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# IoT-Based Smart Patient Health Monitoring with Ambulance Tracking System for Pakistan

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***Abstract-*** Healthcare is one of the most important applications of the Internet of Things (IoT), which can be used to investigate the health status of a remote patient. In this paper, an IoT-based health monitoring and ambulance tracking system is proposed. In the IoT-based health monitoring system, various parameters related to a patient's health such as heartbeat, electrocardiography, temperature are measured by certain medical devices (sensors) and transmitted through IoT devices; while in an ambulance they are sent to an internet cloud where they are stored and analyzed for pre-treatment purposes. The main premise of the research is that when an emergency occurs, the ambulance should reach the hospital as quickly as possible and send the information about the patient's condition to the hospital in question to prepare for treatment. Meanwhile, pre-treatment can also be initiated in the ambulance if the doctor recommends it after checking the patient's condition via the IoT platform. The results of this study show that the proposed strategy is very effective in saving the precious lives of patients due to delays in treatment. In addition, it is recommended that the Internet of Things (IoT) provides reliable solutions for effective patient health monitoring and treatment.

***Keywords-*** Smart Ambulance, Biomedical Systems, Internet of Things, Global Positing System

Table I: List of Abbreviations

| Acronyms | Full Name |
|---|---|
| IoT | Internet of Things |
| GPS | Global Positing System |
| ECG | Electrocardiography |
| ARM | Advance RISC Machines |
| ICU | Intensive Care Unit |
| GPRS | General Packet Radio Service |
| PC | Personal Computer |
| HTTP | Hyper Text Transfer Protocol |
| AFE | Analog Front End |
| ATMEL | Advanced Technology for Memory and Logic |
| LCD | Liquid Crystal Display |
| LAN | Local Area Network |
| SMS | Short Message Service |
| Wi-Fi | Wireless Fidelity |

## I. INTRODUCTION

Emergency patient transportation is a major area that lacks proper resource management for every individual when needed. Quick treatment can save precious lives and it can be accomplished by devising an efficient strategy so thatan ambulance can arrive at the hospital in time and thereby reducing the delay caused by traffic obstruction in populated areas. This research plans to formulate a reliable and quick solution by equipping patients with different biomedicalsensors, which would gather the vital parameters regarding their health and thencan transmitthem to the hospital unit. Thesetransmitted parameterscan bemonitored and analyzed by the concerned physicianat the hospital and hence allowing the concerned persons in the ambulance to start the pre-treatment and desired medicines. The hospital unit can also suggest any precautions that the patient has to do depending on his type of injury or illness.

## II. LITERATURE REVIEW

A tremendous amount of research and implementation has been done in health monitoring and ambulance tracking[1], few of them will be presented here.In [2], an approach is suggested where a patient's heartbeat, bloodpressure, and temperature are measured and compared with a threshold via a microcontroller, the GPS provides information onthe position of the monitored person all the time and if the situation is critical, it sends the message to the doctor about sensor's parameters and the position of

the patient through GSM module. In [3], IoT based accident detection method is proposed which can effectively detect accidents and by using GPS it can send thelocation of the ambulance. In [4], an accident detection system is presented which can detect the accident using the assumption that braking distance is proportional to the square of speed. In [5], a wireless health monitoring system is proposed which can measure and transmit temperature, heartbeat, and ECG by using Bluetooth technology. In [6], GPS and map matching-based vehicle accident detection systemsaresuggested that can effectively detect accidents. In [7], a detailed survey is provided on wearable sensor-based systems for health monitoring,diagnosis,and the development of biosensor systems for efficient health monitoring.

In [8], ARM7 has been proposed for real-time health monitoring of ICU patients. By establishing HTTP communication to the server via GPRS, it can successfully transmit the sensed data of ICU patients to the server PC. In [9], different sensors like blood pressure and heartbeat rate sensors have been employed to monitor thecondition of the patient. Afterward, these parameterswere transmittedto the hospital's database. Further, traffic light signals have been controlled using GPRS messages through the cloud to reach the destination as soon as possible.In [10], AFE has been used to design a single-channel portable ECG device. Further, the device is tested using a 12-lead ECG acquisition technique to extend the capability of portable ECG homecare devices, which makes ECG analysis much more accessible.

In [11], a healthcare system using IoT and Android is proposed. In theirwork, a medicine box placed at home is wirelessly connected to the hospital where the doctor can assign the timing of certain medicines and the box will alert the patient usingan android application through IoT, to remind the patient for taking the desired medicines on time.In [12], theauthoradopts a digital temperature sensor to realize the design of a digital thermometer based on an ATMEL microcontroller. The microcontroller is the main control chip and is equipped with a temperature detection module, LCD module, keyboard control module, and temperature alarm module. The digital thermometer can not only achieve the temperature display but also generate an audible and visual alarm whenever the temperature detected exceeds the threshold.

In [13], the system is composed of an acquisition device and a digital temperature sensor DS18B20. For monitoring temperature, it is connected through a LAN network to a computer for remote monitoring purposes. In [14],an Arduino-basedhealth monitoring system is proposed. This system consists of body temperature and heartbeat sensors; the data of these sensors is monitored and sentusing Arduino. The Arduino displays the data of sensorsusingan LCD monitor. The measured data is successfully transmitted using a wireless system.

In [15], an IoT system is suggestedas a solution for themeasurement and monitoring of the temperature at the data center.The desired temperature data is sent over the internet through a cloud-based platform. When the temperature rises above the safe operating zone and reaches a high value, the system sends alerts through an email and SMSto predefined recipients automatically. The proposed wireless sensor-based monitoring system includes a Wi-Fi router, temperature sensors, and an ESP8266 module. In [16], the authors have developed a prototype, which monitors the inter-beat interval and heart rate. The proposed prototype was realized using ESP8266 hardware modules, web socket library, nodes, and JavaScript.JavaScript was used for the implementation of the signal-processing algorithm.

The health care services for disabled people at home are presented in [17]. This paper proposes an implementation of the system, which monitors the room and issues an alert whenever it detects a potential hazard. The patient is equipped with sensory devices to ensure the safety of the patient at home.In order of emergency, the patients may have too little time to survive before they arrived at the hospital. This work is further explored in [18], by implementing an online system for the remote health monitoring of the patients in an ambulance. The results show that the proposed system works efficiently.Patient monitoring has also been investigated using the Raspberry Pi controller and IoT cloud [19]. The ECG of the patient is recorded using sensors and sent to the doctor to check the condition of the patient. If the condition is too critical, the desired actions will be initiated as per instruction by the doctor. In [20], a smart IoT-based patient monitoring system is developed for asthma patients. In this system, the respiration rate is recorded using different smart sensors and then sent via the cloud to the concerned physician.

In [21], an IoT-based adaptive ambulance detection and traffic control system is proposed which uses image processing for identification and IoT for communication between hospitals, traffic signals, and ambulances.In [22], a mobile application-based ambulance tracking system is proposed for real-time location and availability of ambulances in emergencies. In [23], an IoT health monitoring system is proposed for emergency alerts in hospitals by incorporating sensors and microcontrollers.

In this research work, we have used different sensors like temperature sensors, heartbeat sensors, and ECG sensors. The temperature sensor is utilizedtomeasure

the temperature of the patient whereas the heartbeat sensor measures the pulses or heartbeat of the patient. ECG sensor measures the electrocardiogram of the patient. The GPS module provides the value of longitude and latitude. These values of longitude and latitude are displayed on an LCD.These different parameters are collected and stored on the Arduino UNO microcontroller and then sent to the internet cloud using well known IoT platform known as ThingSpeak so that data can be accessed anywhere via mobile application. This mobile application displays the data of all sensors. Hospital staff can acquire medical data regarding the condition of the patient from the IoT cloud using the web server. In this server, all data will be saved and only authentic users will be able to see it. If the ambulance is delayed due to traffic congestion or some other issues, hospital staff can see the condition of the incoming patient, and if needed quick treatment of the patient can be started within the ambulance as suggested by the concerned physician. The proposed IoT-based system is economical, efficient, and reliable; it can be accessed anywhere using a web server or mobile application. Keeping in view the advantages of IoT based systems, an effort has been made in this work to propose an IoT based smart patient health monitoring and ambulance tracking system. The contributions of this work are as follows:

i. A complete hardware-based prototype was implemented consisting of multiple sensors for patient health monitoring and ambulance tracking.
ii. Acquire the patient's sensor data and transmit it to the hospital/server via a Wi-Fi module using an Arduino microcontroller.
iii. Reading the coordinates of the ambulance using a GPS module and then sending these coordinates to the respective hospital to report the arrival of the ambulance.
iv. Displaying all sensor data on the server and mobile application in real time and displaying the location of an ambulance on the map.

The organization of this paper is as follows: In Section 2, a block diagram of the proposed system and its description areprovided. Section 3presents the software and hardware implementation of the proposed system. Results and discussions have beenprovided in Section 4. Finally, the whole paper is concluded in Section 5.

*Block Diagram of the Proposed System and Its Description*

The block diagram of the suggestedsmart patient health monitoring and ambulance tracking systems is provided in Figure 1. The description of all blocks is also provided in this section.

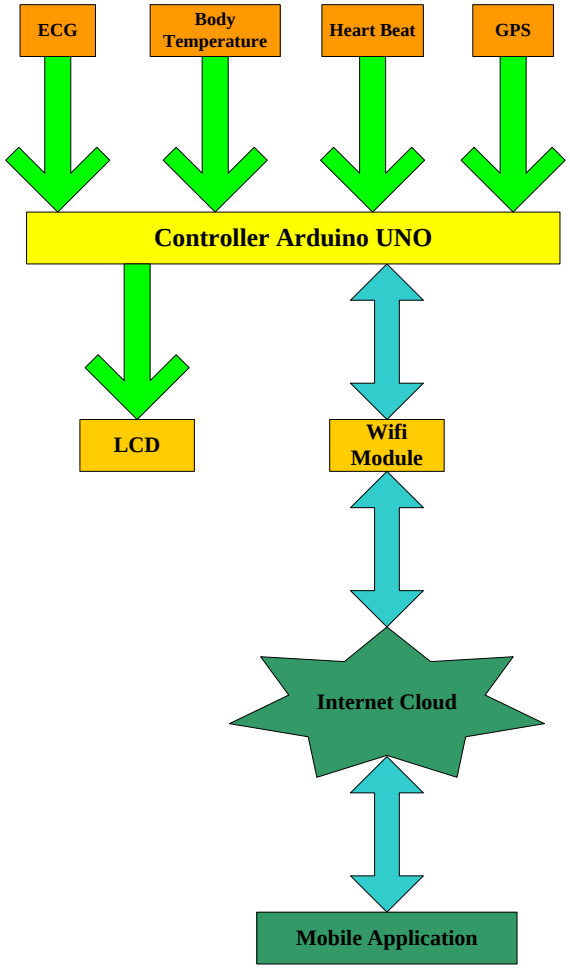


Figure 1: Block Diagram of ProposedSystem

*Sensors*

The DS18b20 is a type of digital temperature sensor that is used to measure temperature in dense applications. It measures the temperature from -55to +125degree Celsius with ± 0.5degree Celsius accuracy. The DS18b20 sensor gives 9-12 bit Celsius temperature measurement and uses 1-wire communication. To transfer the data, each sensor has one output pin, which is connected to a Wi-Fi module; so it is a very excellent option to measure temperature at multiple points without compromising moredigital pins of the controller. It is more feasible to measure the temperature of the human body. In this paper, the DallasTemperature.h library is used for the interfacing of DS18b20 with an Arduino microcontroller. We have used OneWire.h Library for one wired device communication of DS18b20 with Arduino.

In ECG, electrodes are placed on the specificpoints of thebody, and a graph between voltage and time is obtained which shows the electrical activity of the heart.The depolarization of cardiac muscles

followed by repolarization in each cardiac cycle cause small electrical changes in the heart. The saidchanges are detected using these electrodes. The ECG provides valuable data and holds an essential piece of the assessment of heart patients.An ECG is simply a sketch of the diversity of electrical activity of the heart muscle with time, usually, for easier analysis, it is printed on paper. Like other human body muscles, cardiac muscle also contracts in response to the electrical depolarization of muscle cells. The ECG is the result of this electrical activity when recorded for a few seconds and amplified. We have used the ECG sensor module AD8232 in this work. The electrodes of the AD8232 sensor connected to the skin convert the heartbeat signal to an electric signal. It measures continuous heartbeat and provides its data rate.The sample of an ECG wave is shown in Figure 2.

Figure 2: Sample of an ECG wave

Heartbeat is the number of times our heart beats during each minute also called beats per minute (BPM). When the fingertip is placed on the heartbeat sensor for about one minute, it provides the digital output of the heartbeat. The sensor module, similar to LDR and photodiode, includes a light-emitting diode and a detector in its package. When the tissue in the finger is illuminated by the led in sensor, some of the light is absorbed by the blood and some is reflected by the receiver which detects the light. The light absorbed depends upon the amount of blood in that tissue. The detector gives output in the form of an electrical signal which is proportional to the heartbeat rate.The hardware of the sensor circuit includes amplification and noise cancellation. It is considerably quicker and more reliable to acquire pulse readings with the help of this sensor.

GPS is a satellite-based network having many interconnected satellites, which are used for navigation purposes. Each satellite transmits low-power signals and orbital parameters that grant GPS gadgets to interpret. GPS gadgets or devices are GPS recipients who utilize this data to find an area or location of a client.If we find the two GPS coordinates known as latitude and longitude, then the position will be of the user will be 2D. Similarly, if we have three GPS coordinates latitude, longitude, and altitude; then the position will be 3D. We have interfaced the GY-NEO6MV2 module with an Arduino microcontroller. For the configuration and operation of the GPS moduleindifferent functions related to GPS, we have used the TinyGPS++.h library. Further, we have used SoftwareSerial.h built-in library for the communication of the GPS module with the Arduino controller.

NEO-6M GPS module has its antenna but it is so small and takes a long time to receive a GPS signal. We are using a GPS antenna to boost the GPS signal. GPS antenna draws a current of about 10mA and provides a gain of about 28dB. The antenna cable is five meters long so it can easily reach anywhere, we want to use it. This antenna has a magnetin it, which is used to stick it to the metal surface of the ambulance.

*Controller*

Arduino UNO is a microcontroller which is manufactured by Atmel Corporation. It is based on an ATmega328p chip. Arduino UNO is commonly used for different electronics projects due to its open-source platform. It has 14 digital I/O pins, 6 analog input pins, a USB connection, a power jack, an ICSP header,16MHz crystal, and a reset push button. It can be powered with a 9V external battery or 5V USB cable. The Arduino is used to interact with any other Arduino, with other microcontrollers, or with a computer. UART serial communication can be achieved using an ATmega328P microcontroller using digital pin 1 ($T_x$) and digital pin 0 ($R_x$). The Arduino software has a functional serial monitor, which supports the transmission and reception of data. Two small LEDs ($R_x$ and $T_x$) on the Arduino board glow, when data is received or transmitted respectively. In this research, we have employed the Arduino UNOto process and store the data of sensors. The Arduino communicates with the sensors and receives data from them. Further, that data is sent to the internet cloud by interfacing the Wi-Fi module with Arduino.

*Wi-Fi Module*

The Node-MCU refers to firmware instead of developer kits. Node-MCU firmware was developed to make the life of developers easier and to replace AT commands with Lua scripting. The ESP8266 (Node-MCU)was invented by a Chinese manufacturer; it is cost efficientWi-Fi chip, which has full capability of microcontroller and TCP/IP stack.

*Internet Cloud*

To upload the sensor reading to the open-source internet cloud, we have used the ESP8266 Wi-Fi module. This module is interfaced with Arduino UNO

for sending the data to the ThingSpeak server. After configuring the Wi-Fi module with Arduino UNO as a TCP client, we can send the data to the ThingSpeak server which is an open-source IoT platform to analyze and visualize the live sensory data. The communication between ESP8266 with Arduino is achieved using SoftwareSerial.hlibrary which is followed by AT commands for configuration purposes. Using the write API key, we can send the sensor's data to the cloud.

The main objective is to control the switching between the two energy sources i.e. wind and solar energy through the ESP8266 Wi-Fi module without any inconvenience. In IoT, wireless transmission of data is obtained throughESP8266 a module to the cloud,to manage the sources of energy. The sensor devices are connected to the Arduino controller and the controller processes the data received from the devices. The processed data from the controller is sent to the user interface on the mobile. In the recent past[24], IoT has been explored for the solution of different engineering problems and it can be suggested that IoT is an emerging research area that can be used for multidisciplinary applications. The IoT is also a major part of this research and is demonstrated in Figure 3. The ThingSpeak platform quickly collects and analyzes data from internet-connected sensors.

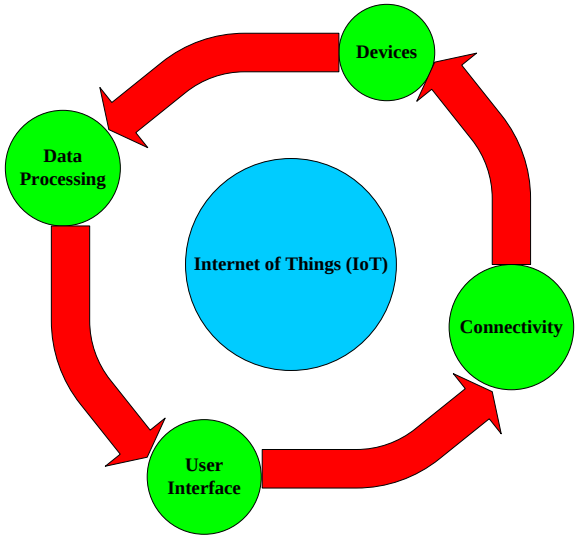


Figure 3: Internet of Things

*Mobile Application*

We have built an Android application to display the data and location of an ambulance. This application was made usingthe MI app inventor using graphical programming. This application has two parts; one is for sensor data and the other is for an ambulance location map.The mobile application has 2 interface screens. On the first screen,we can see the status of different sensors, where the digital values of all sensors are displayed as shown in Figure 4.


Figure 4: Mobile Application Screen 1

On the first screen, there is a button at the bottom "Ambulance Location", when we click on it, it leads to the second screen. On the second screen, the map is displayed to show the exact location (longitude and latitude) of the ambulance as shown in Figure 5.

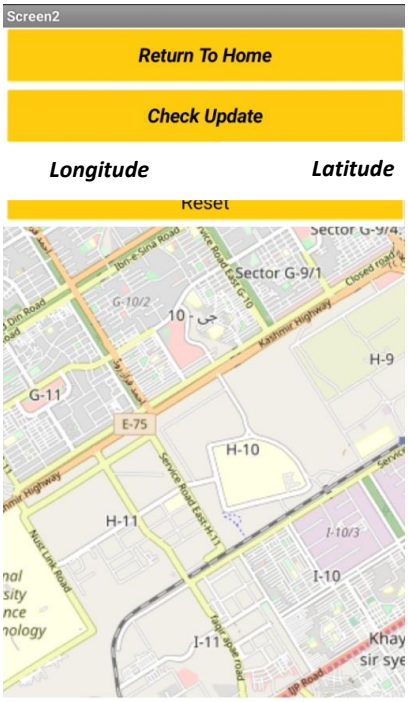


Figure 5: Mobile Application Screen 2

## III. IMPLEMENTATION OF THE PROPOSED METHODOLOGY

This section includes the results of both software simulation and hardware implementation. We have interfaced all the sensors, Wi-Fi Module,and GPS with the Arduino controller. The compilation of software code is done using Arduino IDE.

*Software Simulations*

The software simulations are performed on Proteus software. All sensors were tested separately in this section. We have done the simulation of the temperature sensor with Arduino UNO in Proteus. We used the LM35 temperature sensor in the simulation because there is no sensor of DS18b20 in Proteus. The outputs of the temperature sensor at different temperatures were recorded successfully. A snapshot at 37.15°C is provided in Figure 6.We have also done the simulation of the heartbeat sensor in Proteus software. The heartbeat sensor is connected to the Arduino UNO using a single wire. The sensor sends the data to the Arduino as we vary the position of the potentiometer knob.

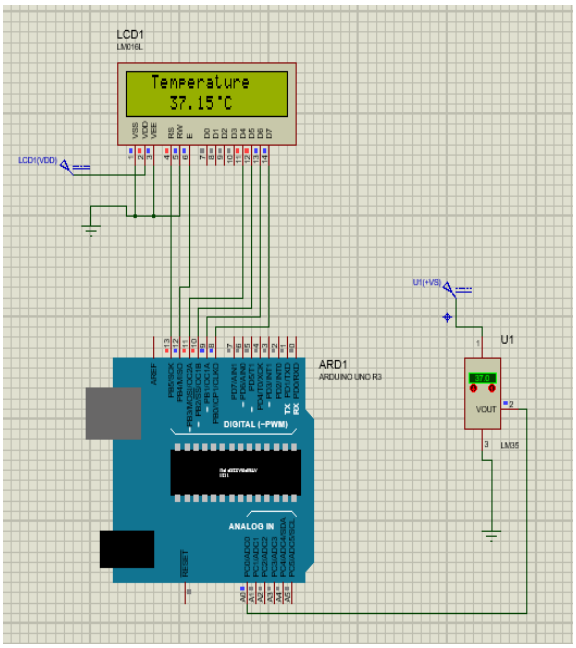


Figure 6: Output of Temperature Sensor in Proteus

The output of the heartbeat sensor is displayed on the LCD as shown in Figure 7.

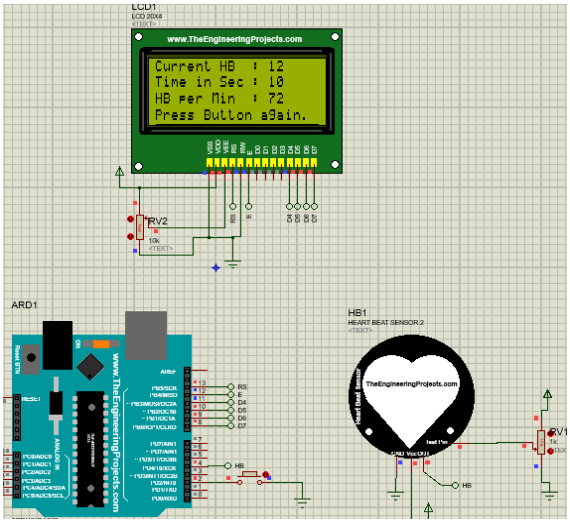


Figure 7: Heartbeat Sensor Simulation

Once the data is collected from the patient and stored on the controller,it is uploaded to the internet cloud by using a Wi-Fi module and stored also on the ThingSpeak server. The simulations of the other two sensors i.e. ECG and GPS module were difficult to perform on software due to the unavailability of relevant modules in the software, that's why we have tested the output ofECG and GPS modules onthe hardware prototype.

*Hardware Implementation*

We have designed a prototype hardware module for the implantation of our proposed methodology as shown in Figure 8. All sensors are connected to an Arduino controller in realtime, which communicates with the Wi-Fi module to transmitthe sensor's datato the mobile application through the IoT platform.

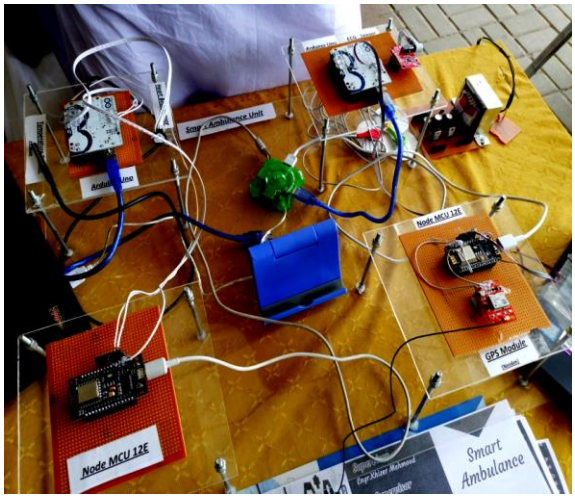


Figure 8: Hardware Prototype

## IV. RESULTS AND DISCUSSION

In this section, real-time results of the sensors are captured for monitoring and evaluation purposes. To track the position of an ambulance,we have used NEO 6M GPS module for determining the GPS coordinates (latitude and longitude). Figure 9 shows the hardware of the GPS module connected with Arduino and Wi-Fi modules.

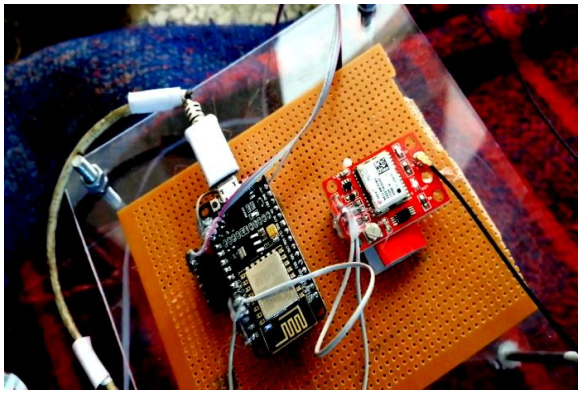

Figure 9: Real-time GPS module connected to Arduino and Wi-Fi module

The GPS coordinates were sent to the ThingSpeak website where they were displayed using a graph. At time 8:24 GMT +0500, the latitude (N) is 33.661026 and the longitude (E) is 73.020437 as highlighted in Figures 10(a) and 10(b) respectively.

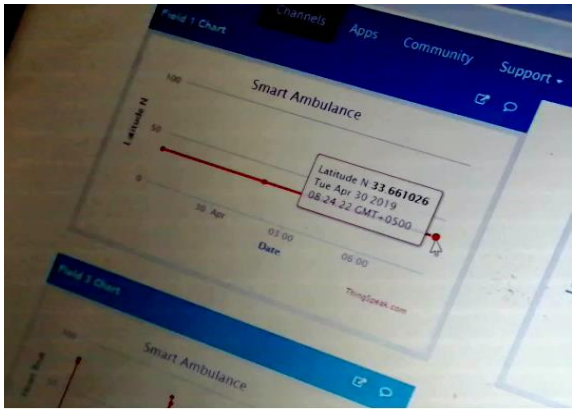


Figure 10(a): Real-time latitude output on ThingSpeak

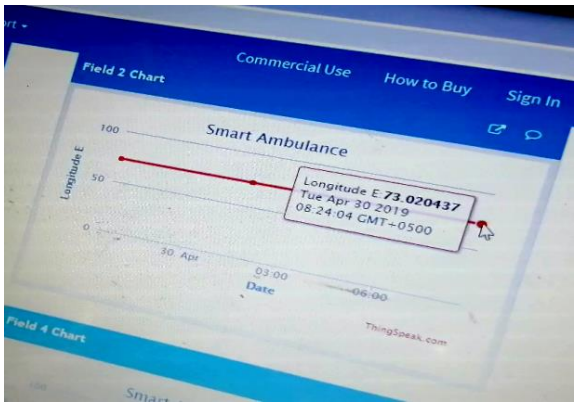


Figure 10(b): Real-time longitude output on ThingSpeak

The values of latitude and longitude values are also sent to the mobile application using the Wi-Fi module (Node-MCU). These coordinate points are displayed in the mobile application and also the location is shown onGoogle Maps. The coordinates received on the mobile appwerecompared with those displayed onthe ThingSpeak server. It can be seen in Figure 11, that at time 8:24, the latitude (N) is 33.661026 and the longitude (E) is 73.020437, which arethe same as shown on the ThingSpeak server.

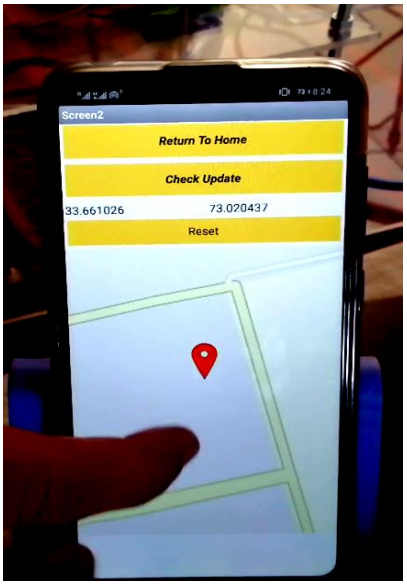


Figure 11: Real-time longitude and latitude output on Mobile App

The ECG module (AD8232) has been used to determine the electrical activity of the heart. This electrical activity can be charted as Electrocardiogram (ECG).ECG is used to diagnose various heart conditions. The hardware of the ECG module with 3 electrodes connected to Arduino is shown in Figure 12.

Figure 12: ECG module with electrodes connected to Arduino

The ECG sensor has 3 electrodes, the yellow electrode is attached to the right side of the chest and red one is attached to the left part of the chest and the green electrode is attached to the bottom right side of the abdomen as shown in Figure 13. We have attached this sensor to one of our research fellow to acquire the desired ECG in a real-time environment.

Figure 13: ECG electrodes connected to the body in Real-time

The electrodes of the ECG sensor convert the heartbeat signal to an electric signal and the AD8232 module reduces noise and amplifies that signal. The Arduino controller receives the data from AD8232 and displays the Electrocardiogramwith the integration of IDE software as shown in Figure 14.

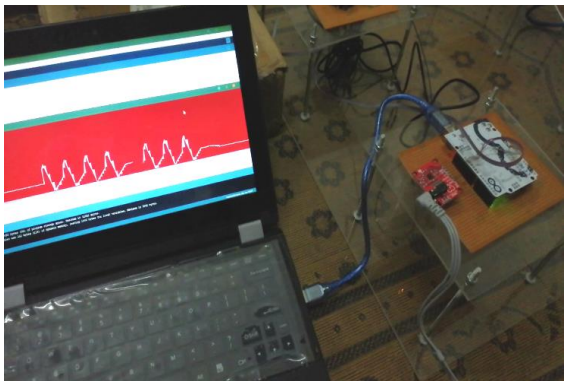

Figure 14: Real-time ECG

The heartbeat sensor measures the heartbeat rate of the person who places his thumb or any fingertip on the sensor for almost one minute and then displaysthat person's heartbeat in real-time. The sensor value becomes zero when the person lifts his finger from the sensor. Figure 15 shows the working of the heartbeat sensor.

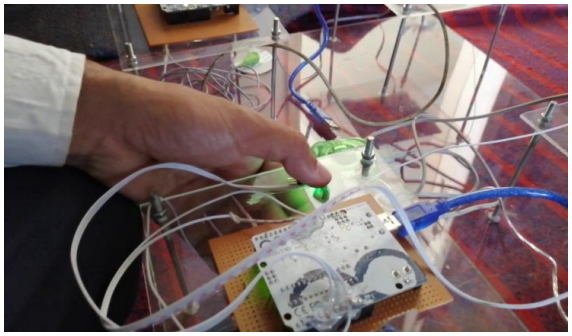

Figure 15: Real-time Heartbeat measurement

When another research fellow placed his thumb on the heartbeat sensor for almost a minute, we observed his heartbeat value on the mobile app which was 72 as shown in Figure 16.


Figure 16: Real-time heartbeat value displayed on Mobile app

The heartbeat sensor value is not only displayed on the mobile app but also on the ThingSpeak server. As we can see in Figure 17, the value of the heartbeat displayedon the ThingSpeak server is the same as shown onthe mobile app seen before.

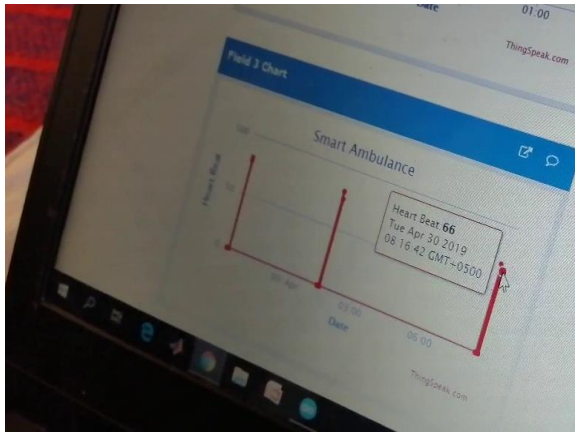


Figure 17: Real-time heartbeat value displayed on the ThingSpeak server

The DS18b20 temperature sensor is an efficient and economical temperature sensor module. We mostly used this sensor at room temperature and generally, the room temperature was 24 to 30 $^{O}$C. At a certain point, the measured temperature was 30 $^{O}$C as shown in Figure 18.

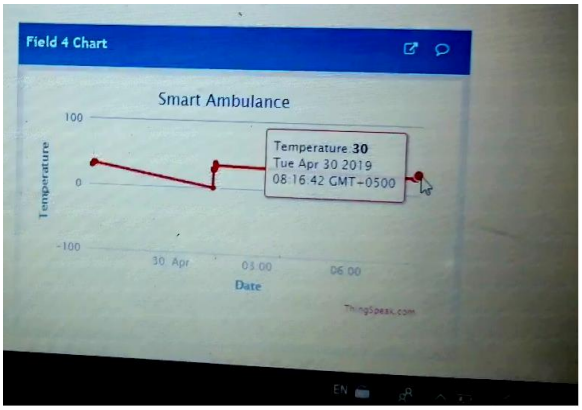


Figure 18: Real-time Temperature measurement using DS18b20

Finally, we measured and recorded the data of all sensors at different intervals of time. For a certain period, the temperature sensor gives constant room temperature and when we tried to heat it extra, its value changed. Similarly, the heartbeat sensor gives different values, when different persons measured their heartbeat and become zero when the finger is lifted from the sensor. The GPS coordinates remainedthe same due to experimentation at the same lab place. Figure 19demonstrates the summary of the whole experiment. It can be seen that all the sensors are functional and the desired data of sensors can be easily accessed using the ThingSpeak server or mobile application.


Figurer 19: Data of all sensors on ThingSpeak server

Table 2 shows the comparison of the proposed system with various state of the art system available in the literature. It is observed from Table 2 that the proposed system offers more features than the others.

Table II: Comparison of Proposed Method with State of the Art

| Method | Communication | Sensors | Tracking Mechanism |
|---|---|---|---|
| Proposed | Arduino, IoT (Thigspeak) | Temperature, Heartbeat, ECG | GPS |
| [2] | Arduino, GSM | Temperature, Heartbeat, ECG | GPS |
| [19] | Raspberry Pi, IoT (Cloud) | ECG | NA |
| [20] | IoT (Cloud) | Respiration rate sensor | NA |

## V. CONCLUSION

Patient health monitoring and ambulance tracking are crucial problems in morepopulous countries. There is a need for necessary innovative research in this area to save important lives of human beings.Keeping in view these constraints, a real-time solution issuggested in this research work. The proposed solutioncomprises IoT-based smart patient health monitoring and ambulance tracking systems to acquire the desired solution. In this system, we have successfully interfaced the GPS module, temperature, heartbeat, and ECG sensor module with the Arduino controller. After the implementation of the whole

system, we can transmit the patients' parameters inside an ambulance like his heartbeat, ECG, and temperature to the server via IoT.In addition,the GPS module efficiently tracked the ambulance's location and guessedthe expected time of arrival. In future work, other parameters regarding patient health, smart traffic light monitoring, vitals monitoring and recommendations, and multi-agent systems can be added to modify the proposed ideaFurther, a sms alert to the hospitals regarding the condition of the patient and availability of medical facilities back to the ambulance can be incorporated in the existing study to make this system more practical [25-31].

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