Smart IoT-Enabled Saline Monitoring System

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ABSTRACT--Traditional hospital procedures for saline monitoring through manual methods produce frequent human mistakes that present safety threats to patient health. A Smart Saline Monitoring System powered by IoT automatically establishes saline level detection capabilities through continuous alert delivery to nurses before saline bags become empty. The device implements an ESP32 microcontroller alongside a load cell operating with an HX711 amplifier for precise saline measurement. The system uses a TIP122 transistor together with a 12V solenoid plunger to maintain the required saline flow levels. The system sends live data through an IoT dashboard where nurses maintain ongoing visibility for monitoring activities. This system contains a 16x2 LCD display which provides medical staff with instant access to vital system data including saline level measurements and status indicators. Its innovative design creates environments which protect patients while diminishing healthcare professionals' workload and speeding up medical response times to improve modern hospital management systems.

Keywords: ESP32, HX711, Blynk IoT, LCD, Solenoid Plunger, TIP122.

I. INTRODUCTION

Healthcare expenses keep increasing while medical conditions and the number of patients continue to rise. The rising healthcare needs create substantial workload for medical workers which can degrade their ability to deliver proper medical services. IoT-enabled devices show tremendous value in healthcare settings because they automate regular tasks to decrease human workloads. Patients benefit from cost-efficient healthcare because low-cost IoT solutions enable these systems to operate without extra staff addition. The Blynk mobile application represents a user-centric solution which enables medical staff to track several patients without manual strain through its intuitive features.

Regular checks of fluid level within the bottle were necessary. The absence of an immediate bottle replacement creates a pressure distinction that drives blood to enter the empty saline. Bubbles that form on human blood streams result from this process which eventually leads to death. A hospital employee must continuously inspect fluid levels to prevent vacuum pressure changes inside the bottle. The system works poorly during dark hours along with other situations. Through its implementation this system stops fatal air bubbles from entering the human bloodstream. This problem requires a solution through an IoT-based fluid monitoring system. The device transmits status information to host unit interfaces where results become visible. This system recovers patients efficiently. Healthcare sectors stand among the list of users for this technology.

Several works are being done to monitor the saline water level which includes the use of a photodiode based [1] wherein only the predefined levels can be monitored, whereas in Loadcell based approach continuous monitoring of the Saline is possible [2]. Intravenous infusion is one of the most important clinical treatments. The progress and flow rate of intravenous infusion must be strictly controlled to avoid serious medical accidents [3]. Different authors [4, 5] have researched the notification system issue in their publications. The buzzer sound function serves as an alert mechanism to nurses according to the authors [4]. The buzzer sound alert system produces disruptive noises, but hospitals need to operate without sound. The buzzer system lacks capabilities to extend its functionality for telehealth purposes. The SMS messaging system described by the authors in [5] allows notifications to be sent through mobile numbers aimed at nurses. The system utilizes GSM technology according to [6] as an open cellular technology to transmit data services.

II. LITERATURE REVIEW

Different researchers studied how IoT-based saline monitoring could lead to better hospital automation technology and patient protection systems. Two different types of monitoring systems exist which use optical sensors with Wi-Fi connection capabilities [1], The effectiveness of this technology relies on proper lighting during operation or load cells with GSM alerts detection [2]. The available monitoring systems require manual intervention for flow control or experience problems with network reliability [4]. The weight sensor-based monitoring system provides ongoing trackability, yet it needs no automatic changes to saline flow parameters [5].

A sensor-based saline flow control system removed precision limitations yet raised the system costs to an unacceptable level. The integration of cloud-based alerts through GSM and IoT networks for enhanced monitoring exists but depends on reliable network connection according to researchers [6]. A low-cost image processing-based system for rural hospital saline droplet measurement served as an affordability solution [7]. Different research combined automatic saline reversal mechanisms to stop air embolisms during procedures while not providing alert notifications [8].

The cost-effective saline flow control system [9] delivers affordable and simple usability without automated features. A fully automated system featuring single-window control and automatic bottle substitution offers complete automation, but its higher cost and complexity may make it unaffordable for smaller healthcare facilities [10]. Fuzzy logic techniques work with admittance methods to measure real-time water levels with high accuracy, but their implementation and calibration process remains complex to handle [11]. Smart fluid level monitoring systems combine with IoT-based health monitoring capabilities in order to offer expanded functionality by including saline monitoring alongside vital signs tracking yet this expansion might lead to excessive data for users to handle [12, 13].

Research findings highlight the development of sensor-based systems focused on creating user-friendly platforms that deliver real-time notifications. Smart ICU monitoring by [14] connects saline level alerts with intensive care unit vital readings while this system depends on reliable internet access and power source functionality. The combination of IR sensors and load cells with MQTT communication in contactless technology systems [16] increases hygiene and minimizes wear effects while potentially causing accuracy issues in diverse environmental conditions [15]. Two papers titled IRJET Smart Saline [17] and live tracking solutions [18] supply dependable alert capabilities while remaining easy to implement but count on manual saline replacements to achieve full automation. These systems enhance medical safety while decreasing nursing work, but their implementation requires balancing the costs with system refinement and general adoption capabilities.

This paper proposes precise measurement of saline levels occurs through the load cell in our IoT-based smart saline monitoring system that also employs a solenoid plunger to control flow activation. The system delivers online saline substance tracking combined with automatic control features that surpass manual operation and network restriction requirements. The system includes an LCD display for real-time monitoring at the site while Blynk provides remote access to saline level displays and performs time estimations.

III. PROPOSED SYSTEM

The proposed system integrates both a load cell and an ESP32 microcontroller to perform instantaneous data gathering and processing and wireless data transfer. The system design features optimization of power efficiency as well as seamless combination of hardware elements and cloud monitoring capabilities for distant data tracking. The system methodology contains four essential stages including sensor interfacing as well as microcontroller configuration followed by data communication and cloud integration steps. The system hardware involves a saline bottle fixture over a stand having a load cell sensor which uses an HX711 amplifier for accurate weight measurement. The amplified signals fed into the ESP32 microcontroller allow the device to process the information to detect saline trends while implementing automatic actions when specific thresholds are met. Through the system control logic, the solenoid plunger receives automated power supply to perform flow regulation. The system includes an alert system which sends alerts through IoT-enabled interfaces to medical staff about needing their intervention.

This IoT-enabled smart saline monitoring system reduces the dependency on manual saline level checks, enhancing efficiency, safety, and responsiveness in medical settings. The integration of weight-based monitoring with automated control mechanisms ensures optimal resource utilization and timely intervention, making the solution scalable and adaptable for different healthcare scenarios.

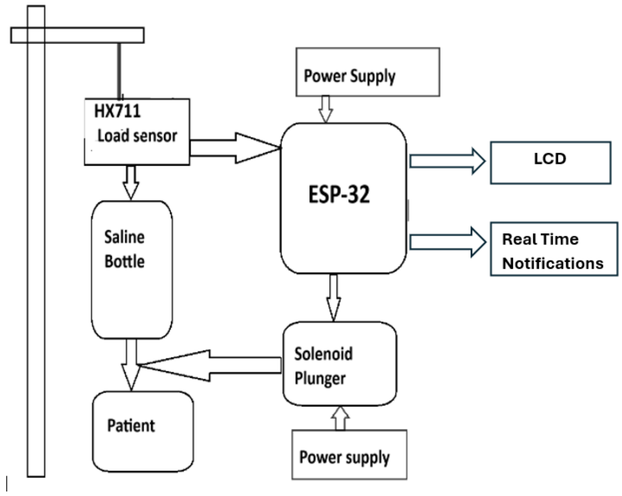

Fig.1. Proposed Block Diagram of the system.

The block diagram of the proposed system is shown in Figure 1. It represents a smart system designed to monitor and manage a patient's saline drip using an ESP-32 microcontroller. At the heart of the setup is a load sensor (HX711) attached to the saline bottle, which continuously measures its weight. As the saline flows to the patient, the sensor detects any drop in weight and sends that data to the ESP-32. The ESP-32 processes this information and takes necessary actions when the saline level becomes critically low. It displays alerts on an LCD screen for nearby medical staff and sends real-time notifications, over Wi-Fi, to ensure remote monitoring.

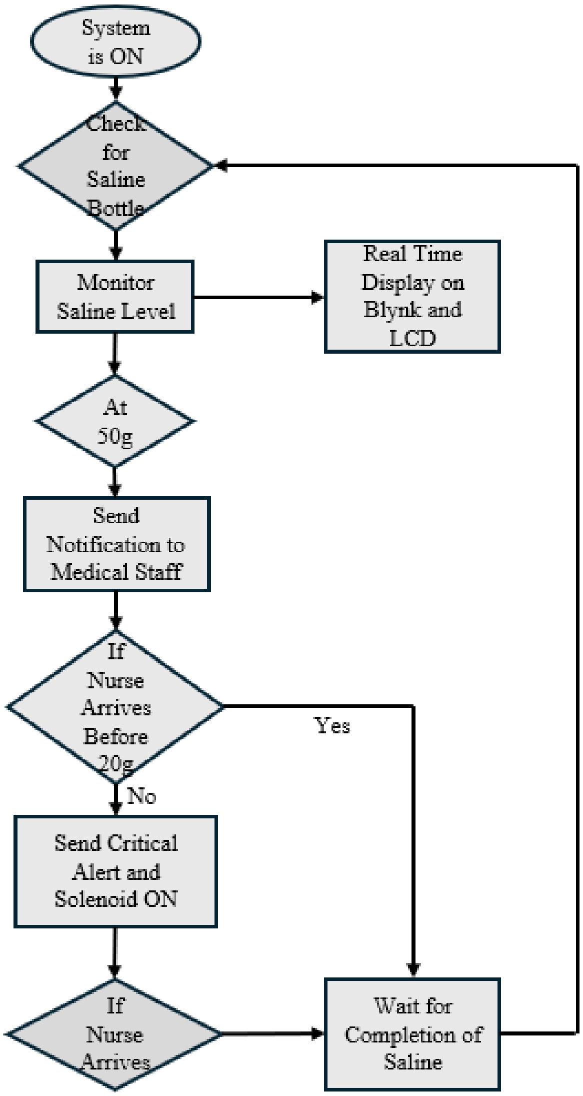

Fig 2 Flow Chart of Proposed System.

The operational flow of the proposed smart saline monitoring system is depicted in Figure 2. The process begins when the system is powered on. Once activated, the system continuously monitors the weight of the saline bottle through the load sensor. This data is simultaneously displayed in real-time on both the LCD screen and the Blynk mobile application for continuous local and remote monitoring.

When the system detects that the saline weight has reached 50g, it triggers a warning notification to the medical staff, prompting timely attention. If the nurse arrives and replaces the bottle before the weight drops to the critical threshold of 20g, normal operation continues without intervention. However, if no action is taken and the weight falls below 20g, the system automatically activates the solenoid plunger to stop the saline flow and sends a critical alert to avoid complications such as air embolism.

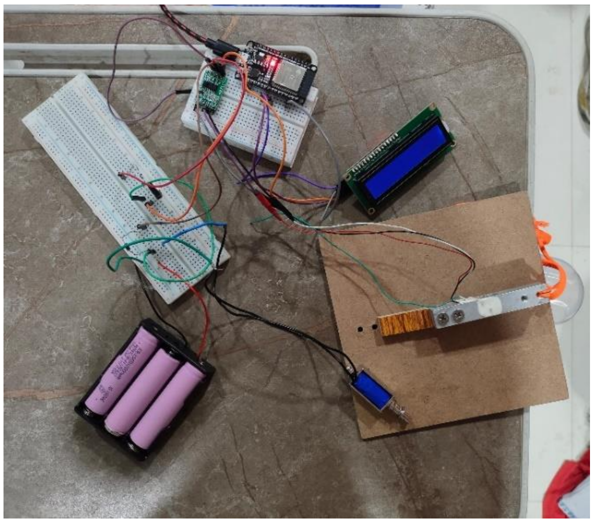

Fig.3. Hardware Prototype

To enable automated saline flow control, the system was programmed to activate a solenoid plunger when the saline weight dropped below 20g. The response time was tested and validated to occur within 1.5 to 2 seconds, ensuring timely intervention. The solenoid activation was further optimized by limiting power supply to two seconds, preventing overheating and ensuring smooth operation. Additionally, the system featured a structured alert mechanism, generating early warnings at 50g and critical intervention alerts at 20g, both of which were delivered via the Blynk app and displayed on an LCD screen. The notifications were tested for real-time efficiency, achieving an alert delivery time of 1 to 2 seconds.

The system's integration and scalability were ensured through cloud-based logging and compatibility with hospital networks. Blynk Cloud provided remote access and historical trend analysis, which can be leveraged for future integration with Electronic Health Records (EHR). The local LCD display ensured immediate access to saline weight information and alerts, reducing dependence on manual monitoring. The flexible architecture of the system allows for future expansion, ensuring its adaptability in evolving healthcare environments. Overall, this methodology ensures the system operates efficiently with minimal human intervention, providing a scalable and cost-effective solution for real-time saline monitoring and patient safety.

IV. RESULTS

The evaluation conducted measurements based on a complete hardware system joined with an Android app alongside cloud storage for experimental testing. A test of the system occurred under simulated patient conditions to confirm its performance in real-time saline measurement together with automatic bottle adjustments and refined flow control capabilities.

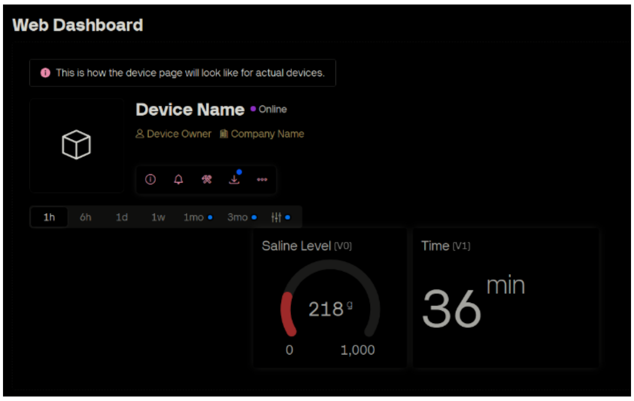

Fig 4 Web Dashboard of a Patient

This prototype of the IoT-based smart saline monitoring system underwent rigorous testing under testing environments for performance verification and accuracy confirmation and reliability verification. The system detected real-time weight changes of the saline bottle through its integration of the HX711 load cell with the ESP32 microcontroller. The patient received saline solution through the system, so the weight reduction process was processed throughout. The Blynk IoT platform together with an LCD screen received the preliminary alert once the saline level reached 50 grams while displaying the warning to all parties nearby and remotely. When the saline weight reached 20 grams the ESP32 activates the solenoid valve to terminate saline flow automatically. Patient safety received an enhancement from the implemented mechanism that prevented possible risks by using automatic intervention at the right time.

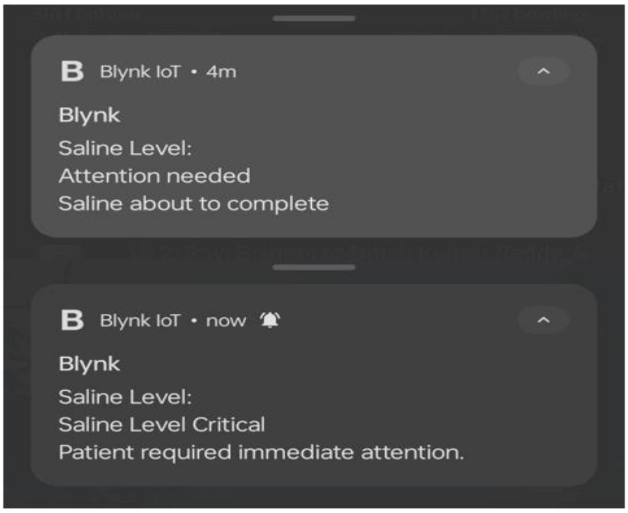

Fig 5 Alert Notifications to the Device.

Saline bottle depletion time estimation was one of the capabilities of the system. The system estimated bottle-emptying timing by dividing the average flow rate with data obtained from real-time weight changes during the procedure. Through its predictive functionality, healthcare staff were able to make informed decisions before IV fluids were depleted, thereby reducing the need for continuous manual oversight. The system showed dependable accuracy for weight detection during testing and sent alerts to the hospital without any significant delay at an average speed of less than two seconds. The system accurately predicted actual emptying times because its estimation deviated only by less than 5% precision in its calculations. The IoT technology integration enabled simple data transfer and proven alerts between different devices. Both laboratory and operational experiments indicate that the new approach represents a convenient financial and scalable system which effectively supports clinical fluid management practices.

V. CONCLUSION

This research delivers an operational intelligence-based technique for IoT-controlled saline monitoring and automatic flow management. The correct monitoring of saline levels becomes crucial in Indian hospital care facilities particularly those with numerous patients because improper measurements can lead to severe conditions including air embolism alongside reverse blood flow. The system solves these problems through continuous time-based saline bottle weight measurement that generates both onsite and offsite notification alerts. The system improves patient protection while decreasing healthcare staff's present workload for supervision duties.

This medical device combines high functionality with affordability and deployability that enables its practical addition to India's current healthcare facilities across major healthcare institutions and rural primary care centres. The prototype system currently tracks saline quantities while offering automation. The system demonstrates promising prospects for commercial manufacturing and extensive deployment in Indian healthcare facilities which will advance safe and intelligent medical procedures.

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