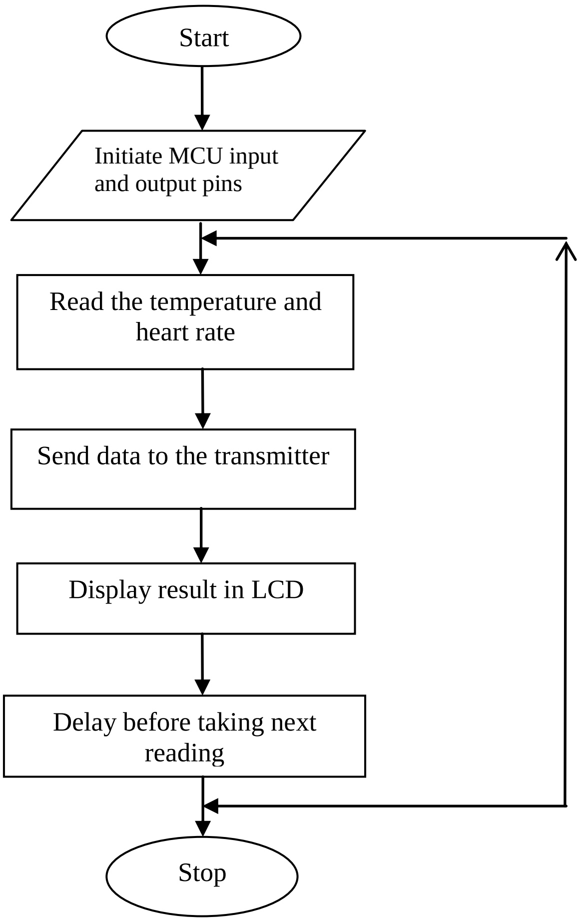

Fig. 3.4: Flow chart for transmitter section

C. Receiver Section of the WPIHMS system

The signal from the transmitting section is received by the RF link receiver antenna. It works as a wireless data link, establishing connection between the ınsmitting and receiving sections of the system. The ceived signal is sent to the Intel Galileo which processes the data and sends it to the doctor's LCD for processed parameter display. Also the processed parameters are sent to the doctor's phone through GSM shield and to the internet cloud for storing and sharing. The GSM shield acts as a GSM modem that sends SMS to the doctor's phone once the value of the patient's health data goes above a certain threshold. The fig. 3.5 below shows the block diagram of the receiver section. The Internet cloud stores the patient's data in a database and can be assessed online through internet enabled computer anywhere. The LCD placed in the doctor's office displays result of the patient's parameters within a certain programmed period of time.

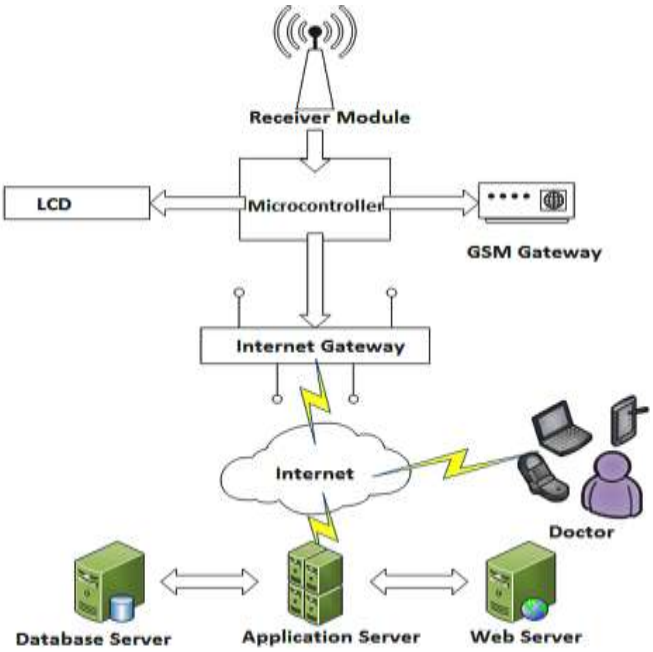

Fig. 3.5: Block diagram of Receiver section[4]

Also, fig 3.6 below shows the connection of the receiver section. The Intel Galileo board has microcontroller that processes the received signals from the RF antenna of the transmitter section. The LCD is connected to the pins 4, 5, 6, 7, 8 of the GSM shield, which is mounted on top of the Intel board and connected to all the pins of the Intel board. The RF link receiver is connected to the pins A0-A5 of the GSM shield and SIM card inserted in the SIM slot of the GSM shield, as this would be used as the mobile link in other to send SMS to the doctor's phone.

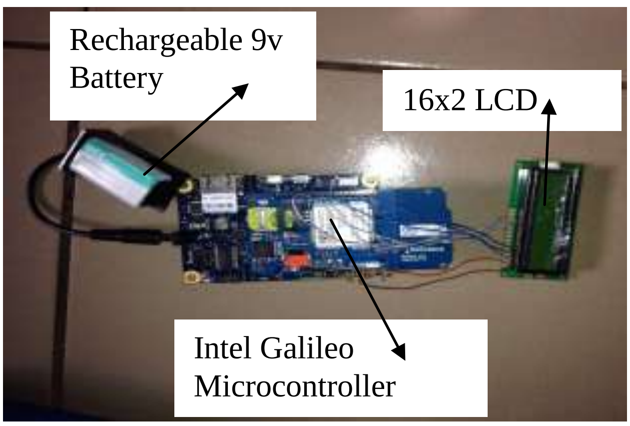

Fig 3.6: A snapshot of the receiver section of WPIHMS system

D. WPIHMS 's Receiver Flow chart

The flow chart in the fig 3.7 below shows the receiver section that was used to realize the program part which controls the receiver section of the system. The system starts by checking the Microcontroller input and output pins through the antenna. If the Microcontroller receives a value from the transmitter antenna, it will analyse and compare with the pre-defined programmed value. Again, if it does not receive any value from the transmitter, it will continue checking. On the other hand, if the value received from the transmitter is less than or equal to the threshold value, then the value will be displayed as an output on the LCD display unit to be seen by the doctor or health worker. An SMS alert will be sent to the doctor if the value supersedes or is flagged as an emergency value. Also, an alarm system will be triggered to alert the doctor in charge of the health patient. The displayed information would last for at least 20 minutes before the system removes the data in its display unit for another display. This process continues displaying of the health patient's parameters for doctor's notification and quick action.

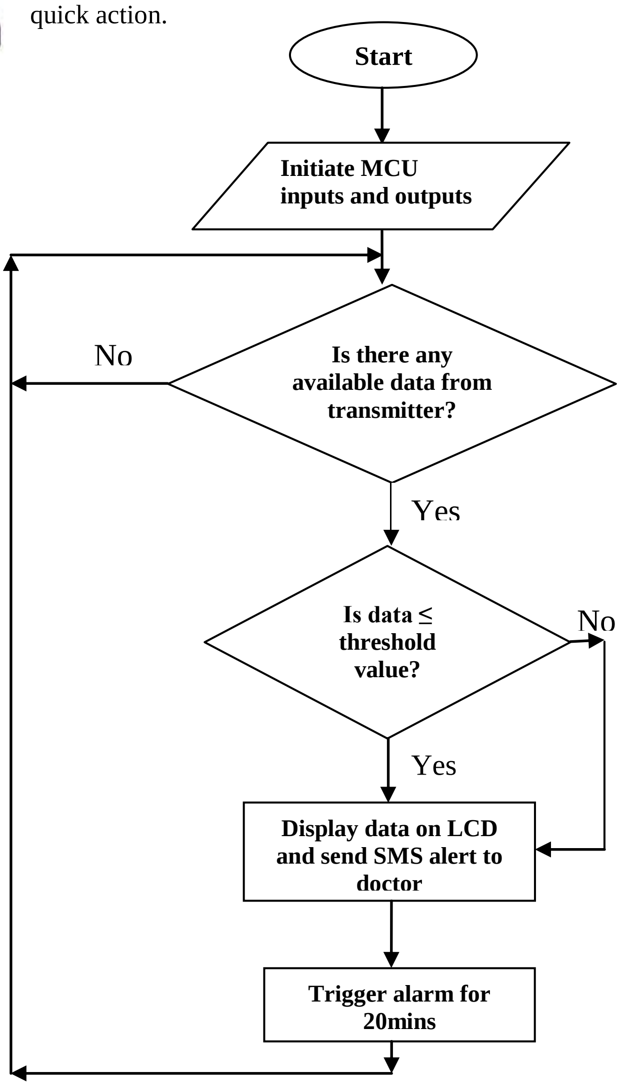

Fig 3.7: Flow chart of the Receiver section

E. WPIHMS Operations & Circuit

Wireless Patient Intelligent Health Monitoring System (WPIHMS) operates using +5v supply voltage from the external regulated battery source or direct plug to the USB port of the Laptop. When properly set and powered ON, the transmitter section and receiver section are initialized for operations through the embedded C language. At the transmitter section, the Pulse sensor is designed to be worn by the patient and temperature sensor placed anywhere on the patient's body which capture patient body temperature as well as the pulse rate. Both are sent to the Arduino Microcontroller which processes the data, display the parameters on the patient's LCD and send the same parameters through RF antenna of the transmitter to the doctors' end wirelessly.

At the receiver section which is in doctor's office as well as mobile phone; the receiver RF antenna receives the transmitted signal with the same Radio frequency and sends to the Intel Galileo processor which processes the received data, activate alarm for 20 seconds to attract doctor's attention. Then display the processed data on the LCD unit in the doctor's office. Also SMS message of the same parameters are sent using the GSM shield through SIM card to doctor's phone in case he or she is not in the hospital vicinity for urgent attention to the patient. The complete circuit connection of WPIHMS is shown in fig.3.8 below.

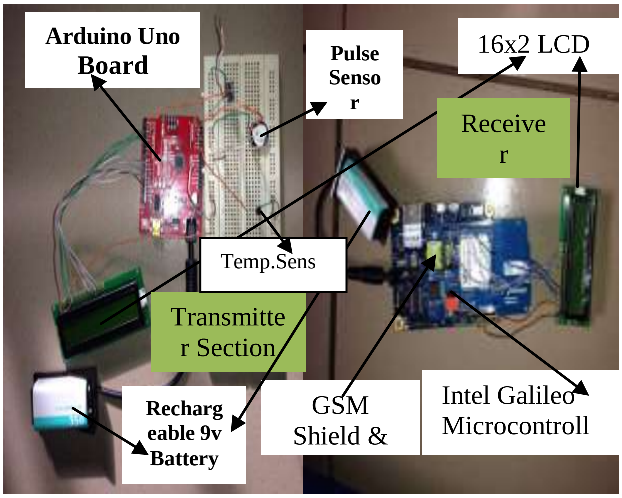

Fig 3.8: Transmitter & Receiver of the WPIHMS

F. WPIHMS Programming Language

The programming Language used to develop the system codes that control the designed system is Arduino Embedded C language. The codes follow the flow chart procedures as shown in figure 3.4 and figure 3.7 above. The Arduino development environment (IDE) is shown in figure 3.8 below.

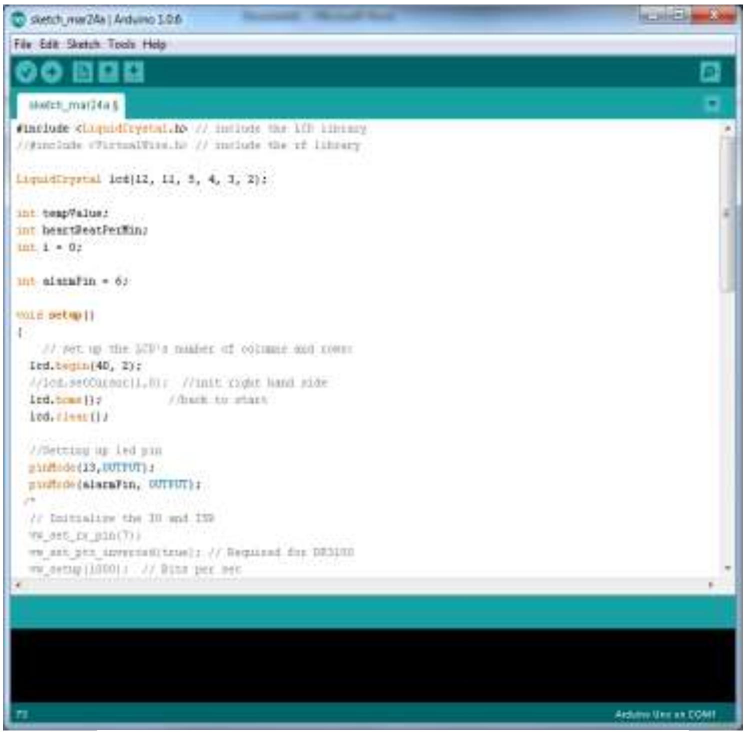

Fig.3.8: Arduino IDE Sketch_Mar24a

The embedded C codes for transmitter section are shown below.

#include <LiquidCrystal.h> // include the LCD library
//initiating parameters for first patients
int tempSensorPin = A1; //select the input pin for the LM35
int tempValue = 0; //variable to store the value of the temperature from the LM35
int heartBeatPerMin = 0;
int heartBeatPerSec = 0;
int pulseSensorPin = 6; //selects the input pin for the pulse sensor
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
void setup() {
// set up the LCD's number of columns and rows:
lcd.begin(40, 2);
lcd.home(); //back to start
lcd.clear();
//Setting up sensor pins
pinMode(13,OUTPUT);
pinMode(tempSensorPin, INPUT);
pinMode(pulseSensorPin, INPUT);
Serial.begin(9600); }
void loop() {
tempValue = analogRead(tempSensorPin);
tempValue = (5.0 * tempValue * 100.0)/1024.0; //convert the analog data to temperature
digitalWrite(13, 1);
Serial.write(tempValue); //send the temperature value to transmitter
Serial.flush(); //wait for outgoing data to send completely
digitalWrite(13,0);

```
 lcd.home();   //back to start
 lcd.print("TMP:");
 lcd.setCursor(4,0);
 lcd.print(tempValue);
 lcd.setCursor(0,1);
 int isHeartBeat = 0;    //sets pin for pulse to false
 int j = 0; //variable that checks if the current pulse has
been read before 0 = new data, 1 = old data
 for(int i=0; i<5000; i++){
    isHeartBeat = digitalRead(pulseSensorPin);   //read
the state of the pin to see if there is a heart pulse
    if (j == 0)  //is it a new pulse data{
      if(isHeartBeat) {
        heartBeatPerSec++;
        j = 1;  // record the current pulse as an old data }
    }
    if(!isHeartBeat)  {
      j = 0;  }
    delay(1);    // gets values once every millisecond for
3000ms (0 to 2999 msec)(1x3000msec = 3000msec =
3sec)
              //  so  the  compiled  value  in
heartBeatsPerSec are the actual heart rate for every 2
second }
heartBeatPerMin    =    (heartBeatPerSec/3)*60;    //
calculates beats per minute from beats per sec value
 digitalWrite(13,1);
 Serial.write(heartBeatPerMin);
 Serial.flush();// wait for outgoing data to be sent
completely
 digitalWrite(13,0);
   lcd.print("BPM:");
   lcd.setCursor(4,1);
   lcd.print(heartBeatPerMin);
   heartBeatPerMin = 0;
   heartBeatPerSec = 0;
    delay(1);}
```

The receiver section embedded codes were not included but the reader can request through email and it will be sent.

IV. RESULT AND DISCUSSION

The simulation of the WPIHMS system design was done using PROTEUS software. The system was divided into two parts as earlier mentioned; both were integrated to achieve the design objectives and communication purposes. The transmitter and receiver sections result obtained at different conditions are explained below.

A. Transmitter Section(Patient side)

1) Transmitter unit result at low conditions: The result obtained in simulating designed transmitter circuit at low temperature and pulse rate are shown in fig 4.1 below. At 33°C, the human body temperature is at low and is said to be critical, and at 60 bits per minute (BPM) the pulse rate is also at low. The values are obtained from the temperature sensor and pulse rate sensor that are placed at the transmitter section. These signals are sent in volts to the Arduino in other to be read and convert into digital forms. The result displayed on the LCD unit shows the signal values received from the temperature and pulse sensors in real time during the testing period.

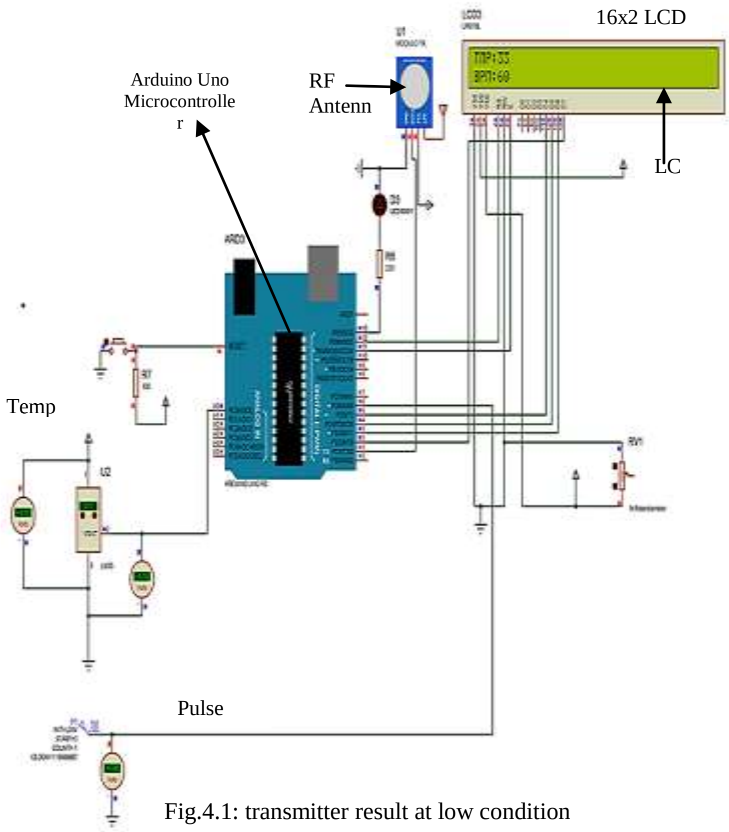

Fig.4.1: transmitter result at low condition

2) Transmitter unit result at normal conditions: The result obtained from the transmitter unit at normal temperature condition is shown in fig 4.2 below. This shows a temperature reading at 37°C, which is the normal human body temperature. This value is obtained from the temperature sensor which is placed at the transmitter unit that transmits the signal to the Arduino. The Arduino converts the signal and further sent to the receiver through the RF antenna unit. The temperature value is displayed on the LCD at the transmitter section.

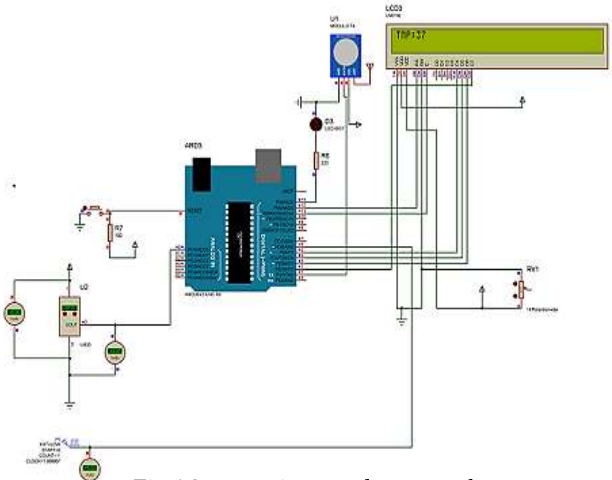

Fig.4.2: transmitter result at normal

3) Transmitter unit result at extreme or high conditions: The result obtained from the transmitter unit at high temperature and pulse rate are shown in fig 4.3 below. The values displayed on the transmitter unit LCD are 39°C against BPM 120. The temperature value is high for human being because any value above 37°C is flagged as extreme and serves as a symptom of high fever. Also the BPM value is recorded as120, which is also a high pulse rate as any value above 100 is deduced as being extreme, irregular and critical. These values are displayed on the transmitter LCD, and transmitted to the receiver LCD, which is placed in the doctor's office.

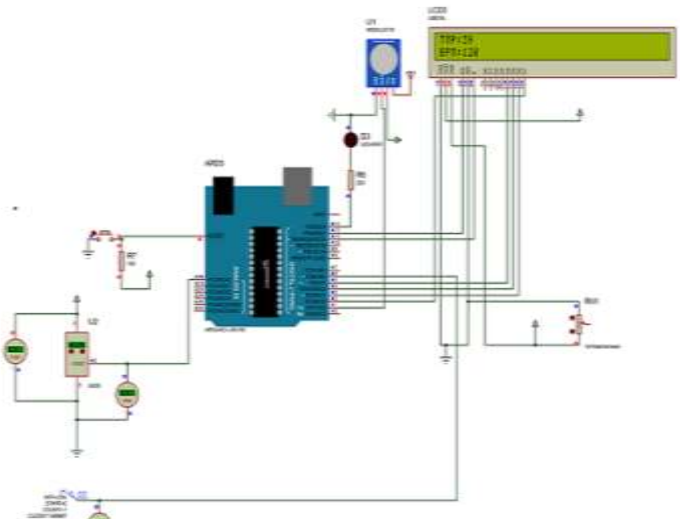

Fig.4.3: transmitter result at high

The receiver unit results obtained at different conditions are shown below.

B. Receiver Section (Doctor side)

1) Receiver unit result at low conditions: The result obtained from the simulating of the receiver circuit at low condition is shown in fig 4.4 below. This shows a temperature reading at 33°C, which is a low human body temperature. The result is transmitted to the receiver unit from the transmitting section. As the receiving unit will be at the doctor's office, the display unit (LCD) at the doctor's office will display the temperature and pulse rate of the patient. An alarm is incorporated in the circuit to trigger at any temperature below 34°C, and also at a pulse rate of 60BPM and below. This alarm will continue for 20 minutes until it is reset by the doctor or health worker in charge. An SMS containing the details of the patient's temperature and pulse rate parameters will be sent to the doctor's phone for proper recording and acknowledgement, especially if the doctor is not physically present at that moment.

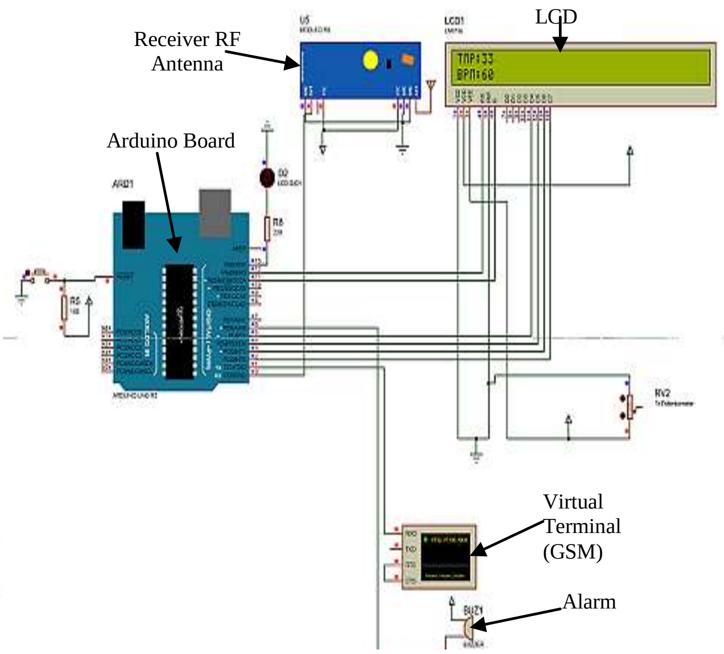

Fig.4.4: Receiver result at low condition

2) *Receiver unit result at normal conditions:* The result obtained from the receiver unit at normal temperature condition is shown in fig 4.5 below. This shows a temperature reading at 37°C, which is the normal human body temperature. This value was sent from the transmitter section through RF antenna to the receiver RF antenna. The antenna sends the signal to the Arduino Intel Galileo which processes and displays it on the doctor's LCD.

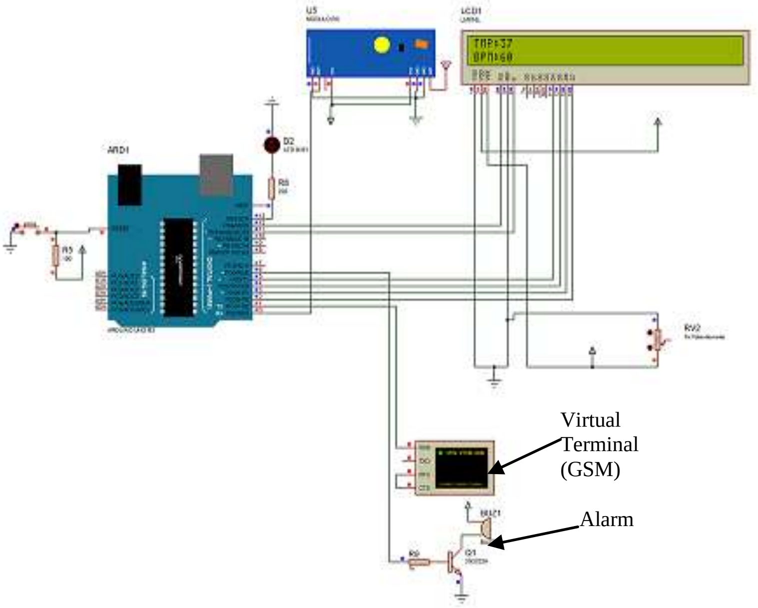

Fig.4.5: Receiver result at normal condition

3) Receiver unit result at high conditions

The result obtained from the receiver unit at high temperature and pulse rate are the same as sent from the transmitter unit as shown in fig 4.5. The RF link transmitter receives the signal from the transmitter unit, sends to Arduino (where the processing is done) and the result is displayed on the LCD in the doctor's office. An alarm is activated when signals of high temperature and pulse rate parameters are received. The alarm is programmed to continue for 20 minutes until the system is reset by the doctor or health worker.

C. SMS Technology

The GSM shield card is inserted on the Arduino board expansion slot provided and configured for SMS communication to Mobile phone through AT program codes. The network SIM card slot is found on the GSM shield board where any network SIM card can be slotted for use. The Arduino GSM Shield as shown in fig. 4.6 connects the Arduino to the internet using the GPRS wireless network. Just plug this module onto the Arduino board, insert a SIM card from an operator offering GPRS coverage and follow a few simple instructions to start controlling your world through the internet. You can also make or receive voice calls, although would require an external speaker for that function.

Fig.4.6: Arduino GSM Shield board

V. CONCLUSIONS

A Wireless Health monitoring system that can wirelessly monitor vital signs such as the temperature and pulse rate of patients in real-time and notify medical personnel immediately in case of emergencies has been designed, simulated and implemented. The system monitors patient's health status, such as pulse rate and temperature; in case any of these parameters exceeds preset critical values, the RF antenna module transmit the parameters to pre-defined phone number in form of SMS using a GSM module and display the information in the doctor's LCD for update.

The proposed system combines two commonly used technologies namely, Global System for Mobile (GSM) and Radio Frequency technology to achieve the work objectives. All the information obtained from the human body via sensors is sent to the microcontroller system as digital values. The values obtained from the pulse rate and temperature sensors are also displayed on the LCD in alphanumerical form at the transmitter and receiver sides. With the aging of the world, the wireless patient monitor is expected to improve the health care system across the globe.

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