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IoT-Based ICU Patient Monitoring System

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Abstract: *In today's rapidly evolving healthcare environment, the ability to continuously and remotely monitor patients' vital signs is essential, especially in rural or non-clinical settings where traditional monitoring methods fall short. To tackle this challenge, our project presents a smart, IoT-based health monitoring system designed to provide real-time tracking of patients' physiological data and support timely medical intervention.*

The system is built around the NodeMCU microcontroller, which handles data collection and wireless transmission. It is integrated with key biomedical sensors such as the DS18B20 (temperature), MAX30102 (heartbeat and oxygen saturation), and an ECG sensor for capturing heart activity. These components work together to deliver consistent, live updates on patient health indicators like body temperature, pulse rate, and cardiac rhythms.

Collected data is transmitted in real-time to the ThingSpeak IoT platform via the ESP8266 module, enabling healthcare professionals to access organized and visualized patient metrics remotely through a secure online dashboard. To further enhance emergency responsiveness, the system incorporates a GSM module (SIM800L/SIM900A), which sends SMS alerts to medical personnel or caregivers when critical deviations in patient data are detected, making it reliable even in areas with limited internet access.

This adaptable and scalable solution is suited for deployment in various healthcare contexts, including hospitals, rural clinics, elder care, telehealth services, and post-operative monitoring. By enabling continuous, remote health tracking, the system promotes proactive care, reduces unnecessary hospital visits, and supports more efficient use of healthcare resources.

Keywords: *healthcare environment*

I. INTRODUCTION

In today's fast-paced healthcare environment, there is a growing demand for systems that can continuously monitor patients without the need for constant physical supervision. Our project introduces an IoT-based remote patient monitoring system designed to track vital parameters such as body temperature, heart rate, and ECG in real time. Built using the NodeMCU microcontroller and integrated biomedical sensors, the system transmits live data to a cloud platform, allowing healthcare providers to access patient information remotely. Additionally, a GSM module ensures that emergency alerts are sent via SMS when abnormal readings are detected, making it highly suitable for rural or low-connectivity areas. This scalable solution aims to improve the quality of care, support timely medical interventions, and reduce the burden on healthcare infrastructure.

II. METHODOLOGY

The development of the IoT-Based Real-Time Remote Patient Monitoring System follows a modular and layered approach, ensuring accurate data acquisition, reliable transmission, and effective alert management. The first step involves setting up the hardware infrastructure. The NodeMCU (ESP8266), a low-power, Wi-Fi-enabled microcontroller, acts as the core processing unit. It interfaces with various biomedical sensors, including the DS18B20 temperature sensor, the MAX30102 for measuring heart rate and blood oxygen levels, and an ECG sensor for monitoring electrical heart activity. Each sensor is calibrated and connected to specific GPIO pins of the NodeMCU using jumper wires, ensuring secure and stable connections for real-time data flow.

The DS18B20 temperature sensor operates on a single-wire digital protocol, making it efficient for real-time temperature monitoring. It measures body temperature with a high degree of accuracy and sends the data to the NodeMCU at regular intervals. The MAX30102, which uses infrared and red LEDs, detects variations in blood flow to calculate both pulse rate and oxygen saturation (SpO_2). The ECG sensor, often based on the AD8232 chipset, is used to capture the electrical signals generated by the heart. This sensor provides an analog output, which is filtered and converted into readable waveforms for cardiac analysis. The integration of these sensors provides a holistic view of a patient's vital health status.

Once the data is gathered from all sensors, the NodeMCU processes it internally. Threshold values for each parameter are predefined in the firmware, which is uploaded via the Arduino IDE. These thresholds help in determining whether the current readings are within normal health ranges. If any value exceeds the safe limit—such as a high temperature, rapid pulse rate, or irregular heartbeat—the system flags the condition as critical. At this point, the GSM module (SIM800L or SIM900A), which is connected to the NodeMCU through UART serial communication, is triggered to send SMS alerts. These alerts are sent instantly to caregivers, medical staff, or family members, notifying them about the specific abnormality detected.

In parallel with alert generation, the system performs real-time data transmission to the cloud. Using the Wi-Fi capabilities of the ESP8266, the NodeMCU uploads all sensor data to the ThingSpeak IoT platform. ThingSpeak acts as a central cloud storage and visualization service, where each sensor's data is plotted on dynamic graphs in real time. The ThingSpeak API allows secure and organized data storage in separate channels, each associated with a particular sensor. Through a custom web dashboard, healthcare professionals can log in from any device to monitor patient health status from anywhere. This ensures flexibility and quick access to critical health data for timely interventions.

To maintain continuous monitoring, the system runs in a loop, performing sensor readings, data analysis, cloud updates, and emergency checks in real time. The firmware code is designed to minimize latency and optimize performance, ensuring that there are no significant delays between reading acquisition and alert transmission. A feedback mechanism is implemented to check for failed transmissions, enabling the system to retry sending alerts if needed. This fault-tolerant design is especially crucial for emergency scenarios where delayed notifications can result in serious health risks. The overall process is automated, eliminating the need for manual oversight and enabling continuous patient surveillance 24/7.

Furthermore, the system is built with scalability and flexibility in mind. Additional sensors like blood pressure monitors, motion detectors, or glucose sensors can be integrated into the existing framework with minimal code changes. The modular nature of the hardware setup makes it easy to customize the system based on patient needs. The project is ideal for various applications, including ICUs, post-operative care, elderly health monitoring, rural clinics, and home-based care. With future upgrades, features like wearable integration, AI-based health prediction, and EHR connectivity can further enhance its utility, making this system a smart step forward in the future of telehealth and digital healthcare.

III. LITERATURE SURVEY

The paper titled "IoT based Transformer Health Monitoring System" presents a comprehensive approach towards enhancing the reliability and efficiency of distribution transformers through continuous monitoring using IoT (Internet of Things) technology. The authors emphasize the critical role of distribution transformers in electrical power systems and the need for constant monitoring to ensure their optimal performance. The paper addresses common issues such as overloading, oil leakages, overheating, and overcurrent faults that can lead to transformer failures and proposes a solution based on IoT for real-time monitoring and fault detection. The introduction section provides a background on distribution transformers, highlighting their significance in electrical networks and the challenges associated with their maintenance and monitoring. The authors stress the importance of proactive measures to detect faults and prevent critical failures, underscoring the role of real-time monitoring systems in achieving this goal. The methodology section outlines the proposed approach for transformer health monitoring using IoT devices and sensors. The paper describes the components utilized in the monitoring system, including Arduino microcontrollers, temperature sensors, current sensors, voltage sensing devices, and IoT modules such as ESP8266. The methodology involves collecting data from

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various sensors, processing it using microcontrollers, and transmitting it to a centralized server for analysis and storage. A key aspect of the proposed system is its ability to monitor critical parameters such as oil level, temperature, and current in real-time, enabling early detection of potential faults or abnormalities. The paper discusses the functionality of each sensor and device employed in the monitoring system, highlighting their roles in capturing relevant data for transformer health assessment. The conclusion section summarizes the benefits of the IoT-based monitoring system, emphasizing its superiority over manual monitoring methods in terms of efficiency, reliability, and timeliness. The authors assert that the proposed system enables utilities to proactively identify and address issues before they escalate into critical failures, thereby improving the overall reliability and performance of distribution transformers. The future work section suggests potential avenues for further research and development, such as expanding the monitoring system to include additional parameters or integrating advanced analytics for predictive maintenance. The authors emphasize the importance of continuously monitoring transformer performance and leveraging data analytics to enhance decision-making processes in power utilities.

Block Diagram:

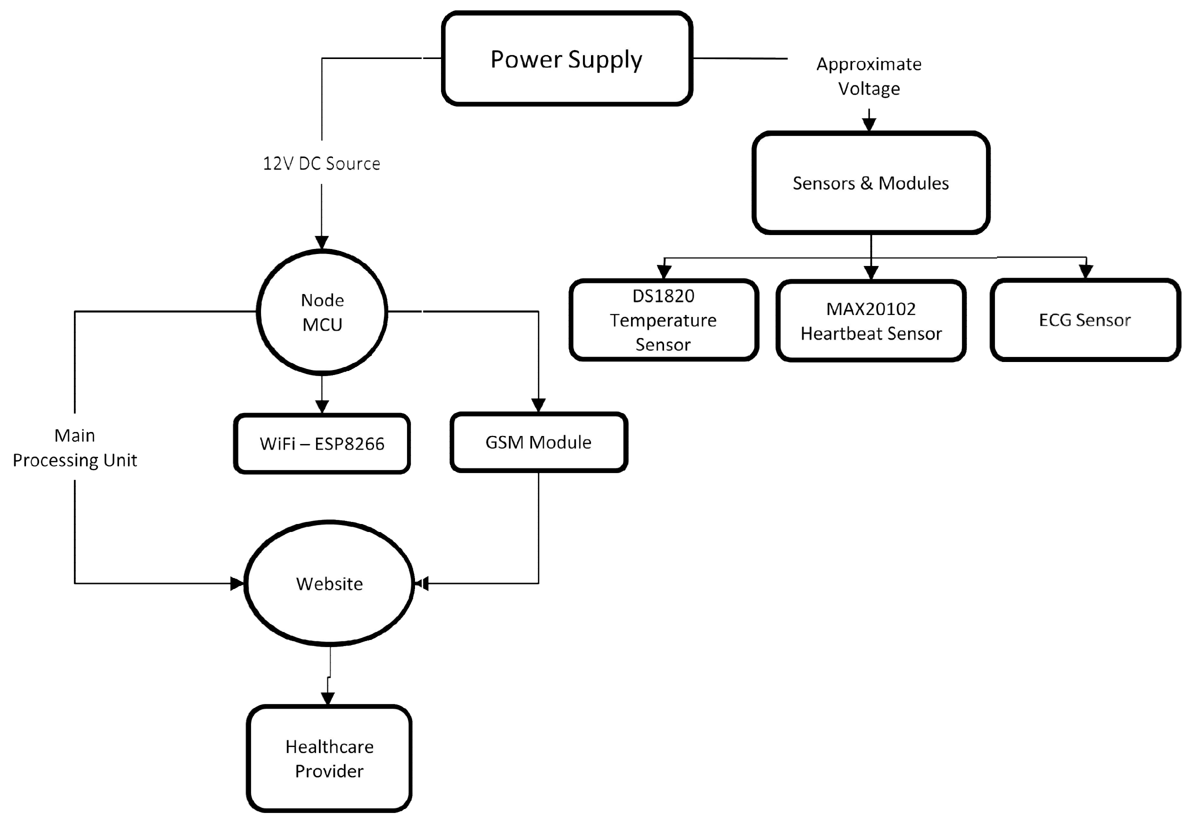

Figure No 1. Block Diagram of IoT-Based ICU Patient Monitoring System

IV. RESULTS

The developed prototype of the IoT-Based Real-Time Remote Patient Monitoring System is shown in the figure below. The hardware implementation includes the NodeMCU (ESP8266) microcontroller, DS18B20 temperature sensor, MAX30102 heart rate and SpO_2 sensor, ECG sensor, GSM module, and supporting components mounted on a single-board setup.

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In this implementation :

- The DS18B20 sensor accurately measures body temperature and provides digital readings to the microcontroller.
- The MAX30102 sensor monitors heart rate and oxygen saturation using infrared and red LEDs.
- The ECG sensor captures cardiac activity, which is processed and displayed as waveform data.
- The NodeMCU (ESP8266) handles real-time data processing and transmits the collected vitals
- The GSM module is used to send SMS alerts when the system detects abnormal readings or critical health deviations.

This real-time demonstration verifies the seamless functioning of data acquisition, transmission, and emergency alerting. The system consistently monitored patient vitals, sent timely alerts, and displayed health data on a web-based dashboard. It proved to be accurate, reliable, and well-suited for use in hospitals, home healthcare, and remote monitoring scenarios.

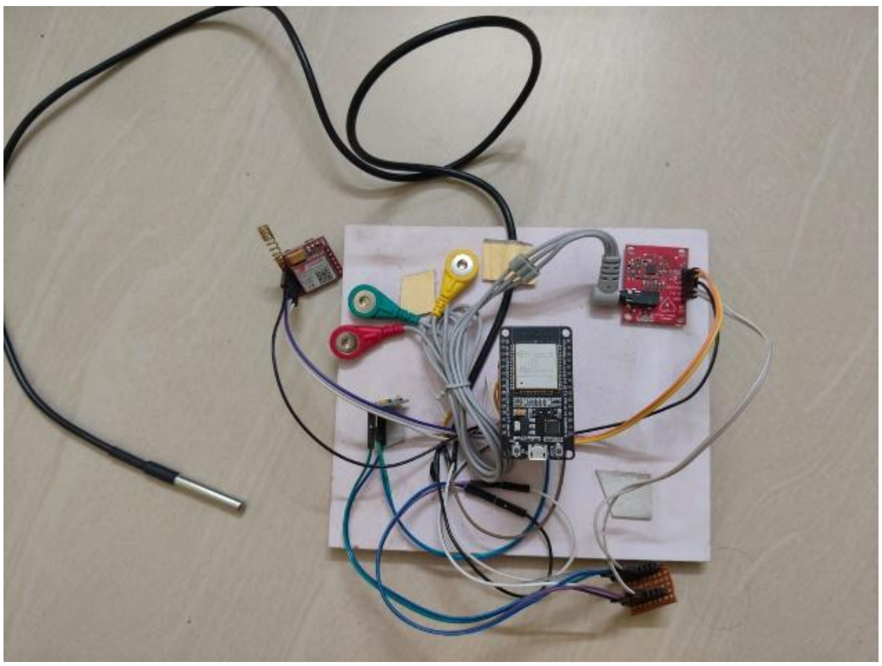

Figure no.2: Working prototype of the ignition system

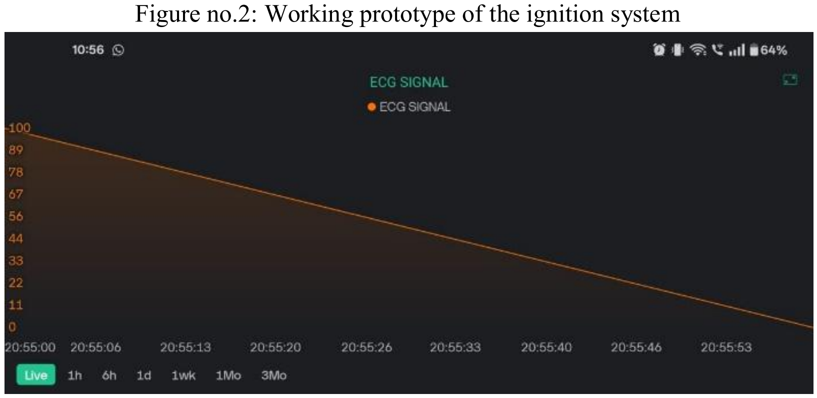

Figure no.3: ECG Signal

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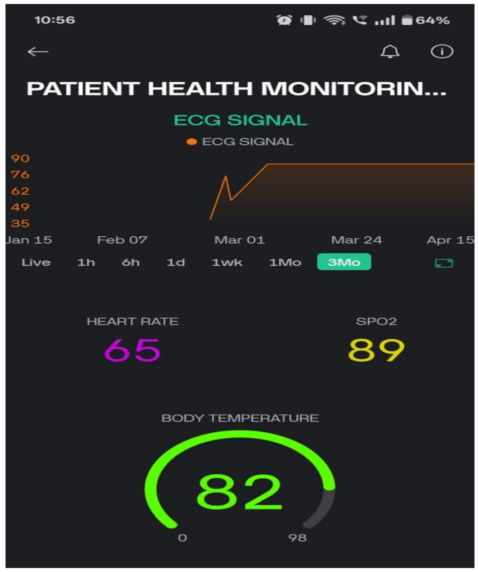

Figure no.2: Mobile Application Interface

V. CONCLUSION

The IoT-Based Real-Time Remote Patient Monitoring System offers an innovative and practical approach to continuous healthcare monitoring, effectively addressing the shortcomings of conventional methods. Utilizing the NodeMCU (ESP8266) microcontroller in combination with biomedical sensors such as the DS18B20, MAX30102, and ECG sensor, the system efficiently captures and processes vital health data. The real-time transmission of this information to a cloud-based dashboard enables healthcare providers to access patient metrics remotely, supporting timely and informed medical decisions.

By incorporating GSM-based emergency alerts, the system ensures immediate communication during critical health events, even in regions with limited internet connectivity. This feature enhances patient safety by facilitating quick responses. Overall, the project not only improves the accessibility and reliability of health monitoring but also promotes proactive healthcare management for both patients and caregivers. Its scalable design makes it suitable for various settings—from hospitals to remote home care—marking a step forward in the advancement of smart healthcare solutions.

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