Inventory Management System with Real-Time Stock Reduction and Alerts Using IoT

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***Abstract*—IoT-based Inventory Management System (IMS) designed to automate inventory control in retail environments. The system integrates RFID scanning, barcode detection, and ultrasonic sensors to update stock levels in real-time. A React-based frontend with a Node.js backend and Supabase database provides a seamless user interface, live data syncing, and automatic low-stock alerts. The system reduces human error, enhances operational efficiency, and supports instant alerting through emails and buzzers, helping prevent stockouts and overstocking. Future enhancements like AI-based forecasting and mobile integration are also discussed.**

***Index Terms*—IoT, Inventory Management, RFID, Barcode Scanner, Supabase, Real-Time Monitoring, Automation**

I. Introduction

Inventory control plays a pivotal role in the efficiency and profitability of businesses, especially in sectors like retail, pharmaceuticals, and warehousing. Accurate inventory management ensures that products are available when needed, minimizes excess stock, and prevents stockouts that could lead to lost sales or dissatisfied customers. However, traditional inventory systems are often plagued by limitations such as manual data entry, delayed updates, lack of transparency, and susceptibility to human error. These inefficiencies not only increase operational costs but also compromise customer satisfaction and decision-making accuracy.

With the advent of Industry 4.0 and the Internet of Things (IoT), there is a growing opportunity to automate and optimize inventory control processes through smart, connected technologies. This paper proposes a scalable IoT-based inventory management system that integrates both hardware and software modules to deliver real-time stock monitoring, automated alerts, and centralized control. By leveraging RFID, ultrasonic sensors, barcode scanning, and cloud integration, the system provides a seamless, low-maintenance, and cost-effective solution suitable for small to large-scale businesses.

This approach eliminates the need for manual stock counting and traditional paper-based methods, reducing operational inefficiencies and errors. Furthermore, the system provides instant notifications via email and buzzer when inventory drops below predefined thresholds, enabling timely restocking and preventing disruptions in operations. The platform also includes a dashboard interface for monitoring inventory, analyzing sales, and generating reports, making it a comprehensive tool for modern inventory management.

II. Literature Survey

Automated inventory management systems have attracted considerable attention due to the increasing need for efficient stock control and reduced human error. Various approaches have been explored, combining IoT technologies, cloud computing, and smart analytics.

Wu et al. [1] proposed a fast inventory mechanism optimized for energy efficiency in Ambient IoT networks, focusing on large-scale deployments but lacking real-time alerting features. Similarly, Karri et al. [2] developed a hardware-based RFID tracking system using NodeMCU, which provided effective stock monitoring but did not integrate cloud storage or user dashboards.

Research by Singh et al. [3] introduced a barcode and RFID hybrid system for retail inventory, emphasizing data accuracy but requiring manual intervention for alerts. Gupta and Sharma [4] explored cloud integration with IoT sensors for warehouse management, achieving centralized data control but with limited frontend usability.

Chatterjee et al. [5] implemented ultrasonic sensors for real-time shelf monitoring, but their system lacked comprehensive alerting and product identification mechanisms. A study by Hernandez et al. [6] demonstrated the benefits of cloud dashboards in supply chain transparency, advocating for mobile-accessible interfaces.

Lee and Park [7] developed an RFID-based pharmaceutical inventory system with automated alerts, yet their solution did not incorporate barcode scanning or multi-platform synchronization. In contrast, Chen et al. [8] utilized BLE sensors for

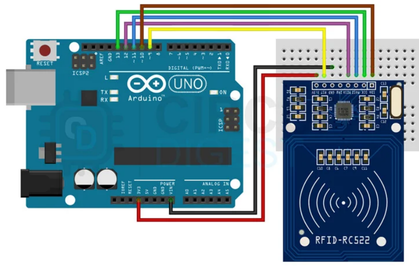

Fig. 1: RFID

stock monitoring but faced challenges with signal interference affecting data accuracy.

Jain and Kumar [9] proposed a scalable IoT inventory solution integrating cloud services and push notifications but with minimal hardware implementation detail. Patel et al. [10] designed a real-time inventory system leveraging RFID and barcode scanning, focusing on retail but lacking in alert automation.

Recent advancements by Singh and Verma [11] highlight AI-based predictive analytics for stock optimization, promising further improvements in inventory control. Lastly, Rodriguez et al. [12] emphasize user-centric dashboard design to enhance operational decision-making in warehouse environments.

Our proposed system synthesizes these insights by combining RFID and ultrasonic sensing, barcode identification, cloud database integration via Supabase, and a modern real-time dashboard with automated alerts, providing a comprehensive and scalable solution for diverse inventory management needs.

III. Proposed System

The proposed system is a smart, IoT-based inventory control system that automates stock monitoring, identifies products, and alerts stakeholders in real-time. It integrates various sensing and communication technologies with cloud infrastructure to ensure accurate, efficient, and scalable inventory management. The system is designed to be flexible and can be deployed across different environments such as retail shops, pharmacies, and warehouses.

- **RFID Module:** Used to uniquely identify and track products in the inventory. Each item is tagged with an RFID tag, and RFID readers detect when an item is added or removed.
- **Ultrasonic Sensor:** Monitors shelf or bin stock levels by measuring the distance between the sensor and the topmost item, estimating quantity in real-time.
- **Barcode Scanner:** Enables easy product identification and billing through barcode scanning using a mobile app or scanner device.
- **Microcontroller (e.g., NodeMCU ESP8266):** Collects data from sensors and communicates with the cloud database over Wi-Fi.

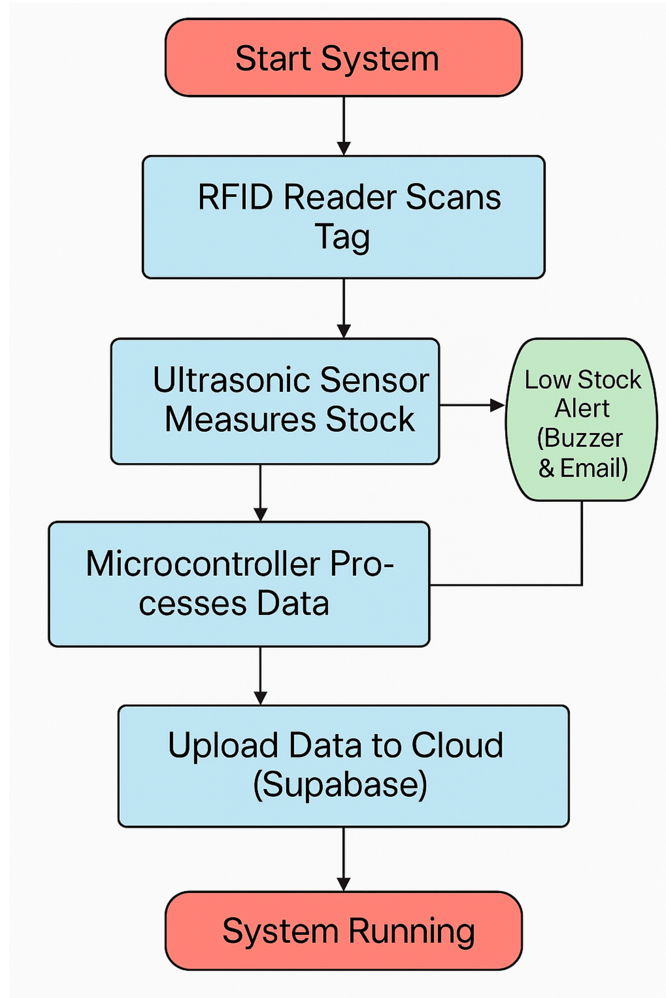

Fig. 2: Flow chart

- **Cloud Database (Supabase):** Stores inventory data, product details, transaction logs, and alert history. Ensures remote access and synchronization across platforms.
- **Alert System:** Triggers alerts via buzzer and sends email notifications when stock falls below a user-defined threshold.
- **Dashboard Interface:** A web-based or mobile dashboard that provides real-time insights into inventory status, sales, and alerts. Offers analytics and downloadable reports.

A. Working Principle

1) Products are tagged with RFID labels or barcodes during initial entry.
2) As items are removed or added to the shelves, RFID and ultrasonic sensors detect changes in inventory.
3) The microcontroller transmits this data to the Supabase cloud in real-time.
4) When inventory reaches a minimum threshold, alerts are triggered both locally (via buzzer) and remotely (via email).

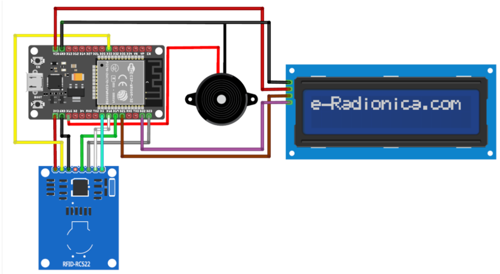

Fig. 3: Circuit Diagram

5) All data is visualized through a secure dashboard, accessible from multiple devices.

B. Advantages

- Minimizes human intervention and errors.
- Enables real-time stock visibility and remote monitoring.
- Scalable and cost-effective for various business sizes.
- Allows proactive inventory restocking, reducing downtime.
- Supports multi-device access for seamless operations.

IV. Proposed Algorithm

The proposed system continuously monitors inventory levels using a combination of RFID and ultrasonic sensors, and facilitates product identification and billing through barcode scanning. It maintains real-time synchronization with a cloud database, triggers alerts for low-stock conditions, and updates a dashboard interface.

A. System Workflow

1) **Initialization:**
   - Initialize hardware components: RFID reader, ultrasonic sensor, barcode scanner, microcontroller, buzzer.
   - Setup cloud database connection (Supabase).
   - Define threshold values T_i for each product i, indicating minimum acceptable stock level.
2) **Continuous Monitoring Loop:**
   - **RFID Scanning:** Capture unique identifier UID_i of items entering or leaving the inventory.
   - **Ultrasonic Sensing:** Measure distance d from sensor to the top of the inventory stack.
   - **Stock Quantity Calculation:**

     $$Q_i = \left\lfloor \frac{H - d}{h_i} \right\rfloor$$

     where H is the shelf height, d is the measured distance, and h_i is the average height of a single product unit i.
   - **Barcode Scanning:** Read product barcodes during sales or restocking.
   - **Database Update:** Synchronize inventory data and transactions to the cloud.
3) **Low-Stock Alert:**
   - Check if $Q_i \leq T_i$.
   - If yes, trigger buzzer alert and send an email notification.
   - Log alert event in the database.
4) **Dashboard Refresh:** Update user interface with latest stock levels, sales data, and alert statuses.
5) **Power Optimization:** Introduce a delay Δt between monitoring cycles to balance responsiveness and power usage.

algorithm algorithmic

B. Algorithm

Algorithm 1 Real-Time IoT Inventory Monitoring and Alert System

Initialize RFID reader, ultrasonic sensor, barcode scanner, buzzer, and cloud database. Set threshold values T_i for all products i. system is running Scan RFID tags to detect item changes. Measure distance d using ultrasonic sensor. Calculate current stock quantity:

$$Q_i = \left\lfloor \frac{H - d}{h_i} \right\rfloor$$

Scan barcode for product identification and billing. Update inventory data in the cloud database. $Q_i \leq T_i$ Activate buzzer alert. Send email notification to inventory manager. Log the alert in the database. Refresh dashboard with updated stock and alert information. Wait for Δt seconds before next iteration.

V. Methodology

This section describes the design and implementation details of the proposed IoT-based inventory management system, covering hardware components, software architecture, data flow, and system integration.

A. System Architecture

The system integrates hardware sensors for physical stock measurement, cloud database for data storage, and software interfaces for real-time monitoring and alerting. It consists of three main modules:

- **Sensing Module:** Includes RFID readers, ultrasonic sensors, and barcode scanners to detect inventory items, measure stock levels, and identify products.
- **Processing and Communication Module:** Utilizes microcontrollers (e.g., NodeMCU or ESP8266) to process sensor data and communicate with the cloud database over Wi-Fi.
- **Cloud and User Interface Module:** Cloud-based database (Supabase) stores inventory data, triggers alerts, and serves a web/mobile dashboard to users.

B. Hardware Components

- **RFID Reader and Tags:** Used for automatic identification and tracking of items. Each product is tagged with a unique RFID tag which is scanned to update inventory.

- **Ultrasonic Sensor:** Measures the distance between the sensor and the top surface of the inventory stack. This measurement helps calculate the current quantity of stock.
- **Barcode Scanner:** Facilitates product identification during billing and inventory audits.
- **Microcontroller (NodeMCU/ESP8266):** Reads sensor inputs, processes the data locally, and communicates with the cloud.
- **Buzzer:** Acts as an audible alert when stock falls below predefined thresholds.

C. Software Architecture

- **Data Acquisition:** Sensor data is collected continuously. RFID reader detects item presence or removal; ultrasonic sensor measures stock height; barcode scanner identifies product codes.
- **Data Processing:** The microcontroller converts raw sensor inputs into meaningful stock quantities. For ultrasonic sensors, distance measurements are converted to stock count using calibrated product height parameters.
- **Cloud Communication:** Processed data is sent to the Supabase cloud database using RESTful APIs or WebSocket connections for real-time updates.
- **Alert System:** The cloud monitors stock quantities against threshold values. On detecting low stock, it triggers buzzer alerts via commands to the microcontroller and sends email notifications to inventory managers.
- **Dashboard Interface:** A web-based dashboard displays current stock levels, sales data, and alert history. The dashboard supports real-time updates and cross-device synchronization.

D. Data Flow and Operations

1) Products tagged with RFID are placed on shelves.
2) The ultrasonic sensor continuously measures the height of stacked products.
3) The microcontroller reads sensor data, calculates quantity using the formula:
$$Q_i = \left\lfloor \frac{H - d}{h_i} \right\rfloor$$
where H is the maximum shelf height, d is the measured distance from the sensor to the top of the stack, and h_i is the height of a single product unit.
4) Barcode scanning is performed during billing or stock audits to verify product details.
5) Inventory data is uploaded to the cloud database in real-time.
6) Threshold checks are performed on the cloud; alerts are triggered if stock falls below predefined limits.
7) Alerts activate the buzzer and send email notifications.
8) The dashboard reflects updated inventory and alert status, accessible via web or mobile devices.

E. System Integration and Testing

- Hardware components were integrated and calibrated to ensure accurate sensor readings.
- Communication protocols were tested for reliability and low latency.
- The cloud database schema was designed for efficient storage and quick retrieval of inventory and alert data.
- The dashboard UI was tested for responsiveness and ease of use.
- The entire system was evaluated in a simulated retail environment to verify real-time monitoring and alert accuracy.

VI. Related Work

Automated inventory management systems have been widely researched, with various approaches leveraging IoT and cloud technologies to improve stock monitoring and control.

A. Energy-Efficient IoT Inventory Mechanisms

Some researchers have focused on developing fast and energy-efficient inventory mechanisms for IoT environments. These systems prioritize low-power sensor nodes and lightweight communication protocols to enable continuous monitoring while preserving battery life. However, they often lack real-time user interfaces and alerting capabilities.

B. Hardware-Centric Solutions

Other approaches concentrate on hardware-oriented implementations using microcontrollers such as NodeMCU combined with RFID technology. These systems provide reliable identification of inventory items and basic stock tracking. Nevertheless, many do not scale well to larger deployments and lack integration with cloud databases or real-time alert systems.

C. Cloud-Based Inventory Management

Cloud computing has been incorporated into inventory systems to facilitate centralized data storage and remote access. These solutions improve data availability and allow for multi-user collaboration. However, many existing systems do not fully automate low-stock alerts or real-time synchronization, often relying on manual data updates.

D. User Interface and Dashboard Integration

Some systems integrate dashboards for monitoring sales, stock levels, and generating reports. While these interfaces enhance user interaction, they frequently depend on manual data input or offline synchronization, which can introduce errors and delay responses to inventory changes.

E. Limitations and Motivation

Despite progress in individual components, there remains a lack of comprehensive inventory solutions that combine real-time physical stock measurement (using RFID and ultrasonic sensors), cloud synchronization, automated low-stock alerts via email and buzzer, and an interactive, real-time dashboard. Our proposed system addresses these limitations by implementing a full-stack IoT architecture designed for seamless real-time monitoring, alerting, and multi-platform synchronization.

VII. FUTURE WORK

While the proposed IoT-based inventory management system effectively enhances real-time stock monitoring and reduces manual errors, there remain numerous opportunities for further improvement and innovation:

- **Integration of Artificial Intelligence:** Future work can focus on integrating AI and machine learning models to analyze historical inventory data and sales trends. Predictive analytics could optimize stock levels by forecasting demand fluctuations, seasonal trends, and potential supply chain disruptions, thereby minimizing both overstock and stockout scenarios.
- **Enhanced Sensor Fusion:** Incorporating additional sensors such as weight sensors, temperature and humidity sensors, and cameras could improve inventory accuracy, particularly for fragile or perishable goods. Multi-sensor fusion techniques can offer more robust and comprehensive monitoring.
- **Blockchain Technology for Data Integrity:** Employing blockchain for transaction logging can enhance security and transparency. This would ensure tamper-proof records of stock movements, useful for audit trails and regulatory compliance, especially in pharmaceuticals and high-value goods.
- **Mobile and Voice-Enabled Interfaces:** Developing dedicated mobile applications and voice assistants could allow inventory personnel to interact with the system more intuitively. Push notifications, voice commands, and on-the-go stock updates will improve operational flexibility and responsiveness.
- **Edge Computing for Scalability:** Deploying edge computing nodes closer to sensor clusters can reduce latency and bandwidth consumption by processing data locally. This is essential for large warehouses or distributed retail chains where real-time response and data privacy are critical.
- **Automated Supply Chain Integration:** Future versions could automate reorder processes by integrating with suppliers' ERP systems. This would close the loop between inventory monitoring and procurement, enabling just-in-time inventory replenishment and reducing carrying costs.
- **Advanced Alert Customization and Analytics:** Expanding the alert system to support customizable thresholds, multi-level notifications, and integration with various communication channels (SMS, app alerts, Slack, etc.) can enhance operational control. In-depth analytics dashboards could provide KPIs and actionable insights to decision-makers.
- **Environmental Impact Monitoring:** By tracking environmental factors affecting stock quality (e.g., temperature fluctuations for pharmaceuticals), the system can proactively prevent spoilage or damage, ensuring compliance with quality standards.

VIII. CONCLUSION

This paper has presented a comprehensive, scalable IoT-enabled inventory management system that addresses critical challenges faced by traditional inventory control methods. By integrating RFID technology and ultrasonic sensors, the system achieves accurate real-time stock quantification without relying on manual entry. The use of barcode scanning further facilitates efficient product identification and billing processes.

Centralized cloud synchronization using a modern database platform ensures that inventory data remains consistent and accessible across devices and locations. The system's automated low-stock alert mechanisms, comprising buzzer signals and email notifications, enable timely interventions that reduce the risks of stockouts and overstocking.

Additionally, the inclusion of a real-time dashboard empowers inventory managers with actionable insights, enhancing transparency and operational efficiency. This integration of hardware sensing, cloud technologies, and user-friendly interfaces represents a significant advancement over existing solutions.

By reducing manual labor, minimizing human errors, and providing instantaneous feedback, the system promises substantial improvements in inventory accuracy and management efficiency for retail shops, pharmacies, and warehouses alike. The flexible architecture allows easy adaptation and scaling for diverse deployment scenarios.

In conclusion, the proposed system lays the groundwork for smarter, more responsive inventory management, with promising directions for future enhancements including AI-driven demand forecasting, blockchain security, and edge computing. Such innovations will further elevate inventory control systems to meet the dynamic needs of modern supply chains and retail environments.

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