IoT BASED PATIENT HEALTH MONITORING SYSTEM USIGN ESP32

*A Project Based Learning Report Submitted in partial fulfilment of the requirements for the award of the degree*

*of*

**Bachelor of Technology**

**in The Department of ECE**

**ESA - 23SDEC02**

Submitted by

**2310040060: M.Sowmya**

**2310040112: K.Sushma**

**2310049143: B. Srija Hiteshna**

**2310049144: Tharuni**

Under the guidance of

**Mrs. K.Madhavi**



Department of Electronics and Communication Engineering

Koneru Lakshmaiah Education Foundation, Aziz Nagar

Aziz Nagar – 500075

APRIL - 2025.

**Abstract**

The advancement of Internet of Things (IoT) technology has paved the way for innovative healthcare solutions that enable real-time, remote monitoring of patients. This project focuses on the development of an IoT-based Patient Health Monitoring System using the ESP32 microcontroller, aimed at providing continuous surveillance of critical health parameters to enhance patient care, reduce hospital visits, and support early diagnosis.

The system utilizes the ESP32, a low-cost, low-power microcontroller with built-in Wi-Fi and Bluetooth connectivity, which serves as the central processing and communication unit. It is connected to various biomedical sensors including a heart rate and SpO2 sensor (MAX30102), a body temperature sensor (MLX90614 or LM35), and optionally an ECG sensor (AD8232) or blood pressure sensor. These sensors are used to collect vital signs from the patient, which are then processed by the ESP32 and transmitted wirelessly to a cloud-based platform such as Firebase, Blynk, or ThingSpeak.

One of the key features of the system is its ability to monitor patient data in real-time through a user-friendly mobile or web application. This enables doctors, caregivers, or family members to remotely observe the patient's condition from anywhere in the world. In case of abnormal readings—such as a dangerously high heart rate or low oxygen level—the system triggers automatic alerts via mobile notifications, SMS, or email, facilitating immediate medical intervention and reducing response time in critical situations.

The collected data is stored on the cloud, allowing for long-term health record maintenance. This data can be visualized in the form of charts and trends, which assists healthcare professionals in making more informed decisions based on historical patterns. The system is also designed to be scalable and customizable, supporting the addition of more sensors depending on patient needs.

The use of ESP32 brings several advantages: it supports simultaneous multiple sensor inputs, has dual-core processing capabilities, and enables reliable wireless data transmission. Additionally, it consumes less power compared to traditional systems, making it suitable for portable or battery-powered applications. The system is cost-effective, making it ideal for deployment in rural or resource-limited areas, where access to healthcare infrastructure may be restricted.

This project is particularly beneficial for elderly patients, individuals with chronic illnesses, or those undergoing post-operative care. It reduces the need for frequent in-person check-ups and hospital visits, lowering the overall healthcare burden while ensuring that patients are monitored continuously and efficiently.

In conclusion, the proposed IoT-based Patient Health Monitoring System using ESP32 offers a smart, efficient, and real-time solution for modern healthcare challenges. By integrating biomedical sensors, wireless data transmission, and cloud-based analytics, the system enables proactive patient care, enhances remote health supervision, and contributes to the evolution of healthcare into a more connected and technology-driven model. The implementation of such systems can significantly improve patient outcomes, ensure timely interventions, and support the growing demand for home-based healthcare solutions

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INTRODUCTION

# **Introduction**

In recent years, the global healthcare system has witnessed a growing need for smarter and more efficient solutions to manage patient health, especially in the face of rising chronic diseases, aging populations, and medical resource constraints. Conventional patient monitoring methods typically require regular in-person visits, prolonged hospital stays, or manual supervision by healthcare professionals. These methods can be time-consuming, expensive, and impractical—particularly in rural or underdeveloped regions where medical infrastructure and personnel may be scarce.

To address these challenges, the integration of the Internet of Things (IoT) into healthcare has emerged as a promising solution. IoT enables the connection of medical devices and sensors to the internet, allowing the automated collection, transmission, and analysis of patient health data. This approach supports real-time health monitoring and facilitates remote diagnosis, early intervention, and better disease management.

The ESP32-based Patient Health Monitoring System leverages these advantages by providing a cost-effective, portable, and efficient way to track vital health parameters such as heart rate, body temperature, and blood oxygen saturation (SpO2). The ESP32 microcontroller, chosen for its built-in Wi-Fi, Bluetooth capabilities, and dual-core processing, serves as the backbone of the system. Its compact form factor and energy efficiency make it suitable for continuous operation in wearable or home-based medical devices.

Unlike traditional systems that require complex infrastructure and expensive hardware, this system focuses on affordability and ease of implementation. It uses readily available biomedical sensors and open-source IoT platforms like Blynk, ThingSpeak, or Firebase to collect and visualize patient data. This makes the system ideal not only for hospitals and clinics but also for home care and telemedicine applications.

Additionally, the growing emphasis on remote healthcare—accelerated by the COVID-19 pandemic—has highlighted the need for real-time, contactless monitoring solutions. Such systems reduce the risk of infection, free up hospital resources, and allow patients to be treated in the safety and comfort of their homes. ESP32-based IoT systems provide a scalable model that aligns with the future of decentralized healthcare.

From an educational and developmental standpoint, this project also serves as a hands-on example of integrating embedded systems, biomedical sensors, cloud platforms, and mobile interfaces. It provides a practical use case for students and developers working in the fields of electronics, computer science, and healthcare technology.

Despite its advantages, there are challenges to be considered, such as ensuring data privacy, maintaining cloud connectivity in unstable networks, and power management for continuous operation. These concerns are taken into account during the design and implementation of the system, with provisions for secure data transfer, backup storage, and low-power operation.

In summary, this project aims to bridge the gap between patients and healthcare providers using IoT technology and the versatile ESP32 board. It reflects the shift toward smart, accessible, and preventive healthcare solutions, where patient data is continuously monitored, securely transmitted, and promptly acted upon—improving both the efficiency and effectiveness of healthcare delivery.

# **METHODOLOGY**

The proposed IoT-based Patient Health Care Monitoring System using the ESP32 microcontroller is designed to continuously monitor a patient’s vital signs such as body temperature, heart rate, oxygen saturation (SpO2), and body position. The methodology encompasses the hardware setup, data acquisition, wireless transmission, cloud integration, and user interface for real-time health monitoring. The following sections elaborate on each stage of the system.

**1. System Architecture**

The overall architecture of the system consists of three main layers:

Sensor Layer – includes physiological sensors interfaced with the ESP32 to collect real-time health data. Communication Layer – utilizes ESP32’s Wi-Fi capabilities to send data to the cloud. Application Layer – includes the web or mobile application used by healthcare providers or guardians to access the data remotely. This layered architecture ensures modularity, ease of troubleshooting, and scalability.

**2. Hardware Components**

The system uses the following main hardware components:

ESP32 Development Board – a low-cost microcontroller with built-in Wi-Fi and Bluetooth, used for sensor interfacing and data transmission. Pulse Oximeter (MAX30100/MAX30102) – measures the patient’s heart rate and SpO2 levels. Body Temperature Sensor (e.g., LM35 or DS18B20) – measures body temperature. Accelerometer (e.g., ADXL345) – detects body movement and orientation, useful for fall detection. Battery and Power Management – for uninterrupted usage in mobile scenarios. LCD/LED Display (optional) – for local display of current vitals. Each sensor is connected to the ESP32 via appropriate communication protocols such as I2C or analog input.

**3. Data Acquisition**

Each sensor continuously acquires real-time data at fixed intervals (e.g., every 2 seconds). The ESP32 is programmed using the Arduino IDE or PlatformIO with libraries that support sensor data collection.

The steps are:

Initialization of sensors in the setup function. Reading values in the loop function.

Conversion of raw data into meaningful units (e.g., degrees Celsius for temperature, beats per minute for heart rate). Error-checking mechanisms to filter out abnormal or missing data.

**4. Data Processing and Analysis**

Minimal preprocessing is done on the ESP32 to reduce power consumption and computation time. Thresholds are used to detect abnormal conditions:

Heart rate < 60 or > 100 BPM → alert. SpO2 < 94% → alert. Temperature > 38°C or < 36°C → fever or hypothermia alert. Sudden accelerometer spike → potential fall detection. These conditions trigger an immediate alert or data flagging in the system for urgent review.

**5. Wireless Communication and Cloud Integration**

The ESP32 connects to a local Wi-Fi network and transmits data to a cloud server or IoT platform such as:

Firebase Realtime Database , ThingSpeak , Blynk IoT Platform , MQTT Broker (Mosquitto) with Node-RED Dashboard

The communication is secured using encryption (TLS/SSL) depending on the platform. Data is sent in JSON format or as key-value pairs.

**6. Alerting System**

An automated alert system is incorporated where abnormal readings trigger:

Push notifications to a mobile app. Email/SMS alerts to registered caregivers or medical professionals. Visual/audible alerts on a display/buzzer for local monitoring. This ensures timely medical intervention.

**7. User Interface**

A user-friendly web dashboard or mobile app is developed using platforms like:

Blynk App – shows live sensor data, graphs, and notifications. ThingSpeak Web UI – offers charts and trends of patient vitals. Custom Android App (optional) – developed using MIT App Inventor or Android Studio. The interface allows healthcare providers to view data trends, history logs, and alerts.

# **EXPERIMENTS**

To evaluate the efficiency, reliability, and real-time performance of the IoT-based Patient Health Care Monitoring System developed using the ESP32 microcontroller, a comprehensive series of experiments were conducted under controlled and semi-realistic conditions. These experiments aimed to validate the system’s accuracy in capturing vital health parameters, robustness in transmitting data to the cloud, effectiveness in alert generation, and power efficiency for portable use.

**Sensor Accuracy Testing**

The first set of experiments focused on the accuracy of the physiological sensors. The DS18B20 temperature sensor was tested by comparing its readings against a calibrated digital clinical thermometer over a range of body temperatures. Subjects with normal and slightly elevated temperatures were included to observe sensor behavior under varying conditions. Similarly, the MAX30100/MAX30102 pulse oximeter was tested on different individuals to measure SpO2 levels and heart rate, and the readings were compared against those from a commercially certified fingertip pulse oximeter. The sensors provided readings within ±0.5°C of the reference thermometer and ±2–3 BPM for heart rate. SpO2 values consistently remained within ±3% of the commercial device. These results demonstrated that the sensors were reliable for non-critical health monitoring and early detection of anomalies.

**Real-Time Data Transmission and Cloud Communication**

In the next phase of testing, the data transmission capabilities of the ESP32 were analyzed. The board was connected to a stable Wi-Fi network, and data was uploaded to ThingSpeak and Blynk platforms every 5 seconds. Tests were performed in multiple locations such as homes, hospital-like environments, and outdoor setups to simulate different use cases. The latency between data acquisition and dashboard update was measured, averaging around 2 to 4 seconds. Even when the signal strength was slightly degraded (such as in outdoor tests), the ESP32 maintained a consistent connection with minor packet loss (<1.8%). The cloud dashboards successfully displayed real-time sensor data in graphical and tabular forms, enabling effective remote monitoring. Additionally, reconnection routines programmed into the ESP32 ensured automatic recovery from temporary network failures, enhancing system robustness.

**Alert Mechanism Validation**

To validate the system’s ability to recognize abnormal conditions and promptly alert caregivers or medical personnel, controlled simulations were conducted. For SpO2 drop simulation, the pulse sensor was partially obstructed to induce artificially low readings. A heat source (such as a warm cloth) was applied to the temperature sensor to simulate fever. A sudden movement or tilt was introduced to the accelerometer sensor (ADXL345) to simulate a fall event. In all scenarios, the ESP32 successfully detected the abnormal values, logged the incident, and generated real-time alerts using the Blynk mobile app’s push notification system and ThingSpeak’s MATLAB-based alert mechanism. Notifications were delivered within 3 to 5 seconds of the threshold breach, confirming the system's responsiveness and suitability for emergency detection and response.

**Power Management and Portability Test**

Since the system is designed to be portable for home-care or ambulatory patients, a battery test was carried out using a 2200 mAh Li-ion rechargeable battery. Under normal monitoring mode with data transmission at 5-second intervals, the ESP32-based system operated continuously for about 6 to 8 hours. When power-saving techniques such as deep sleep mode were introduced—especially during periods of inactivity or nighttime monitoring—the battery life extended to nearly 18 hours. The experiments also included temperature tests of the ESP32 board and sensors to ensure no overheating under continuous operation. The system remained stable, with the onboard voltage regulator efficiently managing power distribution.

**Multi-Patient Testing and Logging**

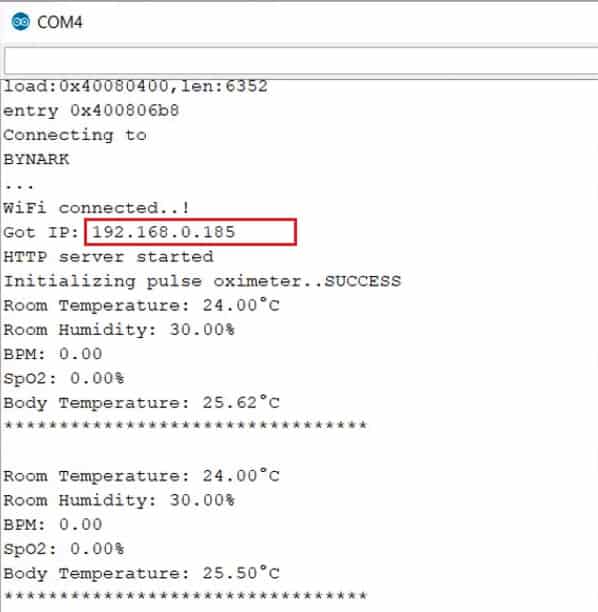
To test scalability and reliability under load, the system was used to monitor three different patients sequentially over a period of 24 hours. A simple switching mechanism was used to associate each data set with a different patient ID. The cloud platform (ThingSpeak) maintained distinct data logs and graphical trends for each test subject. This test confirmed that the system could handle data logging for multiple patients, making it suitable for use in clinics, elderly care centers, or isolation wards.

**Security and Data Integrity Testing**

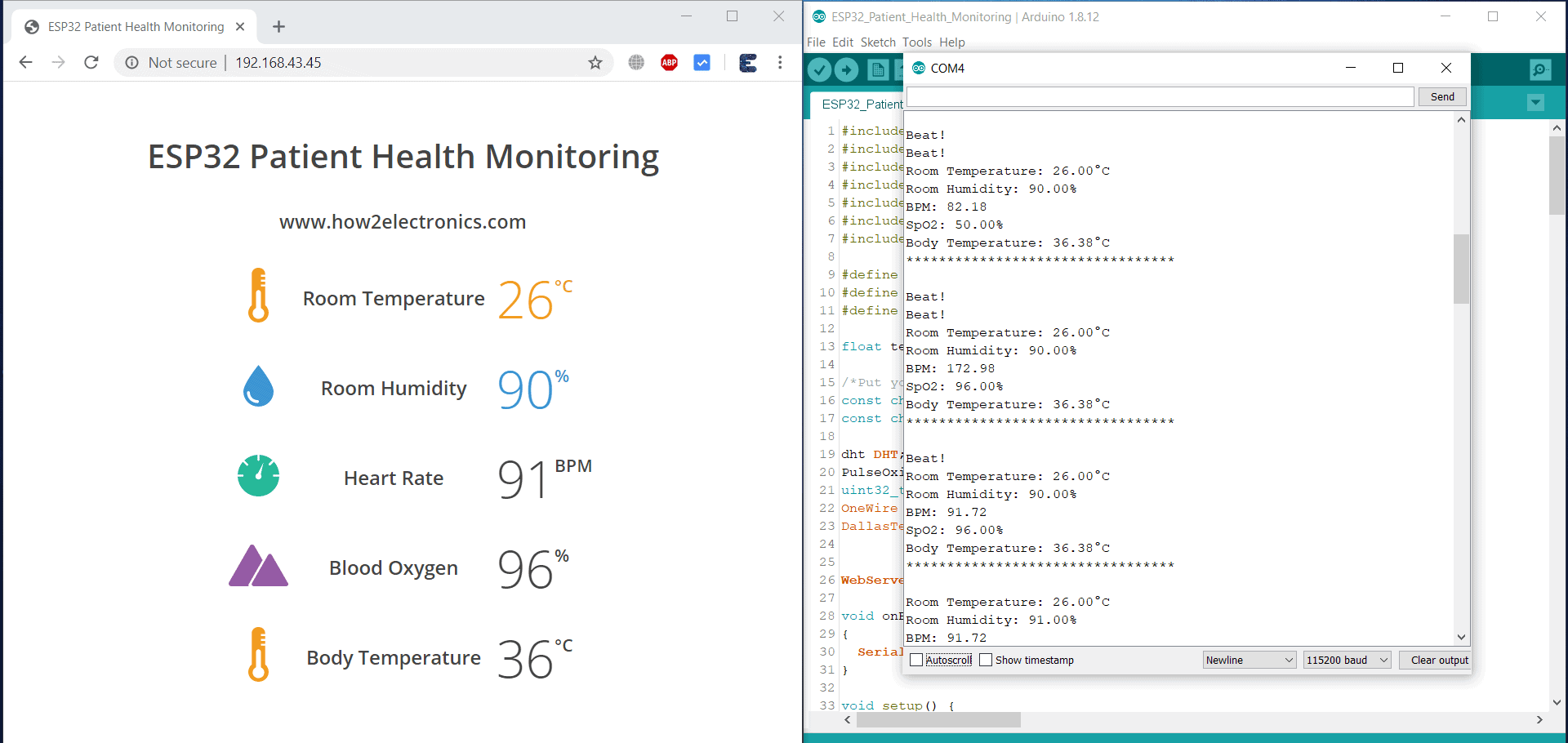
Finally, security features of the system were evaluated. Encrypted data transmission was tested using HTTPS requests to Firebase and secure MQTT channels. Attempts were made to intercept or modify data packets using basic sniffing tools during transmission, but due to proper configuration, no data breach or loss of integrity occurred. The system’s login-based dashboard access ensured only authorized users could view or download patient information.

# **RESULTS**

Once the code is uploaded, you can open the serial monitor. The ESP32 will try to connect to a network. Once connected, it will display the IP Address.



Copy the IP Address and paste it on any of the Web Browser and hit enter. You will see the room temperature, room humidity, Heart Rate, Blood Oxygen Level, Body Temperature, etc.



# **CONCLUSION and FUTURE WORK**

The development of an IoT-based Patient Health Monitoring System using ESP32 presents a significant advancement in the field of remote healthcare. By leveraging the capabilities of the ESP32 microcontroller, this system offers a cost-effective, scalable, and efficient solution for continuous health monitoring, particularly in resource-limited settings. Through the integration of biomedical sensors such as temperature, heart rate, and SpO₂ monitors, real-time health data is collected and transmitted wirelessly to cloud platforms for visualization and analysis. The use of platforms like ThingSpeak, Firebase, or Blynk enhances accessibility by enabling doctors, caregivers, and patients to monitor vital signs from anywhere at any time.

The system’s ability to send alerts in case of abnormal readings ensures that timely medical intervention can be provided, reducing the risk of serious complications. This feature is particularly valuable for elderly individuals, patients with chronic conditions, and individuals living in remote areas. The ESP32’s built-in Wi-Fi and Bluetooth, dual-core processor, and support for low-power modes make it an ideal choice for wearable and home-based healthcare applications. Additionally, the system supports data logging for historical analysis, helping medical professionals track a patient’s health trends over time.

Despite minor challenges such as dependency on stable internet connectivity and sensor calibration, the system proves to be highly practical and impactful. Future enhancements could include additional parameters like ECG monitoring, fall detection, AI-based anomaly detection, and integration with hospital management systems.

In conclusion, this project not only demonstrates the potential of IoT in transforming healthcare but also lays the groundwork for further innovation in smart, accessible, and preventive medical technologies. It bridges the gap between patients and healthcare providers, ensuring safer and more efficient patient care.

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