An Integrated Intravenous (IV), Temperature, and Heart Rate Monitoring System for Healthcare Applications

Vigneswara Rao Gannapathy[*1], Ahamed Fayeez Tuani Ibrahim[2], Mazran Esro[3], Siti Aisyah Anas[4], Yogan Jaya Kumar[5], Siva Kumar Subramaniam[6]

[1,2,3,4]Fakulti Teknologi dan Kejuruteraan Elektronik dan Komputer, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, 76100 Melaka, Malaysia.

[5]Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, 76100 Melaka, Malaysia.

[6]School of Engineering and Built Environment, College of Business, Technology and Engineering, Sheffield Hallam University, Sheffield S1 1WB, United Kingdom.

***Corresponding Author**

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ABSTRACT

This study presents the development of an ESP32-based Internet of Things (IoT) system for integrated monitoring of intravenous (IV) fluid levels, room temperature, and heart rate. The system incorporates a load cell, DHT22 sensor, and heart rate sensor to enable real-time data acquisition and wireless transmission. Collected data are displayed on an LCD and transmitted to the Blynk application, with automated alerts activated when IV fluid levels drop below a predefined threshold or when abnormal physiological readings are detected. Experimental validation demonstrates consistent performance in real-time monitoring and notification delivery, reducing reliance on manual observation and minimizing potential errors. The findings indicate that the proposed system provides a reliable framework for enhancing patient monitoring efficiency and supporting timely clinical decision-making in healthcare environments.

Keywords: Internet of Things (IoT), ESP32 microcontroller, Intravenous (IV) fluid monitoring, Real-time patient monitoring, Biomedical sensors, Healthcare automation

INTRODUCTION

Intravenous (IV) therapy remains one of the most common and essential procedures in modern healthcare, playing a vital role in the administration of fluids, medications, and nutrients to patients. Accurate regulation of IV infusion is critical, as deviations in fluid balance may lead to severe complications such as dehydration, overhydration, or incorrect drug dosage. Traditional manual monitoring methods, however, are prone to human error and often require continuous supervision by healthcare providers. These limitations present significant challenges, particularly in high-dependency environments such as intensive care units (ICUs), where real-time and precise monitoring of patient conditions is crucial.

Recent advancements in the Internet of Things (IoT) and embedded systems have enabled the design of intelligent healthcare solutions that automate monitoring tasks and support clinical decision-making. IV drip monitoring systems, for instance, are increasingly enhanced with sensors that track infusion rates, detect anomalies such as air bubbles or occlusions, and alert medical staff for timely intervention. Beyond fluid monitoring, integrating physiological and environmental parameters such as heart rate and room temperature offers a more comprehensive perspective of patient health, further strengthening safety and efficiency in healthcare operations.

In response to these challenges, this study presents the development of an integrated intravenous (IV), room temperature, and heart rate monitoring system based on ESP32 microcontroller technology. The system incorporates a heart rate sensor, DHT22 temperature and humidity sensor, and load cell amplifier for IV bag weight measurement, with outputs displayed on an LCD screen and transmitted via IoT platforms. Automated alerts are generated whenever IV fluid levels drop below a predefined threshold or when abnormal physiological readings are detected, enabling timely responses by healthcare professionals.

The primary objectives of this study are: (i) to enhance traditional IV fluid administration by integrating continuous monitoring of heart rate and room temperature, and (ii) to automate the monitoring process while providing instant alerts to doctors or nurses, thereby improving patient safety and reducing reliance on manual supervision. The scope of the system extends beyond basic monitoring, envisioning future integration with electronic medical records, wearable technologies, and intelligent frameworks driven by artificial intelligence (AI) and machine learning (ML). These advancements aim to strengthen clinical decision-making, improve patient outcomes, and optimize resource utilization in healthcare settings.

BACKGROUND STUDIES

This section examines key findings and insights from prior studies relevant to the development of an integrated intravenous (IV), room temperature, and heart rate monitoring system. It begins with a discussion on the use of integrated IV systems in healthcare applications, particularly during the COVID-19 pandemic. This area of research is significant as it aligns with the primary goal of this project. The section then explores the concept of integrated IV systems, highlighting their principles and relevance to the project's objectives. Furthermore, it considers the application of IV monitoring in healthcare using the ESP32 microcontroller, emphasizing its role in enabling real-time monitoring and improving patient care.

During the COVID-19 pandemic, intravenous therapy emerged as a pivotal element in the treatment of patients with severe symptoms. It served as the primary means of administering fluids, electrolytes, and medications for those requiring intensive care. This route of administration ensured rapid delivery of antivirals, corticosteroids, and antibiotics, in addition to supporting hydration and nutrition in patients unable to consume orally due to illness or intubation. Total parenteral nutrition (TPN) was particularly critical for individuals with extended ICU stays and gastrointestinal complications.

Previous studies [1], [2], [3], [4], [5] highlight that IV monitoring played a significant role in managing critically ill COVID-19 patients. Continuous measurement of hemodynamic parameters, such as blood pressure, heart rate, and oxygen saturation, enabled healthcare providers to identify early clinical deterioration. Fluctuations in fluid status or hemodynamic instability signaled the need for immediate adjustment in fluid therapy, vasopressor administration, or mechanical ventilation strategies.

Healthcare applications that incorporate the monitoring of temperature, heart rate, and IV bag status are essential in improving treatment efficiency, particularly for COVID-19 cases. These systems enable timely administration of fluids, medications, and supportive therapies, reducing the likelihood of complications. According to [6], the integration of such monitoring technologies has proven to be highly beneficial in supporting decision-making processes in patient management.

Temperature monitoring plays a fundamental role in the early identification of COVID-19 cases, as fever is one of the primary symptoms of the infection. Continuous temperature tracking enables healthcare providers to detect abnormal readings quickly, ensuring prompt initiation of isolation and testing protocols to minimize the risk of transmission. Beyond its role in diagnosis, this approach also facilitates ongoing evaluation of hospitalized patients by allowing clinicians to follow the progression of the disease through temperature trends.

Research has emphasized that continuous monitoring supports timely medical interventions and helps identify worsening symptoms or complications [2], [6], [8]. Other works [6], [7] have also shown that temperature fluctuations can reflect disease progression and highlight potential deterioration. Moreover, monitoring temperature provides a reliable means of evaluating treatment effectiveness, as consistent changes in patient temperature patterns indicate whether therapies are achieving their intended effects [6], [8], [9].

Heart rate monitoring provides vital information on cardiovascular function and overall patient health, which is especially important in managing COVID-19 cases. Fluctuations in heart rate often reflect physiological stress and can indicate potential complications such as respiratory distress, sepsis, or myocardial injury. These conditions are frequently observed in severe cases of the disease, making continuous monitoring a key aspect of patient assessment.

Scholars in [6] and [10] reported that elevated heart rates can be early signs of hypoxemia or systemic inflammatory responses. Likewise, continuous tracking enables clinicians to detect abnormalities such as tachycardia or arrhythmias that may arise from viral complications. Studies in [6], [11] further highlight that real-time monitoring allows timely interventions, including oxygen supplementation or vasopressor administration, which improve patient outcomes. In addition, ongoing feedback from heart rate monitoring helps healthcare providers evaluate the effectiveness of treatment and make necessary adjustments promptly [6], [11].

Intravenous therapy is a cornerstone in treating severe COVID-19 patients, ensuring the delivery of fluids, medications, and nutritional support directly into the bloodstream. Accurate monitoring of IV bag status is essential for the safe and efficient administration of therapy, as it prevents complications caused by under-infusion or over-infusion. This includes monitoring infusion rates, medication concentrations, and fluid volumes to maintain correct dosage and treatment schedules.

The importance of precise monitoring has been emphasized in [12] and [13], where real-time IV monitoring was shown to minimize adverse events. Studies further indicated that timely detection of complications, such as occlusions in IV lines or air embolisms, significantly improves treatment safety [13]. Furthermore, IV monitoring reduces the risk of human error in dosage and medication delivery, ensuring consistency in patient care and avoiding critical treatment failures.

The concept of Integrated IV Systems has advanced as a holistic solution for improving intravenous therapy delivery. These systems combine infusion pumps, IV tubing, monitoring sensors, and medication management tools into a unified framework that streamlines treatment processes. Such integration reduces human error, enhances workflow efficiency, and ensures precise and timely delivery of fluids and medications.

As demonstrated in [14], integrated systems provide multiple safety layers through technologies such as barcode-based dose verification and alarm systems that detect complications in real time. Beyond efficiency, integrated IV systems focus on patient-centered care by increasing comfort and ensuring accurate therapy administration. Collectively, these features contribute to better outcomes, improved safety, and standardized healthcare practices.

The ESP32 microcontroller has emerged as a powerful tool for developing IoT-based IV monitoring solutions in healthcare. Its built-in Wi-Fi and Bluetooth features make it particularly suitable for real-time data acquisition, remote control, and integration into smart healthcare systems. Incorporating ESP32 into IV infusion systems not only facilitates data-driven insights but also enhances patient safety through precise control and monitoring.

Studies in [15] confirm that ESP32-based systems provide benefits such as remote monitoring, data logging, alert generation, and integration with Electronic Health Records (EHR). These capabilities contribute to improved treatment precision, enhanced clinical decision-making, and greater operational efficiency in healthcare facilities.

Furthermore, ESP32 enables healthcare providers to monitor IV infusion parameters remotely through connected devices such as smartphones or computers. This allows real-time supervision of infusion rates, fluid volumes, and medication levels, thereby ensuring treatment accuracy. Remote control capabilities further enhance flexibility, allowing clinicians to adjust infusion parameters or respond to anomalies immediately.

Research in [16] highlights that this capability is particularly critical during emergencies, as it allows rapid intervention even when healthcare professionals are not physically present at the bedside. Such functionality reduces delays in treatment and significantly improves patient safety.

The use of ESP32 also supports data logging, where infusion data such as dosage, flow rate, and timestamps are stored for later review. This feature enables longitudinal analysis of patient responses and system performance.

According to [17] and [18], comprehensive data analysis facilitates optimization of treatment protocols and workflow efficiency. For instance, identifying patterns of over-infusion or under-infusion allows providers to refine therapy strategies and minimize resource wastage. Consequently, ESP32 contributes to both personalized treatment and improved healthcare management.

The ESP32 can be programmed to generate alerts whenever anomalies are detected in infusion systems. Parameters such as line occlusion, low fluid levels, or incorrect dosage rates can be monitored continuously, with notifications sent to healthcare providers through mobile applications or local displays.

As demonstrated in [19], such alert systems minimize the likelihood of undetected errors and ensure rapid corrective action. This proactive mechanism is vital for ensuring uninterrupted and safe IV therapy.

Integrating IV monitoring data with EHR systems enhances accuracy in documentation and streamlines patient management. Automatic recording of infusion data ensures that vital information, such as medication dose and infusion duration, is readily accessible in the patient's medical record.

Studies in [20] indicate that EHR integration promotes care continuity, as all members of the healthcare team can access up-to-date treatment information. This improves coordination, reduces human error in manual entry, and enhances treatment planning.

Incorporating ESP32 into IV systems ultimately enhances both safety and comfort for patients. Remote supervision ensures that infusion errors are minimized, while real-time alerts provide confidence that treatments are being carefully managed.

According to [21], such technologies not only prevent complications such as over-infusion but also optimize patient experiences by reducing unnecessary interruptions and improving overall reliability of care.

During the COVID-19 pandemic, IV therapy proved indispensable in managing critically ill patients, particularly those in intensive care units. Continuous monitoring of temperature, heart rate, and IV bag status was essential in guiding treatment and preventing complications. The integration of IoT-enabled systems, particularly those leveraging ESP32 microcontrollers, introduced new possibilities in healthcare delivery through remote monitoring, automated alerts, and integration with electronic records. Collectively, these advancements enhance patient safety, improve treatment efficiency, and reduce the risk of human error, thereby supporting better clinical outcomes and more effective resource management.

Previous works have demonstrated the effectiveness of integrating IoT and smart technologies for continuous monitoring and timely alerts in different application domains [22], [23].

SYSTEM DEVELOPMENT

This section presents the methodology adopted in the development of the integrated intravenous (IV), temperature, and heart rate monitoring system using ESP32 for healthcare applications. The methodology encompasses both hardware and software design components that collectively support the system's functionality. The development process was structured to ensure systematic progression from problem identification to system implementation and testing. The workflow begins with requirement analysis, followed by system design, hardware integration, software programming, and finally, validation of system performance. By outlining these steps, the methodology provides a clear framework that guided the project throughout its duration.

The flowchart as shown in Figure 1 describes the process of a patient health monitoring system using sensors and an ESP32 microcontroller. The process begins when the system detects signals from the sensors. These sensors check key patient health parameters such as the intravenous (IV) fluid level, heart rate, and room temperature. The collected sensor values are then processed by the ESP32 microcontroller.

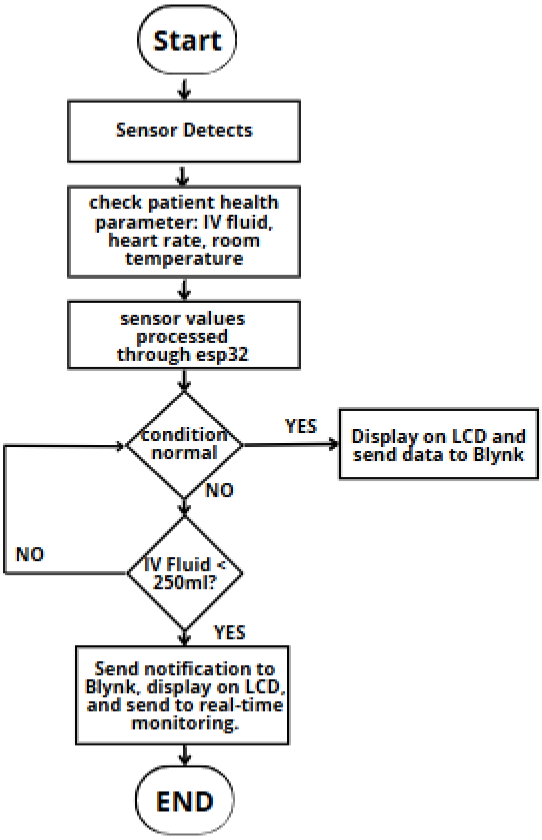

Figure 1: System Flowchart

Next, the system evaluates the processed data. If the patient's condition is normal, the information is displayed on an LCD screen and simultaneously sent to the Blynk platform for remote monitoring. However, if the condition is not normal, the system further checks whether the IV fluid level has dropped below 250 ml. If the IV fluid level is not below this threshold, the system continues monitoring without triggering alerts. If the IV fluid level falls below 250 ml, the system immediately sends a notification through Blynk, displays the alert on the LCD, and forwards the information to real-time monitoring, ensuring that healthcare staff are informed promptly. In summary, this flowchart illustrates an automated monitoring and alert system that ensures patient health parameters are continuously tracked, with instant notifications provided in abnormal or critical situations.

Schematic Diagram

This system is designed to monitor a patient's pulse rate, room temperature, and IV fluid weight in real time, with the results displayed on a 16x2 LCD screen. All components are controlled and coordinated by the ESP32 microcontroller, which serves as the central processing unit of the system.

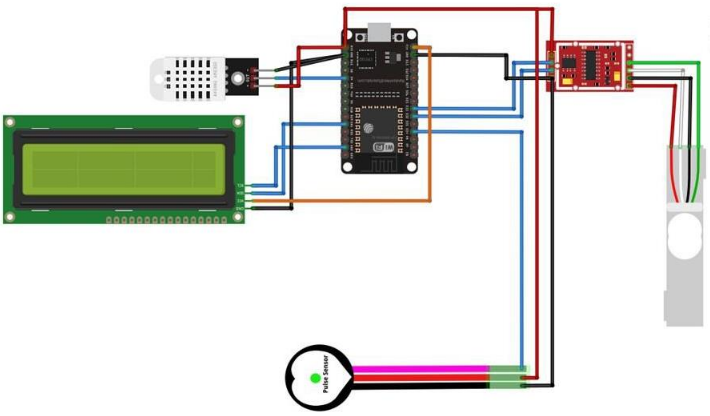

Figure 2: Schematic Diagram of the System

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The pulse sensor detects heartbeats by capturing changes in blood flow, typically from the finger or wrist. As shown in Figure 2, it consists of three connections: power (red), ground (black), and signal output (green). The signal is transmitted to an analog input pin of the ESP32, where it is processed to calculate the heart rate. To monitor environmental conditions, a DHT22 sensor is integrated to measure both temperature and humidity. It includes three connections: power (red), ground (black), and a data output (yellow), which delivers digital readings directly to the ESP32.

For visual output, the 16x2 LCD display presents real-time values of pulse rate, temperature, and IV fluid weight. The display is interfaced with the ESP32 using four data lines (green, blue, yellow, and orange), each connected to designated digital pins. The IV fluid weight is measured using a load cell paired with an HX711 amplifier. The load cell has power (red), ground (black), and dual signal outputs (green and white), while the HX711 converts the analog signal into digital data readable by the ESP32. When the IV fluid level drops below a predefined threshold, the system generates alerts to notify healthcare providers.

The ESP32 is powered via its Vin pin, supporting both USB and external supply options. It collects input data from all sensors, processes the readings, and outputs the results to the LCD in real time. Additionally, the system transmits processed information via Wi-Fi or Bluetooth to a cloud platform, where a dedicated Blynk application displays vital signs and issues notifications when abnormalities are detected.

By integrating IV fluid monitoring, temperature sensing, and heart rate tracking into a single platform, the system provides healthcare professionals with critical information in a clear and accessible format. This unified approach enhances patient safety, supports early detection of abnormalities, and enables remote access to patient data, thereby strengthening clinical decision-making and promoting more efficient healthcare delivery.

System Composition

ESP32 Microcontroller

Figure 3: ESP32 Microcontroller

The core of the proposed system is the ESP32 microcontroller, selected for its affordability, processing capability, and integrated Wi-Fi/Bluetooth connectivity, making it well suited for IoT-based healthcare applications. The ESP32 interfaces with multiple sensors to acquire patient data in real time. A load cell coupled with an HX711 amplifier is employed to measure the weight of the IV bag, ensuring accurate tracking of fluid volume. A DHT22 temperature and humidity sensor monitors the surrounding environment, while a pulse sensor captures variations in blood flow to determine the patient’s heart rate.

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The ESP32 is programmed using the Arduino IDE and functions as the central processing unit. It acquires sensor readings through analog and digital interfaces, processes the data, and transmits the results via Wi-Fi or Bluetooth to a cloud platform or mobile application. A 16x2 LCD display is incorporated to provide immediate on-site feedback by presenting real-time values of IV fluid weight, heart rate, and temperature.

Collected data is not only displayed locally but also synchronized with the Blynk application, enabling remote monitoring and timely alerts. For example, when the IV fluid weight falls below a predefined threshold, the system automatically issues notifications to healthcare providers. The hardware and communication components are tested extensively to validate accuracy, stability, and responsiveness across different operating conditions, ensuring reliable performance in clinical environments.

Heart Rate Sensor

The heart rate sensor is employed to monitor the patient's pulse by detecting physiological changes in blood flow. In this project, a sensor such as the XD-58C is utilized, which operates on the principle of photoplethysmography (PPG). The sensor projects light through the skin and measures the amount of reflected light, which fluctuates in response to variations in blood volume with each heartbeat. These fluctuations enable accurate detection of the cardiac pulse.

Figure 4: Heart Rate Sensor

The sensor is interfaced with the ESP32 microcontroller, which acquires the raw signal, processes it, and computes the patient's heart rate. Processed data is then transmitted to a cloud platform or mobile application via Wi-Fi or Bluetooth, enabling healthcare professionals to access and monitor heart rate values in real time.

System testing involves validating the sensor's response to varying heart rates and confirming the stability and accuracy of the measurements under different conditions. Once fully configured, the heart rate sensor operates continuously, delivering real-time monitoring and generating alerts when abnormal patterns or critical thresholds are detected. This functionality supports timely clinical interventions and enhances patient safety.

Temperature and Humidity Sensor (DHT22)

The DHT22 is a digital-output sensor designed to measure both temperature and humidity with high accuracy and reliability. It integrates a capacitive humidity sensor and a thermistor to sense environmental conditions, providing the results as a digital signal through its data pin, thereby eliminating the need for analog-to-digital conversion. The sensor operates on a supply voltage of 3 - 5 V and consumes a maximum of 2.5 mA during measurement, making it suitable for low-power applications. It offers a wide measurement range, with humidity spanning 0–100% and temperature ranging from –40 °C to 80 °C, both with an accuracy of ±0.5 °C.

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Figure 5: DHT22 Temperature Sensor

Due to its precision and ease of integration, the DHT22 has been widely adopted in applications such as remote health monitoring, wearable devices, and home automation systems. Compared to the DHT11, the DHT22 provides superior accuracy and broader measurement ranges, making it a preferred option in projects where precise environmental monitoring is critical. Within this system, the DHT22 enables real-time monitoring of room temperature and humidity, with data transmitted to cloud platforms or displayed locally on the LCD, thereby supporting comprehensive patient monitoring and environmental assessment.

Load Cell Amplifier

The HX711 is a precision 24-bit analog-to-digital converter (ADC) specifically designed for weigh scale and industrial control applications. It is commonly integrated into weighing systems, laboratory instruments, and industrial automation projects that require accurate load measurements.

A load cell functions as a transducer that converts mechanical force (weight) into a minute electrical signal. Since this signal is very weak, it must be amplified before being processed by a microcontroller. The HX711 fulfills this role by amplifying the low-level signal from the load cell and converting it into a digital output.

Figure 6: HX711 Load Cell Amplifier

The HX711 communicates with a microcontroller (e.g., ESP32) via two main pins:

- **DT (Data):** Transfers the digitized weight data.
- **SCK (Clock):** Synchronizes data transmission.

It operates with a supply voltage of **2.6V to 5V**, making it compatible with most microcontrollers.

In practical applications, the HX711 takes raw load cell data, amplifies it, and transmits it digitally for further processing. The microcontroller can then calculate the actual weight and use the data for tasks such as:

- Real-time weight monitoring (e.g., IV bag tracking in healthcare).
- Integration with IoT systems for cloud-based data storage.
- Display on local or remote interfaces.

With its high resolution, stability, and ease of integration, HX711 is widely adopted for projects requiring precise weight and load measurement.

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Load Cell Sensor

A load cell is a transducer (sensor) used to measure force or weight by converting mechanical force into an electrical signal that can be processed by electronic systems such as microcontrollers. They are widely applied in weighing scales, industrial machinery, and load monitoring systems.

Figure 7: Load Cell Sensor

The most common type is the strain gauge load cell, which is built around a metallic structure that undergoes slight deformation when subjected to a load. Strain gauges, attached to the surface of this structure, experience changes in electrical resistance as the metal deforms. This resistance variation is directly proportional to the applied force, enabling accurate measurement of weight or load.

Since the electrical output from strain gauges is very small (in the millivolt range), it must be amplified before further processing. This is typically achieved using an amplifier such as the HX711, which boosts the signal and converts it into a digital form. The amplified data is then transmitted to a microcontroller (e.g., ESP32), which processes the information to calculate the weight and can further use it for control, monitoring, or IoT applications.

Liquid Crystal Display (LCD)

A Liquid Crystal Display (LCD) is a flat-panel display module that utilizes the light-modulating properties of liquid crystals in combination with polarizers to present visual information. Unlike emissive displays, LCDs rely on a backlight or reflector as the light source.

For embedded systems, character-based LCD modules (e.g., 16×2 or 20×4) are widely used to display numerical values, system status, or alert messages. These modules operate by organizing pixels or character segments into a matrix, allowing the microcontroller to control the display output through parallel or serial communication.

In the proposed system, the LCD serves as the primary local user interface, presenting real-time data such as IV fluid weight, patient body temperature, and heart rate. This enables healthcare personnel to monitor critical parameters directly on-site, in addition to cloud-based monitoring.

Figure 8: LCD Display

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Blynk Platform

Blynk is an Internet of Things (IoT) platform that enables remote monitoring and control of hardware devices through mobile applications. It consists of three main components: the mobile app, which provides a customizable user interface; the Blynk Cloud, which handles secure data transmission; and the Blynk libraries, which allow microcontrollers such as the ESP32 to communicate with the platform.

In the proposed system, Blynk is integrated with the ESP32 to display patient data including IV fluid weight, room temperature, and heart rate in real time on a mobile device. The platform also provides alert notifications if parameters exceed predefined thresholds, enabling healthcare personnel to respond promptly. By combining cloud connectivity with an intuitive mobile interface, Blynk enhances the accessibility and usability of the proposed system for healthcare applications.

As a summary, the system employs an ESP32 microcontroller as the central unit, interfaced with a heart rate sensor, a DHT22 temperature and humidity sensor, a load cell with HX711 amplifier for IV fluid measurement, and an LCD display for local data visualization. The ESP32 processes the sensor inputs and transmits the data via Wi-Fi or Bluetooth to the Blynk platform, enabling remote monitoring by healthcare professionals.

Each sensor serves a specific role: the heart rate sensor measures pulse rate, the DHT22 monitors ambient temperature and humidity, and the load cell tracks IV fluid weight. The LCD provides on-site real-time readings, while the Blynk mobile application offers remote access and generates alerts when parameters exceed defined thresholds.

The developed system enhances patient monitoring by automating vital sign tracking, facilitating early detection of abnormalities, and improving accessibility of patient data for healthcare providers.

SYSTEM FUNCTIONALITY

This section presents the evaluation and analysis of the integrated monitoring system for intravenous (IV) bag weight, room temperature, and heart rate, developed on the ESP32 platform for healthcare applications. The system addresses challenges in both hospital and home care environments by enabling real-time data acquisition, local display, and remote access through the Blynk application. The evaluation focuses on the accuracy, reliability, and responsiveness of the system under different operating conditions.

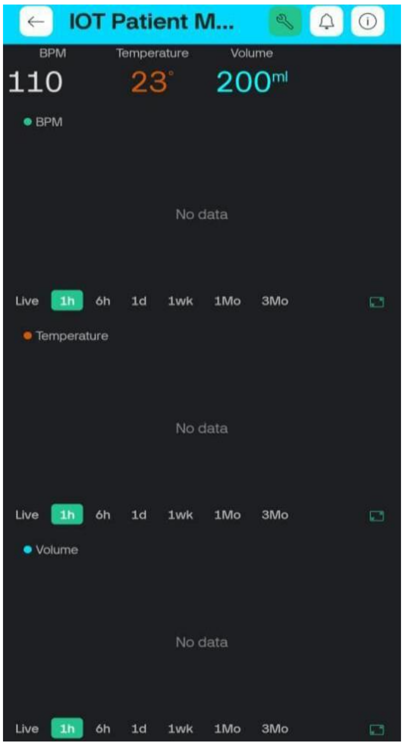

Figure 9: The Blynk Application Layout When Not Connected to Wi-Fi

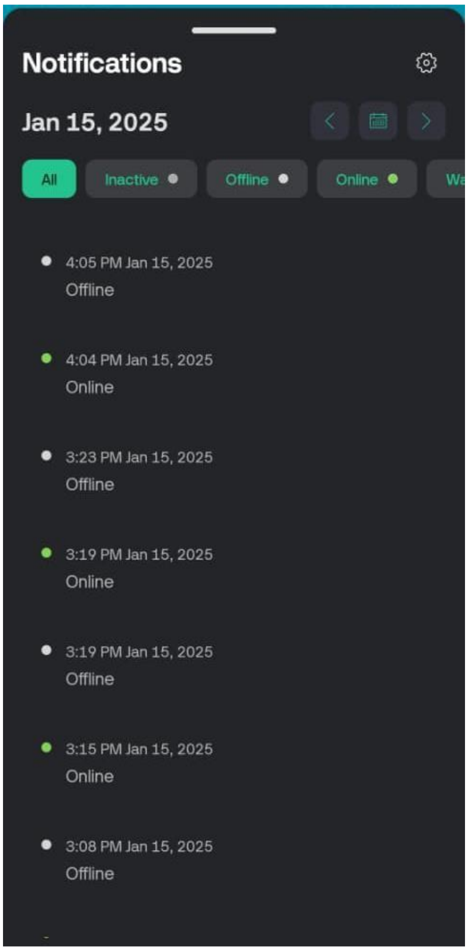

Figure 10: Blynk status in the project, indicating whether it is online or offline

Figure 11: Proposed Hardware

The system's functionality was validated through a case study emphasizing IV bag weight measurement, heart rate monitoring, and room temperature tracking. Data acquisition and transmission were tested using both hardware display (LCD) and the Blynk application.

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Figures 9, 10, and 11 illustrate the hardware and Blynk status when the system is idle or affected by disruptions such as Wi-Fi disconnection or power interruptions. In these scenarios, the Blynk application indicates a “no data” status.

Figure 12 shows a graphical representation of the patient’s vital signs. The heart rate is measured at 76 BPM, which lies within the normal adult range, with minor fluctuations attributable to physiological variations such as activity or stress. The room temperature is recorded at 27 °C, a stable and acceptable condition. The IV bag measurement indicates 166.86 ml remaining from an initial 500 ml volume. Once the volume drops below 250 ml, the system triggers a warning notification via the Blynk application, ensuring timely intervention by healthcare providers.

Figure 13 presents the notification interface of the Blynk application. This alert mechanism provides an early warning for low IV fluid levels, prompting healthcare staff to replace the IV bag without delay, thereby enhancing patient safety and treatment continuity.

Figure 12: Proposed Monitoring (Graph of the patient's vital signs over time).

The results confirm that the integrated monitoring system operates reliably in capturing and transmitting patient data. The ESP32 effectively processes sensor inputs and ensures real-time updates on both the local LCD and the Blynk application. The alert mechanism demonstrated robustness, consistently notifying healthcare providers when IV bag volume fell below the critical threshold.

The heart rate and temperature readings were stable and within expected ranges, validating the accuracy of the sensors under test conditions. Importantly, the system maintained local functionality during Wi-Fi disconnection, thereby reducing the risk of monitoring gaps.

Overall, the system demonstrates strong potential for clinical and home care deployment. It automates routine monitoring tasks, minimizes manual checks, and reduces the workload on healthcare staff. By integrating real-time monitoring, local display, cloud connectivity, and automated alerts, the system improves healthcare efficiency, patient safety, and early detection of critical conditions. However, enhancements such as integrating threshold-based alerts for abnormal heart rate or temperature readings could further improve clinical utility.

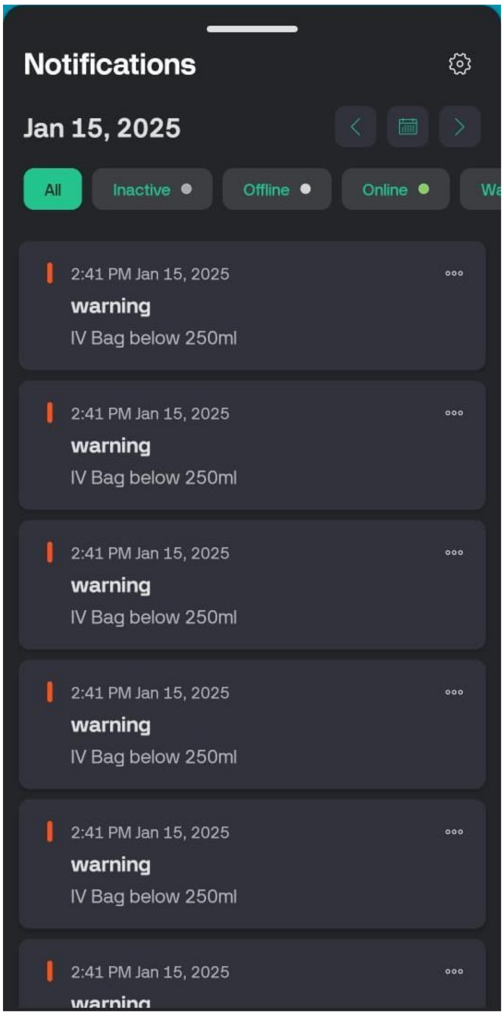

Figure 13: Notification from the Blynk application

COMPARATIVE EVALUATION AND FUTURE ENHANCEMENTS

To strengthen the practical significance of the proposed ESP32-based integrated monitoring system, a comparative evaluation with existing IV monitoring technologies was conducted. Conventional IV systems often depend on manual observation or single-parameter automation, limiting their efficiency in continuous and remote healthcare monitoring. Prior studies such as Rosdi and Huong [16] and Ghosh et al. [19] demonstrated IoT-enabled IV monitoring systems but were restricted to saline level detection and lacked multi-sensor integration. Similarly, Hwang et al. [13] applied deep learning techniques for IV bag monitoring but required complex data processing and infrastructure, which reduced accessibility and scalability in low-resource environments.

The proposed system, advances these designs by integrating three critical monitoring functions, IV bag weight, room temperature, and heart rate, into a single IoT-enabled platform. This multi-sensor integration, powered by the ESP32 microcontroller, provides continuous real-time data acquisition and automated alerts through the Blynk application. The system's design emphasizes low cost, scalability, and immediate responsiveness, making it suitable for both hospital and home-care settings.

The performance of the proposed system was qualitatively validated, demonstrating stable real-time monitoring and reliable alert generation. For future studies, quantitative performance parameters such as data transmission latency, measurement accuracy, and error margins should be incorporated to establish medical-grade reliability and reproducibility.

To enhance practical deployment, security, power, and data management improvements are recommended. The integration of data encryption protocols can secure wireless transmissions and protect patient privacy. A battery backup module can sustain monitoring during power interruptions, ensuring operational continuity. Additionally, implementing cloud-based data storage would enable long-term patient record management, remote analysis, and predictive trend detection using machine learning models.

Moreover, developing a web-based dashboard and analytics interface could improve accessibility for healthcare professionals by providing visual insights into historical trends, anomaly detection, and performance reporting. Drawing from previous research on IoT-based monitoring and reporting frameworks [22], [23], these enhancements could transform the proposed system into a comprehensive smart healthcare solution, bridging real-time monitoring, intelligent analysis, and clinical decision support for modern medical environments.

CONCLUSION

This study has demonstrated the successful design and implementation of an integrated monitoring system for intravenous (IV) bag weight, room temperature, and heart rate using the ESP32 microcontroller. The system addresses critical needs in healthcare by enabling real-time and continuous monitoring of essential patient parameters. Among its key contributions is the development of a cost-effective solution that utilizes readily available sensors, while maintaining accuracy and reliability in operation. The proposed system in this study provides continuous monitoring of IV fluid levels, room temperature, and heart rate, with automated alerts delivered through the Blynk application whenever thresholds, such as low IV fluid levels, are reached. This proactive feature enhances patient safety by identifying potential issues at an early stage, preventing complications, and reducing the workload of healthcare professionals by automating monitoring tasks and providing immediate access to patient data.

Although the system has been tested and proven to function effectively, several areas of improvement can be considered for future development. One direction involves integrating the proposed system with Electronic Health Records (EHRs) to streamline patient data management and improve continuity of care. Incorporating advanced data analytics, such as machine learning techniques, could further enhance the system’s intelligence by predicting potential health risks and supporting personalized treatment plans. Expanding wireless communication options, such as LoRaWAN or NB-IoT, would strengthen coverage and reduce power consumption, especially in remote monitoring applications.

Another improvement is the miniaturization of the system into a wearable design, making it more practical for home-based healthcare. The addition of more sensors, such as blood pressure monitors and pulse oximeters, would provide a more comprehensive overview of patient health.

Finally, developing a web-based dashboard for healthcare professionals could improve the clarity of data presentation and support better clinical decision-making. By pursuing these enhancements, the propoased system has the potential to evolve into a more robust, scalable, and intelligent healthcare monitoring platform, ultimately contributing to improved patient outcomes and greater efficiency in healthcare delivery.

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