

Simulation of IOT-Based Smart Refrigeration System

Amulya Vinathi Malipatil
dept. of computer science(CY)
RV college of Engineering
Bengaluru, India
amulyavm.cy23@rvce.edu.in

Meda Mounika
dept. of computer science(CY)
RV college of Engineering
Bengaluru, India
medamounika.cy23@rvce.edu.in

KB Ramesh
dept. of electronics and instrumentation
RV college of Engineering
Bengaluru, India
rameshkb@rvce.edu.in

Abstract—Our project presents a simulated Smart Refrigerator Management System designed to track food items and generate expiry alerts. Using LPC2138, DHT11, and RFID technology, the system monitors stored items, providing notifications when items approach their expiry date. The simulation highlights the use of digital tracking for effective food management, allowing users to make informed decisions regarding food usage. By replicating real-world scenarios, the system aims to reduce food waste through timely reminders and efficient inventory management, offering a practical solution for improved food storage and reduced wastage in households.

Index Terms—Smart Refrigerator System, RFID Technology, Expiry Monitoring, Food Wastage Reduction, DHT11 Temperature Sensor, Embedded System Design, LPC2138 Microcontroller, Real-time Alerts

I. INTRODUCTION

Food wastage is a significant global issue, particularly in households where items are often discarded due to unnoticed expiry dates or improper storage. This contributes to economic loss and negatively impacts environmental sustainability. With increasing emphasis on responsible consumption, there is a critical need for systems that enable efficient food waste management.

Our paper presents a simulated smart refrigerator system designed to monitor food storage and generate expiry alerts. The simulation demonstrates the effectiveness of digital tracking and timely notifications in supporting informed food usage decisions. By replicating real-world storage scenarios in a virtual environment, the system provides a practical framework for improving food management practices and reducing avoidable waste.

II. LITERATURE REVIEW

The integration of Internet of Things (IoT) technologies into household appliances has led to significant advancements in food storage and management systems. Smart refrigerators equipped with sensors and connectivity features have been developed to monitor food items, track expiration dates, and reduce waste. Raheja et al. [1] provided a comprehensive review of IoT-based smart refrigerators, highlighting their capabilities in inventory management and energy efficiency.

In the realm of food waste reduction, IoT and big data technologies have been employed to enhance resource efficiency. A study by Islam et al. [2] discussed various models and algorithms that utilize IoT sensors and big data analytics to minimize food wastage across the supply chain. These technologies enable real-time monitoring and predictive analysis, facilitating proactive measures to prevent spoilage.

Further innovations include the use of RFID technology and environmental sensors in smart refrigeration systems. Terso Solutions [3] introduced RFID-enabled refrigerators that automatically track inventory and ensure product integrity by maintaining optimal temperature ranges. Additionally, AI and IoT integration in smart fridges, as discussed by Intuz [4], allows for features such as automated expiration alerts, inventory tracking, and nutritional insights, enhancing user convenience and promoting sustainable consumption practices.

These developments underscore the potential of IoT-based smart refrigeration systems in addressing food waste challenges and improving household food management.

III. METHODOLOGY

The system was developed encompassing the following phases:

A. Problem Definition

To simulate a smart refrigerator management system capable of tracking food expiry dates and monitoring temperature conditions to prevent spoilage. The system is designed using the LPC2138 microcontroller and simulated in Proteus 8.13. RFID tags are used to identify items automatically, while a keypad allows manual entry of item data. A DHT11 sensor provides real-time temperature readings. Expiry alerts and temperature warnings are displayed via a virtual terminal. The control logic is developed in Embedded C using Keil μ Vision.

B. Component Selection and Tools

Hardware components (Simulated using Proteus): LPC2138 Microcontroller (ARM7-based); RFID Reader and Tags (simulated using virtual terminal input); DHT11 Temperature Sensor; 4x3 Matrix Keypad; Virtual Terminal (UART display); Power supply, wires, and connectors. Software components: Keil μ Vision 4 – for writing and compiling embedded

C code; Proteus Design Suite 8.13 – for designing, simulating, and testing the embedded system circuit.

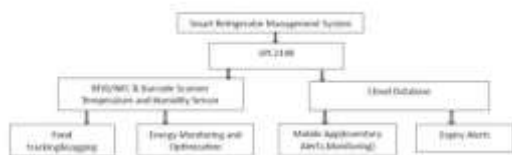


Fig. 1. Block diagram of Smart Refrigeration Management System

C. RFID and Keypad-Based Item Entry

The system is configured to accept food item data through two methods: RFID tag scanning and keypad input. When an RFID tag is scanned, its unique ID is received via UART and processed by the LPC2138 to register the corresponding item and its expiry period. Alternatively, users can manually enter item codes and expiry durations through the 4x3 matrix keypad. Once entered, the item is stored in the system's memory, and a timer begins to track the remaining validity period in days.

D. Expiry Countdown and Temperature Monitoring

The LPC2138 uses internal timers to simulate the passage of real-world time. Each cycle corresponds to a "virtual day," reducing the expiry countdown for each item. Simultaneously, the DHT11 sensor is polled to read temperature values. If the temperature exceeds a predefined threshold (e.g., 25°C), the system flags the possibility of spoilage. The microcontroller evaluates each item's expiry status and temperature conditions to determine whether an alert needs to be generated.

E. Alert Generation and User Interface

Based on expiry status and temperature data, the system generates alerts through the virtual UART terminal. Messages such as "Item Expired," "Temperature High – Spoilage Risk," or "X Days Remaining" are displayed in real-time, simulating notifications a user would see on a refrigerator screen. This interface helps the user keep track of stored items, manage their consumption efficiently, and avoid waste.

F. Testing and Validation

After development, the system is thoroughly tested in the Proteus simulation environment. Various RFID inputs are simulated via the virtual terminal, and manual entries are provided using the keypad. The system's responses—expiry tracking, spoilage detection, and alert messages—are verified through UART output. The temperature threshold response is tested by adjusting DHT11 values to simulate heat, and the expiry countdown logic is validated by observing item data as virtual days progress.

IV. SYSTEM DESIGN

The Smart Refrigerator Management System is built using the LPC2138 ARM7 microcontroller, designed to track food item expiry and monitor storage temperature in real-time. The simulation is developed in Proteus 8.13, and the embedded logic is written in Embedded C using Keil μ Vision. The system uses RFID for automatic identification, DHT11 for temperature sensing, a keypad for manual item entry, and a virtual terminal for displaying expiry alerts.

A. LPC2138 Microcontroller

The LPC2138 is the central controller responsible for interfacing with all input and output devices in the system. It communicates with the RFID reader and DHT11 sensor, handles manual input through the matrix keypad, tracks item expiry using software timers, and outputs messages to a virtual terminal using UART0. The RFID reader sends data via the UART RXD0 pin, while the TXD0 pin is connected to the virtual terminal to simulate real-time UART output for alerts and feedback. GPIO pins are used to scan the keypad matrix for item entry and expiry days. The microcontroller periodically polls the DHT11 sensor connected to a GPIO pin to read temperature values. Based on time progression simulated using internal timers, the microcontroller compares the stored expiry period with elapsed time and generates alerts. If the temperature exceeds a threshold, spoilage warnings are sent to the UART output. The LPC2138 processes all sensor inputs and user commands, controls data flow, and coordinates expiry and temperature-based alerts.

B. RFID Reader Module

The RFID reader module is used for identifying food items through unique tag IDs. Each tag corresponds to a particular item in the refrigerator. The reader transmits data serially to the LPC2138 through UART. In the Proteus simulation, RFID input is emulated by typing predefined tag values into the virtual terminal, simulating an RFID scan event. When an RFID tag is detected, the microcontroller retrieves the corresponding item and expiry data and stores it internally. This automation allows for seamless item registration without requiring manual data entry.

C. Matrix Keypad (4x3)

The 4x3 matrix keypad serves as a secondary manual input method. It is used to enter food item codes and assign expiry durations in days when RFID input is unavailable. The keypad is interfaced with the LPC2138 through GPIO pins. The microcontroller continuously scans the row and column lines to detect key presses and translates them into corresponding numbers. This input method is especially useful in simulation to add or test custom items and expiry times. Once data is entered, the system logs the item and starts the expiry countdown.

D. DHT11 Temperature Sensor

The DHT11 sensor is integrated into the system to monitor the ambient temperature within the refrigerator. It is connected to the microcontroller through a GPIO pin and periodically polled to read the current temperature. The LPC2138 processes the digital temperature value and checks if it crosses a defined spoilage threshold (e.g., 25°C). If the temperature is too high, a warning message is generated and displayed via the UART terminal. This ensures users are alerted if the storage environment becomes unsuitable for food preservation, simulating the real-world function of protecting against spoilage.

E. Virtual Terminal

The virtual terminal is connected to the UART output of the LPC2138 and acts as a display for real-time feedback. It is used to show messages such as item added, remaining expiry days, expired item alerts, and temperature warnings. This terminal output helps in observing the system's behavior during simulation and debugging. All command acknowledgments, expiry alerts, and spoilage notices are shown here, making it the primary interface for monitoring the system in Proteus.

F. Real-Time Clock Simulation (Software-based)

The system uses internal software timers in the microcontroller to simulate the passage of real-world time. Each iteration of the timer represents a day, allowing the system to decrement the expiry period of each item stored. As the expiry date approaches, the system sends warnings. Once an item's expiry reaches zero, an alert is triggered to indicate that the item should be discarded. This RTC simulation allows expiry tracking without using an external clock module and mimics real-time progression within the simulation environment.

G. Internal Data Storage

Food items, tag IDs, expiry durations, and timestamps are stored internally within arrays or structures in the embedded C program. When an RFID scan or keypad input is registered, the system logs the item and associates it with a timer. These records are updated as simulated time progresses. Expiry conditions are checked against each stored item, and appropriate alerts are issued. This enables the management of multiple food items simultaneously and supports efficient expiry tracking and alert generation.

V. RESULTS AND DISCUSSION

The simulation of the Smart Refrigeration Management System delivered promising outcomes in terms of automated food monitoring, temperature tracking, and expiry alert generation. The following discussion presents the major system components, observed behaviors, encountered challenges, and the potential for future upgrades.

A. RFID-Based Item Detection and Logging

The RFID module successfully simulated automatic item entry through virtual tags in Proteus. Whenever a new item tag was scanned, its ID and associated data (e.g., item type, entry time) were logged and displayed on the LCD. The system ensured no duplication by cross-checking IDs, offering a seamless and user-friendly logging mechanism for stored food items.

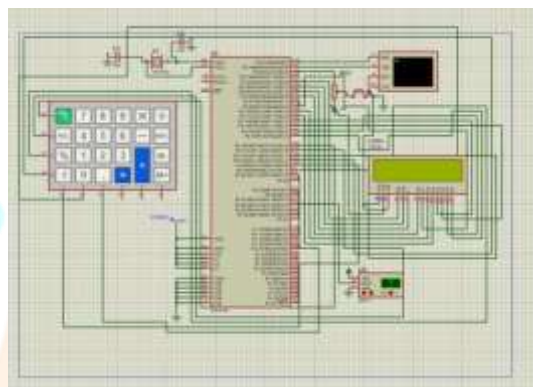


Fig. 2. Circuit diagram of IOT-Based Smart Refrigeration System using LPC2138 Microcontroller in Proteus Design Suite version 8.13

B. Temperature Monitoring with DHT11 Sensor

The DHT11 sensor simulated ambient temperature detection, which was displayed in real-time on the virtual terminal. The system monitored environmental conditions inside the refrigerator and flagged potential spoilage risks if the temperature exceeded a critical threshold. This enables proactive actions to preserve food quality.

C. LCD Display and UART-Based Feedback

The 16x2 LCD provided user-friendly feedback by showing current item status, expiry alerts, and temperature updates. Additionally, the UART interface in Proteus offered detailed logs for debugging and validation of system behavior, ensuring accurate communication between modules.

D. System Modularity and Upgrade Potential

The project's modular structure enables easy adaptation for real-world enhancements. Features such as GSM-based SMS alerts, camera integration for visual inventory, or smartphone control via Bluetooth/Wi-Fi can be integrated without changing the base logic. This scalability supports use cases in both domestic and commercial refrigeration units.

E. Challenges Addressed

Sensor Simulation Accuracy: Calibrating simulated data from DHT11 and RFID modules required fine-tuning to reflect realistic values and response behavior. **Clock Synchronization:** Ensuring precise expiry tracking via the virtual RTC demanded synchronization with item entry time, avoiding false alerts.

Interface Stability: LCD and UART message updates were op-timized to avoid overlap or delays, ensuring reliable feedback to the user.

subsectionFuture Directions Integration with IoT cloud plat-forms to store inventory and temperature history for analytics. Addition of camera modules for barcode recognition and spoilage detection using image processing. Mobile application interface for remote control and alerts. Machine learning-based prediction of spoilage based on temperature trends and item type. The simulation confirms the effectiveness of a smart, automated refrigeration monitoring system that enhances food management, reduces waste, and empowers users with timely, actionable data.

VI. CONCLUSION

The Smart Refrigeration Management System successfully demonstrates how embedded systems and IoT can transform conventional refrigeration into an intelligent, user-aware ap-pliance. By integrating RFID-based item tracking, temperature monitoring using DHT11, and expiry detection through a vir-tual RTC, the system ensures real-time alerts and reduces the risk of food spoilage. Simulated in Proteus and programmed using Keil microVision for the LPC2138 microcontroller, the system offers a reliable and scalable solution for efficient food management. The UART-based alert mechanism and LCD feedback enhance usability and transparency. Overall, this project establishes a practical foundation for future real-world implementations that aim to promote sustainability, minimize food waste, and improve convenience in both domestic and commercial refrigeration environments.

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