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IoT-Based Saline Bottle Monitoring and Control System Using Wi-Fi and Android Application

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Abstract: Continuous monitoring of intravenous (IV) saline bottles is important during fluid administration because the saline level needs to be observed until the required quantity has been delivered. In conventional practice, the bottle is generally checked manually by healthcare personnel. This can be difficult when several patients require attention at the same time. To address this problem, this paper presents an IoT-based saline bottle monitoring and control system using ESP32-C3, capacitive sensing, Wi-Fi, and an Android application.

The proposed system uses an XW02E-based capacitive sensing arrangement mounted externally on the saline bottle to detect changes in the saline level. The ESP32-C3 processes the sensor output and transmits the saline status through Wi-Fi to the Android application. LED and buzzer indicators are used for local status indication and alerts. When the saline level reaches the defined critical condition, a servo-operated flow-control mechanism is activated to stop the saline flow. The Android application provides the saline status and notification information to the user.

A working prototype was developed and tested under controlled conditions to verify the operation of the saline-level sensing, wireless communication, alert generation, and ON/OFF flow switching mechanism. The developed prototype demonstrates the practical implementation of combining saline-level monitoring with automatic ON/OFF flow switching in a compact IoT-based system. Further testing with different bottle types and real healthcare conditions is required to evaluate its performance for practical deployment.

Keywords: IoT, Saline Bottle Monitoring, Saline Flow Control Switch, ESP32-C3, Capacitive Sensing, Wi-Fi, Android Application, Smart Healthcare.

I. INTRODUCTION

Intravenous (IV) saline administration is commonly used in hospitals and healthcare facilities for providing fluids to patients. During saline administration, the bottle needs to be monitored so that appropriate action can be taken when the saline level becomes low or reaches a critical condition. In conventional practice, this monitoring is generally performed manually by nursing staff. When healthcare personnel are responsible for several patients at the same time, continuous observation of individual saline bottles can be difficult.

Delayed detection of a low or empty saline bottle may interrupt fluid administration and can increase the possibility of blood backflow into the IV line. It also requires healthcare personnel to check the saline bottle repeatedly. Therefore, a system that can monitor the saline level continuously and provide timely information can help reduce the need for frequent manual observation.

The use of **Internet of Things (IoT)** technology provides a way to connect a sensing unit with a processing device and a mobile application for remote monitoring. In this work, an **ESP32-C3 microcontroller**, an **XW02E-based capacitive sensing arrangement**, **Wi-Fi communication**, and an **Android application** are used to develop a saline bottle monitoring system. The sensing arrangement is mounted externally on the bottle and detects changes associated with the saline level without direct contact with the liquid.

The proposed system processes the detected saline condition using the ESP32-C3 and sends the status through Wi-Fi to the Android application. **LED and buzzer indicators** provide local status information, while the mobile application

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provides notifications for predefined saline-level conditions. In addition, a **servo-operated flow-control mechanism** is included to stop the saline flow when the critical condition is detected.

Figure 1 shows the overall architecture of the proposed system. The main contribution of this work is the development of a prototype that combines **saline-level sensing, wireless monitoring, alert generation, and automatic ON/OFF flow switching**. The prototype was tested under controlled conditions to evaluate saline-level detection, wireless communication, alert generation, and **ON/OFF flow switching** operation.

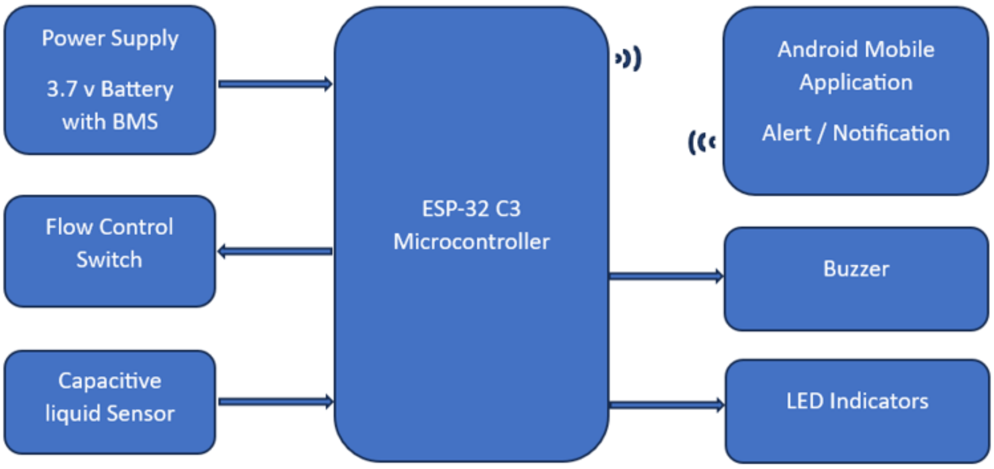

Figure 1: Block Diagram of the Proposed IoT-Based Saline Bottle Monitoring and Control System.

II. LITERATURE REVIEW

Numerous efforts have been made to improve saline bottle monitoring through automation and IoT technologies. **Landge and Shirgan [1]** proposed a saline monitoring system using **IR sensors**, a microcontroller, and an Android application for saline level detection and alert generation. **Ghosh et al. [2]** developed an **ESP32-based monitoring system** using a **load cell sensor** and **MQTT communication** for remote monitoring of saline bottles. These studies demonstrated the potential of automated saline monitoring for improving **patient safety** and reducing **manual monitoring requirements**.

However, existing approaches have certain limitations. **IR sensor-based systems** may be affected by bottle characteristics, sensor positioning, and environmental conditions, while **load cell-based systems** require calibration and additional hardware for weight measurement. These factors can increase system complexity and maintenance requirements. In addition, several existing systems mainly concentrate on saline-level monitoring and alert generation, while **automatic ON/OFF flow switching** is not included in many approaches.

Based on these observations, the proposed research focuses on combining **non-contact capacitive sensing**, **ESP32-C3-based processing**, **Wi-Fi communication**, and an **Android application** for saline-level monitoring. The proposed prototype further includes a **servo-operated ON/OFF flow switching mechanism** to switch the saline flow when a critical level is detected. The implementation and testing of these features are presented in the following sections.

III. PROBLEM STATEMENT

Traditional saline monitoring systems rely heavily on **manual observation** by nurses and healthcare staff. This approach can become difficult in hospitals where healthcare personnel are responsible for monitoring multiple patients simultaneously. Delayed detection of **low or empty saline bottles** may result in interruption of fluid administration, increased workload, and a greater possibility of **blood backflow**.

There is a need for an **automated monitoring system** that can:

- Continuously monitor **saline bottle levels**.
- Generate **alerts** when the saline level becomes low or reaches a critical condition.
- Provide **automatic ON/OFF flow switching** when the critical condition is detected.

- Enable **remote monitoring** through a mobile application.

The objective of this research is to develop a **simple and cost-effective saline monitoring system** that integrates **capacitive sensing**, an **ESP32-C3 microcontroller**, **Wi-Fi communication**, and an **Android application**, along with a **servo-operated ON/OFF flow switching mechanism** to reduce manual supervision and improve patient safety.

IV. PROPOSED METHODOLOGY

The proposed system consists of five main components for **saline level detection**, **data processing**, **wireless monitoring**, **alert generation**, and **automatic ON/OFF flow switching**. The sensor detects changes in the saline level, while the **ESP32-C3 microcontroller** processes the sensor information and communicates the detected status to the Android application through Wi-Fi.

A. Saline Level Detection

The proposed system uses a **capacitive sensing technique** based on the **XW02E IC** to detect changes in the saline level. The sensing electrode is placed externally on the saline bottle and does not come into direct contact with the saline solution. As the saline level changes, the capacitance detected by the sensing arrangement also changes. The resulting sensor signal is provided to the ESP32-C3 for determining the corresponding saline condition.

B. ESP32-C3 Processing Unit

The **ESP32-C3 microcontroller** serves as the main processing unit of the system. It receives the signal from the sensing module and determines the saline condition based on the predefined threshold levels. The controller also manages the **LED and buzzer indicators**, communicates the saline status to the Android application through Wi-Fi, and activates the **ON/OFF flow switching mechanism** when the critical condition is detected.

C. Android-Based Monitoring

An **Android mobile application** is used to monitor the saline bottle status remotely. The application receives the status information from the ESP32-C3 through Wi-Fi and displays the corresponding saline condition. Notifications are generated when the saline level reaches the defined warning or critical condition, allowing the user to take appropriate action.

D. Automatic ON/OFF Flow Switching

The system includes a **servo-operated mechanism for ON/OFF switching of saline flow**. When the saline level reaches the critical condition, the ESP32-C3 activates the servo mechanism to **stop the saline flow**. An alert is generated at the same time to inform the user about the critical condition. The mechanism provides an automatic response to the detected condition and is intended to reduce the possibility of blood backflow and minimize immediate manual intervention.

E. Power Management System

The prototype is powered by a **3.7 V rechargeable lithium-ion battery** and uses a **TP4056 charging module** for battery charging. The power arrangement is intended to support portable operation of the prototype.

Real-Time Data

- Saline Level Status: Full, Low, Empty
- Sensor Output Status
- Device Connectivity Status
- Battery Status
- Alert Status

Output Labels

- Full Level Detected
- Low Level Warning
- Empty Level Alert
- Notification Generated
- Flow Switching Activated

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V. IMPLEMENTATION

The proposed **Smart Saline Bottle Monitoring and ON/OFF Flow Switching System** was implemented using an **ESP32-C3 microcontroller**, **XW02E Touch IC**, **servo motor**, **TP4056 charging module**, and a **3.7 V lithium-ion battery**. The developed prototype monitors the saline level through the capacitive sensing arrangement and processes the detected condition using the ESP32-C3. The saline status is transmitted through Wi-Fi to the Android application, while the local indicators provide status alerts and the **servo-operated mechanism performs ON/OFF switching of the saline flow** under critical conditions.

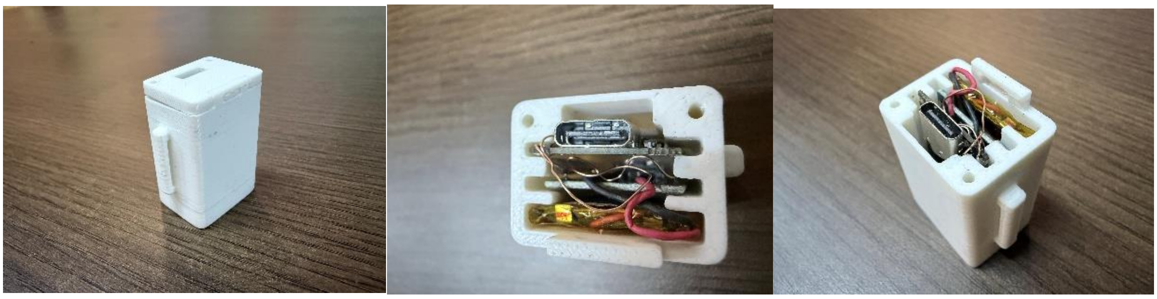

Figure 2: Prototype and Internal Hardware Arrangement of the Proposed Smart Saline Bottle Monitoring and ON/OFF Flow Switching System.

A. Hardware Implementation

The hardware prototype was implemented by integrating the following components:

- **ESP32-C3 microcontroller** – used for processing the sensor output, controlling the system, and handling Wi-Fi communication.
- **XW02E Touch IC** – used for the capacitive sensing arrangement to detect changes in the saline level.
- **Servo motor** – used for automatic control of the saline flow when the critical condition is detected.
- **LED indicators** – used to provide local status indications.
- **Buzzer** – used to provide warning and critical alerts.
- **TP4056 charging module** – used for charging the rechargeable lithium-ion battery.
- **3.7 V lithium-ion battery** – used as the power source for the prototype.

The sensing arrangement is mounted externally on the saline bottle without direct contact with the saline solution. The sensor output is processed by the ESP32-C3, which controls the indicators, buzzer, and servo mechanism according to the detected saline condition.

B. Android Application Implementation

An **Android mobile application** was developed to monitor and control the connected saline monitoring devices. The application provides an interface for adding a device and entering details such as **room number, bed number, and IP address**. It also provides **monitoring and control options** for each connected device.

The application displays the **saline status**, device information, and monitoring condition for individual beds. The **Monitor** and **Control** options allow the user to enable monitoring and control functions for the selected device. The application also displays the device IP address, which helps in identifying the connected monitoring unit.

The application provides a **centralized interface for monitoring multiple connected devices**. Each device is associated with a specific room and bed number, allowing healthcare personnel to identify the corresponding saline monitoring unit easily. The device status and control information are displayed separately for each connected unit, making the application suitable for organized monitoring of saline bottles in different patient locations.

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The application was tested with the ESP32-C3-based prototype to verify **device connectivity, monitoring status, control operation, and saline-level status display**. The developed interface provides a centralized way to monitor connected saline devices from a mobile device.

Figure 3: Android Application Interface for Saline Bottle Device Monitoring and Control.

C. ON/OFF Flow Switching Implementation

A **servo-operated mechanism** was integrated with the prototype to switch the saline flow between **ON and OFF states**. When the saline level reaches the critical condition, the ESP32-C3 activates the servo mechanism to **switch OFF the saline flow**. This provides an automatic response to the detected critical condition and is intended to reduce the possibility of blood backflow.

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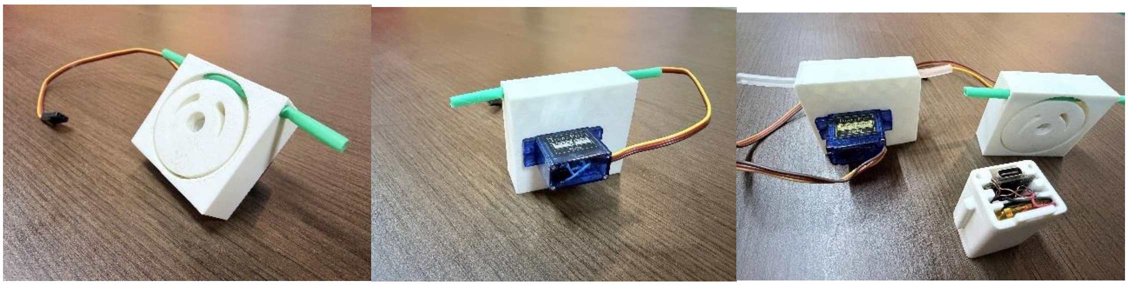

Figure 4: Servo-Controlled ON/OFF Flow Switching Mechanism of the Proposed System.

D. Prototype Testing

The developed prototype was tested under different saline-level conditions to verify the operation of the sensing, communication, alert, and **ON/OFF flow switching** functions. During testing, the system detected changes in the saline level and transmitted the corresponding status to the Android application. Warning and critical notifications were generated according to the detected condition, and the servo mechanism was activated at the critical condition.

The prototype testing focused on the following functions:

- Saline-level detection
- Wireless transmission of saline status
- Android application status display
- Warning and critical alert generation
- Servo-based ON/OFF flow switching

The testing confirmed the operation of the integrated functions under the tested prototype conditions. Further testing with different bottle types and operating conditions is required to evaluate the system under practical healthcare environments.

VI. DISCUSSION AND FUTURE SCOPE

The developed prototype was evaluated under controlled conditions to verify the operation of **saline-level detection, wireless status transmission, alert generation, and ON/OFF flow switching**. During testing, changes in saline level were detected and the corresponding status was transmitted to the Android application. The servo-operated mechanism also responded to the defined critical condition and switched the saline flow to the required state.

The externally placed sensing arrangement enables saline-level detection without direct contact between the sensing electrode and the saline solution. The combined monitoring and **ON/OFF flow switching** functions provide an automatic response to the critical condition and can help reduce the need for immediate manual intervention.

The prototype has some limitations. The performance of the **capacitive sensing mechanism** may vary with the material, shape, thickness, and dimensions of different saline bottles. The present prototype was tested under controlled conditions, and further validation is required under different operating conditions. The **ON/OFF flow switching mechanism** also requires further evaluation for consistent operation with different tube arrangements and saline bottle conditions.

Future Scope

- Testing the system with different **types, shapes, and sizes of saline bottles**.
- Improving the **Android application** for centralized monitoring of multiple patients and devices.
- Integrating **cloud-based storage** for maintaining saline-level and monitoring records.
- Adding **SMS and emergency notification features** for healthcare personnel.

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- Investigating **advanced non-contact sensing techniques** to improve measurement reliability and reduce maintenance requirements.

- Developing **low-power and energy-efficient operation** for continuous monitoring.

- Conducting **long-term testing and real-world hospital validation** to evaluate system performance and reliability.

- Exploring **AI and Machine Learning techniques** for predicting saline consumption and providing early warnings before critical conditions occur.

The developed prototype provides a foundation for combining **saline-level monitoring and automatic ON/OFF flow switching** using IoT technology. Further testing, refinement, and real-world validation are required before considering the system for practical healthcare deployment.

VII. CONCLUSION

This paper presents a **Smart Saline Bottle Monitoring and ON/OFF Flow Switching System** developed for continuous monitoring of saline levels and timely response to critical conditions. The developed prototype was tested under controlled conditions and demonstrated **saline-level detection, wireless status transmission, alert generation, and automatic ON/OFF flow switching**.

The externally mounted **capacitive sensing arrangement** enables saline-level detection without direct contact with the liquid. The integration of monitoring and **ON/OFF flow switching** provides an automatic response when the critical condition is detected and can help reduce repeated manual observation during saline administration.

Further work will focus on testing the system with **different saline bottle types**, improving the **Android application**, optimizing the sensing and **ON/OFF flow switching mechanisms**, and conducting **long-term testing in real healthcare environments**. These improvements will help evaluate the practical performance and reliability of the proposed system for wider healthcare applications.

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