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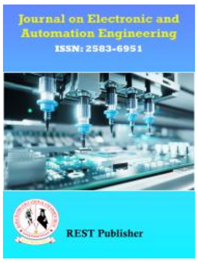

A Portable IoT-Based Health Monitoring Framework Using ESP32 for Isolated and Home-Based Patient Care

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Abstract: *The creation of an affordable Internet of Things (IoT)-based patient health monitoring system with the ESP32 microcontroller is shown in this study. In order to measure critical factors including blood oxygen saturation (SpO_2), heart rate, and body temperature, the system incorporates biomedical sensors. Real-time data collecting is carried out, and the outcomes are shown on a web interface that is hosted by a companion mobile application and the ESP32's integrated web server. It is appropriate for remote health monitoring applications, including patients in remote areas like homes or special wards, because of its design, which places an emphasis on price, mobility, and ease of deployment. When crucial health thresholds are crossed, the system's alert systems let medical experts know via smartphone notifications and web pop-ups, allowing for prompt medical intervention.*

Keywords: *IoT, ESP32, Patient Health Monitoring, Real-Time Web Interface, Mobile Application, Biomedical Sensors, Remote Monitoring, Alert System*

1. INTRODUCTION

Vital signs must be continuously monitored in order to identify health abnormalities early, particularly in environments with limited resources or remote locations[1]. Conventional monitoring technologies are impractical for continuous, real-time surveillance outside of clinical settings and may require large, cumbersome equipment. A solution is provided by the emergence of IoT technologies, which have made it possible to create small, affordable, and networked health monitoring devices. The goal of this project is to create an ESP32-based system that employs a web interface and a mobile application to measure important health indicators and visualize data in real time.[2]

2. LITERATURE REVIEW

This paper builds upon existing research in the areas of microcontroller platforms, sensor technology, and cost-effectiveness.

The choice of microcontroller is pivotal in the design of health monitoring systems. Factors such as processing capability, power consumption, and connectivity play a significant role in the selection of a microcontroller[3], [4], [5]. The ESP32 microcontroller has emerged as a preferred choice due to its integrated Wi-Fi and Bluetooth capabilities, dual-core processing, and low power consumption[6], [7]. Study shows ESP32, as a versatile device, allows for seamless integration with various biomedical sensors, facilitating real-time data acquisition and transmission.[8], [9] Research show its suitability for continuous monitoring of vital signs such as heart rate, temperature, and SpO_2.[3] The ability to access real-time health data remotely is a significant advancement in patient monitoring. ESP32's Wi-Fi capabilities allows healthcare professionals to monitor patients' health status remotely. A study by [6], [10] implemented an IoT-based patient health monitoring system using an ESP32 web server, enabling real-time monitoring of vital signs such as pulse rate, temperature, and SpO_2.

The accuracy and reliability of a health monitoring system heavily depend on the selection of appropriate sensors. For heart rate and SpO_2 measurements, the MAX30100 sensor is widely used due to its integrated infrared and

red LEDs, along with a photodetector, allowing for precise readings.[11] The DS18B20 digital temperature sensor is favoured for its high accuracy, ease of interface via a 1-Wire interface, and ability to function over a wide temperature range.[12] For environmental monitoring, the DHT11 sensor provides both temperature and humidity readings, contributing to a comprehensive understanding of the patient's surroundings.[12], [13] These sensors, when integrated with the ESP32, create a robust system capable of continuous health monitoring.[6], [14][15]
Affordability is a critical consideration, especially in resource-constrained settings. The integration of low-cost sensors such as the MAX30100 for heart rate and SpO_2 measurements, and the DS18B20 for body temperature, with the ESP32 microcontroller, has enabled the development of economical health monitoring devices.[16] The user-friendly design ensures that individuals with minimal technical expertise can operate the devices effectively.[17], [18]

3. SYSTEM DESIGN AND ARCHITECTURE

A. Hardware Components

A web-based dashboard, a microcontroller unit, and sensor modules make up the tightly integrated framework that forms the architecture of the patient health monitoring system. The sensor suite consists of the DHT11 sensor, which records ambient temperature and humidity to give physiological parameters an environmental context; the DS18B20 digital temperature sensor, which provides precise body temperature readings; and the MAX30100 pulse oximeter, which measures heart rate and blood oxygen saturation (SpO_2). The ESP32 microcontroller, which is at the heart of the system, manages connectivity through its integrated Wi-Fi, real-time processing, and sensor data collecting. Additionally, it houses a small web server that displays the collected data on an easy-to-use web dashboard that can be accessed from any device connected to the same network that has a browser. Continuous, remote vital sign monitoring is made possible by this well-thought-out design, which guarantees prompt knowledge of important health changes. This is especially helpful for patients in remote locations like home care or quarantine wards, where it may not be possible to provide urgent in-person medical supervision.

B. Circuit Diagram

The sensors are interfaced with the ESP32 as follows:
A 4.7kΩ pull-up resistor is connected between the data line and VCC for the DS18B20 sensor to ensure proper communication.

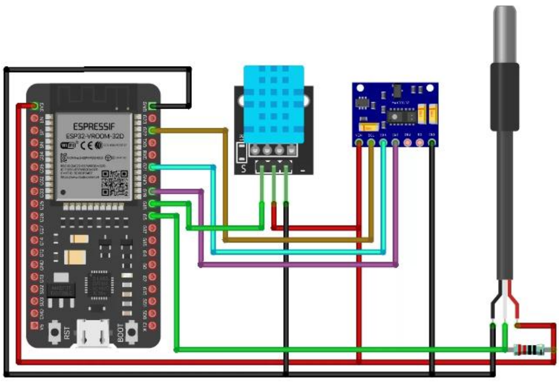


FIGURE 1. (a) Circuit diagram of the proposed system

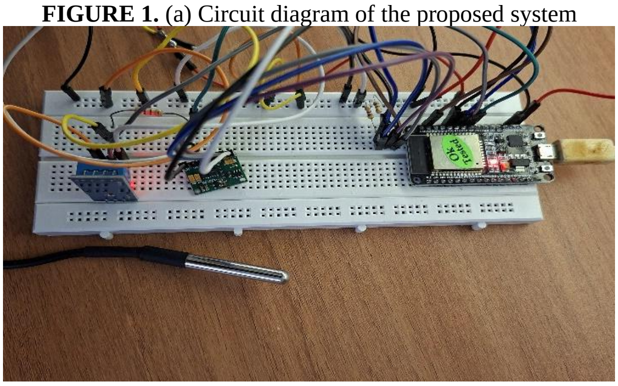


FIGURE 1. (b) Circuit of the proposed system

C. Sensor Working Principle

A collection of precision sensors is integrated into the Internet of Things-based Patient Health Monitoring System in order to record vital environmental and physiological characteristics. In order to calculate heart rate and blood oxygen saturation (SpO_2), the MAX30100 pulse oximeter sensor uses red and infrared LEDs in conjunction with a photodetector that examines how light is absorbed by blood. This is a crucial function for identifying hypoxemia and keeping an eye on cardiovascular health. A thermistor and a capacitive humidity sensor are used by the DHT11 sensor, which measures ambient temperature and humidity, to provide calibrated digital outputs that provide context for the environment. The DS18B20 digital temperature sensor, which employs a 1-Wire interface and thermistor-based sensing to produce high-resolution digital readings under a variety of situations, is used for precise body temperature assessment. All sensors are calibrated against common medical devices and put through extensive testing in a variety of settings to guarantee data reliability and system stability. The creation of a reliable, scalable, and user-focused health monitoring system that can facilitate remote patient care is supported by this thorough methodology.

D. Software Implementation

The Arduino IDE is used to program an ESP32-based patient health monitoring system, which incorporates a number of libraries for network and sensor connectivity. In particular, the DallasTemperature library, in combination with OneWire, is utilized to obtain accurate body temperature data from the DS18B20 sensor; the DHT library is utilized to process ambient temperature and humidity from the DHT11 sensor, and the MAX30100_PulseOximeter library is utilized to obtain heart rate and SpO_2 measurements. To guarantee accuracy and dependability, the data from each sensor is filtered after being gathered at predetermined intervals, such as once per second for the MAX30100, 1.5 seconds for the DS18B20, and twice a second for the DHT11. The WebServer.h library is used to serve real-time sensor data over an integrated HTTP web server, and the WiFi.h library is used to connect the ESP32 to a Wi-Fi network. Any browser-connected device on the same network can access the web interface, which was created with HTML and JavaScript and is hosted on the ESP32. Furthermore, a React Native-developed cross-platform mobile application connects to the ESP32 server to provide real-time health metrics and send out notifications on important occasions, allowing for remote health monitoring on tablets or smartphones.

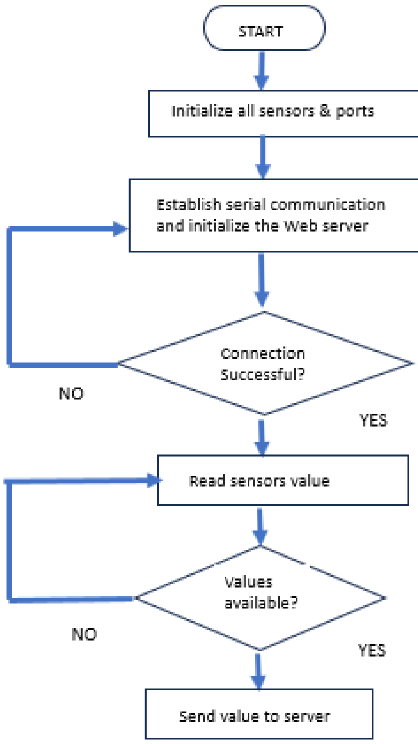


FIGURE 2. Flowchart of the proposed system's process

E. Alert Mechanism

By assessing important physiological thresholds, such as hypoxemia ($SpO_2 < 90\%$), tachycardia (heart rate > 100 BPM), fever (body temperature > 38°C), and hypothermia (body temperature < 35°C), the system is intended to continuously monitor and identify crucial health situations. To detect the onset of Systemic Inflammatory Response Syndrome (SIRS), a potentially fatal illness, it also evaluates combinations of these factors. The system automatically starts a dual-alert mechanism when any of these thresholds are crossed. It sends a push notification to the companion mobile application and creates a real-time pop-up notification on the web interface to notify on-site medical personnel. This way, remote healthcare providers are informed in real time and can react quickly to the patient's worsening condition.

4. RESULTS

The IoT-based patient monitoring system that has been put into place efficiently records and shows a wide range of environmental and physiological parameters that are necessary for remote medical evaluation. These include body temperature, expressed in degrees Celsius for the identification of conditions like fever or hypothermia; ambient temperature and humidity, which contextualize the patient's surroundings and may have an impact on general well-being; blood oxygen saturation (SpO_2), a crucial indicator for respiratory efficiency; and heart rate, expressed in beats per minute (BPM), which offers information about cardiovascular activity. Both a specialized mobile application and a web interface that can be accessed through a browser smoothly display the system's real-time data acquisition. Particularly in situations involving remote or isolated care, these platforms guarantee constant, real-time view of the patient's health status, empowering medical professionals and caregivers to make prompt and well-informed decisions.

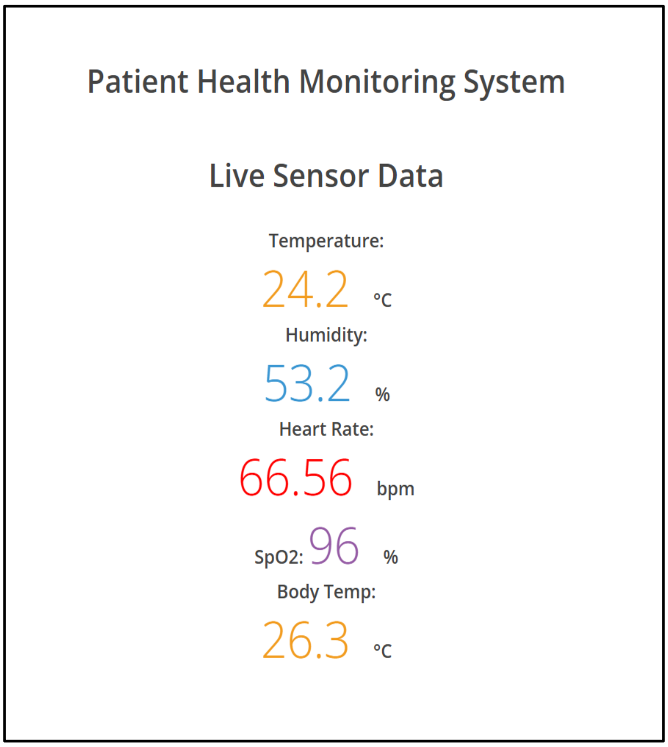
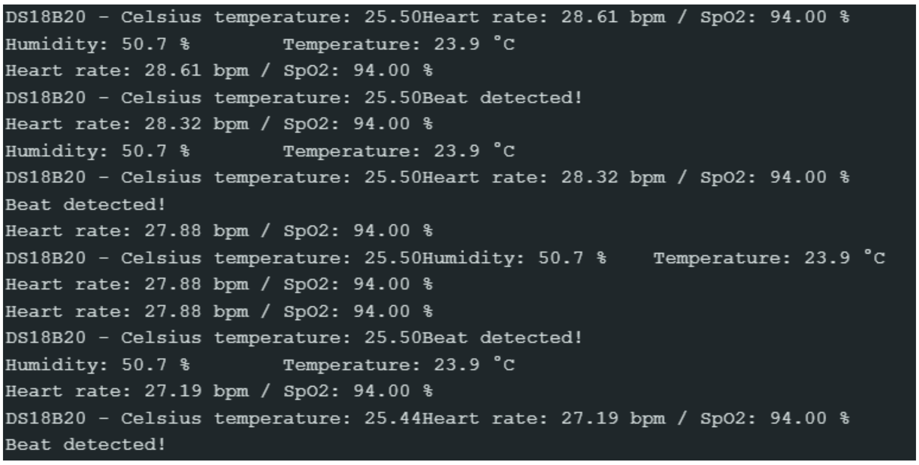


FIGURE 3. webpage display



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DS18B20 - Celsius temperature: 25.50Heart rate: 28.61 bpm / SpO2: 94.00 %
Humidity: 50.7 %        Temperature: 23.9 °C
Heart rate: 28.61 bpm / SpO2: 94.00 %
DS18B20 - Celsius temperature: 25.50Beat detected!
Heart rate: 28.32 bpm / SpO2: 94.00 %
Humidity: 50.7 %        Temperature: 23.9 °C
DS18B20 - Celsius temperature: 25.50Heart rate: 28.32 bpm / SpO2: 94.00 %
Beat detected!
Heart rate: 27.88 bpm / SpO2: 94.00 %
DS18B20 - Celsius temperature: 25.50Humidity: 50.7 %    Temperature: 23.9 °C
Heart rate: 27.88 bpm / SpO2: 94.00 %
Heart rate: 27.88 bpm / SpO2: 94.00 %
DS18B20 - Celsius temperature: 25.50Beat detected!
Humidity: 50.7 %        Temperature: 23.9 °C
Heart rate: 27.19 bpm / SpO2: 94.00 %
DS18B20 - Celsius temperature: 25.44Heart rate: 27.19 bpm / SpO2: 94.00 %
Beat detected!
```

FIGURE 4. Serial monitor display

5. DISCUSSION

A workable approach for remote, real-time vital sign monitoring in remote locations is the suggested ESP32-based patient health monitoring system. The system guarantees affordability and scalability by utilizing open-source platforms and cost-effective components, which makes it appropriate for implementation in specialized wards and home care. Timely interventions during crucial health events are made possible by the smooth communication between patients and healthcare providers made possible by the combination of web and mobile applications. Hypoxemia, tachycardia, fever, and hypothermia can be identified thanks to the system's capacity to track vital signs such body temperature, heart rate, and SpO_2. By ensuring that medical personnel are promptly notified of any deviations from normal ranges, the warning mechanisms—which include smartphone notifications and web pop-ups—improve patient safety.
Nevertheless, there are drawbacks to the existing implementation. Reliance on Wi-Fi connectivity could be problematic in places where internet availability is erratic. Furthermore, only a small number of vital signs are currently monitored by the system. The system's usefulness could be further increased by adding data analytics and broadening the scope of monitored metrics.[19]

6. CONCLUSION

The ESP32 microcontroller is used in this study to create an inexpensive, Internet of Things-based patient health monitoring system. Key vital indicators are efficiently measured by the system, which also offers real-time data display via mobile and web interfaces. It is a promising option for remote health monitoring because of its low cost, portability, and simplicity of deployment, especially in distant areas. The alert systems guarantee prompt medical attention, which could enhance patient results.

Future Work:
Future enhancements to the system may include:
- **Expanded Sensor Integration**: Incorporating additional sensors to monitor parameters such as blood pressure, respiratory rate, and ECG for comprehensive health assessment.
- **Data Analytics and Machine Learning**: Implementing algorithms to analyze trends and predict potential health issues, facilitating proactive care.[20]
- **Cloud Connectivity**: Storing patient data on cloud platforms to enable remote access and long-term health tracking.
- **Enhanced Connectivity Options**: Integrating alternative communication modules like GSM or LoRa to ensure reliable data transmission in areas with limited Wi-Fi coverage.
- **User Interface Improvements**: Developing more intuitive interfaces for both patients and healthcare providers to enhance user experience.

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