International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 10, Issue 4, pp 209-215, April-2026
https://doi.org/10.47001/IRJIET/2026.104030

Portable Patient Vitals Monitoring Device

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***Abstract* - The increasing demand for comprehensive and continuous health monitoring has led to the development of advanced portable medical devices. This paper presents a Portable Patient Vitals Monitoring Device with Integrated Non-Invasive Blood Pressure (NIBP) Measurement, capable of monitoring multiple physiological parameters in real time. The proposed system integrates biomedical sensors including a pulse sensor, ECG sensor, DHT11 sensor, and an NIBP module to measure heart rate, cardiac activity, environmental conditions, and blood pressure (systolic and diastolic). An ESP32 microcontroller is used as the main processing unit to acquire, analyze, and display the sensor data on an LCD screen. The NIBP module operates using the oscillometric method, where an air pump inflates the cuff and a pressure sensor detects arterial oscillations to determine blood pressure values. The system also incorporates a buzzer for immediate local alerts during abnormal conditions. For remote emergency response, an Arduino Nano interfaced with GPS and GSM modules transmits the patient's health status along with real-time location via SMS to caregivers or medical professionals. Experimental results demonstrate that the system effectively monitors multiple vital parameters and provides timely alerts with location tracking. The integration of blood pressure measurement enhances the reliability and completeness of the monitoring system. The proposed device is portable, cost-effective, and suitable for home healthcare, elderly monitoring, and remote medical assistance, thereby improving patient safety and reducing response time during critical situations.**

Keywords: Portable Health Monitoring, NIBP, Blood Pressure Measurement, ESP32, ECG Sensor, GSM, GPS, Remote Healthcare, IoT in Healthcare.

I. INTRODUCTION

The rapid advancement of healthcare technologies has created a growing need for continuous, accurate, and real-time monitoring of patient health conditions. Traditional monitoring systems used in hospitals are often expensive, bulky, and require constant supervision by medical professionals. These limitations make them unsuitable for continuous monitoring outside clinical environments, especially for elderly individuals, patients with chronic diseases, and those requiring post-operative care. As a result, there is a strong demand for portable, cost-effective, and reliable health monitoring systems that can operate independently and provide timely medical assistance.

Vital physiological parameters such as heart rate, electrocardiogram (ECG), blood pressure, and environmental conditions play a critical role in assessing a patient's health status. Among these, blood pressure is one of the most important indicators for detecting cardiovascular diseases such as hypertension and hypotension. Conventional blood pressure measurement methods require manual operation and are not suitable for continuous monitoring. The integration of a **Non-Invasive Blood Pressure (NIBP)** module using the oscillometric method enables automatic and accurate measurement of systolic and diastolic pressure without requiring clinical expertise.

Recent developments in embedded systems and wireless communication technologies have enabled the design of smart healthcare devices capable of real-time data acquisition, processing, and transmission. Microcontrollers such as ESP32 and Arduino Nano provide high processing capability, low power consumption, and easy interfacing with sensors and communication modules. By integrating biomedical sensors such as pulse sensors, ECG sensors, and NIBP modules, it is possible to monitor multiple vital parameters simultaneously within a single compact device.

The proposed system focuses on developing a **Portable Patient Vitals Monitoring Device with integrated NIBP measurement**, capable of monitoring heart rate, ECG signals, blood pressure, and environmental parameters. The ESP32 microcontroller processes the sensor data and displays it on an LCD for real-time observation. In the event of abnormal health conditions, the system activates a buzzer to provide immediate alerts. Additionally, a manual emergency switch allows the patient to trigger alerts when needed.

To enhance emergency response capabilities, the system incorporates GPS and GSM modules through an Arduino Nano. When a critical condition is detected, the system sends an SMS alert containing the patient's health status and real-time location to caregivers or medical professionals. This

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ensures timely assistance, even when the patient is alone or located far from healthcare facilities.

Overall, the proposed system aims to provide a **comprehensive, portable, and intelligent healthcare monitoring solution** that supports continuous monitoring, early detection of health abnormalities, and rapid emergency communication. The integration of NIBP measurement significantly improves the effectiveness of the system by enabling complete cardiovascular monitoring, making it highly suitable for modern healthcare applications.

II. LITERATURE REVIEW

With the rapid growth of healthcare demands and aging populations, continuous patient monitoring systems have gained significant research attention. Traditional hospital-based monitoring systems are effective but suffer from limitations such as high cost, lack of portability, and dependency on medical staff. This has motivated researchers to develop portable, wearable, and IoT-enabled patient health monitoring solutions.

Smith et al. (2021) proposed an IoT-based health monitoring system that continuously monitors heart rate and body temperature using wearable sensors. The collected data is transmitted to a cloud platform for remote access by healthcare providers. Although the system enables remote monitoring, it relies heavily on internet availability and does not include location-based emergency alerts, limiting its usefulness in critical conditions.

Kumar and Patel (2021) developed a portable ECG monitoring device using Arduino and biomedical sensors. Their system successfully detected basic cardiac abnormalities and displayed ECG signals locally. However, it lacked integration with communication modules such as GSM or GPS, making emergency notification and real-time assistance impractical during sudden health failures.

Meena et al. (2022) introduced a smart patient monitoring system using ESP32 and wireless sensors to monitor pulse rate and body temperature. The data was uploaded to a web server for visualization. While the system demonstrated low power consumption and ease of use, it did not incorporate an emergency alert mechanism or manual panic switch for patients.

A study by Zhang et al. (2022) focused on wearable ECG and heart rate monitoring using IoT and machine learning techniques to predict cardiac abnormalities. The system showed high prediction accuracy but required complex computational resources and cloud-based processing, making it less suitable for low-cost, portable implementations.

Patil et al. (2023) designed a GSM-based patient monitoring system that sends SMS alerts when vital signs exceed threshold values. Although the system effectively handles emergency alerts without internet dependency, it monitors limited parameters and lacks integrated GPS tracking to identify the patient's location during emergencies.

Rao and Singh (2023) developed a healthcare monitoring system combining pulse sensor, temperature sensor, and GSM module for elderly care. The system demonstrated effective alert transmission but did not include ECG monitoring, which is critical for detecting serious cardiac conditions.

In 2024, Al-Hassan et al. proposed a wearable health monitoring device using ESP32 with cloud and mobile application support. The device allowed remote visualization of health data and historical analysis. However, the necessity of constant internet connectivity and absence of manual emergency triggering reduced its reliability in rural or low-connectivity areas.

More recently, Verma et al. (2025) presented an integrated patient monitoring system combining ECG, heart rate sensors, and GSM-GPS modules. The system effectively provided real-time alerts and location-based emergency notifications. However, the design complexity and higher power consumption indicated the need for further optimization to make the system more portable and cost-effective.

III. GAP ANALYSIS

From the analysis of existing patient health monitoring systems, several limitations have been identified. Many proposed systems focus on monitoring only one or two vital parameters such as heart rate or body temperature, which may not provide complete information about the patient's health condition. Some systems rely heavily on internet connectivity and cloud platforms for data transmission, which makes them unreliable in areas with poor network availability. Additionally, many existing solutions do not include integrated emergency alert mechanisms with location tracking, making it difficult for caregivers to respond quickly during critical situations.

Furthermore, several systems lack portability and user-friendly interfaces, limiting their practical use for elderly patients or individuals requiring continuous monitoring at home. There is also limited integration of multiple biomedical sensors such as ECG and pulse sensors in a single compact

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device along with real-time alert generation and GPS-based emergency communication.

Therefore, there is a need to develop a **portable, low-cost, and reliable patient vitals monitoring device** that can monitor multiple physiological parameters simultaneously, provide real-time alerts, and automatically send emergency notifications along with the patient's location to caregivers or medical professionals. This gap motivates the development of the proposed system.

IV. METHODOLOGY

The proposed system is developed to monitor multiple patient vital parameters, including heart rate, ECG, environmental conditions, and blood pressure using a **Non-Invasive Blood Pressure (NIBP) module**. The methodology involves the integration of biomedical sensors, microcontrollers, and communication modules to ensure continuous monitoring and real-time emergency response.

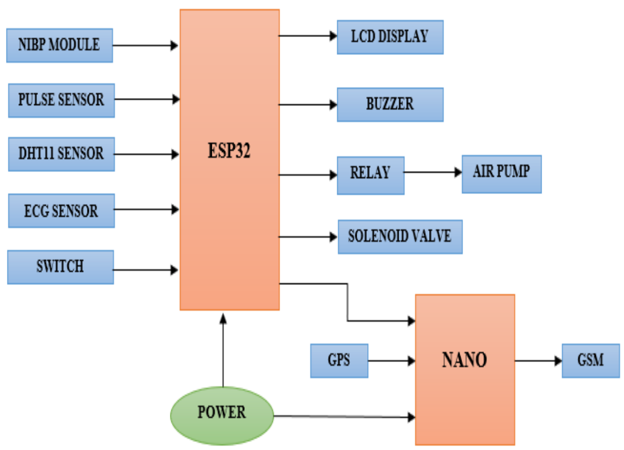

Figure 1: Block Diagram of Proposed System

The system begins with the acquisition of physiological data using sensors such as the pulse sensor, ECG sensor, DHT11 sensor, and the NIBP module. These sensors are interfaced with the ESP32 microcontroller, which acts as the central processing unit. The ESP32 continuously collects data from all sensors and processes it by comparing the measured values with predefined threshold limits to determine the patient's health condition.

For blood pressure measurement, the NIBP module operates using the oscillometric method. When a measurement is initiated, the ESP32 activates the air pump to inflate the cuff wrapped around the patient's arm. As the cuff inflates, the pressure sensor within the NIBP module detects arterial oscillations. Once the required pressure level is reached, the system gradually deflates the cuff using a solenoid valve. During deflation, the ESP32 processes the oscillation signals to calculate systolic and diastolic blood pressure values. These values are then displayed on the LCD along with other vital parameters.

All the measured parameters, including heart rate, ECG signals, temperature, humidity, and blood pressure, are displayed in real time on the LCD screen. Under normal conditions, the system continues monitoring without interruption. If any abnormal condition is detected, such as irregular heart rate or abnormal blood pressure levels, the ESP32 activates a buzzer to provide an immediate alert.

Additionally, a manual emergency switch is incorporated to allow the patient to trigger an alert if required. In case of an emergency, the ESP32 sends a signal to the Arduino Nano, which is interfaced with GPS and GSM modules. The GPS module retrieves the real-time location of the patient, and the GSM module sends an SMS alert containing the patient's health status and location to predefined emergency contacts.

The system operates on a portable power supply, making it suitable for wearable or mobile applications. This methodology ensures continuous monitoring, accurate measurement of multiple vital parameters including blood pressure, and immediate communication during critical situations, thereby enhancing patient safety and healthcare efficiency.

V. SYSTEM IMPLEMETATION

The implementation of the **Portable Patient Vitals Monitoring Device with NIBP Module** involves the integration of hardware components, embedded programming, and communication systems to achieve real-time health monitoring and emergency alert functionality.

1. Hardware Implementation

The hardware system is built using two microcontrollers: ESP32 and Arduino Nano. The ESP32 acts as the main controller responsible for data acquisition and processing, while the Arduino Nano is used for handling GSM and GPS communication.

Sensor Integration

- **Pulse Sensor** is connected to the analog input of ESP32 to measure heart rate.
- **ECG Sensor** is interfaced to capture cardiac signals.
- **DHT11 Sensor** is connected to measure temperature and humidity.

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- **NIBP Module** is integrated with ESP32 to measure systolic and diastolic blood pressure using a cuff, pressure sensor, air pump, and solenoid valve.

Actuator and Output Devices

- **LCD Display** is interfaced to display real-time patient vitals.
- **Buzzer** is connected to provide audio alerts during abnormal conditions.
- **Servo Motor** is used for indication or emergency response actions.

NIBP Control Circuit

- The **air pump** is controlled using a relay or MOSFET driver circuit connected to ESP32.
- The **solenoid valve** is used for controlled deflation of the cuff.
- Proper isolation and power management are ensured to prevent damage to the microcontroller.

Communication Modules

- **GPS Module** is connected to Arduino Nano to obtain real-time location.
- **GSM Module** is used to send SMS alerts with patient data and GPS coordinates.

2. Software Implementation

The system is programmed using Embedded C / Arduino IDE.

ESP32 Programming

- Sensor data acquisition from pulse, ECG, DHT11, and NIBP module
- Signal processing and threshold comparison
- Control of buzzer, servo motor, air pump, and valve
- Display of real-time data on LCD

Arduino Nano Programming

- Serial communication with ESP32
- GPS data parsing to extract latitude and longitude
- GSM module control using AT commands
- Sending SMS alerts with patient health status and location

3. NIBP Measurement Implementation

The NIBP module is implemented using the oscillometric method:

1. The cuff is placed on the patient's arm.
2. ESP32 activates the air pump to inflate the cuff.
3. Pressure sensor detects oscillations in arterial blood flow.
4. ESP32 processes the signal to determine:
    - Systolic pressure
    - Diastolic pressure
5. The solenoid valve releases air gradually after measurement.
6. BP values are displayed and used for further analysis.

4. System Operation

1. The system initializes all sensors and modules.
2. Continuous monitoring of vital parameters begins.
3. Data is displayed on LCD in real time.
4. If abnormal conditions are detected:
    - Buzzer is activated
    - NIBP measurement may be triggered (if required)
5. Emergency condition triggers:
    - GPS location retrieval
    - SMS alert via GSM module

5. Testing and Validation

- The system was tested with real-time inputs from sensors.
- NIBP readings were compared with standard digital BP monitors for validation.
- GSM module successfully sent alerts with GPS location.
- The system showed stable and reliable performance during continuous operation.

The system implementation demonstrates successful integration of sensing, processing, and communication units into a single portable healthcare device. The addition of the **NIBP module enhances the system capability** by enabling blood pressure monitoring, making it a complete and efficient patient monitoring solution.

VI. RESULT AND DISCUSSIONS

The proposed **Portable Patient Vitals Monitoring Device with NIBP Module** was successfully implemented and tested to evaluate its performance in real-time health monitoring and emergency alert generation. The system integrates multiple sensors and communication modules to provide continuous monitoring of physiological parameters such as heart rate, ECG signals, temperature, humidity, and blood pressure.

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1. Hardware Setup and Integration

The complete hardware prototype was assembled using ESP32, Arduino Nano, pulse sensor, ECG sensor, DHT11 sensor, NIBP module, LCD display, buzzer, servo motor, GPS module, and GSM module. All components were properly interfaced and powered using a portable power supply.

The system operated reliably, with all sensors functioning correctly and transmitting data to the ESP32 for processing. The integration of the NIBP module, including the cuff, air pump, and solenoid valve, was successfully achieved, enabling automatic blood pressure measurement.

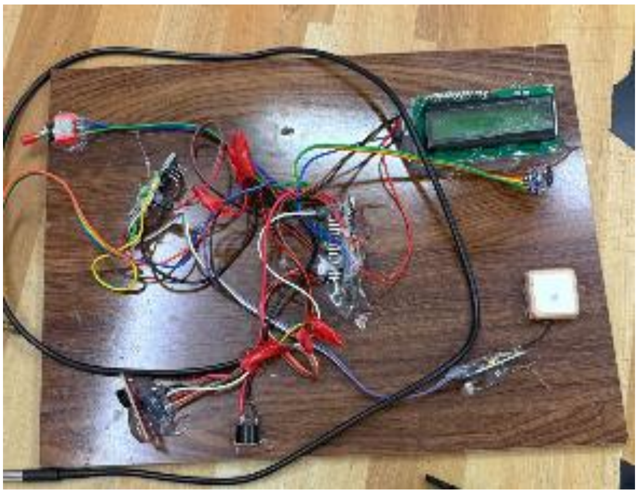

Figure 2: Hardware Setup of the Proposed System

2. Real-Time Monitoring Results

The device continuously monitored and displayed vital parameters on the LCD screen. The pulse sensor provided accurate heart rate readings, while the ECG sensor captured cardiac activity effectively. The DHT11 sensor measured environmental temperature and humidity, ensuring additional patient safety.

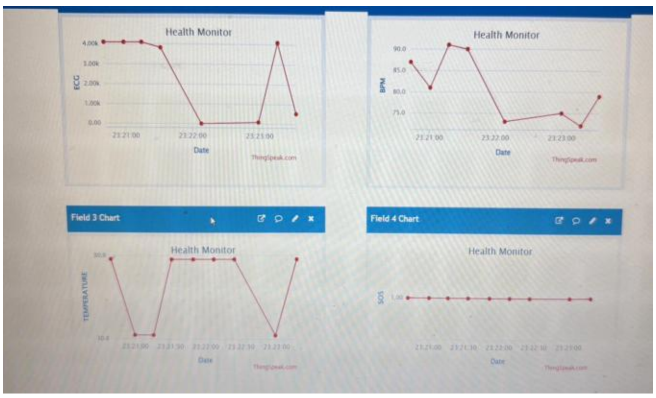

Figure 3: IOT Graph Multi-Parameter Readings Including BP

The NIBP module successfully measured systolic and diastolic blood pressure using the oscillometric method. The cuff inflated and deflated properly, and the ESP32 processed the pressure signals to compute accurate BP values. These values were displayed on the LCD along with other parameters.

3. Emergency Alert and GSM Communication

When abnormal conditions such as irregular heart rate or abnormal blood pressure were detected, the system activated the buzzer to provide an immediate alert. Additionally, the ESP32 sent a signal to the Arduino Nano to initiate emergency communication.

The GPS module accurately retrieved the real-time location of the patient, and the GSM module successfully transmitted SMS alerts containing the patient's health status along with GPS coordinates. The received message included a location link that could be used to track the patient.

The SMS alerts were delivered within a few seconds, demonstrating reliable communication performance.

4. System Performance Analysis

The system demonstrated stable and continuous operation during testing. Sensor readings were consistent, and the integration of multiple parameters improved the reliability of health monitoring. The addition of the NIBP module enhanced the system by enabling blood pressure measurement, which is crucial for detecting cardiovascular conditions.

The response time of the alert system was minimal, ensuring rapid notification during emergencies. The device proved to be portable, cost-effective, and efficient for real-time patient monitoring.

The experimental results confirm that the proposed system effectively monitors multiple vital parameters and provides timely alerts in case of abnormal conditions. The integration of the NIBP module significantly improves the system's capability by enabling comprehensive cardiovascular monitoring.

The GSM-GPS based alert system ensures that caregivers can quickly respond to emergencies with accurate location information. The system is highly suitable for home healthcare, elderly monitoring, and remote medical applications.

Overall, the device achieves its objective of providing a **reliable, multi-parameter, and portable patient monitoring**

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solution with enhanced safety and rapid emergency response capabilities.

VII. CONCLUSION

The **Portable Patient Vitals Monitoring Device with NIBP Module** has been successfully designed and implemented to provide continuous and real-time monitoring of essential physiological parameters, including heart rate, ECG signals, temperature, humidity, and blood pressure. The system utilizes the ESP32 microcontroller for data acquisition and processing, while the Arduino Nano manages GSM and GPS communication for emergency alert transmission.

The integration of the **Non-Invasive Blood Pressure (NIBP) module** significantly enhances the system by enabling accurate measurement of systolic and diastolic pressure using the oscillometric method. The measured parameters are displayed on an LCD screen, allowing real-time observation of the patient's health condition. In case of abnormal readings, the system generates immediate alerts through a buzzer and sends SMS notifications along with the patient's location to caregivers or medical professionals.

The experimental results demonstrate that the system operates reliably, with accurate sensor readings and prompt alert transmission. The portable design, low cost, and ease of use make it suitable for home healthcare, elderly monitoring, and remote medical applications.

Overall, the proposed system provides a **comprehensive, efficient, and cost-effective healthcare monitoring solution**, improving patient safety by enabling early detection of health abnormalities and ensuring timely medical assistance during emergencies.

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Citation of this Article:

Vaibhav Doke, Akshay Darandale, Karan Londhe, & Dr. Manju Pandey. (2026). Portable Patient Vitals Monitoring Device. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(4), 209-215. Article DOI https://doi.org/10.47001/IRJIET/2026.104030

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