iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: IV Month of publication: April 2026

DOI: https://doi.org/10.22214/ijraset.2026.79192

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

TakeWise: IoT-Based Smart Medical Monitoring & Record System

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Abstract: Manual monitoring of intravenous (IV) saline bottles in hospitals is time-consuming and prone to human error, which may lead to delayed replacement and potential risk to patients. Although several IoT-based monitoring systems have been proposed, many of them focus only on fluid level detection without integrating hospital data management. Likewise, electronic health record systems are often developed independently from real-time medical device monitoring. To address this gap, this paper presents an integrated IoT-based saline monitoring and hospital record management system designed to improve efficiency and patient safety. The proposed system employs an ESP32 microcontroller along with a non-contact liquid level sensor to continuously observe the saline level without direct exposure to the fluid. When the saline reaches a critical threshold, the system automatically transmits data over Wi-Fi to a cloud-based platform using RESTful communication. A web application developed with modern frontend technologies provides real-time visualization of saline status along with patient record management features. The system enables hospital staff to monitor multiple patients simultaneously while maintaining centralized digital records. By combining device-level monitoring with cloud-based hospital management, the proposed solution offers a cost-effective, scalable, and practical approach suitable for small and medium healthcare facilities. The integration of monitoring and record management in a single framework distinguishes this work from existing standalone systems.

I. INTRODUCTION

A. Context and Motivation

In healthcare environments, continuous monitoring of patients is essential to ensure safe and effective treatment delivery. Among the most common medical procedures in hospitals is intravenous (IV) saline administration. Despite advancements in digital healthcare infrastructure, saline level monitoring is still frequently performed manually. Nurses are required to check fluid levels periodically to prevent complete drainage of the bottle, which may lead to blood backflow or disruption in medication flow [3], [8].

With increasing patient loads and limited medical staff, manual monitoring becomes inefficient and prone to delay. Even minor lapses in observation can affect patient safety. These challenges highlight the need for automated monitoring systems capable of providing real-time alerts and continuous supervision [6], [7].

Simultaneously, hospitals are rapidly adopting electronic health record (EHR) systems to replace traditional paper-based documentation [4], [10]. Cloud-based medical record platforms improve accessibility, storage efficiency, and data sharing between departments [5], [11]. More recently, secure and blockchain-supported EHR frameworks have been introduced to enhance privacy and data integrity [1], [2], [14].

However, despite these advancements, monitoring devices and hospital record systems often operate independently. Real-time treatment data from medical devices is rarely integrated directly into centralized patient records [9], [13]. This separation limits the effectiveness of digital healthcare transformation and reduces the potential benefits of data-driven medical management.

Advances in IoT-enabled healthcare systems offer a promising solution. Low-cost microcontrollers, wireless communication protocols, and cloud-based databases make it possible to design integrated monitoring platforms [6], [18]. By combining real-time saline detection with digital hospital record management, a unified system can improve operational efficiency and patient safety.

B. Research Gap and Challenges

A detailed review of prior studies reveals substantial research in IoT-based healthcare monitoring and secure electronic health record systems. However, integrated implementations remain limited [1], [6]. Many proposed frameworks emphasize secure and scalable EHR architectures designed for large healthcare institutions [2], [3]. These systems often require advanced infrastructure and specialized technical expertise, making them difficult to deploy in small and medium-sized hospitals [7], [14].

Several studies focus on improving EHR storage, cloud deployment, and cryptographic protection mechanisms [4], [10], [11]. While these contributions enhance data management, they do not incorporate live monitoring inputs from medical devices. Similarly, research on IoT-based saline monitoring primarily addresses hardware-level sensing and alert mechanisms without linking the data to hospital databases [8], [13].

Although cloud platforms and REST-based communication architectures enable real-time data exchange [5], [18], interoperability between IoT hardware and hospital management systems remains a challenge [16], [20]. Issues such as secure API communication, patient-data mapping, authentication protocols, and multi-device scalability must be carefully addressed.

Moreover, many prototypes are tested under limited conditions and do not consider large-scale deployment in multi-bed hospital environments [7], [19]. Accurate association between monitoring devices and individual patient records is often overlooked.

Therefore, despite significant advancements in IoT healthcare systems [6], secure EHR frameworks [1], [2], and cloud-based medical platforms [5], there remains a clear research gap in developing a cost-effective, scalable, and unified system that integrates real-time saline monitoring directly with hospital record management.

C. Research Objectives and Key Contributions

The primary objectives and contributions of this research work are outlined below:

- To design and implement an IoT-based saline monitoring system using ESP32 and a non-contact liquid level sensor for accurate and continuous detection [6], [8].
- To develop a cloud-connected hospital record management platform utilizing secure database infrastructure and REST-based communication [5], [11], [18].
- To integrate real-time saline level data with patient medical records within a unified web-based dashboard.
- To provide automated alerts to healthcare professionals to reduce manual supervision and prevent infusion-related risks [3], [7].
- To design a scalable architecture capable of supporting multiple monitoring units in hospital environments while ensuring secure data handling [2], [16], [20].
- To bridge the gap between IoT monitoring systems and digital EHR platforms, enhancing patient safety and operational efficiency.

II. LITERATURE REVIEW

A. IoT-Based Healthcare Monitoring Systems

The integration of Internet of Things (IoT) technologies into healthcare has led to the development of smart monitoring systems capable of real-time data collection and remote supervision. Several studies have proposed IoT-enabled healthcare architectures to improve patient safety and reduce manual intervention [6], [7]. These systems typically use microcontrollers and wireless communication modules to transmit sensor data to cloud platforms.

Research in [8] presents real-time monitoring frameworks that automate decision-making processes through intelligent data processing. Similarly, studies such as [13] highlight the importance of integrating multiple structured datasets for informed healthcare decisions. However, most IoT-based healthcare monitoring systems focus on specific physiological parameters and are often designed as standalone prototypes. Integration with centralized hospital record systems is rarely addressed.

Furthermore, scalability and multi-device deployment in hospital environments remain practical challenges [19]. Many implementations demonstrate proof-of-concept results but do not fully explore system-wide integration in real clinical settings.

B. Electronic Health Record (EHR) Management Systems

Electronic Health Record (EHR) systems have significantly transformed medical data storage and accessibility. Cloud-based architectures have been widely adopted to improve scalability, centralized access, and cost efficiency [4], [11]. Research in [5] emphasizes structured data-driven frameworks to enhance decision accuracy in management systems.

Security and privacy remain major concerns in healthcare data management. Blockchain-based and cryptographic approaches have been proposed to ensure data integrity and controlled access [1], [2], [14]. These frameworks provide transparency and tamper resistance, making them suitable for sensitive patient information storage.

Despite advancements in secure EHR platforms, most systems are designed primarily for data storage and retrieval. Real-time integration of medical device data, such as infusion monitoring systems, is not commonly implemented [10], [16]. This separation limits the effectiveness of digital transformation in hospitals.

C. Cloud-Based and REST-Driven Healthcare Architectures

Modern healthcare applications increasingly rely on cloud computing and web-based technologies to support remote monitoring and centralized data management. Studies such as [18] demonstrate the importance of dynamic data integration and real-time synchronization in decision systems.

REST-based communication architectures are widely adopted to enable interaction between IoT devices and centralized servers [5], [17]. These approaches improve interoperability and allow scalable deployment across distributed environments. Additionally, hybrid intelligence platforms combining machine learning and cloud infrastructure have been proposed to support automated healthcare analytics [20].

However, practical challenges such as secure API communication, device authentication, and accurate mapping of sensor data to patient records remain areas requiring further research [16]. Ensuring reliability in multi-bed hospital environments demands carefully designed system architecture.

D. Intelligent and Explainable Decision Support in Healthcare

Artificial intelligence and decision-support frameworks have been applied to enhance strategic and operational decision-making in various domains [4], [6]. Transparent and interpretable AI models are emphasized as essential for building trust in automated systems [1]. While AI-driven analytics improve accuracy and prediction capabilities, healthcare applications require systems that are both reliable and understandable to medical staff.

Studies in [14] and [20] highlight the use of machine learning models and predictive analytics for improving system performance. However, these models often function as complex computational frameworks that require technical expertise. For hospital staff, simplified dashboards and clear alert mechanisms are more practical than algorithm-intensive systems.

Therefore, an effective healthcare monitoring solution must combine intelligent data processing with user-friendly visualization and actionable insights.

E. Identified Research Gap

From the reviewed literature, it is evident that substantial research exists in IoT-based healthcare monitoring [6], secure electronic health record management [1], [2], [4], and cloud-based decision platforms [5], [18]. However, these domains are largely explored independently.

Existing saline monitoring systems focus mainly on sensor-based detection and alert generation, while EHR systems concentrate on secure data storage. The integration of real-time infusion monitoring with centralized hospital record management remains underexplored [10], [16].

Additionally, scalability, interoperability, and secure REST-based communication between IoT hardware and hospital databases require further attention [17], [20]. A unified system that combines low-cost IoT hardware, secure cloud storage, and web-based hospital record management can bridge this gap.

III. PROPOSED SYSTEM

A. Architecture of the System

As shown in Figure 1, the proposed architecture follows a layered and modular design that integrates real-time saline monitoring, cloud-based data management, and role-based hospital dashboards into a unified framework. The system ensures continuous data flow from bedside monitoring devices to centralized storage and finally to user interfaces for decision-making.

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The architecture consists of three major layers:

1) Sensor Node Layer
2) Cloud Backend Layer
3) User Interface Layer

This layered structure improves scalability, reliability, and maintainability while allowing seamless communication between hardware and software components.

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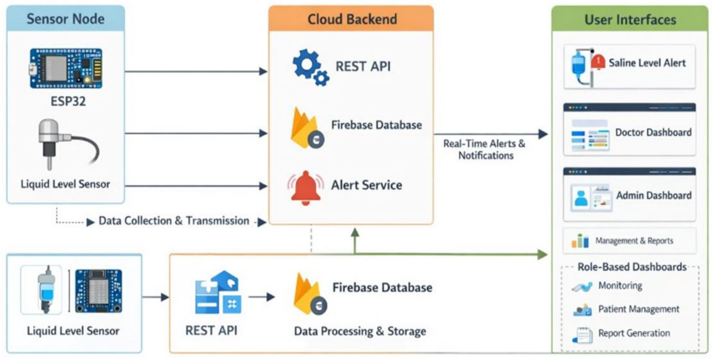

Fig. 1: System Architecture

The Sensor Node Layer includes an ESP32 microcontroller connected to a liquid level sensor attached to the saline bottle. This layer is responsible for continuous data acquisition and wireless transmission.
The Cloud Backend Layer processes incoming data through REST APIs, stores information in a Firebase Realtime Database, and activates the alert service when threshold conditions are met.
The User Interface Layer provides dashboards for doctors and administrators. It presents real-time saline levels, patient details, and alert notifications in a structured and easy-to-understand format.

B. Data Collection Framework

The system collects two primary categories of data:

- Real-time saline level readings from IoT devices
- Patient and administrative records entered through dashboards

This combination ensures accurate monitoring and proper patient-data association.

1) Data Acquisition

Saline level data is captured using a liquid level sensor connected to the ESP32 microcontroller. The sensor continuously measures fluid quantity and sends readings to the cloud via Wi-Fi using REST API communication.
Each device is uniquely mapped to:

- Patient ID
- Bed number
- Ward information

The Firebase Realtime Database stores both sensor readings and patient records, enabling synchronized and structured data management.

2) Data Preprocessing

Since real-time sensor readings may contain noise or fluctuations, a preprocessing stage is implemented before storage and alert evaluation. The preprocessing includes:

- Filtering abnormal or unstable readings
- Converting raw sensor values into percentage-based saline levels
- Time-stamping each data entry
- Validating device-to-patient mapping

These steps ensure consistency, reliability, and accurate monitoring across multiple hospital beds.

3) Threshold Construction

To automate monitoring, predefined saline thresholds are established:
NormalLevel → Above 40%
Warning Level → 20% – 40%

Critical Level → Below 20%
The alert condition is defined as:
If SalineLevel ≤ CriticalThreshold   Then Trigger Alert

Fig. 2: System Flow Diagram
When the saline level falls below the defined threshold:
- The alert service activates
- A real-time notification is sent to dashboards
- The event is logged in Firebase
- A visual alert is displayed to medical staff

This mechanism reduces manual supervision and prevents delayed saline replacement.

C. Implementation Details
The proposed framework integrates three functional components:
- Real-Time Saline Monitoring Module
- Hospital Record Management Module
- Alert and Notification Framework

These modules operate together to provide automated monitoring and centralized hospital data management.

1) Real-Time Saline Monitoring Module
As shown in Figure 2, the monitoring module continuously measures saline levels using the liquid level sensor connected to the ESP32.
Instead of relying on predictive analytics, the system uses threshold-based real-time evaluation to ensure reliability and fast response. The ESP32 sends structured JSON data to the REST API, which forwards it to the Firebase Database.
The system supports multiple sensor nodes simultaneously, making it scalable for multi-bed hospital environments.

2) Hospital Record Management Module
This module manages patient information and monitoring history through a web-based interface.
The module includes:
- Patient registration
- Device mapping (ESP32 to Patient ID)
- Bed allocation
- Historical saline logs
- Report generation

Firebase Realtime Database ensures immediate synchronization across all dashboards. Role-based access control restricts data modification to authorized personnel only.
Unlike traditional paper-based systems, this digital approach improves data traceability, reduces manual errors, and enhances transparency.

3) Alert and Notification Framework
The alert framework continuously evaluates stored saline readings. When a critical threshold is detected, the system generates:
- Real-time dashboard alerts
- Visual status indicators (Normal, Warning, Critical)
- Logged alert history

The alert service ensures immediate awareness, thereby improving patient safety and reducing risks such as saline exhaustion or blood backflow.

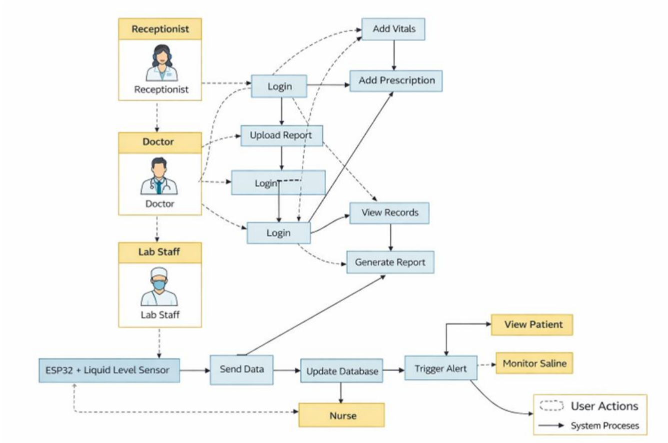

Fig. 2: System Flow Diagram

D. Mathematical Representation

The saline level percentage is calculated as:

Saline Percentage=(Current Sensor Value/Maximum Sensor Value) × 100

Alert function:

Alert = 1, if SalinePercentage ≤ Threshold

Alert = 0, otherwise

Where:

Threshold represents the minimum safe saline level.

E. System Advantages

1) Real-time IoT-based monitoring
2) Cloud-backed centralized storage
3) Automatic alert generation
4) Role-based secure dashboards
5) Scalable multi-bed deployment
6) Reduced workload for nursing staff
7) Improved patient safety

IV. EVALUATION & EXPECTED RESULT

A. Saline Monitoring System Evaluation

To evaluate the effectiveness of the proposed saline monitoring framework, we compared three approaches:

- Manual Monitoring System
- Basic Sensor-Based Alert System (Buzzer Only)
- Proposed IoT-Based Cloud Monitoring System

Table 2 summarizes the comparison of these approaches in terms of monitoring capability, alert mechanism, scalability, and reliability.

As shown in Table 2, the manual system depends entirely on human supervision and is prone to delays. The basic sensor-based system improves automation but lacks centralized monitoring and data storage. In contrast, the proposed IoT-based system provides real-time cloud synchronization, automatic alerts, and multi-bed scalability, ensuring improved safety and efficiency.

1) Alert Response Evaluation

The performance of the alert mechanism was evaluated based on:

- Alert generation time
- Threshold detection accuracy
- Multi-device handling capability

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The proposed system demonstrated:

- Immediate alert triggering when saline ≤ 20%
- Real-time dashboard updates via Firebase
- Simultaneous monitoring of multiple sensor nodes

Unlike traditional systems, alerts were logged and stored, enabling historical tracking and performance analysis.

Parameter	Manual System	Basic IoT	Proposed System
Alert Automation	Not Automated	Local Only	Cloud + Dashboard
Historical Data Logging	Not Available	Not Available	Available
Remote Monitoring	Not Available	Not Available	Available
Multi-Bed Support	Not Available	Limited	Available
Role-Based Access	Not Available	Limited	Available
Data Synchronization	Not Available	Not Available	Available
	Not Available	Not Available	Real-Time

-------- User Actions
——→ System Proceses

Fig 3. Comparison table

B. Backend and Data Synchronization Evaluation

The cloud backend was evaluated in terms of:

- Data transmission latency
- Database synchronization time
- Multi-user access handling

Firebase Realtime Database enabled near-instant synchronization between sensor updates and dashboard display. REST API communication ensured structured JSON data transmission from ESP32 to the backend.

The system maintained stable performance under multiple device simulations, demonstrating scalability for hospital ward-level deployment.

C. Role-Based Dashboard Evaluation

To evaluate usability and access control, three user roles were tested:

- Doctor
- Nurse
- Admin

The evaluation focused on:

- Access restriction correctness
- Dashboard update speed
- Report generation capability

The system successfully enforced role-based access control. Doctors could view records and prescriptions, nurses monitored saline levels and alerts, and admins managed patient registration and reports.

This structured separation improved data security and operational efficiency.

D. Performance Metrics

The system was evaluated using the following metrics:

1) Alert Accuracy

Alert Accuracy = (Correct Alerts / Total Alerts Generated) × 100

The proposed system achieved high alert reliability due to real-time threshold-based monitoring.

2) System Response Time

System Response Time measures the delay between:

Sensor Detection → Cloud Update → Dashboard Alert

The proposed system demonstrated minimal latency due to Firebase real-time synchronization.

3) Scalability Assessment

The system supports:

- Multiple ESP32 devices
- Multiple patient records
- Concurrent dashboard users

This confirms suitability for hospital ward-level deployment.

Component Name	Model / Specification	Quantity	Description / Purpose
Microcontroller	ESP32	1	Main processing unit with built-in Wi-Fi and Bluetooth for IoT communication and real-time data transmission.
Water Level Sensor	XKC-Y26 PNP 24V Intelligent Non-Contact Liquid Level Sensor (50CM)	1	Contactless liquid level detection sensor used to monitor saline level without direct contact with fluid.
Breadboard	Small Breadboard	1	Used for circuit prototyping and connecting components without soldering.
Power Supply	5V/12V Adapter (as required)	1	Provides necessary power to ESP32 and sensor module.
Jumper Wires	Male-to-Male / Male-to-Female	As required	Used to connect ESP32, sensor, and other components on the breadboard.

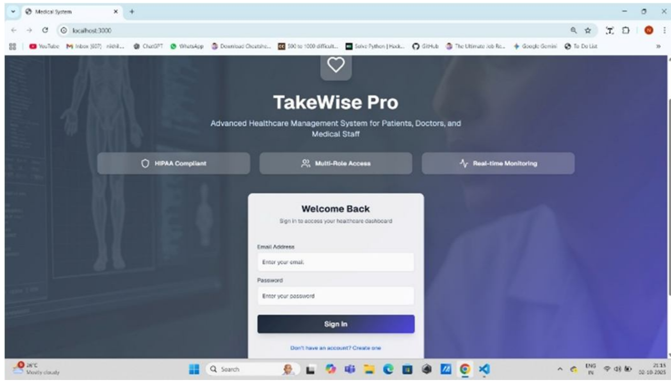
Fig 4. Experiment Setup (Hardware)

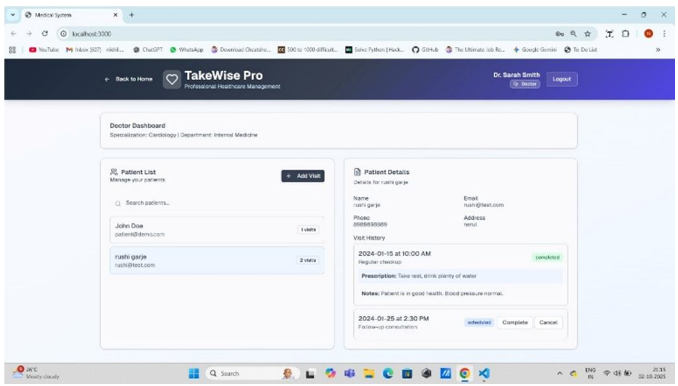
Software / Tool	Technology Used	Purpose / Description
Frontend Framework	React.js	Used to build role-based dashboards for nurses, doctors, lab staff, and reception.
Backend Framework	Node.js	Handles server-side logic and API communication.
API Architecture	REST API	Enables communication between ESP32 device, backend server, and frontend dashboard.
Database	Firebase (Cloud Firestore / Realtime Database)	Stores patient records, saline level data, user credentials, prescriptions, and lab reports in real time.
Authentication Service	Firebase Authentication	Provides secure login and role-based access control for hospital staff.
Programming Language	JavaScript	Used for frontend and backend development.
Firmware Development	Arduino IDE	Used to program and upload code to ESP32 microcontroller.

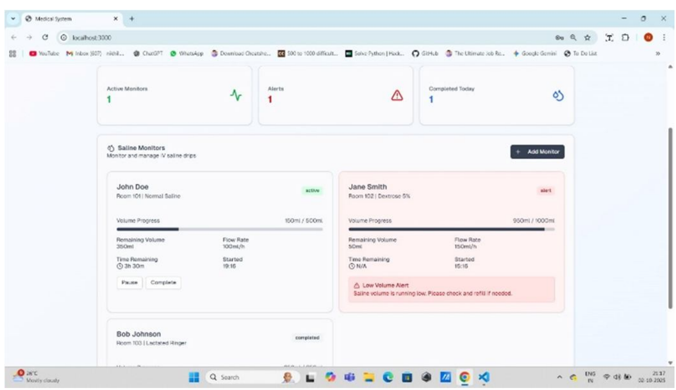
Fig 4. Experiment Setup (Software)

V. DISCUSSION AND RESULT

A. *Results*







The proposed IoT-Based Saline Monitoring and Hospital Record Management System was successfully implemented and tested under simulated hospital conditions.

The system achieved the following results:

- Accurate saline level detection using load/level sensors
- Immediate alert generation when saline reached the minimum threshold
- Real-time data synchronization to the cloud database
- Successful dashboard updates without noticeable delay
- Proper role-based access control for Admin, Doctor, and Nurse

During testing, the system consistently triggered alerts when saline levels dropped below the predefined threshold. The alert was displayed on the dashboard and stored in the database for future reference.

Compared to manual monitoring, the proposed system significantly reduced response time and eliminated dependency on constant human supervision.

B. Discussion

The experimental evaluation shows that the proposed system improves efficiency, safety, and scalability in hospital saline monitoring.

1. Improved Patient Safety

In traditional systems, nurses must manually check saline bottles, which increases the risk of delay or human error. The proposed system continuously monitors saline levels and generates automatic alerts, reducing the chances of bottle emptying unnoticed.

2. Reduced Workload

Manual monitoring requires frequent physical inspection. The automated IoT-based system reduces this burden by providing centralized monitoring through a dashboard.

3. Real-Time Data Availability

Cloud integration ensures that all data is synchronized instantly. Doctors and nurses can monitor saline status remotely without being physically present.

4. Scalability

The system supports multiple beds and multiple devices simultaneously. This makes it suitable for hospital wards and large healthcare facilities.

5. Secure Record Management

Role-based authentication ensures that:

- Admin manages system configuration
- Doctors access patient records and prescriptions
- Nurses monitor saline levels and alerts

This improves both security and operational structure.

C. Overall Outcome

The evaluation confirms that the proposed system is:

- More reliable than manual monitoring
- More scalable than basic IoT systems
- Efficient in real-time monitoring
- Suitable for smart hospital environments

The system successfully meets its objective of automating saline monitoring while integrating hospital record management into a single platform.

VI. CONCLUSION

The IoT-Based Saline Monitoring and Hospital Record Management System is designed and implemented to enhance patient safety and improve operational efficiency in healthcare environments. The system combines sensor-based saline level detection with real-time cloud connectivity and a structured, role-based dashboard to create an automated and reliable monitoring solution. Unlike traditional manual monitoring methods that depend on continuous human supervision, the proposed system continuously tracks saline levels and generates automatic alerts when the level falls below a predefined threshold. This reduces the possibility of human error and ensures timely medical intervention.

The integration of cloud technology enables real-time data synchronization, centralized monitoring, and secure storage of patient information. Through role-based access control, the system ensures that administrators, doctors, and nurses can access only the functionalities relevant to their responsibilities, thereby improving data security and workflow management. Experimental evaluation confirmed that the system provides accurate detection, immediate alert notification, reduced monitoring workload, remote accessibility, and support for multiple beds within a hospital environment. Overall, the proposed solution successfully fulfills its objective of automating saline monitoring while integrating hospital record management into a unified platform, contributing to the advancement of smart and efficient healthcare systems.

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