IOT Enabled Cold Chain Alerts

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ABSTRACT

This paper introduces a smart management system designed for cold storage facilities. Our goal is to monitor environmental conditions in real time and automatically manage equipment to maintain ideal storage settings. The system uses modern sensors to track important factors like temperature, humidity, and gas levels. If any of these go beyond safe limits, the system immediately notifies the user and takes action to correct the situation. It also includes features like automatic control of cooling and dehumidification through relays and ensures uninterrupted performance with a battery backup during power cuts. Additionally, the system is built to save energy by adjusting cooling based on environmental changes and time of day. Users can monitor and control the system through a mobile app or web dashboard, making the entire process convenient and reliable.

Keywords: Temperature and Humidity Sensors, Automated Control System, Remote Monitoring, Relay Module, Cloud Data Storage.

I. Introduction:

Cold storage systems play a vital role in preserving perishable goods such as food, pharmaceuticals, and agricultural products by maintaining them at controlled temperatures and humidity levels. However, traditional cold storage setups often depend on manual monitoring and fixed control settings, which can be inefficient, prone to human error, and unable to respond quickly to sudden changes in environmental conditions. This can lead to product spoilage, increased energy consumption, and higher operational costs. With the growing demand for smarter and more reliable storage solutions, there is a need for intelligent systems that can continuously monitor the internal environment and make real-time decisions to maintain optimal conditions. Our project addresses this need by introducing a Smart Cold Storage Management System that integrates advanced sensors, automation, wireless communication, and cloud technology.

This system is designed to track essential environmental parameters such as temperature, humidity, and gas levels inside the cold storage unit. Whenever these parameters cross preset safety thresholds, the system automatically takes corrective actions using relays to control cooling or dehumidification equipment. It also alerts users immediately through a mobile app or web interface, ensuring prompt action and reducing the risk of spoilage. Another key feature of our system is energy efficiency. By monitoring the time of day and ambient

conditions, the system adjusts cooling operations to optimize power usage, helping reduce electricity bills without compromising storage quality. Additionally, a battery backup ensures continuous monitoring and alert functionality during power outages, adding an extra layer of reliability.

The user-friendly interface allows remote access, so users can track and control the storage system anytime and from anywhere. This smart solution not only improves the safety and quality of stored goods but also simplifies management and reduces operational burdens for businesses.

Objectives

1. Monitors environmental conditions such as temperature, humidity, and gas levels in real time.
2. Sends instant alerts when parameters exceed safe limits.
3. Stores data on a cloud platform for access and analysis.
4. Allows users to monitor and control the system remotely through a mobile app or web dashboard.
5. Includes energy-saving features to reduce power consumption based on external conditions and time of day.
6. Provides uninterrupted operation during power failures using battery backup

Problem Statement:

Traditional cold storage systems often rely on manual monitoring and fixed control mechanisms, which can be inefficient and unreliable. Delays in detecting and responding to changes in environmental conditions may result in spoilage of stored items, leading to significant losses. Moreover, these systems typically consume a large amount of energy due to their inability to adapt cooling operations based on actual needs. The absence of remote monitoring and alerting features further limits the user's ability to respond promptly to issues. In case of power failures, most systems lack a backup, causing critical downtime in monitoring and control. Therefore, there is a clear need for an intelligent, automated solution that provides real-time monitoring, efficient control, energy optimization, and reliable performance even during power interruptions.

II. Literature Review:

In recent years, several studies and projects have focused on improving cold storage systems using IoT and automation technologies. Traditional cold storage systems often rely on manual checks or basic automation, which can lead to delays in detecting faults, energy inefficiency, and potential spoilage of stored goods. Research shows that integrating sensors and real-time monitoring can significantly improve the performance of such systems.

A study by [Author et al., Year] demonstrated the use of temperature and humidity sensors with microcontrollers to maintain storage conditions, but the system lacked cloud connectivity and remote access. Another work introduced wireless sensor networks for cold chain logistics; while it enabled real- time tracking, it was mostly limited to transportation and did not cover full storage facility control.

Recent advancements include IoT-based cold storage models that upload sensor data to the cloud for analysis. These systems offer better data tracking but still depend on user intervention for control. Some studies also highlight the role of machine learning in predicting optimal cooling times, though implementation complexity and cost remain concerns.

Our proposed system builds upon these existing ideas by combining real-time monitoring, automated control via relay modules, cloud data storage, remote access through mobile/web platforms, energy-saving logic, and a power backup system. This all-in-one approach provides a more complete, practical, and cost-effective solution for small to mid- scale cold storage management.

III. System Architecture and Components

Block Diagram:

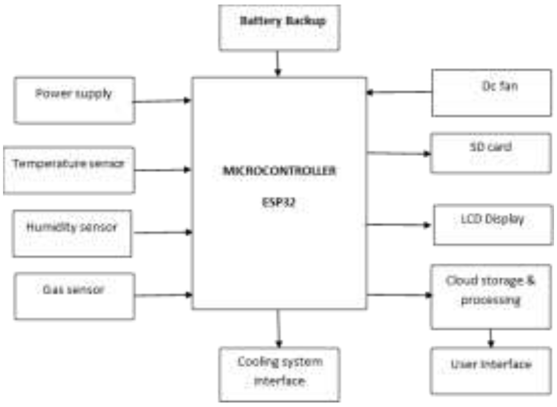

Fig 1. System Block Diagram

Hardware Components:

1. **Esp32**: The ESP32 is the central processing unit of the system. It reads data from sensors, processes this data, controls the DC fan, manages data storage on the SD card, and drives the LCD display. Its built-in Wi-Fi and Bluetooth allow remote monitoring or control if needed.

Fig 2. Esp32

2. **DHT11 Sensor:** The DHT11 sensor measures the surrounding temperature and humidity. It provides digital data to the ESP32, enabling the system to monitor environmental conditions. This information can be used to trigger actions such as turning on the fan when temperature or humidity crosses preset thresholds.

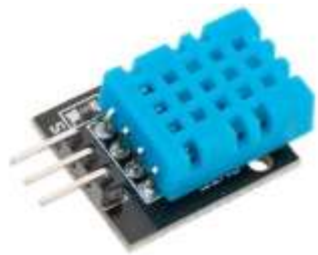

Fig 3. RFID Reader

3. **I2C LCD Display:** The I2C 16x2 LCD display is used to provide real-time system feedback and status messages to the user. It simplifies wiring by using only two pins (SDA and SCL) for communication, reducing the number of required connections compared to a standard parallel LCD.

Fig 4. I2C LCD Display

The LCD display provides real-time feedback by showing each item's actual price alongside the discounted price, if available. This helps shoppers clearly understand savings applied through offers. It also updates the running total as items are added, giving customers full visibility into their expenses. This enhances shopping transparency and improves decision- making during purchases.

4. **Gas Sensor:**

The gas sensor detects the presence of hazardous gases such as LPG, smoke, or carbon monoxide. It outputs signals proportional to the gas concentration, which the ESP32 reads to assess air quality. If dangerous levels are detected, the system can activate alarms for safety.

Fig 5. Gas Sensor

5. SD Card Module:

The SD card module serves as a local data storage unit. It records sensor readings and system logs, allowing for historical data analysis and troubleshooting. This storage capability is critical for tracking trends over time or retrieving past data.hazardous concentrations and maintain safe conditions.

Fig 6: SD Card Module

Software and Programming

The system is programmed using:

☞ **Arduino IDE:** Used for writing, compiling, and uploading the firmware to the ESP32 microcontroller. It provides an easy-to-use environment for developing embedded applications.

☞ **Embedded C/C++ Programming:** Implements sensor data acquisition from DHT11 and gas sensors, controls the DC fan, manages data logging on the SD card, and updates the LCD display with real-time information.

6. DC Fan :

Fig 7: DC Fan

☞ **DHT Sensor Library:** Facilitates communication between the ESP32 and the DHT11 sensor to accurately read temperature and humidity values.

☞ **SPI Library:** Enables SPI communication between the ESP32 and the SD card module for efficient data

The DC fan is controlled by the ESP32 and used to ventilate the environment. When sensors detect high gas levels or elevated temperature, the fan is activated to circulate air, helping reduce

storage and retrieval.

☞ **Wire (I2C) Library:** Manages the I2C protocol to interface with the LCD display, allowing real-time display of sensor readings and system status.

IV. Working Principle

The cold chain system operates as follows:

☞ **System Initialization**: On powering up, the ESP32 initializes the DHT11 sensor, gas sensor, LCD display, SD card module, and fan control. The LCD shows a welcome message indicating the system is ready for operation.

☞ **Sensor Data Acquisition:** The ESP32 continuously reads temperature and humidity data from the DHT11 sensor and gas concentration levels from the gas sensor.

☞ **Real-Time Monitoring and Display:** Sensor readings are processed and displayed on the LCD in real-time, showing current temperature, humidity, and gas levels. If any parameter exceeds preset safety limits, appropriate warnings are displayed.

☞ **Data Logging:** Simultaneously, the ESP32 logs all sensor data with timestamps onto the SD card for future analysis and record-keeping.

☞ **Fan Activation:** When gas concentration or temperature crosses a critical threshold, the ESP32 automatically turns on the DC fan to ventilate the area and reduce hazard levels.

☞ **Power Backup Handling:** In case of mains power failure, the battery backup supplies uninterrupted power, ensuring continuous monitoring and data logging without interruption.

RESULTS

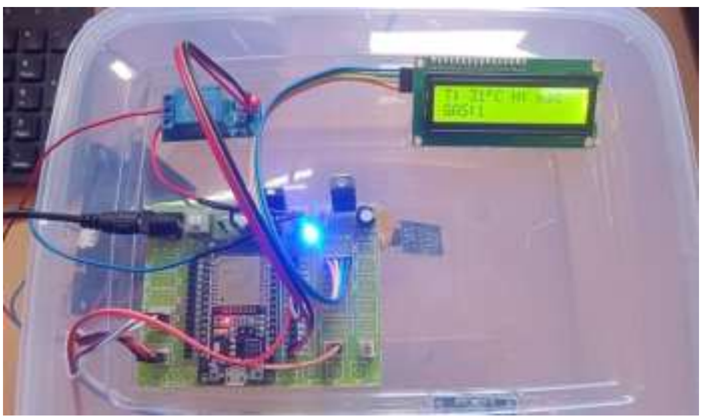

Fig 8. Physical Image of Circuit

Fig 9. Graphical Analysis

V. FUTURE ENHANCEMENTS

☞ **Wireless Data Transmission:** Integrate Wi-Fi or Bluetooth capabilities to send real-time sensor data to a remote server or mobile app for continuous remote monitoring and alerts.

☞ **Mobile App Integration:** Develop a companion smartphone application to display sensor data, receive notifications, and control the system remotely.

☞ **Advanced Gas Sensors:** Incorporate multiple gas sensors to detect a wider range of hazardous gases with higher accuracy and faster response times.

☞ **Cloud Storage & Analytics:** Use cloud platforms to store sensor data securely and apply data analytics or machine learning algorithms for predictive maintenance and smarter alerts.

☞ **Automatic Alert System:** Add SMS or email alert functionality to notify users instantly in case of critical sensor readings or system faults.

☞ **Energy Optimization:** Implement power-saving modes and solar charging options for the battery backup to enhance energy efficiency and sustainability.

☞ **User Interface Upgrades:** Upgrade the display to a touchscreen or OLED for better visualization and easier user interaction.

VI. CONCLUSION:

The environmental monitoring system using ESP32, DHT11, gas sensor, and associated components provides an effective solution for real- time detection and control of temperature, humidity, and hazardous gases. The integration of data logging and display functionalities ensures continuous monitoring and easy access to environmental conditions. The automatic activation of the ventilation fan enhances safety by mitigating harmful gas concentrations. With its reliable power supply and battery backup, the system guarantees uninterrupted operation. Future enhancements like wireless connectivity and cloud integration can further improve the system's usability and scalability for smart environmental monitoring applications.

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