

IoT-Powered Smart Blood Bank for Real-Time Inventory Monitoring and Management

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Abstract— To ensure transfusion safety and reduce waste in healthcare facilities, dependable blood storage and inventory visibilities are crucial. Traditional methods of blood bank management depend on manual monitoring and regular inspections. This leads to incorrect stock records, delayed detection of temperature changes, and possible security holes in storage access and potential security vulnerabilities in storage access. This paper presents an intelligent blood and management system utilizing the internet of Things (IoT) to improve storage reliability, traceability, and operational efficiency. The Proposed solution integrates sensor-based inventory detection, multi-zone temperature monitoring, and RFID assisted identification within a unified IoT architecture that supports secure storage access and automated data acquisition. You can check the status of your inventory, the weather, and system alerts in real time with a web-based monitoring interface. This lets you keep an eye on things from a distance and act quickly when you needed. Additionally, an intelligent power management framework with battery backup ensures uninterrupted operation during power disturbances, thereby preserving storage integrity. The experimental evaluation shows that the system can accurately detect stocks, keep an eye on temperature, control access reliably, and keep working even when the power goes out. The proposed approach reduces manual intervention, improves monitoring accuracy, and minimizes blood wastage, making it a practical and scalable solution for deployment in hospitals and blood banks.

Keywords— IoT, Blood Management, RFID, Temperature Monitoring, Inventory Tracking, Power Backup, and ESP32.

I. INTRODUCTION

An IoT technology can manage automatic blood supplies and availability status, and storage conditions whether it is safe or not, which helps us to keep accurate maintenance and correct records.[1]. It is important to manage blood well to avoid shortages and waste. Smart devices are used by this system to keep an eye on blood stock and storage conditions all the time. This helps maintain accurate information and ensures blood is ensuring safe and on time when needed [2]. Blood, a vital resource, demands careful handling and storage. Unfortunately, in numerous blood banks, the process of updating inventory and checking what is available

is still a manual affair, often leading to inefficiencies and wasted time. This system leverages contemporary technology, linking storage units and monitoring devices via the internet. This system provides instant updates about blood stock and storage status, making the management process faster, more reliable, and more organized [3]. In an emergency, it's very important to manage blood supplies well. This automated system makes it easier to keep track of blood supplies, which cuts down on manual work and makes sure that blood is always available quickly and accurately. Blood banks are obligated to meticulously manage blood resources to prevent both shortages and delays. Conversely, manual systems are often characterized by slower processing times and diminished accuracy [5]. In healthcare, it's very important to give the right blood at the right time. Traditional blood bank systems may struggle with real-time updates and proper monitoring. This management system uses smart technology to automatically track blood availability [6]. Traditional blood bank management can be slow and error-prone whereas the system which is used to connect devices to automatically monitor blood stock and storage conditions in real time [7]. Getting blood quickly is very important for saving lives. However, traditional blood bank systems often lack real time tracking and efficient communication. The system uses connected technology to monitor inventory, update information instantly and improving coordination [8]. Quick and accurate blood supply is vital in healthcare. The information which is reliable ensuring safe and faster response during emergencies [9]. Proper handling of blood inventory is crucial in hospitals. Traditional methods can be slow and less reliable [10]. Efficient blood bank management is vital for emergencies and manual systems could be slow whereas the system uses internet connected sensors [11].

II. LITERATURE REVIEW

An IoT-based blood bank system uses Wi-Fi and sensors to keep an eye on blood stocks and expiration dates in real time. It reduces manual errors, improving accuracy, and ensures timely availability of blood [12]. To improve inventory management that enhances accuracy, efficiency, and reliability in blood bank operations. The system minimizes human intervention facilitates decision-making [13]. The

system that automates donor records, inventory tracking, and reporting. This approach reduces human mistakes, fast ups the works and they find quickly information and reliability of blood bank operations [14]. Blood banks are often face problems with maintaining records by man power, slow communication and happen mistakes in their inventory. IoT approaches enable automated tracking, alerts, and centralized data management, enhancing operational efficiency and ensuring timely availability of blood units [15]. This system employs to continuously monitor stock status and storage status. It offers admin quickly notifications and dashboard warnings, which minimizes delays and danger incidents and improves blood inventory management. It demonstrates how technology- driven monitoring can enhance efficiency and safety in blood bank operations [16]. The systems that use RFID and sensors to keep an eye on storage conditions and keep track of donors, which makes them more accurate and cuts down on mistakes. Raspberry pi and cloud integration enable real time monitoring and remote data access, enhancing efficiency and reliability [17]. Modern blood bank systems leverage IoT technologies to automate stock, monitoring, donor information, and expiry tracking. These solutions help for human mistakes, streamline operations, and ensure timely access to blood when at emergencies [18]. The system uses IoT technologies like GPS, Node MCU, and Wi-Fi modules to keep track of inventory and update it in real time, making it easier to access. They also transmit data to web platforms for remote access [19].

III. EXISTING DESIGN

Blood banks are facing many problems and operational challenges, mainly manual maintenance, process for blood storage and inventory control. Critical data such as temperature, humidity, and available blood stock are frequently recorded by man power, a practice that heightens the risk of happen human errors and slows down the required responses. Furthermore, the storage areas aren't constantly monitored. Staff members must manually check the temperature levels of storage units, and alarms typically activate only after specific thresholds are breached. In addition, blood inventory information is not updated automatically, and the monitoring system does not fully track the entire cold chain process. This lack of real-time monitoring can affect the safety, quality, and reliability of stored blood. Manual management also makes it more difficult to quickly determine blood availability and maintain accurate donor and inventory records when compared to automated monitoring systems [20].



Fig. 1. Existing System. [20]

This current system uses a cross-match ratio inventory model is figure out each patient's core and the reserve blood

demand. It keeps track of stock using a double cross-match policy and a hybrid issuance method that combines FIFO and LIFO methods. This model is purely numerical and focused on inventory allocation without real-time tracking, automation, or environmental monitoring, which limits its effectiveness and practical usability [21].

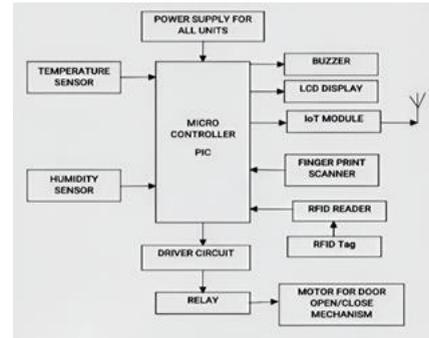


Fig. 2. Block Diagram of Existing System. [21]

Blood bank processes such as inventory tracking, blood storage units, temperature control, temperature alerts and donor location records are managed manually or paper logs, leading to poor real-time visibility and coordination. There is no automated monitoring of storage conditions or a central inventory, which makes it hard to make sure quality, avoid waste, and quickly find blood units or donors in an emergency [22].

IV. PROPOSED SYSTEM

4.1 System Design

The proposed system is an IoT-enabled smart blood storage monitoring platform made up of sensing, identification, control, and communication modules that work together through an ESP32 microcontroller. Each storage box is equipped with load sensors for stock detection and DHT11 sensors for temperature monitoring. RFID modules provide blood packet identification and secure access control, while servo motors operate door locking mechanisms. A hybrid power system consisting of SMPS supply and battery backup ensures uninterrupted operation.

Whenever main AC power supply fails the battery backup switches inverter automatically without interruptions. The ESP32 through the internet and displays on dashboard. The system stores real-time blood data in the cloud, allowing remote access and generating alerts for temperature changes and low stocks.

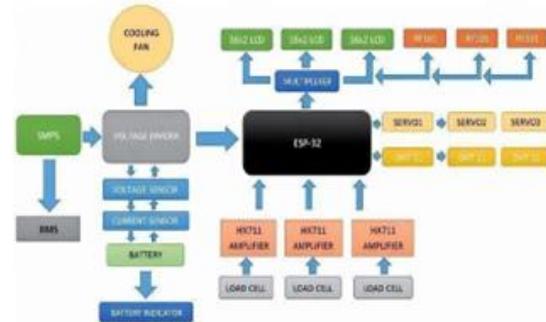


Fig. 3. Block Diagram of Proposed System

4.2 Components and Tools Used

- ESP-32 for controlling Sensors and IoT communication.
- Weight sensors for blood stock detection.
- DHT11 for temperature monitoring.
- MFRC522 RFID for packet identification and door access to open and close by authorized persons only.
- SG90 servo for door lock system.
- 16×2 LCD displays for local monitoring.
- TCA9548A Multiplexer for splitting LCD data.
- ACS712 and ZMPT101B current and voltage sensors for power monitoring.
- Li-On battery for backup power supply.
- SMPS for whole systems power supply.
- Embedded firmware and web server for monitoring interface.

Fig. 4. 16×2 LCD



Fig. 5. ESP32



Fig. 6. DHT11



Fig. 7. HX711



Fig. 8. RFID



4.3 Working Principle

The system employs integrated sensors and identification modules to provide continuous monitoring of blood storage conditions. Load sensors are utilized to ascertain the presence of blood packets and assess stock availability; concurrently, DHT11 sensors are employed to monitor storage temperature, thereby ensuring the maintenance of safe preservation parameters. Identification details are stored on RFID tags affixed to blood packets, and access to storage compartments is facilitated by authorized RFID cards, which activate servo motor-driven locking mechanisms. The ESP32 handles sensor information, displaying it on LCD modules

right there on-site while also sending it to web server for remote observation. A battery backup keeps everything running smoothly, ensuring continuous operation and sending out alerts if the power goes out.

4.4 Implementation Steps

- Combining weight, temperature, voltage and current sensors with ESP32 to get data.
- RFID is used for packet identification and door unlock.
- Servo motors to lock the doors.
- LCD with Multiplexer to read different I2C address with single I2C bus communication in the ESP-32.
- Power monitor and Battery backup for uninterrupted power supply during power failures.
- ESP32 is used to handle sensor data and IoT communication.
- Setup a web server to monitor the real-time data and alerts.

4.5 Algorithm

- Start up the RFID modules and Sensors. Read load sensors data all the time to get the stock availability status.
- Check temperature of the blood storage units and compare the safe threshold values.
- Use an RFID tag to detect the blood packets and verify the blood packet data such type of group, expiry etc.
- If the authentication is valid, opens door, otherwise does not open door and send alert.
- If main power supply failure the backup battery switches the off-grid power supply.
- Displays the local updates such as temperature readings and blood stock levels.
- Transmits system data to webserver
- Repeat monitoring cycle.

The system keeps an eye on blood bank operations all the time by scanning to see how much stock is available and checking the temperature of storage versus established limits. RFID modules can tell blood packages apart and check users, letting only persons who have authorization. The LCD screens and cloud server give real-time updates for remote monitoring, and power conditions are checked to switch to battery backup when there are problems. The system checks expiration dates, sends out notifications for units that are about to expire or are low on stock, processes blood requests by matching available blood types, updates the database after each allocation, and keeps track of all events and alerts.

4.6 Flowchart

The IoT powers the smart blood bank management system, which starts with installing sensors and connecting to a database. It continuously monitors blood supplies, handling requests by confirming compatibility. Requests for blood that is available are checked and updated, and the blood is sent out. The system monitors blood storage units by such as temperature, expiry dates etc. All the time it sends the data to web server and sends out alerts when needed.

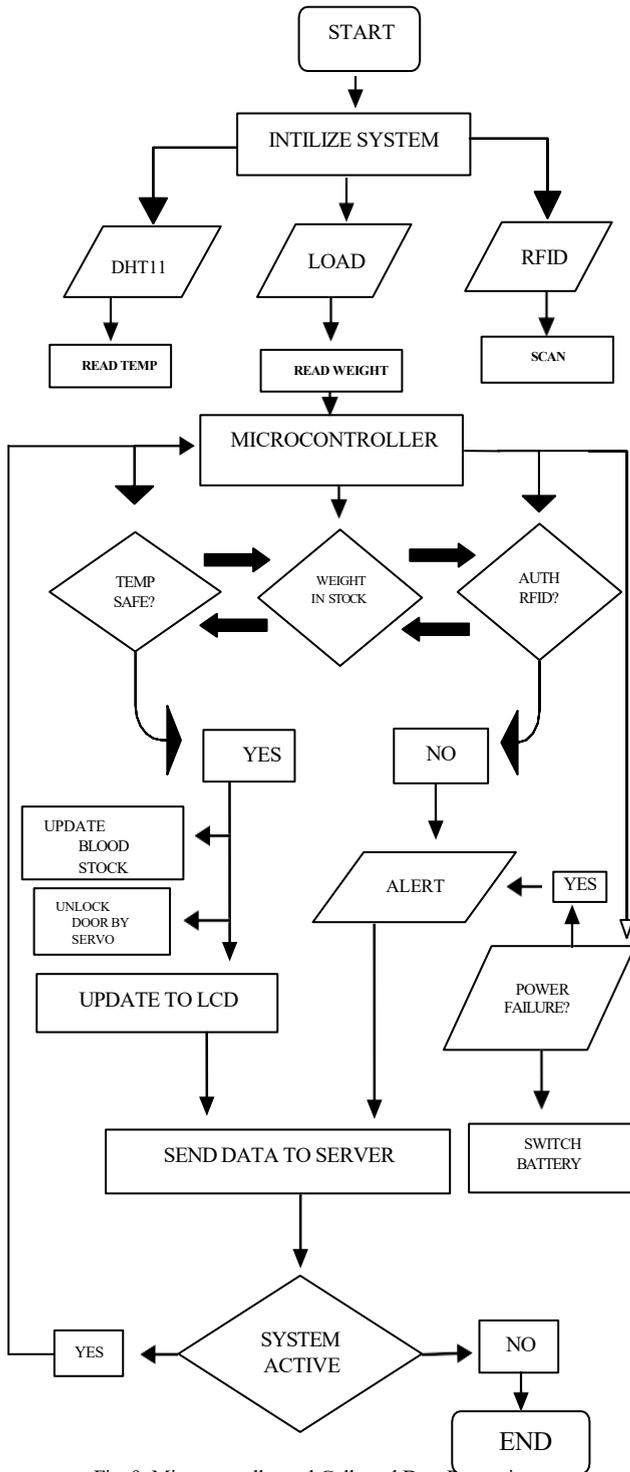


Fig. 9. Microcontroller and Collected Data Processing

4.7 LCD Readings

LCD to provide real-time visual feedback of critical parameters, including blood inventory levels, storage temperature, and system status. The system utilizes an LCD display to provide real-time information on blood storage, including critical details such as temperature and available blood packets. It continuously monitors the temperature of the storage unit, which is essential for preserving blood quality, and in the displayed image. The display also indicates the current inventory, with blood packets available in this case. Sensors connected to a microcontroller measure temperature and track blood quantity, enabling the system to

alert the workers if the temperature levels pass the safe limits, thereby prevents spoilage of blood. This system does more than just monitor stock; it also provides instant updates on blood availability. It also allows IoT connectivity for remote monitoring via the internet connection. Overall, the system enhances efficiency, safety, and reliability in blood bank operations. The LCDs are the primary function is to present critical information in a readily understandable and easily readable format. It is constantly refreshed, which boosts both operational efficiency and safety within the blood bank environment. Shows you real-time visual feedback on important parameters like blood inventory levels, storage temperature, and system status. The LCD provides a quick way for operators to keep the tabs on blood bank, independent of the web dashboard.



Fig. 10. Temperature Readings and Blood Stock

4.8 Hardware Setup

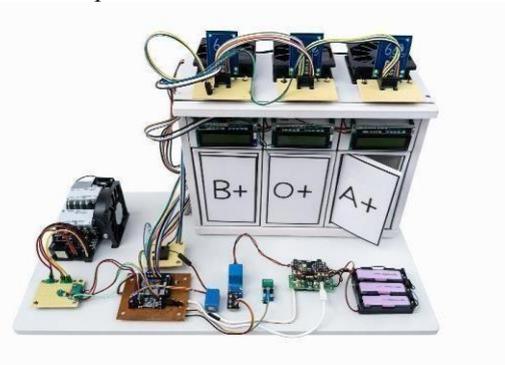


Fig. 11. Integrated Smart Blood Bank

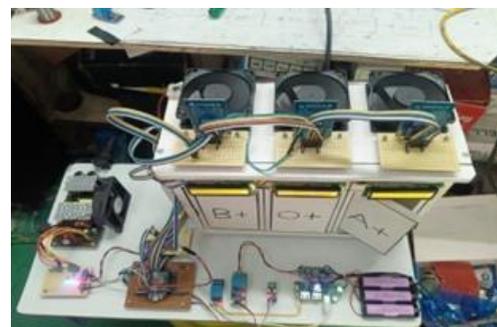


Fig. 12. Top View of Hardware Prototype

TABLE 1. Comparing Existing and Proposed System

Features	Existing System	Proposed System
Inventory Tracking	Manual records, human errors, lack of time, delay and poor maintenance.	Real-time monitoring or sensors (RFID) for instant stock updates.
Temperature Monitoring	Checking temperature periodically, no remote alerts.	Continuous sensing (DHT11) with automated cooling and alerts.
Data Accessibility	Files are stored in local hard-drive or system cloud drive	Cloud-integrated where stock levels can be checked from any location or mobile app.
Efficiency	More time spent on paper work, manual records.	Streamlined workflow where automated bag counting and digital record keeping.
Blood Safety	Difficulty in tracking expiration or storage conditions accurately.	Enhanced safety with history logs of temperature and storage duration.
Emergency Response	Staff must call or message donors manually time-consuming.	Automated SMS or Push alerts to nearest compatible donors or GSM.

V. RESULTS AND DISCUSSION

The effectiveness of the proposed IoT-based smart blood bank management system was evaluated using a hardware prototype. The prototype incorporated three distinct storage compartments, each furnished with load sensors, temperature sensors, RFID modules, and power monitoring circuits. The system's operational performance and reliability were evaluated across a spectrum of operational scenarios. These scenarios encompassed the addition and removal of blood packets, fluctuations in temperature, instances of unauthorized access, and power interruptions. The load sensor tests demonstrated the system's capacity to accurately identify blood packets across the different storage areas, thereby enabling autonomous inventory tracking without human intervention. The testing on all the temperature monitoring system also showed that it could transmit warnings and warning bells when excessive temperatures were found, accurately measure storage conditions, and send alerts when the temperature changed. The RFID-based authentication tests validated the security of the access control system, allowing only authorized users to unlock doors and preventing unauthorized access.

Simulations of power outages were used to assess the power management features. The system successfully switched to lithium battery backup, maintaining operational integrity by keeping sensor monitoring and web server functions active, and by generating alerts when power was lost. Voltage and current monitoring modules provided continuous feedback on power status, which improved system awareness and overall reliability. The web-based monitoring interface effectively displayed real-time data, including inventory status, temperature readings, power metrics, and system notifications. Experimental results indicate that the integrated architecture improves monitoring accuracy, strengthens storage security, and reduces dependence on manual supervision. As a result, the findings collectively suggest that the proposed system provides a reliable and scalable solution for smart blood storage monitoring in healthcare environments. The system provides real-time remote monitoring of blood inventory, temperature, power status, and access logs via a web interface. It automatically generates alerts for any unusual conditions or

low stock levels, allowing for swift intervention. This system boosts efficiency, safety, and reliability, all while minimizing the need for manual oversight.

5.1 Output



Fig. 13. Temperature and Blood monitoring

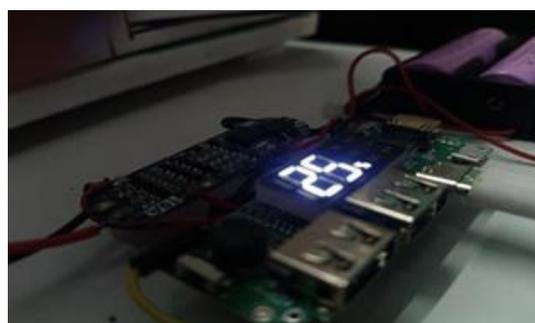


Fig. 14. Backup Battery Level

Blood Group	Packets	Expiry (Days)
A+	45	9
B+	59	7
O+	60	9

Fig. 15. Data Log

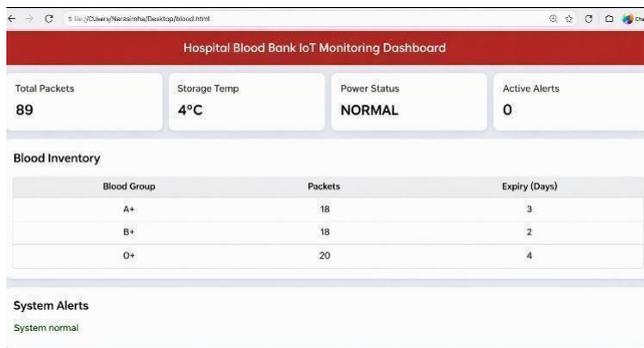


Fig. 16. Web Dashboard

VI. CONCLUSION

This paper presented an IoT based smart blood bank management system designed to enhance storage reliability, inventory visibility, and access security in blood bank environments. The proposed system integrates sensor assisted inventory detection, multi-zone temperature monitoring, RFID based identification with secure access control, and intelligent power management within a unified embedded architecture. The ESP32 based IoT framework enables real-time monitoring through a web-based dashboard, allowing remote supervision of storage conditions and system parameters. Experimental validation of the hardware prototype demonstrated accurate stock detection, reliable temperature monitoring, effective authentication-based door control, and uninterrupted operation during power interruptions through battery backup integration. The proposed system minimizes manual intervention, improves traceability, and reduces blood wastage, making it a practical and scalable solution for deployment in hospitals and blood banks.

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