Low-Cost Edge Based Patient Health Monitoring System with Automated Alert Driven Notification

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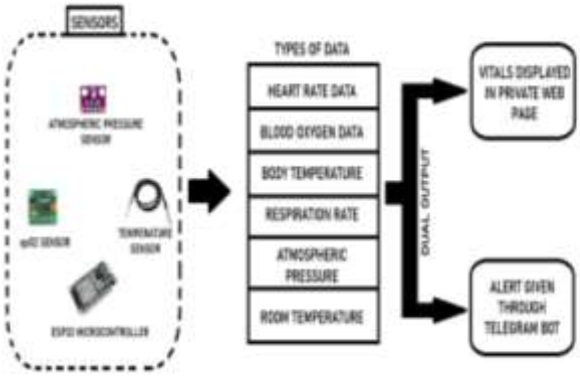


Abstract—The growing demand for affordable healthcare monitoring systems has increased the need for compact and low-cost patient monitoring solutions. This paper presents a low-cost edge-based patient health monitoring system using an ESP32 microcontroller for on-demand physiological data acquisition and processing. The proposed system integrates multiple sensors including MAX30100 for heart rate and blood oxygen saturation (SpO_2), DS18B20 for body temperature measurement,and BMP280 for environmental parameters such as room temperature and atmospheric pressure. The collected data are processed locally using edge computing principles and displayed through a web-based interface hosted on the ESP32. To enhance user awareness, an automated alert mechanism is implemented using a Telegram bot, which sends notifications when the measured parameters exceed predefined threshold limits. Unlike many existing systems that rely heavily on cloud infrastructure, the proposed design minimizes dependency on external servers while maintaining reliable monitoring capability. The system is compact, energy efficient, and developed with a low total hardware cost , making it suitable for low-cost personal health monitoring applications. Experimental results demonstrate the feasibility of the proposed system for real-time multiparameter health observation with minimal latency.

Introduction

Healthcare monitoring is becoming increasingly important as lifestyle diseases and sudden medical emergencies are rising worldwide. Traditional health monitoring systems require patients to visit hospitals frequently for routine checkups, which can be inconvenient, time-consuming, and expensive. In many cases, continuous monitoring is not possible in conventional setups, making it difficult to detect early warning signs of health problems.

With the advancement of Internet of Things (IoT) technology and low-cost microcontrollers, it has become possible to design smart health monitoring systems that can track a patient's vital parameters in real time. Devices such as heart rate sensors, temperature sensors, and oxygen level sensors can be integrated with microcontrollers to continuously measure physiological data.

This project proposes an **IoT-based Patient Health Monitoring System using ESP32** that can monitor vital parameters such as heart rate, body temperature, and blood oxygen level. The collected data is transmitted wirelessly to a cloud platform or mobile device where doctors or caregivers can monitor the patient's health remotely. Such systems are especially useful for elderly patients, people with chronic illnesses, and situations where hospital visits are difficult.

The main objective of this project is to develop a **cost-effective, portable, and real-time health monitoring system** that improves patient safety and allows remote healthcare monitoring.

Literature Survey

1. Edge computing-based emulator design for low latency IoT health monitoring system — Biky Chouhan, Rakesh Pai, Bishwajeet Pandey (2025)-This work presents an IoT-based healthcare monitoring framework that integrates edge computing to reduce latency in patient data processing. The system collects physiological data from wearable sensors and processes them closer to the data source rather than sending all data to the cloud. By using edge devices, the system improves response time and reduces network dependency.The study is relevant to this project because it demonstrates the advantages of local processing for healthcare monitoring systems. Similar to this approach, the proposed project performs sensor data acquisition and processing using the ESP32 microcontroller, enabling quick access to physiological parameters through a local web interface and alert mechanism.

2. HOT Watch: IoT-Based Wearable Health Monitoring System — Jhansi

Bharathi Madavarapu et al.This paper proposes a wearable IoT health monitoring device capable of tracking multiple physiological parameters such as heart rate, ECG, blood oxygen saturation, and body temperature. The system integrates biomedical sensors with wireless communication modules and processes the signals using signal processing algorithms to monitor patient health conditions continuously.

The work is significant to the proposed system because it highlights multiparameter health monitoring using compact hardware devices. The design concept inspired the integration of sensors such as pulse oximeter and temperature sensors in the proposed project to monitor essential vital parameters in a portable and affordable manner.

3. IoT-based health monitoring system (ICACCS 2020) — Tamilselvi V et al.This research presents an IoT-based healthcare system that monitors vital parameters and transmits the collected data to a cloud platform for remote access. The system uses biomedical sensors to measure parameters such as heart rate and body temperature and allows healthcare providers to monitor patients remotely through internet connectivity.

The study demonstrates the importance of remote monitoring and real-time data transmission in modern healthcare applications. The concept is closely related to the proposed system where physiological data are displayed through a web server interface and alert notification system, enabling users to access their health information conveniently.

4. An IoT-enabled patient health monitoring system — D. S. R. Krishnan et al.This paper introduces a patient monitoring framework based on IoT architecture where sensors continuously collect physiological data and transmit them to a central monitoring system. The system focuses on improving patient care through automated monitoring and timely notification to healthcare providers.The work is relevant to the proposed project because it emphasizes the role of sensor integration and wireless communication in healthcare systems. The proposed system also uses similar principles by integrating multiple sensors with an ESP32 microcontroller to provide a low-cost and compact health monitoring solution.

5. IoT-based healthcare-monitoring system towards improving quality of life — Abdulmalek S et al.this study focuses on improving patient quality of life through IoT-based healthcare monitoring technologies. The system collects physiological parameters using wearable sensors and provides real-time monitoring and alerts through connected devices. The architecture supports remote health observation and early detection of abnormal conditions.

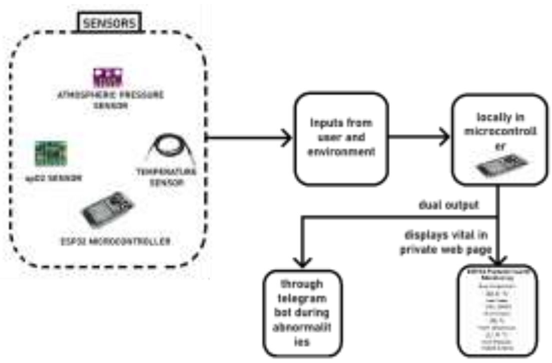
This research supports the idea that continuous monitoring and automated alerts are essential in healthcare systems. Inspired by this concept, the proposed project integrates automated alert notifications through messaging platforms to inform users whenever abnormal parameter values are detected.

6. IoT Based Health Monitoring System — P. Valsalan et al.

This paper presents a basic IoT healthcare monitoring architecture using sensors, microcontrollers, and wireless communication modules. The system focuses on collecting patient data and transmitting it to remote servers for monitoring and analysis. The study emphasizes the role of IoT technologies in improving healthcare accessibility and reducing hospital visits.

The findings of this work are relevant to the proposed system as they highlight the importance of low-cost sensor integration and real-time monitoring for personal healthcare applications. The proposed project builds upon this concept by implementing a compact and affordable monitoring system with edge-based processing and web-based visualization.

Proposed workflow



Proposed System Architecture

The proposed system consists of several hardware and software components that work together to monitor and transmit health data.

1. Sensors

The system uses biomedical sensors to measure the patient's vital signs:

- **Heart Rate Sensor:** Measures the number of heartbeats per minute.
- **Temperature Sensor:** Measures the patient's body temperature.
- **SpO_2 Sensor:** Measures oxygen saturation level in blood.

These sensors continuously collect physiological data from the patient.

2. Microcontroller Unit (ESP32)

The **ESP32 microcontroller** acts as the central processing unit of the system. It performs the following functions:

- Collects signals from the sensors
- Processes the raw sensor data
- Converts analog signals to digital values
- Sends the data through Wi-Fi to a remote server or mobile application

ESP32 is chosen because it has **built-in Wi-Fi and Bluetooth**, making it suitable for IoT applications.

3. Communication Module

The ESP32 transmits the processed data through **Wi-Fi** to a cloud server or IoT platform. This allows real-time monitoring from anywhere with internet access.

4. Display and Alert System

A **local display (LCD or OLED)** can be used to show the current health parameters. In addition, if any value exceeds the safe threshold level, the system can generate an alert notification to caregivers or doctors.

5. Cloud or Mobile Monitoring Interface

The transmitted data is stored and displayed on an IoT dashboard or mobile application. Doctors or family members can view:

- Heart rate trends
- Body temperature
- Oxygen saturation levels

This enables remote medical supervision.

Methodology

The methodology describes the working procedure of the proposed health monitoring system.

Step 1: Sensor Data Acquisition

The biomedical sensors are attached to the patient to measure vital parameters. The sensors continuously detect physiological signals such as heart pulse, temperature, and oxygen saturation.

Step 2: Data Processing

The sensor outputs are sent to the ESP32 microcontroller. The ESP32 processes these signals and converts them into readable numerical values using embedded programming.

Step 3: Wireless Data Transmission

Once the data is processed, the ESP32 transmits it through Wi-Fi to an IoT platform or server. This allows remote monitoring without requiring the patient to be physically present in a hospital.

Step 4: Real-Time Monitoring

The data received on the cloud platform is displayed on a dashboard where doctors or caregivers can monitor the patient's condition in real time.

Step 5: Alert Generation

Threshold values are predefined in the system. If any parameter crosses the safe limit, the system automatically sends alerts or notifications to the concerned person.

Step 6: Data Logging

All health data is stored on the server for future analysis. This helps doctors track the patient’s health history and detect abnormal patterns.

Results and Discussion

The developed IoT-based patient monitoring system successfully measured and transmitted vital health parameters in real time. The sensors accurately detected heart rate, body temperature, and oxygen saturation levels, which were processed by the ESP32 microcontroller.

The system demonstrated reliable wireless communication through Wi-Fi, allowing health data to be viewed remotely through an IoT dashboard. The results showed that the monitoring system could provide continuous health data without requiring the patient to remain in a hospital environment.

The alert mechanism also worked effectively by sending notifications when the measured parameters exceeded predefined safe limits. This feature is important for early detection of medical emergencies.

Compared with traditional monitoring methods, the proposed system offers several advantages:

- Continuous real-time monitoring
- Remote accessibility for doctors
- Reduced hospital visits
- Cost-effective implementation
- Portable and easy to use

However, some limitations were observed. Sensor accuracy may vary depending on placement and environmental conditions. Network connectivity issues may also affect real-time data transmission.

Despite these limitations, the system demonstrates strong potential for improving remote healthcare monitoring.

Conclusion

This project successfully developed an **IoT-based patient health monitoring system using ESP32** capable of measuring and transmitting important health parameters in real time. By integrating biomedical sensors with wireless communication technology, the system enables continuous monitoring of patients outside hospital environments.

The proposed system provides an efficient solution for remote healthcare, especially for elderly patients and individuals with chronic illnesses who require regular monitoring. The system also helps doctors access patient data quickly and respond to emergencies through automated alerts.

Future improvements could include integrating additional sensors such as blood pressure monitoring, implementing advanced data analytics using artificial intelligence, and developing a mobile application for easier user interaction.

Overall, the proposed system demonstrates how IoT technology can enhance modern healthcare by providing **smart, accessible, and real-time patient monitoring solutions**.

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