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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 an important requirement in healthcare environments to ensure uninterrupted fluid administration and patient safety. Conventional saline monitoring methods rely primarily on **manual observation** by healthcare personnel, which may lead to delayed detection of low saline levels, increased workload, and potential risks such as **blood backflow**. To address these challenges, numerous researchers have proposed **Internet of Things (IoT)-based saline monitoring systems** employing different sensing technologies, wireless communication techniques, and mobile monitoring platforms.

This review paper presents a comprehensive analysis of existing **IoT-based saline bottle monitoring systems** reported in the literature. Various approaches, including **Infrared (IR) sensor-based systems**, **load cell-based monitoring techniques**, and **capacitive sensing methods**, are examined and compared. The advantages, limitations, practical challenges, and control mechanisms such as automatic flow control, valve operation, and blood backflow prevention associated with these technologies are also discussed. Furthermore, the paper identifies **research gaps** and highlights future directions for developing **reliable**, **cost-effective**, and **intelligent saline monitoring solutions** for modern healthcare applications. The review emphasizes the growing role of **IoT technologies** in improving patient safety, reducing healthcare workload, and enhancing the efficiency of medical monitoring systems.

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

I. INTRODUCTION

Intravenous (IV) saline administration is one of the most frequently performed medical procedures in hospitals, intensive care units, nursing homes, and other healthcare facilities. Continuous monitoring of saline bottle levels is essential to ensure uninterrupted fluid delivery and maintain patient safety. However, in many healthcare environments, saline levels are still monitored manually by nursing staff through periodic visual inspection. This approach becomes challenging when healthcare professionals are required to monitor multiple patients simultaneously.

Delayed identification of low or empty saline bottles may result in treatment interruption, blood backflow, medication wastage, and increased workload for healthcare personnel. These limitations have encouraged researchers to investigate automated monitoring solutions capable of providing real-time status information and timely alerts. With the rapid advancement of the **Internet of Things (IoT)**, several intelligent healthcare monitoring systems have been developed to improve patient care and reduce dependency on manual supervision.

In addition to monitoring saline levels, modern IoT-based systems are increasingly exploring automatic control mechanisms. These mechanisms include controlling the saline flow using a valve or similar actuator when the saline level falls below a predefined threshold. Such control features can help prevent blood backflow, reduce treatment interruptions, and enhance patient safety by minimizing the need for immediate manual intervention.

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Recent studies have explored the use of various sensing technologies, including **infrared sensors**, **load cells**, and **capacitive sensors** for saline level detection. These systems are often integrated with wireless communication technologies and mobile applications to enable remote monitoring and alert generation. Although significant progress has been made, existing approaches differ in terms of accuracy, implementation cost, maintenance requirements, and practical applicability in healthcare environments.

This review paper provides a comprehensive analysis of existing **IoT-based saline bottle monitoring systems** reported in the literature. Different sensing techniques, communication technologies, monitoring approaches, and alert mechanisms adopted by researchers are critically examined and compared. In addition, the advantages, limitations, research challenges, and future directions associated with these systems are discussed to provide a broader understanding of current developments in smart healthcare monitoring applications.

II. LITERATURE REVIEW

Several researchers have explored the application of **Internet of Things (IoT)** technologies for improving saline bottle monitoring and patient safety in healthcare environments. The primary objective of these systems is to reduce manual supervision, provide timely alerts, and ensure uninterrupted **Intravenous (IV)** fluid administration.

Landge and Shirgan proposed an **IoT-based saline monitoring system** that utilized **Infrared (IR) sensing technology** for detecting saline levels and generating notifications through a mobile application. The system demonstrated the feasibility of remote saline monitoring and highlighted the potential of IoT solutions in reducing the workload of healthcare personnel. However, the performance of **IR sensors** may be influenced by factors such as bottle transparency, sensor alignment, and environmental lighting conditions, which can affect measurement accuracy.

Ghosh et al. developed a smart saline monitoring system using an **ESP32 microcontroller**, **MQTT communication protocol**, and **load cell sensors**. The system continuously monitored the weight of the saline bottle and transmitted status information through a wireless network for remote observation. The proposed approach provided accurate level estimation and real-time monitoring capabilities. Nevertheless, the use of **load cells** increased hardware complexity and required periodic calibration to maintain measurement accuracy and reliability.

Vadodariya et al. presented an **IoT-based saline level monitoring system** designed to provide continuous monitoring and alert generation for healthcare applications. The system successfully reduced the need for frequent manual inspection and improved monitoring efficiency. However, the proposed solution primarily focused on saline level detection and notification mechanisms without incorporating **automatic flow control** or **blood backflow prevention** features.

Chidgopkar and Phatale (2015) proposed an **automatic and low-cost saline level monitoring system** using **IR sensors**, a **Bluetooth module**, and a **CC2500 wireless transceiver**. The system continuously monitored the saline bottle level and transmitted warning notifications to nurses through both a mobile phone and a computer. The proposed solution reduced the need for continuous manual observation and provided a cost-effective monitoring approach suitable for hospitals. However, the system relied on wireless communication modules and **IR sensors**, whose performance could be affected by sensor positioning and environmental conditions.

Kalaivani et al. (2017) developed a **real-time ECG and saline level monitoring system** using an **Arduino UNO**, **IR sensors**, and **Bluetooth communication**. The system simultaneously monitored the patient's ECG signal and the saline bottle level, displaying the collected information through a mobile application. The proposed approach improved patient monitoring by integrating multiple healthcare parameters into a single platform. Nevertheless, the system primarily focused on monitoring functions and depended on continuous wireless connectivity for effective operation.

Chengathir Selvi et al. (2022) presented an **IoT-based saline monitoring system** for continuous monitoring of **Intravenous (IV) saline bottles**. The proposed system employed sensors, a microcontroller, and wireless communication to transmit real-time saline level information to healthcare personnel through a mobile application. The system generated timely alerts when the saline level reached a predefined threshold, thereby reducing manual supervision and improving patient safety. However, reliable network connectivity and continuous power availability were necessary to ensure uninterrupted monitoring performance.

Although most reported studies focus primarily on monitoring and alert generation, recent research trends emphasize the integration of automatic control features. These include the use of electronically controlled valves to stop saline flow automatically when the bottle becomes empty or reaches a critical level. Such control mechanisms can effectively

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prevent blood backflow into the intravenous (IV) tubing, improve patient safety, and reduce the response time of healthcare personnel.

Recent research trends indicate a growing interest in developing **non-contact sensing techniques** for saline level monitoring. **Capacitive sensing methods** have attracted attention because they eliminate direct contact between the sensor and the saline solution, thereby improving hygiene and reducing maintenance requirements. Compared to conventional **IR sensor** and **load cell-based** approaches, **capacitive sensing** offers a simpler installation process and lower implementation cost while maintaining reliable monitoring performance.

The reviewed studies demonstrate that **IoT-based saline monitoring systems** can significantly improve **patient safety** and **healthcare efficiency** through **real-time monitoring**, **wireless communication**, and **automated alert generation**. However, challenges related to **sensor reliability**, **calibration requirements**, **implementation cost**, **large-scale deployment**, **wireless connectivity**, and **long-term system maintenance** remain important areas for further investigation. Future research should focus on developing more **accurate**, **cost-effective**, and **intelligent saline monitoring solutions** capable of supporting modern healthcare environments.

III. CLASSIFICATION OF SALINE MONITORING SYSTEMS

Saline bottle monitoring systems proposed in the literature employ different sensing techniques for detecting and monitoring **intravenous (IV) fluid levels**. The choice of sensing technology directly influences the **accuracy**, **reliability**, **implementation cost**, and **maintenance requirements** of the monitoring system. Based on the sensing mechanism used, existing saline monitoring systems can be broadly classified into **Infrared (IR) Sensor-Based Systems**, **Load Cell-Based Systems**, and **Capacitive Sensor-Based Systems**.

A. Infrared (IR) Sensor-Based Systems

Infrared (IR) sensor-based systems detect saline levels by measuring changes in infrared light transmission or reflection. These systems are widely adopted due to their **simple design**, **low implementation cost**, and **ease of integration** with microcontrollers. The sensor is generally positioned near the saline bottle, and variations in liquid level affect the received infrared signal. Although IR sensors provide an economical monitoring solution, their performance may be influenced by **bottle transparency**, **sensor alignment**, and **environmental lighting conditions**, which can reduce measurement accuracy.

B. Load Cell-Based Systems

Load cell-based monitoring systems estimate saline levels by continuously measuring the weight of the saline bottle. As the volume of saline decreases, the corresponding reduction in weight is monitored and processed to determine the remaining fluid level. This approach offers **high measurement accuracy** and **reliable monitoring performance**. However, load cell-based systems require **periodic calibration**, **additional signal conditioning circuits**, and careful mechanical installation, which increase implementation complexity and overall system cost.

C. Capacitive Sensor-Based Systems

Capacitive sensing techniques detect changes in capacitance caused by variations in liquid level inside the saline bottle. Unlike conventional sensing approaches, capacitive sensors can be mounted externally without direct contact with the saline solution. This **non-contact monitoring method** improves **hygiene**, simplifies installation, and reduces maintenance requirements. Furthermore, capacitive sensing techniques offer a **cost-effective solution** for real-time saline level monitoring and have gained significant attention in recent healthcare monitoring applications.

Besides sensing technologies, several modern saline monitoring systems also incorporate control units consisting of microcontrollers, relay modules, or valves. These components automatically regulate the saline flow based on sensor inputs, enabling both monitoring and control functionalities within a single IoT-based healthcare system.
The classification of existing saline monitoring systems highlights the diversity of sensing technologies employed in healthcare environments. Each sensing approach provides unique **advantages** and **limitations**, making the selection of an appropriate monitoring technique dependent on factors such as **accuracy requirements**, **implementation cost**, **maintenance considerations**, and **practical deployment conditions**.
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IV. COMPARATIVE ANALYSIS OF EXISTING SYSTEMS

A comparative analysis of existing saline bottle monitoring systems is essential for understanding the strengths and limitations of various sensing technologies used in healthcare applications. Researchers have adopted different

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approaches, including **Infrared (IR) sensors**, **load cells**, and **capacitive sensing techniques**, to improve monitoring accuracy and reduce manual supervision.

Table 1 presents a comparison of selected saline monitoring systems based on sensing technology, monitoring capability, advantages, and limitations reported in the literature.

Table 1. Comparative Analysis of Existing Saline Monitoring Systems

Author	Technology Used	Sensor Type	Advantages	Limitations
Landge and Shirgan	IoT Cloud-Based Monitoring	IR Sensor	Low-cost implementation, remote monitoring capability, and mobile alert generation	Performance may be affected by bottle transparency and environmental conditions
Ghosh et al.	ESP32 with MQTT Communication	Load Cell	Accurate saline level measurement, real-time monitoring, and wireless communication	Requires calibration, additional circuitry, and increased implementation cost
Vadodariya et al.	IoT-Based Monitoring System	Level Sensor	Continuous monitoring, alert generation, and reduced manual supervision	Does not provide automatic flow control or blood backflow prevention
Chidgopkar and Phatale	Wireless Saline Monitoring System	IR Sensor	Low-cost implementation, Bluetooth communication, automatic nurse notification, and reduced manual supervision	Performance depends on proper sensor alignment and reliable wireless communication
Kalaivani et al.	Arduino-Based Saline Monitoring System	IR Sensor	Simultaneous ECG and saline monitoring, mobile application support, and improved patient monitoring	Depends on continuous wireless connectivity and is primarily suitable for small-scale healthcare applications
Chengathir Selvi et al.	IoT-Based Saline Monitoring System	IR Sensor	Real-time saline level monitoring, mobile alert generation, improved patient safety, and reduced manual inspection	Requires reliable network connectivity and continuous power supply
Capacitive Sensor-Based Approaches	IoT and Capacitive Sensing	Capacitive Sensor	Non-contact sensing, hygienic operation, simple installation, and reduced maintenance requirements	Performance may vary depending on bottle material and sensor placement

The comparison indicates that each sensing technology offers distinct benefits and limitations. **IR sensor-based systems** provide a cost-effective solution and are relatively easy to implement; however, their performance may be influenced by environmental conditions and bottle characteristics. **Load cell-based systems** offer higher measurement accuracy but require periodic calibration and additional hardware support, increasing system complexity and maintenance requirements.

In contrast, **capacitive sensor-based approaches** provide a non-contact and hygienic monitoring solution without direct interaction with the saline solution. These systems simplify installation and reduce maintenance requirements while maintaining reliable monitoring performance. However, sensor performance may depend on bottle material properties and appropriate sensor placement.

Overall, the reviewed studies suggest that no single monitoring technique completely satisfies all practical healthcare requirements. Future saline monitoring systems should focus on combining **accurate level detection**, **reliable wireless**

communication, **low implementation cost**, and **enhanced patient safety mechanisms** to improve healthcare efficiency and patient care.

V. CHALLENGES IN EXISTING SALINE MONITORING SYSTEMS

Despite significant advancements in **IoT-based saline bottle monitoring systems**, several challenges continue to limit their widespread adoption in healthcare environments. Analysis of the reviewed literature indicates that existing monitoring approaches face technical, operational, and economic limitations that affect their practical implementation. One of the major challenges is **measurement accuracy**. The performance of **IR sensor-based systems** may be influenced by bottle transparency, sensor alignment, and ambient lighting conditions. Similarly, **load cell-based systems** require periodic calibration to maintain accurate measurements, increasing maintenance requirements and operational complexity.

Another important challenge is **implementation cost**. Systems employing load cells, wireless communication modules, and additional signal conditioning circuits often increase overall hardware expenses. These costs may limit large-scale deployment, particularly in resource-constrained healthcare facilities.

System maintenance and reliability also remain significant concerns. Sensors may experience performance degradation over time due to environmental factors, improper installation, or continuous usage. Regular maintenance and calibration are therefore necessary to ensure consistent monitoring performance.

Another challenge is the limited implementation of automatic control mechanisms. Most existing systems only generate notifications after detecting low saline levels, requiring nurses to manually stop or replace the saline bottle. The absence of automatic flow control increases the possibility of blood backflow if medical personnel cannot respond promptly.

Many existing systems primarily focus on **saline level monitoring and alert generation** without addressing **automatic flow control** and **blood backflow prevention**. As a result, healthcare personnel are still required to intervene manually after receiving alerts, reducing the overall effectiveness of the monitoring process.

In addition, challenges related to **wireless connectivity**, **power management**, and **scalability** must be considered when deploying monitoring systems in real healthcare environments. Reliable communication networks and long-term power efficiency are essential for ensuring uninterrupted monitoring and timely notification delivery.

Addressing these challenges is crucial for developing next-generation saline monitoring systems that are accurate, cost-effective, reliable, and suitable for large-scale healthcare deployment.

VI. RESEARCH GAP

The review of existing **IoT-based saline bottle monitoring systems** reveals several research gaps that require further investigation. Although considerable progress has been made in the development of automated saline monitoring solutions, many existing systems focus primarily on saline level detection and alert generation.

Most reported systems utilize **IR sensors** or **load cells** for monitoring purposes. While these approaches provide acceptable performance, they are often affected by factors such as environmental conditions, sensor calibration requirements, installation complexity, and increased implementation cost. These limitations may reduce their suitability for long-term deployment in healthcare environments.

Another significant research gap is the limited integration of intelligent flow control mechanisms. Most existing systems provide monitoring and alert generation but do not automatically stop the saline flow using actuators such as valves. Consequently, blood backflow prevention still depends largely on manual intervention by healthcare personnel.

Furthermore, limited attention has been given to the development of **non-contact, low-maintenance, and cost-effective monitoring solutions** suitable for large-scale hospital deployment. Issues related to system scalability, long-term reliability, power efficiency, and integration with hospital management systems also remain insufficiently explored.

Therefore, future research should focus on developing intelligent saline monitoring systems that combine **accurate level detection**, **non-contact sensing techniques**, **real-time remote monitoring**, and **enhanced patient safety features** while maintaining low implementation cost and operational simplicity.

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VII. FUTURE SCOPE

The review of existing IoT-based saline bottle monitoring systems indicates that there is significant scope for developing more efficient and intelligent healthcare monitoring solutions. Although current systems provide real-time saline level monitoring and alert generation, many still require manual intervention after detecting low saline levels. Future research should focus on developing fully automated systems that combine both **monitoring and control** to improve patient safety.

One important direction is the development of **ESP32-based IoT systems integrated with Wi-Fi and Android applications** for continuous real-time monitoring of saline bottles. Such systems can instantly notify healthcare professionals when the saline level reaches a predefined threshold, allowing timely replacement of the bottle and reducing manual supervision.

Future systems can also integrate **electronically controlled valves or similar actuators** to automatically stop the saline flow when the bottle becomes empty or the saline level becomes critically low. This control mechanism can help prevent **blood backflow into the intravenous (IV) tube**, reduce treatment interruptions, and improve patient safety.

Another important area of research is the development of **low-cost, energy-efficient, and non-contact sensing techniques** that provide reliable saline level detection while minimizing maintenance requirements. These systems should be easy to install and suitable for deployment in hospitals, clinics, and rural healthcare centers.

Furthermore, future studies should focus on improving the reliability of wireless communication, developing user-friendly Android applications for monitoring multiple patients simultaneously, and integrating saline monitoring systems with hospital management systems for centralized patient monitoring.

Overall, future advancements in IoT technology are expected to enable the development of **smart, reliable, cost-effective, and fully automated saline bottle monitoring and control systems** capable of improving healthcare efficiency, reducing the workload of healthcare professionals, and enhancing patient safety.

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VIII. CONCLUSION

This review paper examined various **IoT-based saline bottle monitoring systems** developed to improve patient safety and reduce the dependency on manual monitoring in healthcare environments. Different sensing technologies, including **Infrared (IR) sensors**, **load cells**, and **capacitive sensors**, were analyzed and compared based on their monitoring capabilities, advantages, and limitations.

The literature review indicates that IoT-enabled monitoring systems have significantly improved the efficiency of saline level monitoring through real-time data acquisition, remote notification, and automated alert generation. However, existing systems continue to face challenges related to measurement accuracy, sensor calibration, implementation cost, maintenance requirements, and large-scale deployment in healthcare facilities.

The comparative analysis further revealed that no single sensing technology completely satisfies all practical healthcare requirements. While IR sensor-based systems offer low-cost implementation, load cell-based systems provide improved accuracy, and capacitive sensing approaches enable non-contact and hygienic monitoring. Each technique presents unique strengths and limitations that must be considered during system design and deployment.

Future saline monitoring systems should integrate both intelligent monitoring and automatic control mechanisms. The combination of real-time sensing, wireless communication, Android-based monitoring, and automatic valve control can significantly reduce blood backflow, improve patient safety, and support efficient healthcare management.

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