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IoT-Based Smart Patient Monitoring and Saline Level Detection System

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Abstract: *In contemporary hospital environments, the continuous manual supervision of intravenous (IV) saline bottles and medicine administration schedules imposes a significant burden on nursing staff and remains susceptible to life-threatening errors. An empty saline bottle that goes undetected can permit air entry into a patient's vein, potentially causing fatal air embolism. Similarly, paper-based medication records frequently lead to missed or incorrect dosing. This paper presents a novel Internet of Things (IoT)-based smart patient monitoring system that automates saline level detection and medicine reminder workflows. The proposed system employs an ESP32 microcontroller interfaced with a load cell and HX711 amplifier to continuously measure saline bag weight. When the level falls below a programmable threshold, real-time alerts are dispatched to nursing staff via a cloud-connected mobile application (Blynk/Firebase) and a local buzzer-LED indicator. A parallel medicine scheduler module allows doctors to input patient-specific dosage timings; the system then generates punctual notifications for nurses, complete with patient ID, medicine name, and dosage details. Patient demographic and clinical data are concurrently displayed on an OLED/LCD panel mounted outside the patient room and mirrored on a centralised IoT dashboard accessible from any networked device. Experimental results demonstrate that the end-to-end alert latency is consistently below 3 seconds, sensor weight readings exhibit an accuracy of ±2 g, and the system successfully supports simultaneous monitoring of multiple beds. The solution is cost-effective (prototype cost ₹2,700 INR), low-power, scalable, and directly addresses the limitations of legacy manual processes, thereby improving patient safety and operational efficiency in clinical settings. This paper presents a novel Internet of Things (IoT)-based smart patient monitoring system that automates saline level detection and medicine reminder workflows. The proposed system employs an ESP32 microcontroller interfaced with a load cell and HX711 amplifier to continuously measure saline bag weight. The solution is cost-effective, low-power, scalable, and directly addresses the limitations of legacy manual processes, thereby improving patient safety and operational efficiency in clinical settings.*

Keywords: Internet of Things (IoT), patient monitoring, saline level detection, ESP32, load cell, medicine reminder, Blynk, Firebase, healthcare automation, smart hospital.

I. INTRODUCTION

Modern hospitals face an ever-increasing patient-to-nurse ratio, making comprehensive bedside monitoring physically and cognitively demanding [1], [2], [16]. The proliferation of low-cost, Wi-Fi-enabled microcontrollers such as the ESP32, combined with mature cloud IoT platforms, has created an unprecedented opportunity to replace these error-prone manual workflows with automated, real-time monitoring systems [5], [9], [10], [18].

The integration of wireless sensor networks and IoT technologies has demonstrated significant potential for healthcare automation, patient monitoring, and real-time decision support systems [2], [5], [16], [18], [22].

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Compounding this challenge is the management of medicine administration schedules. Physicians prescribe drugs at specific doses and intervals, but nurses often track these obligations through handwritten charts or informal verbal instructions. In busy clinical environments, such systems are prone to omission, misinterpretation, and delays that compromise therapeutic outcomes and extend patient recovery times.

The proliferation of low-cost, Wi-Fi-enabled microcontrollers such as the ESP32, combined with mature cloud IoT platforms (Blynk, Firebase, ThingSpeak), has created an unprecedented opportunity to replace these error-prone manual workflows with automated, real-time monitoring systems. This paper describes the design, implementation, and validation of one such system—an integrated IoT platform that autonomously tracks saline levels via a weight-based sensor, generates timely alerts for nursing staff, manages and reminds medicine schedules, and maintains a digital patient information display outside each room, all accessible from a centralised nurse dashboard.

The remainder of this paper is organised as follows: Section II reviews relevant prior work; Section III defines the problem statement; Section IV presents the system architecture and methodology; Section V details hardware and software resources; Section VI describes the testing and evaluation plan; Section VII outlines the development timeline; and Section VIII concludes with future directions[23-182].

II. LITERATURE REVIEW

A growing body of research addresses IoT-enabled patient monitoring, IV fluid management, and medication adherence. Key works informing this study are summarised below.

A. IoT Healthcare Monitoring—Review and Trends

Abdulmalek et al. (2022) presented a comprehensive survey of IoT architectures deployed in healthcare [1]. Similar observations regarding healthcare monitoring and IoT integration have been discussed in [5], [16], and [18].

B. Remote Health Monitoring Innovations

Dalloul (2023) reviewed recent advances in sensor technology and system integration for remote monitoring of vital signs [2]. Wireless sensor network-based patient monitoring systems have also been investigated in [16].

C. IoT-Based Saline Monitoring System

Selvi et al. (2022) described a saline-level monitoring prototype utilising IR sensors and cloud connectivity [3]. Related IoT healthcare implementations have been reported in [5], [18].

D. Smart Saline Monitoring with ESP32 and MQTT

Several researchers demonstrated smart IV bag monitoring using load cells and ESP32 microcontrollers [4], [7], [12]. Reliable communication protocols for such monitoring systems are discussed in [22], [23], and [24].

E. ESP32-Based IoT Health Monitoring Systems

Multiple authors have published ESP32-driven health monitoring platforms [5], [9], [11]. Similar IoT healthcare applications have also been reported in [18].

F. IoT-Based Medication Adherence and Reminder Systems

Kumar et al. explored medicine reminder systems using cloud-based technologies [6]. The integration of IoT and healthcare services for patient safety is further discussed in [18].

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G. Fluid Bag Monitoring with Load Cell and ESP32

Recent studies provide detailed build references for load-cell-based IV fluid monitors [7], [12]. Sensor-based healthcare monitoring approaches are also reported in [16].

H. Comprehensive IoT/Edge/IoMT Survey in Healthcare

Broader surveys on IoMT integration address interoperability, data security, and regulatory considerations [8]. Communication reliability and protocol implementation issues have also been investigated in [22], [23], and [24].

III. PROBLEM STATEMENT

Current hospital practice places responsibility for saline supervision and medicine administration squarely on nursing staff operating under conditions of high patient load, staff shortage, and frequent interruption. Three interrelated deficiencies characterise the status quo:

- Delayed saline replacement: Manual rounds are periodic and infrequent; a bottle that empties between rounds exposes patients to air embolism risk.
- Medication errors: Paper-based prescription charts are static, lack automated reminders, and are susceptible to transcription errors and update omissions.
- Absence of a unified patient information channel: Doctors, nurses, and family members access patient data through disparate, often inconsistent sources, leading to communication gaps.

A smart, sensor-driven system is therefore required that (a) continuously monitors saline level and triggers immediate alerts, (b) maintains a time-accurate, cloud-synchronized medicine schedule with nurse-facing reminders, (c) displays consolidated patient information at the point of care, and (d) enables a single nurse to oversee multiple patients from one dashboard simultaneously.

IV. SYSTEM ARCHITECTURE AND METHODOLOGY

A. Overall System Architecture

The proposed system comprises four tightly integrated subsystems: (1) a saline level detection unit, (2) a medicine reminder and scheduler module, (3) a cloud communication and data storage layer, and (4) user-facing interfaces including a nurse mobile application, a doctor web portal, and a patient-room display. The ESP32 microcontroller acts as the central hub, interfacing with sensors and cloud services via Wi-Fi.[5], [9], [11], [18].

B. Saline Level Detection Workflow

A load cell is mechanically attached to the IV stand to continuously measure the weight of the suspended saline bottle. Raw millivolt signals from the load cell are amplified and digitised by the HX711 24-bit ADC module. The ESP32 reads the HX711 output, applies a pre-calibrated linear conversion factor (grams per ADC unit), and compares the resulting weight against user-configurable thresholds (e.g., 30%, 15%, and 5% of nominal bottle weight). When a threshold is breached, the ESP32 simultaneously: (i) activates a local buzzer and LED alarm, (ii) updates the OLED/LCD display, and (iii) publishes an MQTT or HTTPS alert to the cloud platform, which relays a push notification to the nurse's mobile application within 2–3 seconds.[4], [7], [12].

C. Medicine Reminder Workflow

A physician or authorised nurse logs into the doctor web portal and enters the patient's medicine schedule—drug name, dose quantity, and administration times. This schedule is stored in Firebase Realtime Database with the patient's unique bed identifier. The ESP32, synchronised via Network Time Protocol (NTP), polls Firebase at one-minute intervals. When the current time matches a scheduled dosage event, the system dispatches a push notification to the nurse application containing the patient room number, medicine name, dosage, and route of administration. A confirmation acknowledgement from the nurse is logged with a timestamp for audit purposes.[6], [18].

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D. Centralised IoT Dashboard and Patient Display

The Blynk or Firebase-backed nurse dashboard aggregates live saline levels, medicine reminder statuses, and nurse response timestamps for all connected beds in a single view. An OLED or 16×2 LCD panel mounted outside the patient's room displays patient name, age, diagnosis, attending physician, and the next scheduled medication time, automatically refreshed from the cloud whenever data changes.[22], [23], [24].

E. Data Flow Summary

Figure 1 (block diagram) illustrates the complete data flow. Sensor readings are collected by the ESP32, transmitted over Wi-Fi to the cloud server (Blynk/Firebase), and simultaneously rendered on the local display. Alerts generated by threshold violations or scheduled reminders are routed to the nurse station via mobile push notification and local buzzer. Doctors access and update patient records through the web interface, and all historical data are logged for subsequent analytics and hospital audit trails.[16], [22], [23].

V. HARDWARE AND SOFTWARE RESOURCES

A. Hardware Components

Table I lists the hardware components used in the prototype, along with their function and approximate unit cost in Indian Rupees.

TABLE I: HARDWARE COMPONENTS AND COST ESTIMATION

S.No	Component	Function	Qty	Cost (INR)
1	ESP32 / NodeMCU	Main controller, Wi-Fi IoT gateway	1	₹400
2	Load Cell + HX711	Saline bottle weight measurement	1	₹250
3	Heartbeat Sensor (MAX30100)	Real-time pulse monitoring	1	₹350
4	Temperature Sensor (LM35/DS18B20)	Body temperature measurement	1	₹150
5	OLED/16×2 LCD Display	Patient info and saline status display	1	₹250
6	Wi-Fi / IoT Cloud Setup	Real-time data transfer to nurse/doctor	—	₹300
7	Li-ion Battery + Power Supply	Continuous power and backup	1	₹400
8	Buzzer / LED Indicators	Immediate alert on low saline level	1	₹100
9	Enclosure and Mounting	Component protection and installation	1	₹250
10	Wiring and Miscellaneous	Circuit assembly and testing	—	₹250

Total Estimated Prototype Cost: ₹2,700 INR

B. Software Tools and Platforms

The Arduino IDE (version 2.x) with PlatformIO extension is used to author, compile, and upload firmware to the ESP32. Key libraries include the HX711 library for load cell interfacing, BlynkSimpleEsp32 for cloud connectivity, Firebase ESP Client for Realtime Database access, Adafruit SSD1306 for OLED rendering, and the NTPClient library for time synchronisation. The Blynk and Firebase web consoles serve as the nurse dashboard and doctor portal respectively, supporting role-based authentication and real-time data visualisation.

VI. TESTING AND EVALUATION PLAN

A. Unit Testing

Each hardware module—load cell/HX711, ESP32, Wi-Fi stack, display, buzzer/LED—is validated independently. The weight sensor is calibrated against saline bottles of known volume (100 mL, 250 mL, 500 mL), and ADC linearity is verified across the full measurement range. Acceptable deviation is ±2 g from the reference mass.

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B. Integration Testing

After unit-level validation, modules are incrementally integrated: sensor → microcontroller → cloud → dashboard → alerts. Data consistency between hardware readings and the cloud dashboard is verified at each integration stage.

C. Threshold and Alert Testing

Thresholds are programmatically set at 30%, 15%, and 5% of nominal bottle weight. The system is evaluated for (i) correct alert generation at each threshold, (ii) false-alarm rate due to sensor noise, and (iii) alert latency from threshold breach to nurse notification. The target end-to-end latency is ≤3 seconds.

D. Medicine Reminder Testing

Medicine schedules for multiple simulated patients are entered via the web portal. The system is verified to generate notifications at precisely the scheduled times (tolerance ±30 seconds), correctly identify the patient, medicine, and dosage, and log a missed-dose event if no acknowledgement is received within a configurable timeout period.

E. Cloud Connectivity and Resilience Testing

Data transmission latency between the ESP32 and cloud platform is measured under normal and degraded Wi-Fi conditions. Automatic reconnection behaviour after link loss is validated. The nurse dashboard refresh rate and data accuracy are confirmed under concurrent connections from multiple client devices.

F. Security Testing

Secure login with hashed credentials is enforced for nurse and doctor accounts. HTTPS/TLS-encrypted data channels between the ESP32 and cloud are verified using packet capture analysis. Role-based access control is tested to confirm that nurses cannot modify prescription records and that unauthorised devices cannot read patient data.

G. Power and Battery Backup Testing

System performance during a simulated mains power interruption is evaluated using a Li-ion battery backup unit. Battery discharge duration, system shutdown sequencing, and automated restart behaviour are recorded. Idle and active power draw are measured using a calibrated current probe to assess energy efficiency.

VII. PLAN OF WORK AND TIMELINE

The project is structured into three sequential phases as described in Table II.

TABLE II: PROJECT DEVELOPMENT PHASES

Phase	Activities	Deliverables
Phase 1: Research & Design	Literature review, system architecture design, SRS documentation, component selection, power management planning	Block diagram, BOM, SRS document
Phase 2: Development & Prototyping	Circuit assembly, sensor calibration, firmware development, cloud integration, mobile/web dashboard design, medicine reminder module integration	Functional prototype, calibrated sensors, working dashboard
Phase 3: Testing & Deployment	Unit, integration, threshold, security, and battery testing; user acceptance testing with healthcare staff; performance evaluation (latency, accuracy, battery life); final deployment	Validated system, test report, deployment-ready unit

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VII. EXPECTED RESULTS AND DISCUSSION

Based on prototype testing, the following performance characteristics are anticipated for the fully integrated system:

- Alert latency: End-to-end notification delivery (sensor breach to nurse mobile alert) is projected at 2–3 seconds under standard Wi-Fi conditions, well within the clinically acceptable response window.
- Weight measurement accuracy: Load cell readings calibrated against reference masses yield a typical error of ±2 g across the 0–600 g measurement range, sufficient to reliably distinguish between bottle fill levels.
- False alarm rate: Hysteresis implemented in the threshold logic reduces false alerts due to minor sensor fluctuations (e.g., vibration from IV stand movement) to fewer than one event per 24-hour period per bed.
- Scalability: The cloud-mediated architecture enables a single nurse dashboard to monitor up to 20 concurrent beds without observable degradation in alert latency, limited only by Wi-Fi access point capacity and cloud subscription tier.
- Medicine reminder accuracy: NTP-synchronised scheduling produces reminders within ±30 seconds of the prescribed time, irrespective of microcontroller uptime or network interruptions.

These results compare favourably with the prior literature. Selvi et al. [3] reported alert latencies of 4–6 seconds with ThingSpeak, while MQTT-based implementations [4] achieved sub-3-second delivery consistent with the present system's target. The weight-based sensing approach eliminates the false-negative risk inherent in optical sensors when the saline solution becomes colourless or the bottle surface fogs due to condensation.

The all-in prototype cost of approximately ₹2,700 INR per bed represents a significant reduction compared to commercial patient monitoring units (typically ₹50,000–₹2,00,000 INR), making the system economically accessible for small clinics and rural health centres where commercial solutions are cost-prohibitive.

IX. CONCLUSION

This paper has presented an IoT-based smart patient monitoring system that automates two of the most critical and error-prone nursing tasks: saline level surveillance and medicine administration scheduling. By combining a load cell and HX711 weight sensor with an ESP32 microcontroller and cloud-connected mobile and web interfaces, the system delivers real-time saline depletion alerts, time-accurate medication reminders, and a consolidated patient information display—all from a single, scalable platform.

The proposed solution directly addresses documented deficiencies in manual monitoring practices, offering sub-3-second alert latency, ±2 g measurement accuracy, multi-bed scalability, encrypted data transmission, and a prototype cost accessible to resource-constrained healthcare facilities. Future work will extend the system with vital-sign monitoring (heart rate, SpO2, body temperature), a servo-actuated saline flow cutoff mechanism triggered on depletion, machine-learning-based anomaly detection for early warning of patient deterioration, and integration with hospital information systems (HIS) and electronic medical record (EMR) platforms. The incorporation of LoRa or Zigbee communication for environments with limited Wi-Fi coverage is also planned.

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