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Lora IoT Integrated Smart Health Tracking and Emergency Response System

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Abstract: The proposed system is designed to continuously monitor a patient's vital health parameters in real time, ensuring timely detection of any abnormal conditions. It utilizes sensors such as heart rate, body temperature, SpO_2, and humidity sensors to accurately measure essential physiological signals. These sensors collect data that reflect the patient's current health status and transmit it to the Arduino controller for processing and management. The Arduino acts as the central processing unit, responsible for reading sensor values, filtering noise, and ensuring that the collected data is accurate and consistent. To enable long-distance communication between the patient unit and the monitoring center, LoRa-TX and LoRa-RX modules are employed. These modules allow data transmission over several kilometers with minimal power consumption, making the system highly efficient and suitable for use in remote or rural areas. The data received by the LoRa-RX module is then sent to the NodeMCU, which connects the system to the internet. Through IoT platforms, healthcare professionals or caregivers can remotely access and monitor the patient's health data in real time from anywhere. In addition to remote monitoring, the system includes a buzzer that serves as an immediate alert mechanism. If any of the monitored parameters exceed normal thresholds, the buzzer automatically activates, providing an audible warning to alert nearby individuals or medical personnel. This ensures quick response and necessary medical attention in emergency situations. Overall, this system offers an efficient, low-cost, and reliable solution for continuous health monitoring, particularly beneficial for elderly patients, chronically ill individuals, and those in remote regions where access to healthcare facilities is limited.
Keywords: LoRa Communication, Internet of Things (IoT), Remote Patient Monitoring, Arduino Microcontroller, Vital Sign Sensors, SpO Monitoring, Real-Time Health Monitoring, Emergency Alert System.

1. INTRODUCTION

In earlier times, patient health monitoring was primarily performed manually by doctors, nurses, or caretakers who periodically checked the patient's vital signs such as heart rate, body temperature, and oxygen levels. This traditional approach required constant human supervision and was time-consuming, especially in hospitals with a large number of patients. Since healthcare professionals could not continuously monitor every patient in real time, sudden health deteriorations were sometimes detected too late. This problem was even more serious in rural healthcare centers or overcrowded hospitals where medical staff and resources were limited..Due to these limitations, there was a growing need for an automated health monitoring system capable of continuously tracking vital parameters without requiring constant manual intervention. An intelligent monitoring system can ensure that the patient's health condition is observed24 hours a day, allowing doctors to quickly identify abnormal changes and take immediate action during emergencies. To address these challenges, the proposed system integrates multiple biomedical sensors that continuously monitor different physiological parameters of the patient. A heart rate sensor is used to measure the pulse rate, which helps in identifying irregular heartbeats or cardiovascular abnormalities. A body temperature sensor monitors the patient's body temperature to detect fever or abnormal thermal changes. An SpO sensor measures the oxygen saturation level in the blood, which is a critical indicator of respiratory health. In addition, a humidity sensor is used to detect body moisture or sweating levels, which can provide additional information about the patient's physical condition. The entire sensor data collected from the patient is processed using an Arduino microcontroller, which acts as the central processing unit of the system.

The Arduino reads the sensor signals, converts them into digital data, and organizes them for transmission. This data is then transmitted wirelessly using a LoRa transmitter (LoRa-TX) module, which enables long-range communication with very low power consumption. At the receiving end, aLoRa receiver (LoRa-RX) module collects the transmitted data and forwards it to a NodeMCU module. The NodeMCU, which is equipped with Wi-Fi capability, sends the data to a cloud platform where it can be stored and analyzed. Through this cloud-based monitoring system, doctors and caregivers can access the patient's health data remotely using smartphones, computers, or other internet-enabled devices. This architecture allows continuous real-time monitoring of patient health even when the patient is located far from medical facilities. The use ofLoRa communication technology makes the system particularly suitable for rural and remote areas where conventional wireless networks may not be reliable. By combining IoT technology, biomedical sensors, and long-range wireless communication, the system provides a cost-effective, reliable, and scalable healthcare monitoring solution that improves patient safety and enables faster medical response during emergencies.

2. LITERATURE SURVEY

1. Alvarez, F., & Martinez, L. (2025**)** **-** Conducted environmental stress testing on wearable medical sensors used in outdoor healthcare monitoring systems. Their study examined how environmental conditions such as temperature, humidity, and dust influence sensor performance. They proposed IP-rated protective enclosures to enhance device durability. This work highlights the need for reliable hardware protection in long-term health monitoring.
2.AntonyPradeesh,D.,&Subiramaniyam,N.P.(2025) **-** Proposed an IoT-based smart healthcare system integrating LoRa communication with deep learning algorithms. The system collects patient vital parameters and analyzes those using predictive models. Their method improves early detection of abnormal health conditions. This research demonstrates the effectiveness of combining IoT and AI in healthcare monitoring.

3. Balasubramanian, R., & Krishnan, V. (2025) **-** Presented an IoT-based healthcare monitoring system designed for long-range communication. They introduced adaptive routing protocols to reduce packet loss during wireless transmission. Their system improved the reliability of transmitting critical medical data. The study emphasizes the importance of stable communication in remote health monitoring.

4. Banerjee, R., & Chatterjee, S. (2025) **-** Focused on validating physiological datasets used in health monitoring systems. They proposed synchronized ground-truth testing protocols to evaluate system performance accurately. Their research highlights the importance of reliable data collection and validation. This work supports the development to trust worthy Health care technologies.

5. Chen, L., & Zhang, H. (2025) **-** Researched digital filtering techniques used in biomedical signal processing. They proposed adaptive noise cancellation algorithms to reduce motion artifacts in wearable PPG sensors. Their approach improved the accuracy of heart rate and SpO measurements. This study enhances signal quality in wearable healthcare devices.

6. Desai, P., & Shah, K. (2025) - Analyzed packet retransmission mechanisms in LPWAN-based healthcare systems. Their research focused on improving data reliability during critical health monitoring situations. They proposed techniques to reduced at a loss in wireless communication. This study contributes to more reliable healthcare IoT networks.

7. Fernandez, G., &Torres, A. (2025) – Investigated the durability of wearable medical sensors under varying environmental conditions. Their study evaluated long- term performance of sensors in real-world healthcare applications. The research highlighted the importance of robust materials and device protection. This work supports the development of reliable wearable medical devices.

8. Iyer, K., & Raman, S. (2025) - Studied battery management strategies for wearable healthcare devices. They proposed duty cycling and deep-sleep scheduling techniques to minimize power consumption. Their approach significantly increased the battery life of medical monitoring systems. This research supports long-term remote patient monitoring.

9.Kapoor,U.,&Sharma,R.(2025)-Conducted a social acceptance study on wearable emergency healthcare devices. Their research analyzed factors such as usability, comfort, and user trust. The study found that simple and intuitive designs improve device adoption. This research emphasizes the importance of human- centered design in healthcare technology.

10. Kumar, D., & Singh, P. (2025) - Discussed clinical validation standards and regulatory requirements for remote healthcare systems. Their study emphasized safety, accuracy, and compliance with medical device regulations. They highlighted the importance of standardized evaluation methods. This work supports reliable deployment of healthcare monitoring systems.

11. Lavanya, P., & Ramesh, K. (2025) - Introduced a machine learning-assisted LoRa health monitoring framework. Their system used CNN and LSTM models to predict variations in patient vital parameters. The approach enabled predictive healthcare analytics for early disease detection. This research shows the potential of AI in healthcare monitoring systems.

12. Lee, S., & Park, J. (2025) - Focused on security mechanisms for IoT-based healthcare networks. They proposed encryption techniques and secure boot mechanisms to protect patient data. Their research improved data privacy in LoRa communication systems. This study addresses cyber security challenges in healthcare IoT.

13.Mehta,R.,&Shah,D.(2025)-Analyzed LoRa WAN scalability issues in healthcare IoT networks. They proposed adaptive data rate optimization to maintain stable communication. Their research focused on improving connectivity in rural healthcare environments. This work supports large-scale remote patient monitoring systems.

14. Morales,E., & Rodriguez, P. (2025) –Studied alarm fatigue in telemedicine monitoring systems.
They proposed intelligent threshold optimization to reduce false emergency alerts. Their approach improved system efficiency and medical response time. This research highlights the importance of accurate alert mechanisms in healthcare monitoring.

15.Morales,J.,&Diaz,L.(2025)-Examined ethical and privacy concerns in continuous health monitoring systems. Their research discussed responsible deployment practices for IoT healthcare technologies. They emphasized patient data protection and informed consent. This work contributes to ethical healthcare technology development.

16. Narayanan, K., & Reddy, P. (2025) - Investigated optimal sensor placement techniques in wearable medical devices. Their research focused on improving signal quality and measurement consistency. The study evaluated different sensor positions on the human body. This work enhances the accuracy of wearable healthcare monitoring.

17. Nguyen, H., & Tran, T. (2025) - Explored anomaly detection techniques for physiological signal monitoring. They used machine learning models to identify abnormal patterns in patient data. Their approach reduced false alarms in continuous monitoring systems. This research improves automated healthcare diagnostics.

18. Rajan,T.,& Menon,A. (2025)-Introduced a hybrid communication system combining LoRa and GSM modules. The system ensured reliable emergency alerts even during network failures. Their design improved redundancy in healthcare communication systems. This research enhanced reliability in remote patient monitoring.

19. Rao, N., & Gupta, S. (2025) - Studied human- centered design approaches for wearable emergency devices. They recommended simple panic buttons and vibration alerts for elderly users. Their design improved accessibility and usability. This research highlights the importance of user-friendly healthcare devices.

20. Santos, P., & Oliveira, M. (2025) - Investigated the use of edge computing in wearable healthcare devices. Their system performed local data processing to reduce communication delay. This approach improved emergency response time. The research demonstrates the benefits of edge computing in healthcare monitoring.

21.Shafiq,S.,&Ahmed,M.(2025)-Developed a LoRa- enabled remote patient monitoring system for rural healthcare. The system integrated ECG, SpO□, heart rate, and temperature sensors. Their research emphasized long-range communication with low power consumption. This work demonstrated the suitability of LoRa technology for healthcare IoT.

22.Suresh,M.,&Krishnan,R.(2025)-Evaluated GSM- based emergency SMS communication systems in healthcare monitoring. Their study analyzed message delivery delays during emergencies. They proposed acknowledgment-based messaging for reliable alert delivery. This research improved emergency communication reliability.

23. Verma, A., & Singh, R. (2025) - Designed a cloud- based IoT dashboard for remote patient monitoring. Their system enabled real-time visualization of patient vital parameters. Doctors and caregivers could access health data remotely. This research demonstrated the importance of cloud integration in healthcare systems.

24.Wang,Y.,&Liu,X.(2025)-Presented sensor fusion techniques combining accelerometer and PPG signals. They used Kalman filters to improve the accuracy of wearable vital sign estimation. Their method reduced motion-related noise. This research improved the reliability of wearable healthcare monitoring systems.

25. Zhou, Y., & Li, Q. (2025) - Researched low-cost pulse oximetry hardware for wearable healthcare devices. They proposed algorithm improvements to enhance SpO measurement accuracy. Their design reduced hardware cost while maintaining performance. This research supports affordable health care monitoring technologies.

III. PROPOSED SYSTEM

INTRODUCTION

In recent years, the demand for remote patient monitoring systems has grown rapidly due to the increasing need for continuous health observation and timely medical intervention. The proposed system is designed to provide an efficient and reliable solution or monitoring a patient's vital health parameters in real time. It integrates multiple biomedical sensors such as heart rate, body temperature, SpO, and humidity sensors, enabling accurate and continuous tracking of the patient's physiological conditions. An Arduino microcontroller serves as the central processing unit, responsible for collecting, controlling, and processing data from all connected sensors. To ensure reliable long-distance communication, LoRa-TX and LoRa-RX modules are employed, allowing seamless data transmission between the patient monitoring unit and a central NodeMCU receiver. The NodeMCU then uploads the received health data to the internet, enabling remote access for doctors and healthcare providers through IoT- based monitoring platforms. Additionally, the system includes a buzzer alert mechanism that activates whenever abnormal sensor readings are detected, ensuring immediate attention from medical authorities. This combination of real-time monitoring, long-range communication, and instant alerting makes the system highly suitable for rural health monitoring, elderly care, and emergency medical applications, where timely information can save lives.

OBJECTIVE:

The keypoints are:

- To utilize an Arduino microcontroller for efficient data acquisition, control, and processing of multiple biomedical sensor readings.
- To implement LoRa-based wireless communication for reliable, long-distance data transmission between the patient unit and the monitoring station.
- To employ aNode MCU receiver for collecting and managing sensor data transmitted from the LoRa transmitter module.

SYSTEM ARCHITECTURE

- The system architecture integrates multiple modules that communicate with the Arduino microcontroller, which serves as the central processing unit. The overall system is divided into four major layers:
- **Input Layer:** Consists of biomedical sensors such as the heart rate sensor, body temperature sensor, SpO sensor, and humidity sensor that continuously monitor the patient's vital health parameters in real time.

- **Processing Layer:** The Arduino controller collects, processes, and manages the sensor data before preparing it for wireless transmission. It ensures accurate data handling and detects any abnormal physiological variations**.**
- **Communication Layer**: LoRa-TX and LoRa-RX modules enable reliable long distance wireless communication between the patient monitoring unit and the central Node MCU receiver, ensuring uninterrupted data transfer even over extended ranges.
- **Output Layer:** The NodeMCU uploads the received health data to the internet for remote monitoring through IoT platforms, while a buzzer provides real-time alerts to medical authorities or care givers in case of abnormal readings.

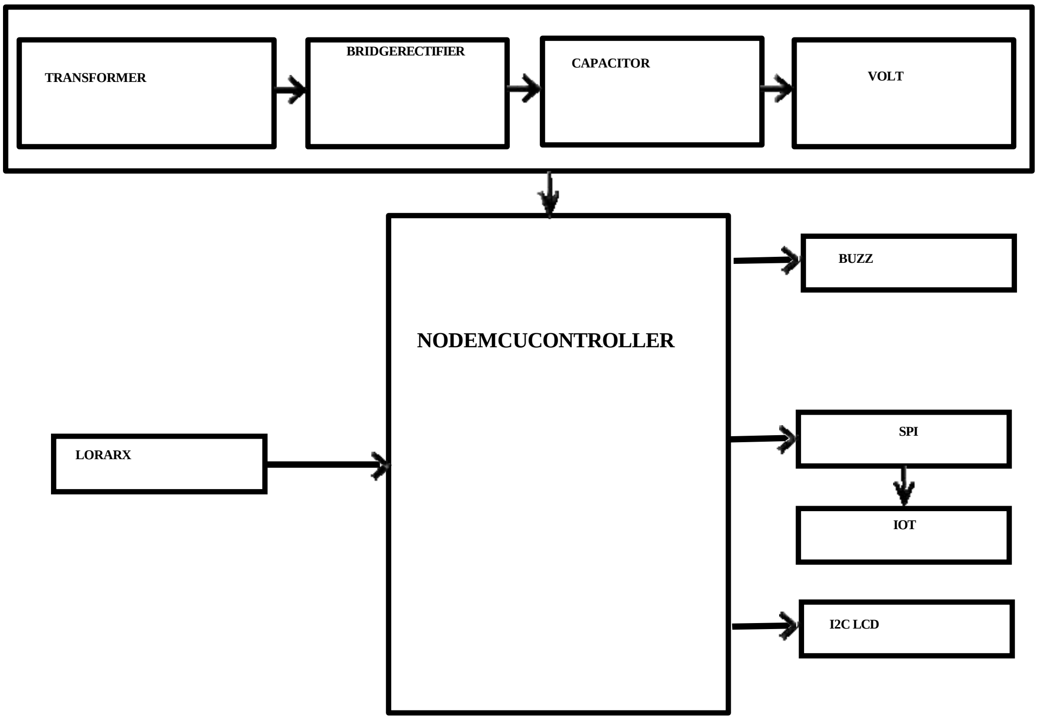

Fig3. 1RX-Block Diagram of Proposed System

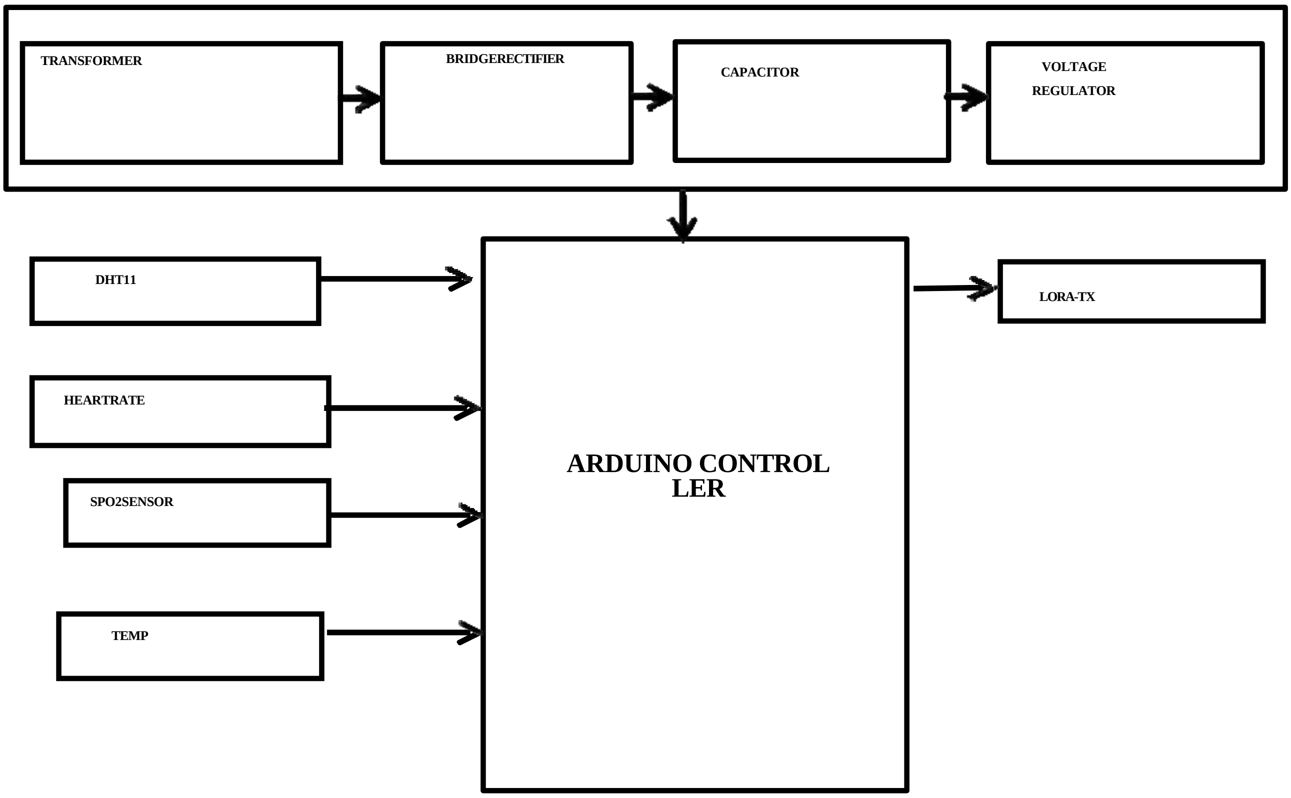

Fig3.1TX-Block Diagram of Proposed System

3.2 SYSTEM OPERATION

1. Initialization Phase:

When powered ON, the Arduino initializes all connected sensors and LoRa communication modules.

- The HeartRate, Temperature, SpO, and Humidity sensors are activated and begin calibration.
- The LoRa-TX module initializes and attempts to establish a link with the LoRa-RX receiver.
- The Green LED blinks until the communication link between the transmitter and receiver is established.
- Once all sensors and LoRa communication are ready, the Green LED glows steadily, indicating system readiness.

2. Data Acquisition Phase:

The system continuously measures the patient's vital parameters in real time.

- Heart Rate Sensor: Monitors the pulse rate.
- Temperature Sensor: Measures body temperature variations.
- SpOSensor: Calculates oxygen saturation levels.
- Humidity Sensor: Detects surrounding environmental humidity.
- The Arduino collects and processes all sensor data and prepares it for transmission.

3. Data Transmission Phase:

After processing, the Arduino transmits the collected data wirelessly via the LoRa-TX module.

- The LoRa-RX module connected to the NodeMCU receives the transmitted data reliably over long distances.
- The NodeMCU decodes the received data and prepares it for online transmission.
- The Green LED on the receiver side indicates successful data reception.

4. Cloud Monitoring Phase:

The Node MCU uploads the received health parameters to the internet for remote monitoring.

- The data is displayed on a cloud-based IoT platform or web dash board for real-time access by healthcare providers or family members.
- The system ensures continuous data logging for further medical analysis and record keeping.

5. Emergency Alert Phase:

If any abnormal health condition is detected based on threshold values:

- The Buzzer activates immediately to provide an audible warning signal.
- The Red LED flashes to indicate an emergency or abnormal reading.
- The system can send alert notifications to the concerned authorities or caregivers through the network.
- The alert remains active until the readings return to normal.

6. Normal Mode:

When all sensor readings are within normal range:

- The Buzzer remains OFF.
- The Green LED glows steadily to indicate normal operation.
- The system continues to monitor and transmit data in the background for real-time health tracking.

3.5 APPLICATION

The LORA-IoT Integrated Smart Health Tracking and Emergency Response System is designed to provide long-range, low-power, and real-time health monitoring with integrated emergency alert mechanisms. The following are the key application areas of the proposed system:

1. **Remote Patient Monitoring (RPM):** The system continuously monitors vital parameters such as heart rate ,SpO, body temperature, and ECG signals. Using LoRa communication, patient data can be transmitted over long distances to healthcare centers without relying on high-power Wi-Fi networks. This is especially useful for rural and remote areas where internet connectivity is limited.
2. **Elderly and Home-Care Monitoring:** The system can be deployed for senior citizens living alone. In case of abnormal health conditions (low oxygen, high heart rate, fever), the device automatically sends alerts to caregivers or family members. A local buzzer alert ensures immediate nearby attention while remote notifications provide additional safety.
3. **Rural and Village Health care Support:** LoRa's long-range communication makes it ideal for village health centers. Community health workers can monitor multiple patients using a central LoRa gateway installed at a primary health center, enabling efficient large-area health supervision.
4. **Emergency Response and Panic Alert System :** The system includes an emergency trigger button or automatic abnormal detection logic. When critical conditions are detected, emergency SMS or gateway alerts are sent to doctors, hospitals, or emergency contacts. This ensures faster medical response during heart attacks, oxygen drops, or other sudden health crises.
5. **Post-COVID and Respiratory Monitoring:** The device is particularly useful for continuous SpO monitoring in patients with respiratory illnesses. It helps detect early oxygen de saturation and provides timely alerts before conditions become critical.
6. **Field and Industrial Worker Health Monitoring:** Workers in mines, construction sites, and hazardous environments can wear the device for continuous health tracking. In case of heat stress, abnormal pulse, or health collapse, the system sends instant alerts to supervisors.

7. **Disaster and Pandemic Management:** During pandemics or disaster situations, healthcare systems are overloaded. This system allows remote triage and monitoring of patients at home, reducing hospital congestion and enabling efficient resource management.
8. **Military and Defense Applications:** For soldiers deployed in remote border areas, the system can transmit health status to command centers via LoRa gateways, ensuring continuous physiological monitoring even in isolated regions.
9. **Smart Hospitals and Telemedicine Integration:** The system can be integrated with cloud dashboards for doctors to visualize real-time patient data. It supports telemedicine services by enabling remote diagnosis and consultation based on live vital readings.
10. **Research and Clinical Data Collection:** The device can collect physiological datasets for research and academic purposes. Continuous monitoring enables analysis of long-term health trends and supports clinical research studies.

Table 4.1 List of Hardware Components

S.No	Component	Specification/ Description
1	ESP32 Microcontroller	32-bitdual-core MCU with Wi-Fi & Bluetooth
2	Heart Rate sensor	Sensing Heart Rate level
3	SPO2SENSOR	Sensing oxidation level
4	Temperature sensor	Sensing Temperature level
5	Lcd display	Visualized a values in display
6	Buzzer	Provides audible indication
7	Transformer	Portable rechargeable power source
8	ESP32Extension Board	For regulated 5V and 3.3V supply
9	Resistors(220Ω, 10kΩ)	Used for current limiting and pull-down
10	Breadboard and Jumper Wires	For prototyping and testing connections

3. SYSTEM REQUIREMENTS

INTRODUCTION

The LORA-IoT Integrated Smart Health Tracking and Emergency Response System requires a carefully selected set of hardware components to ensure accurate health monitoring, long-range communication, low power consumption, and reliable emergency response. The hardware architecture is divided into sensing, processing, communication, alerting, and power management modules. At the core of the system is a microcontroller unit (MCU) such as ESP32 or Node MCU. This acts as the central processing unit, responsible for collecting sensor data, performing preliminary signal processing, implementing threshold logic for emergency detection, and managing wireless communication through LoRa modules. For health parameter monitoring, biomedical sensors are required. A pulse oximeter sensor (such as MAX30100/MAX30102) is used to measure heart rate and SpO levels using photo plethysmography (PPG). A body temperature sensor (likeDS18B20or LM35) is included to monitor fever conditions. If advanced cardiac monitoring is required, a single-lead ECG sensor module (such as AD8232) can be integrated for real-time heart signal acquisition. Long-range communication is achieved using a LoRa transceiver module (such as SX1278). This module enables low-power data transmission over several kilometers, making it ideal for rural and remote health monitoring. A LoRa gateway is required to receive transmitted data and forward it to a cloud server or hospital monitoring system.

HARDWARE REQUIREMENTS

The hardware section includes various electronic components, modules, and peripherals that together make up the panic card. The hardware configuration is designed to ensure portability, reliability, and power efficiency

1. ESP32 Microcontroller

The ESP32 is a powerful 32-bit dual-core microcontroller developed by Espressif Systems. It is known for its low power consumption, high processing speed, and built-in wireless capabilities (Wi-Fi + Bluetooth). In this project, ESP32 acts as the central control unit that manages all communication between GSM, GPS, LEDs, buzzer, and push buttons.\

Key Features:

- Dual-coreTensilicaLX6processor(upto240 MHz).
- Built-inWi-Fi(802.11b/g/n)andBluetooth 4.2.
- 32 GPIO pins supporting UART, SPI, I2C, ADC, PWM, and DAC.
- Operates at 3.3Vwith a deep sleep current ofless than 10 μA.

Fig 4.1 ESP32

Function in Project:

- Reads input signals from emergency buttons.
- Retrieves GPS data and processes coordinates.
- Sends AT commands to GSM for SMS and calling.
- Controls LEDs and buzzer for user feedback.
- Manages power consumption and resets safely.

2. HEART RATE SENSOR

Heart beat sensor is designed to give digital output of heat beat when a finger is placed on it. When the heart beat detector is working, the beat LED flashes in unison with each heart beat. This digital output can be connected to microcontroller directly to measure the Beats Per Minute (BPM) rate. It works on the principle of light modulation by blood flow through finger at each pulse.

FEATURES:

- Micro controller based SMD design
- Heat beat indication by LED
- Instant output digital signal for directly connecting to microcontroller
- Compact Size
- Working Voltage+5VDC

APPLICATIONS:

- Digital Heart Rate monitor
- Patient Monitoring System
- Bio-Feedback control of robotics and applications

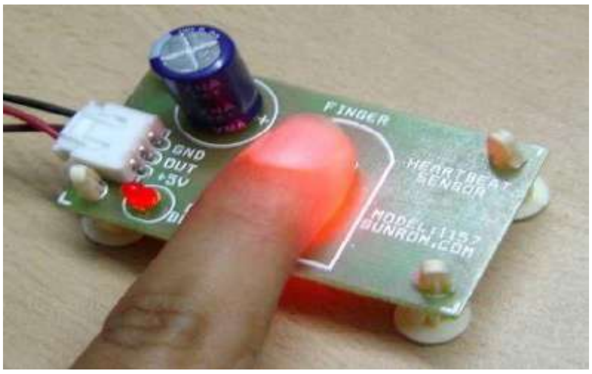

Fig 4.2 – Heart Bear Sensor

Medical heart sensors are capable of monitoring vascular tissue through the tip of the finger or the ear lobe. It is often used for health purposes, especially when monitoring the body after physical training. Heart beat is sensed by using a high intensity type LED and LDR. The finger is placed between the LED and LDR. As Sensor a photo diode or a photo transistor can be used. The skin may be illuminated with visible (red) using transmitted or reflected light for detection. The very small changes in reflectivity or in transmittance caused by the varying blood content to human tissue a real most invisible. Various noise sources may produce disturbance signals with amplitudes equal or even higher than the amplitude of the pulse signal. Valid pulse measurement therefore requires extensive preprocessing of the raw signal. The new signal processing approach presented here combines analog and digital signal processing in a way that both parts can be kept simple but in combination are very effective in suppressing disturbance signals. The setup described here uses a red LED for transmitted light illumination and a LDR as detector. With only slight changes in the preamplifier circuit the same hardware and software could be used with other illumination and detection concepts. The detectors photo current (ACPart) is converted to voltage and amplified by an operational amplifier (LM358).

3. TEMPERATURE SENSOR

The first slave connected to a temperature sensor LM35. This senses the temperature of an engine and provides the level of temperature.

GENERAL DESCRIPTION The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to read out or control circuit type specially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35isratedtooperateovera−55°to+150°Ctemperature range, while the LM35C is rated for a−40° to +110°C range (−10° with improved accuracy). TheLM35seriesisavailablepackagedinhermeticTO- 46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

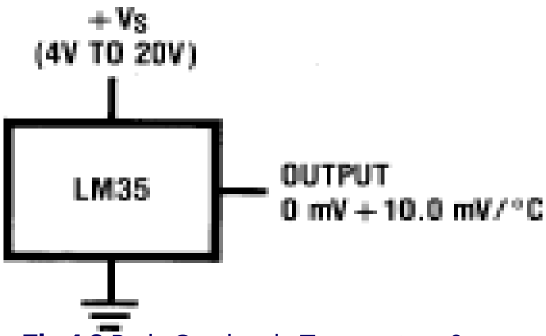

Fig 4.3 Basic Centigrade Temperature Sensor

4. LCD DISPLAY

A liquid crystal display (LCD) is an electronically modulated optical device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystals and arrayed in front of a light source or reflector. It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power.LCD has material, which continues the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules a real most as mobile as they would be in a liquid, but are grouped together in an ordered from similar to a crystal. LCD consists of two glass panels, with the liquid crystal materials sandwiched in between them. The inner surface of the glass plates is coated with transparent electrodes which define in between the electrodes and the crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. When a potential is applied across the cell, charge carriers flowing through the liquid will disrupt the molecular alignment and produce turbulence. When the liquid is not activated, it is transparent. When the liquid is activated the molecular turbulence causes light to be scattered in all directions and the cell appears to be bright. Thus the required message is displayed. When the LCD is in the off state, the two polarizer's and the liquid crystal rotate the light rays, such that they come out of the LCD without any orientation, and hence the LCD appears transparent.

Fig 4.4 LCD

5. BUZZER

A buzzer or beeper is a signaling device, the word "buzzer" comes from the rasping noise that buzzers made when they were electromechanical devices, operated from stepped-down AC line voltage at 50 or 60 cycles. Other sounds commonly used to indicate that a button has been pressed are a ring or a beep This novel buzzer circuit uses a relay in series with a small audio transformer and speaker. When the switch is pressed, the relay will operate via the transformer primary and closed relay contact.

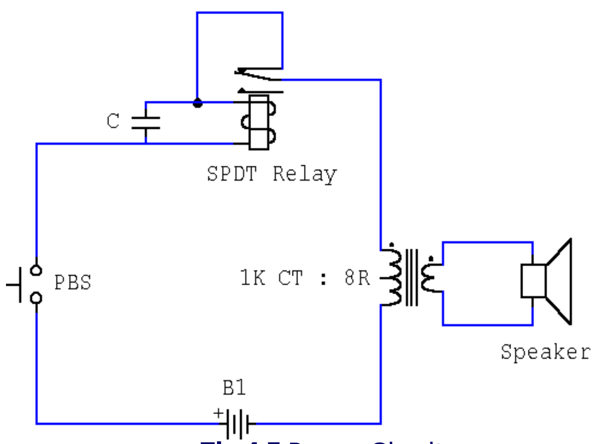

Fig:4.5 Buzzer Circuit

As soon as the relay operates the normally closed contact will open, removing power from the relay, the contacts close and the sequence repeats, all very quickly...so fast that the pulse of current causes fluctuations in the transformer primary, and hence secondary. The speakers tone is thus proportional to relay operating frequency. The capacitor C can be used to "tune" the note. The nominal value is 0.001uF, increasing capacitance lowers the buzzers tone.

Operation Patterns:

- **Continuou stone:** Active medical alert.
- **Pulsed tone:** Active police alert.
- **Short beep:** Alert canceled or safe state restored.

The buzzer ensures that even in darkness or panic situations, the user is audibly informed that an alert has been successfully triggered.

6. (3.7V) Li-ion Battery

The system is powered by a3.7V,2200m Ah lithium-ion rechargeable battery which provides long operational time. It is connected through an ESP32 extension board that regulates voltage to 5V and 3.3V levels for the modules.

Fig 4.6 Battery (3.7V)

Features:

- Rechargeable via micro-USB.
- Integrated protection circuit (overcharge / discharge)
- Provides upto 6–8 hours of standby operation.
- Supports high burst current required for GSM transmission.

Function in Project:

- Powers all modules through regulated supply.
- Provides mobility and portability.
- Low-battery warning is indicated via LED and buzzer.

7. ESP32 Extension Board

The ESP32 extension board simplifies hardware interfacing by including an onboard voltage regulator, USB-to-serial converter, and pin headers for external connections.

Key Features:

- 5V to 3.3V voltage regulation.
- Onboard powers switch and reset button.
- Protection against reverse polarity.
- Micro-USB port for charging and programming.

This board ensures stable operation of GSM and GPS modules while protecting the ESP32 from voltage fluctuations.

8. Resistors

Resistors are used to limit current through LEDs, pull down GPIO inputs, and stabilize signal lines. Typical resistor values used are 220Ω for LEDs and 10kΩ for button pull-downs

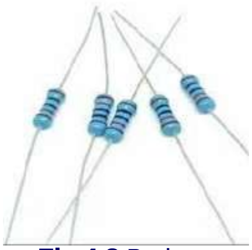

Fig 4.8 Resistor

Functions:

- Protect LEDs from over current.
- Ensure proper logic levels at input pins.
- Reduce electrical noise and interference.

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9. Jumper Wires

Fig 4.9 Wires

A solder less breadboard is used during the prototyping phase to test the connections between ESP32, GSM, and GPS modules. Male- to-female jumper wires are used for quick and flexible connections. Later, the final version can be transferred to a custom PCB for compactness and durability.

CIRCUIT DESIGN

The circuit integrates all modules using the ESP32 microcontroller as the control unit.

- **Buzzer** are connected to digital input pins of ESP32.
- **Heart rate** communicates through UART interface (TX, RX pins).
- **SPO2** is also connected via UART for serial data reception.
- **LCD** are interfaced with GPIO pins for visual feedback**.**
- The LORA is controlled by a GPIO output pin through a transistor driver to handle current load.
- A Li-ion battery powers the circuit through the ESP32 extension board, which provides voltage regulation and over current protection.
- The design ensures that all components operate within safe voltage levels(3.3V–5V).TheESP32 extension board simplifies power routing and charging operations.

HARDWARE OPERATION

Initialization: When the device is powered ON, the ESP32 initializes the GSM and GPS modules. The Green LED blinks until a GSM network is found, and the Yellow LED blinks until GPS coordinates are available.

1. **Button Detection:** The ESP32 constantly monitors the state of each push button. A debounce delay is implemented in software to prevent false triggering.
2. **Message Transmission:** Once an alert button is pressed, the microcontroller reads GPS data, composes a text message with the coordinates, and sends it using the GSM module.
3. **Audible & Visual Feedback:** The buzzer sounds and the Red LED flashes during alert transmission. This feedback ensures that the user knows the alert is active.
4. **Cancel Function:** When the White button is pressed, the alert sequence is stopped, and a —SAFE NOW‖ message is sent to all previously alerted contacts.

SOFTWARE REQUIREMENTS

The software provides the logic that drives the panic card's operation. It includes the firmware programmed into the ESP32 using Arduino IDE.

4.6 If White button pressed:

- o Stop all alert processes.
- o Send SAFE NOW‖ message.
- o Return to idle mode.

Repeat monitoring loop Check for cancel input→Reset states.

The software ensures robust error handling such as GSM retry loops and GPS data validation to avoid failures during operation.

Table 4.3 Software Libraries and Function

Library	Functionality	Purpose in System
Tiny GPS++	Reads NMEA data, extracts latitude/longitude	Provides GPS coordinates for location tracking
Software Serial	Creates additional serial ports	Enables simultaneous GSM and GPS communication
EEPROM.h	Accesses internal flash storage	Stores emergency contact numbers
Wire.h	I2CCommunication	For connecting additional I2C peripherals if needed
Hardware Serial	Handles UART ports	Communicates with GSM and GPS modules
String.h	String handling functions	Format SMS text with map link

Software Tools Used:

- ArduinoIDE2.0–forcodedevelopmentand uploading.
- Tiny GPS++ Library – for parsing NMEA GPS data.
- Software Serial Library – for serial communication with GSM and GPS modules.
- EEPROM Library–for storing emergency contact numbers in non-volatile memory.
- Hardware Serial Library – for UART communication.

Algorithm of Operation

The system software follows a structured algorithm:

1. Start the system and initialize eal modules.
2. Check GSM and GPS connectivity–indicate through LEDs.
3. Monitor input buttons in continuous loop.
4. If Red button pressed:
   - o Fetch GPS coordinates.
   - o Send SMS with Google Maps link.
   - o Call the ambulance contact.
   - o Activate buzzer and Red LED.
5. If Yellow button pressed:
   - o Fetch GPS coordinates.
   - o Send police alert SMS and call.
   - o Activate buzzer in pattern mode.

Software Implementation Details

The Arduino IDE allows programming of ESP32 using C/C++ syntax. The implementation steps include:

1. Library Inclusion: All required libraries are included at the beginning of the code.
2. Pin Initialization: GPIO pins areas signed to inputs and outputs.
3. Serial Communication Setup: Separate serial channels are defined for GSM and GPS.
4. Main Loop: Continuously checks for button input. If any button is pressed, executes the corresponding alert function.
5. GPS Parsing: The GPS module sends data in NMEA format, which is parsed using the Tiny GPS++ library.
6. Message Composition: The system dynamically generates a Google Maps link with current latitude and longitude.
7. SMS Transmission: AT commands are sent to GSM module to send text message. Example:
8. AT+CMGF=1
9. AT+CMGS="number" Followed by the message and Ctrl+Z to send.
10. Call Initiation: A GSM call is placed automatically using AT command ATD<number>;.

4.7 HARDWARE ASSEMBLY AND TESTING

The components are assembled on a breadboard for prototype testing, later transferred to a custom PCB for compactness. Testing included:

- GSM registration check via serial monitor.
- GPS coordinate validation.
- Button pressed bounce verification.
- Message delivery and call initiation timing tests.
- Battery endurance tests for continuous operation.

Average current consumption during idle mode was ~80 mA, and during active GSM transmission,~1.8A pulse was observed.

4.8 SAFETY AND DESIGN CONSIDERATIONS

- All connections use low voltage (3.3V) to ensure user safety.
- Battery protection circuit prevents overcharge/discharge.
- Proper decoupling capacitors are placed near GSM module for stable power.
- Transistor drivers isolate ESP32 pins from high- current GSM bursts.

4. RESULTS AND DISCUSSION

The software simulation of the proposed LoRa IoT Integrated Smart Health Tracking and Emergency Response System was carried out to validate the working of the overall system before real-time hardware implementation.

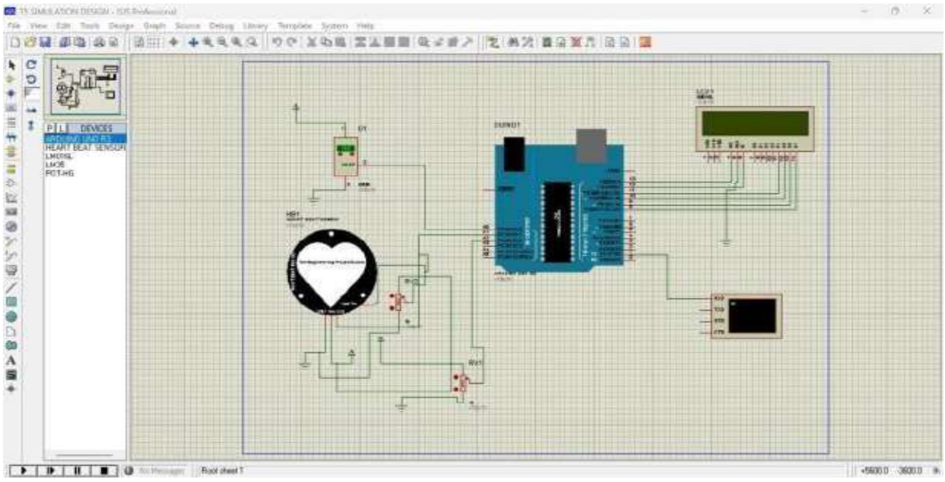

Fig 5.1 Simulation results

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The simulation environment was developed using embedded programming and virtual circuit design tools to test the interaction between the microcontroller, health monitoring sensors, LoRa communication module, GPS module, GSM module, and LCD display. The primary objective of the simulation was to verify data acquisition from sensors, processing by the microcontroller, wireless transmission through LoRa technology, and emergency alert generation during abnormal health conditions. The system was designed to continuously monitor vital parameters such as heart rate and body temperature. In case of abnormal readings, the system automatically triggers an emergency response by transmitting alert messages along with GPS location details. The simulation helped in ensuring that all software modules, communication protocols, and data handling processes function correctly under different operating conditions. The simulation results confirmed the proper functioning of the integrated system. The microcontroller successfully received real-time data from the simulated health sensors. The collected data was processed and displayed on the LCD module, ensuring proper visualization of patient health parameters. When the health values remained within the normal range, the system continued monitoring without triggering any alert. However, when abnormal values such ashigh heart rate or abnormal temperature were simulated, the system immediately activated the emergency protocol. The LoRa module successfully transmitted the health data over long-range communication. Simultaneously, the GSM module generated an SMS alert containing the patient's health status and GPS location coordinates. The GPS module correctly provided latitude and longitude values, which were included in the emergency message.

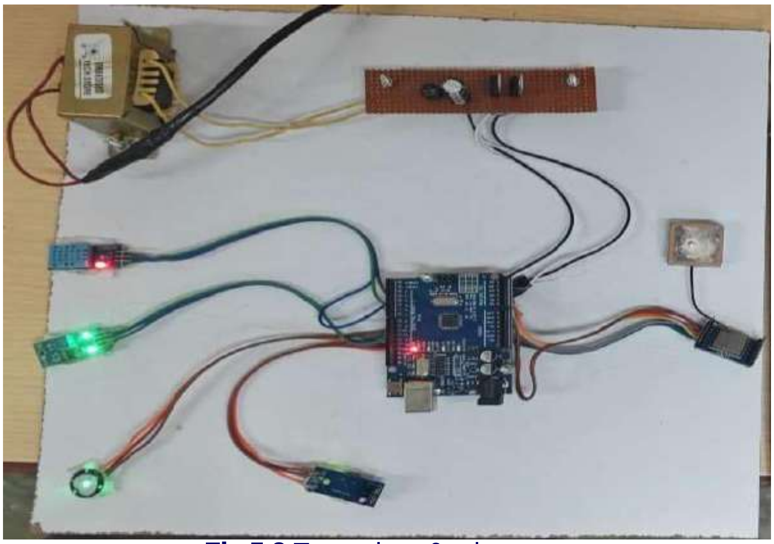

Fig 5.2 Transmitter Section

The LCD display updated the status in real time, indicating whether the system was in normal monitoring mode or emergency mode. The simulation also demonstrated stable communication between modules without data loss. Power consumption behavior and data flow timing were analyzed to ensure system reliability. Additionally, the simulation validated the synchronization between all hardware components under different operating conditions. The system demonstrated quick response time during emergency situations, with minimal delay between abnormal value detection and alert transmission. Error handling mechanisms were also verified, ensuring that temporary signal interruptions or sensor fluctuations did not affect overall system performance. The integrated architecture proved to be scalable and efficient, making it suitable for real-time remote patient monitoring applications with high reliability and accuracy. The above figure represents the transmitter section of the proposed IoT based smart health monitoring and emergency response system. The transmitter unit is responsible for sensing the patient's physiological parameters and transmitting the collected data to the receiver unit or cloud server through wireless communication. The main controller used in this section is the Arduino Uno microcontroller, which acts as the central processing unit of the system. It collects real-time data from various sensors, processes the data, and sends it to the communication module for transmission. The system includes multiple sensors for monitoring different health parameters. A temperature sensor (DHT11) is used to measure the patient's body temperature. A pulse sensor is connected to monitor the heart rate by detecting blood flow variations. Additionally, a gas or respiration sensoris used to monitor breathing conditions or detect harmful gases in the surroundings. These sensors continuously send analog or digital signals to the Arduino. The microcontroller reads these signals, converts them into meaningful values, and compares them with predefined threshold limits programmed in the system. An IoT communication module such as an ESP8266 WiFi module is connected to the Arduino to enable wireless data transmission. After processing, the health data is transmitted wirelessly to the receiver section or cloud platform for remote monitoring. If any abnormal condition is detected, such as high temperature or irregular heart rate, the system can immediately trigger an alert signal. The transmitter section is powered bya regulated power supply unit consisting of a transformer, rectifier, filter capacitor, and voltage regulator.

This power supply circuit converts AC mains voltage into a stable DC voltage required for the Arduino and sensors. Overall, the transmitter section plays a crucial role in real-time health data acquisition, processing, and wireless transmission, forming the core sensing unit of the smart health monitoring system.

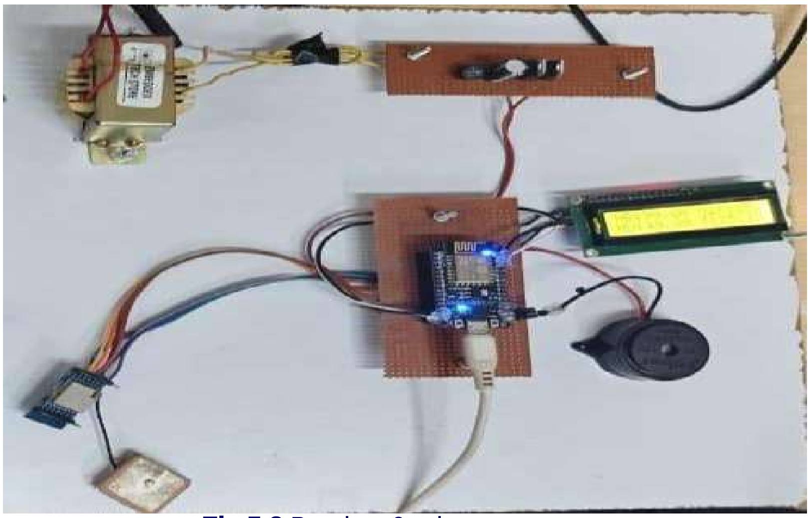

Fig 5.3 Receiver Section

The above figure represents the receiver section of the proposed IoT based smart health monitoring and emergency response system. The receiver unit is responsible for receiving the transmitted health data from the transmitter section through a wireless communication module and displaying the patient's health parameters in real time. The main controller used in the receiver section is a Node MCU (ESP8266) microcontroller, which has built-in WiFi capability for wireless data communication. It acts as the processing and communication unit of the receiver system. A regulated power supply circuit is provided to ensure stable operation of the system. The power supply section consists of a step-down transformer, rectifier diode, filter capacitor, and voltage regulator, which convert AC mains supply into regulated DC voltage suitable for the NodeMCU and other components. This ensures continuous and reliable functioning of the receiver unit. The received health data such as body temperature, heart rate, or other parameters are processed by the NodeMCU and displayed on a 16×2 LCD display module. The LCD provides a real-time visual indication of the patient's health status, making it easy for doctors or caregivers to monitor the condition. Additionally, a buzzer is connected to the system to generate an audible alert when any health parameter exceeds the predefined threshold value. This emergency alert mechanism ensures immediate attention during abnormal situations. Overall, the receiver section plays a crucial role in wireless data reception, real-time display, and emergency alert generation. It enhances the effectiveness of the health monitoring system by enabling remote supervision and quick response during critical conditions. Overall, the receiver section ensures reliable communication between the patient monitoring unit and the monitoring center. By continuously receiving, processing, and displaying the transmitted health data, the system enables effective remote health supervision. The integration of the LCD display and buzzer alert system helps caregivers quickly identify abnormal health conditions and respond immediately. Thus, the receiver unit significantly improves the efficiency, safety, and responsiveness of the IoT-based smart health monitoring and emergency response system.

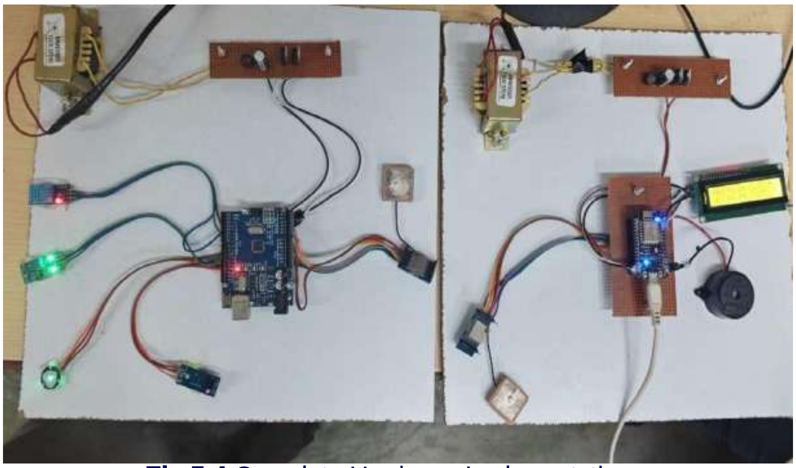

Fig 5.4 Complete Hardware Implementation

The complete hardware implementation of the proposed IoT based smart health monitoring and emergency response system, which consists of both transmitter and receiver sections. In the transmitter section, various sensors such as temperature sensor, pulse sensor, and gas/respiration sensor are connected to the Arduino Uno microcontroller. These sensors continuously monitor the patient's health parameters and send the collected data to provide an emergency alert. Thus, the complete hardware system ensures continuous health monitoring, wireless data transmission, real-time display, and immediate alert generation, making it suitable for remote patient monitoring applications.

5. CONCULISION

The proposed LoRa–IoT Integrated Smart Health Tracking and Emergency Response System demonstrates an effective solution for real-time patient monitoring and emergency alert management. The system successfully integrates health sensors, a microcontroller, a LoRa communication module, and alert mechanisms to continuously monitor vital parameters such as heart rate, temperature, and oxygen saturation. By utilizing LoRa technology, the system achieves long-range communication with low power consumption, making it particularly suitable for rural and remote healthcare environments where traditional communication networks may be unreliable. The implementation of the system enables continuous health monitoring, real-time data transmission, and immediate alerts during abnormal health conditions, thereby assisting caregivers and medical professionals in taking timely action. The use of an LCD display and buzzer further enhances the system by providing local visualization and instant alerts. Overall, the proposed model improves patient safety, reduces response time during medical emergencies, and supports remote healthcare management. Thus, the developed system proves to be a reliable, cost-effective, and scalable healthcare monitoring solution that can significantly contribute to modern smart healthcare infrastructure and remote patient care. the microcontroller for processing. A regulated power supply unit consisting of a transformer, rectifier, filter, and voltage regulator provides stable DC power to all components. After processing, the health data is transmitted wirelessly using an IoT communication module. In the receiver section, a NodeMCU (ESP8266) microcontroller receives the transmitted data through WiFi communication. The received health parameters are displayed in real time on a 16×2 LCD display for easy monitoring. If any parameter exceeds the predefined threshold value, a buzzer is activated.

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