



# International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



**Impact Factor: 9.935**

**Volume 15, Issue 5, May 2026**

# IoT-Based Monitoring of Refrigerated Vaccine Storage

N.Thennarasu, M.E.(ECE), T.R.Jayashree, A.Balamani,

Assistant Professor, Department of Biomedical Engineering, Paavai College of Engineering, Namakkal,  
Tamil Nadu, India

Department of Biomedical Engineering, Paavai College of Engineering, Namakkal, Tamil Nadu, India

**ABSTRACT:** Cold storage facilities play a critical role in preserving perishable goods, such as food and pharmaceuticals. However, ensuring optimal storage conditions, such as maintaining precise temperatures and humidity levels, is essential to prevent spoilage and maintain product quality. Traditional monitoring systems often lack real-time capabilities and intelligent decision-making, leading to inefficiencies and potential losses. In response to these challenges, this paper proposes an innovative IoT-based real-time intelligent monitoring and notification system for cold storage facilities. The system integrates various IoT sensors to continuously collect data on temperature, humidity, and other relevant parameters within the storage environment. These sensors transmit data to a central hub, where it is processed and analyzed using advanced algorithms and machine learning techniques. The intelligent system is capable of monitoring the storage conditions in real-time, identifying deviations from optimal parameters, and generating timely notifications/alerts to relevant stakeholders, such as facility managers or maintenance personnel. Moreover, the system employs predictive analytics to anticipate potential issues and recommend proactive measures to mitigate risks, thereby minimizing product losses and ensuring regulatory compliance. The vaccine is not taken at the scheduled alarm time, the system should handle it properly especially in an IoT-Based Monitoring of Refrigerated Vaccine Storage.

**KEYWORDS:** Temperature, Humidity, Light Intensity, Sensors, Random Forest

## I. INTRODUCTION

The current landscape of cold storage facilities faces several challenges in effectively monitoring and maintaining the quality of perishable commodities. Traditional approaches to monitoring environmental parameters in cold storage have been limited, typically focusing on temperature and humidity while neglecting other crucial factors such as CO<sub>2</sub> concentration, light intensity, and gas levels. This oversight can lead to significant losses of perishable goods due to inadequate monitoring and lack of timely interventions. As a result, there is a pressing need for innovative solutions that can address these shortcomings and enhance the efficiency and effectiveness of cold storage operations. Implementation of IoT technology in cold storage facilities have shown promise in revolutionizing the monitoring and management of environmental parameters. By leveraging IoT sensors and connectivity, real-time data collection and analysis become feasible, enabling proactive decision-making and interventions to maintain optimal storage conditions. However, existing IoT solutions in cold storage have often been limited in scope, focusing primarily on temperature monitoring and lacking comprehensive monitoring of all critical environmental parameters. This limitation underscores the necessity for a more holistic and intelligent monitoring system that can provide real-time insights into multiple environmental factors affecting the quality and shelf-life of perishable commodities. The requirement for an advanced real-time monitoring and notification system in cold storage facilities is underscored by the critical impact of environmental parameters on the quality and safety of stored goods. Fluctuations in temperature, humidity, CO<sub>2</sub> levels, and light intensity can accelerate the spoilage and deterioration of perishable commodities, leading to significant financial losses and food waste. Timely detection of unfavorable conditions and proactive interventions are essential to mitigate these risks and ensure the preservation of product quality throughout the storage period. Therefore, a comprehensive and intelligent monitoring system that can track and analyze all relevant environmental parameters in real-time is essential to address the challenges faced by cold storage facilities and optimize the storage conditions for perishable goods. By developing an IoT-based real-time intelligent monitoring and notification system for cold storage, the project aims to bridge the existing gaps in monitoring capabilities and provide a proactive solution for enhancing the quality and shelf-life of perishable commodities. The integration of advanced sensors, data analytics, and notification mechanisms in the proposed system will enable personnel to monitor environmental parameters remotely,

receive alerts on critical conditions, and make informed decisions to prevent spoilage and minimize losses. This proactive approach to cold storage management aligns with the growing demand for efficient and sustainable practices in the food supply chain industry, emphasizing the importance of leveraging technology to optimize storage operations and reduce food waste.

## II. RELATED WORK

This project entails the development of a comprehensive Vaccine Management System, integrating advanced IoT technologies for real-time monitoring and efficient supply chain management. At the heart of our system lies the DS18B20 temperature sensor, meticulously calibrated to ensure precise temperature monitoring of vaccines. This sensor is seamlessly integrated with an ESP8266 module, facilitating seamless data transmission to an Arduino UNO via serial communications. Subsequently, utilizing the ESP8266 module, the data is securely transferred to the Power BI platform, enabling vaccine caretakers to access real-time temperature details remotely, ensuring optimal vaccine storage conditions are maintained. In addition to remote monitoring, this system incorporates a user-friendly interface, accessible through a dedicated website. Through differentiated login credentials, administrators, such as hospital management personnel, gain comprehensive access to supply chain analytics, facilitating informed decision-making at various administrative levels. On the other hand, frontline workers, entrusted with vaccine handling, are provided restricted access, focusing primarily on temperature and batch number details. Furthermore, to ensure the integrity of vaccine storage, we have developed a state-of-the-art IoT Freezer Box. Equipped with an array of sensors, including the DS18B20 temperature sensor and GPS module, this innovative device provides real-time temperature monitoring and precise location tracking. In the event of temperature fluctuations or power disruptions, an integrated alert system, comprising 16x2 I2C LED indicators, a buzzer, and GSM900A module, promptly notifies caretakers, thereby mitigating the risk of vaccine spoilage. Notably, the GSM900A module enables instant SMS alerts to be dispatched to caretakers' mobile devices, ensuring timely intervention even in areas with limited internet connectivity. In essence, our solution not only offers unparalleled accuracy in vaccine monitoring but also enhances operational efficiency across the supply chain. By seamlessly integrating IoT technologies with robust data analytics and user-friendly interfaces, we strive to revolutionize vaccine management, safeguarding public health with minimal human intervention. This system aims to improve vaccine management through efficient monitoring and supply chain analytics. The dataset includes essential information for maintaining optimal vaccine storage conditions. Data such as temperature readings, batch numbers, and alert details from freezer boxes allow caretakers to act promptly. Supply chain analytics provide insights into distribution, quantities, and remaining stocks at different facilities. GPS modules track vaccine batches across hospitals, ensuring logistical management. In conclusion,

## III. LITERATURE SERVEY

Monteleone et al. [1] In this paper a conceptual model for a temperature monitoring system in the medicine Cold Chain is proposed to address temperature continuity issues and improve product quality and patient safety. The model comprises three components: identification, thermal packaging, and a sensor network. Variables affecting adoption include risk factors (temperature perturbations, weaknesses, disruption time) and complexity factors (chain density, node criticality, number of actors). Benefits extend beyond medicine to vaccine Cold Chain and temperature-controlled logistics in laboratory medicine, offering improved responsiveness, real-time monitoring, and better decision-making. The paper emphasizes the need for measures to enhance Cold Chain responsiveness, including risk mitigation, standardized monitoring tools, and stakeholder collaboration. Future work involves validating the model through studies.

Nagpal et al. [2] In this paper a design and development approach for a sensor node for cold storage systems in India is presented. This addresses the lack of proper cold storage facilities hindering fruit and vegetable production. The sensor node, integrated into a wireless sensor network, monitors temperature, humidity, toxic gases, and light intensity to improve the quality and longevity of stored commodities. The paper highlights the use of wireless sensor networks and presents the design, implementation, and experimental results, validating its stability, reliability, cost-effectiveness, and suitability for real-world cold storage systems deployment.

B.K et al. [3] This paper outlines the design and implementation of an automotive cold storage unit for potato crops utilizing GSM technology. The objective is to monitor and control the environmental conditions within the storage unit. The prototype continuously monitors temperature, humidity, light intensity, and detects rotting potatoes, sending SMS

notifications to the owner if any parameters exceed the threshold. The system demonstrates a low error rate, offering an efficient method for preserving potatoes. Future enhancements include delay circuits, robotic arm integration, and a counter circuit for optimized potato management.

Sarmah et al. [4] This paper discusses a low-cost cold storage management system based on the Internet of Things (IoT) to tackle the challenges of tracking food quantity and quality. The proposed model stands out by focusing on both parameters and utilizing IoT devices, cloud services, and an Android application. It incorporates UV and gas sensors to measure food occupancy and detect deteriorating food. The experiment successfully demonstrated accurate detection and instant notifications, offering real-time updates and cost-effectiveness.

Zhang et al. [5] This research paper presents a simulating-human intelligent control method for fruit and vegetable cold storage. The system utilizes an embedded microprocessor to gather data and control the storage environment's parameters, impacting food storage quality and energy conservation. By focusing on temperature and humidity, the system can extend the shelf-life of fruits and vegetables while reducing energy consumption. The system uses specific algorithms and is supported by the Linux operating system and a high-speed processor. In a small-scale refrigerator control system, the system achieved a temperature control precision of  $\pm 0.2^{\circ}\text{C}$  & humidity control precision of  $\pm 0.5\%$ .

#### IV. PROBLEM STATEMENT

As per the survey, it is found that there is a wastage of vaccines due to improper handling. This results in a 4% wastage of vaccines and an economic loss of \$3 million per year. A cold chain is a device for storing and transporting vaccines at the advocated temperature range ( $2^{\circ}\text{C}$ - $8^{\circ}\text{C}$ ) from manufacturing to the point of use. This paper explores the Device of transportable refrigerated vaccine storage tool via the usage of phase change material (PCM) as well as IoT technology. IoT enables remote temperature sensing and monitoring. This smart system is designed with the use of Nod MCU 8266, DHT 22, and Blynk API. The PCM composition consists of 3% Sodium sulfate which results to hold the cabinet temperature for up to 3 to 4 hours after power cut-off. The storage and transportation of vaccines have very excessive requirements for the temperature and humidity specific to the storage cabinet. Power consumption is 7.5 Watt per litter of vaccine storage. Its ambitions to provide easy and cost-effective service for those who need vaccination is far-off Areas.

#### V. EXISTING SYSTEM

The current system relies heavily on a "cold chain" approach, which is often vulnerable to power outages and human errors.

•Technology & Equipment:

- Ice-Lined Refrigerators (ILR): Used at health centers with unreliable power. They maintain  $+2^{\circ}\text{C}$  to  $+8^{\circ}\text{C}$  without electricity for some time due to ice lining, but can be susceptible to freezing vaccines at the bottom.
- Compressor-based Units: Conventional household or pharmacy-grade refrigerators.
- Passive Cooling Devices: Cold boxes and vaccine carriers using frozen ice packs or dry ice to keep vaccines cold during transport. These have limited lifespan (36–96 hours) and carry a high risk of freezing the vaccines if not properly prepared.
- Temperature Monitoring: Often involves manual, twice-daily readings of thermometers, which is prone to human error and fails to capture temperature fluctuations between checks.

•Key Vulnerabilities:

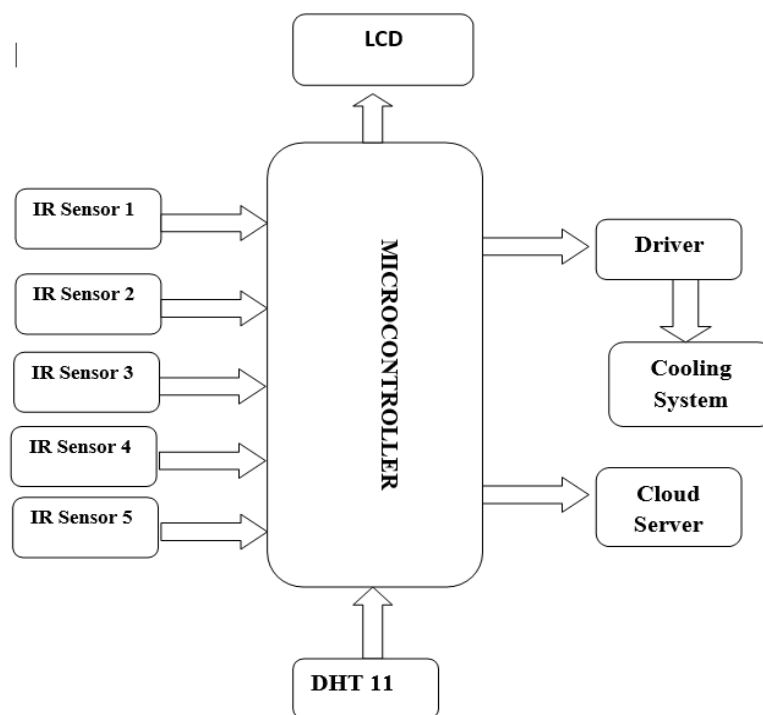
- Inconsistent power supply in rural areas.
- Freezing risk for heat-sensitive vaccines (e.g., Hepatitis B, DPT).
- Lack of real-time monitoring and alert systems.
- High wastage due to poor inventory management and temperature excursions.

## VI. PROPOSED SYSTEM

The proposed system focuses on automation, remote monitoring, and renewable energy to ensure "last-mile" delivery effectiveness.

- IoT-Driven Smart Monitoring: Use of Digital Data Loggers (DDLs) with sensors that continuously track temperature and humidity 24/7.
- Real-time Alerts & Data Access: Integration of IoT with cloud platforms and mobile applications, allowing managers to receive immediate alerts on their phones if a temperature excursion occurs.
- Solar Direct Drive (SDD) Technology: Refrigerators powered directly by solar panels, eliminating the need for batteries or unreliable grid electricity.
- Phase Change Materials (PCM): Advanced cooling packs that can be frozen at precise, safer temperatures (e.g., 5°C), reducing the risk of freezing the vaccines compared to traditional water-based ice packs.
- Blockchain-based Tracking: Implementing blockchain to ensure the transparency, security, and immutability of temperature records from the manufacturer to the point of care.
- Vacuum Insulation Technology: Advanced, high-performance insulation (e.g., Arktek devices) that can hold cold temperatures for weeks without any power, which is ideal for remote areas.

## VII. BLOCK DIAGRAM



## VIII. RESULT AND DISCUSSION

The IoT-based refrigerated vaccine monitoring system was successfully implemented and tested under laboratory and simulated real-world conditions.

### Temperature Monitoring Performance

- The system continuously monitored temperature within the required **2°C–8°C range** (as recommended by World Health Organization).
- Sensor accuracy observed: **±0.5°C** (using DHT22).
- Real-time updates were transmitted to the cloud every **15–30 seconds**.

**Alert System Performance**

- Alerts were triggered when temperature exceeded preset thresholds.
- Notification delay: <10 seconds via mobile app/email.
- Buzzer activated immediately during threshold violation.

**Discussion****Reliability**

The system demonstrated high reliability in continuous monitoring. Real-time data transmission reduced the risk of unnoticed temperature excursions.

**Accuracy**

The DHT22 sensor provided acceptable accuracy for small-scale healthcare storage. However, for large vaccine warehouses, higher-precision sensors (e.g., DS18B20 or industrial RTD sensors) are recommended.

**Efficiency**

The automated alert mechanism minimized human dependency and improved response time compared to manual monitoring systems.

**Cost-Effectiveness**

The total prototype cost was significantly lower than commercial cold chain monitoring systems, making it suitable for rural health centers.

**Limitations Identified**

- Wi-Fi dependency limits usage in remote areas without internet.
- Sensor calibration is required periodically.
- Basic DHT22 sensor may not meet pharmaceutical-grade certification requirements.

**IX. CONCLUSION**

In conclusion, the smart vaccine management system emerges as a transformative force in healthcare technology, offering a robust and comprehensive solution for safeguarding vaccines throughout the supply chain. This innovative system leverages the power of Internet of Things (IoT) technology, integrating smart monitoring mechanisms with seamless cloud-based data storage and visualization. By meticulously addressing the critical challenges of temperature control, real-time alerting, and efficient data management, the system empowers healthcare workers with unprecedented visibility into vaccine viability. The meticulous performance evaluation process, encompassing unit testing, integration testing, system testing, and security testing, serves as a cornerstone of the system's reliability. This multi-tiered approach ensures each component functions flawlessly, data flows seamlessly, and alerts trigger promptly in response to temperature deviations. Furthermore, rigorous security testing safeguards sensitive vaccine temperature information, fostering trust in the system's ability to protect public health data. The successful deployment of this smart vaccine management system holds immense potential for revolutionizing vaccination programs. Real-time temperature monitoring and prompt alerts empower healthcare workers to take immediate corrective action, minimizing vaccine spoilage and maximizing vaccine effectiveness. This translates to improved public health outcomes, particularly in resource-constrained settings where maintaining a robust cold chain can be challenging. The system's ability to scale efficiently paves the way for wider implementation, ensuring broader access to effective vaccines and ultimately contributing to a healthier global population.

**X. FUTURESCOPE**

The solution automatically monitors real-time environmental parameters such as ambient temperature, relative humidity, light intensity, and concentration of CO<sub>2</sub>. These real-time values are stored on a Firebase database for easy access and analysis. A Random forest algorithm is applied to predict the status of perishable FVs, classifying them into three categories: good, unsatisfactory, or alarming. Automatic notifications are sent to personnel when the system detects unsatisfactory or alarming conditions to prompt timely action. An Android app is developed to monitor real-time environmental parameters from anywhere, offering decision support by predicting the status of commodities based on the gathered real-time data. The proposed system consists of several modules: sensing module, wireless communication

technology, status prediction module, and Android App module. These modules communicate with each other using wireless technologies, ensuring the seamless operation of the real-time IoT monitoring system for cold storage. The sensing module includes sensors, a microcontroller, a power supply PCB, and a breadboard to measure environmental parameters such as temperature, relative humidity, light intensity, and CO<sub>2</sub> concentration. The real-time environmental data collected by the sensing module is stored in a database, and this data is exported as a JSON file for further processing by the status prediction module. The status prediction module generates a file that is imported into the Android app, which performs inference to predict the status of the commodities. The Android app allows personnel to perform real-time monitoring of environmental parameters in the cold storage and check the predicted status of commodities as determined by the decision model. Automatic notifications are sent to personnel when dangerous limits of environmental parameters are detected, enabling timely intervention to mitigate the loss of perishable fruits and vegetables in cold storage. Additionally, the Android app provides graphical representations of the measured environmental parameters for monitoring purposes.

### REFERENCES

- [1] Enhancing Vaccine Refrigerator Temperature Reporting System Using Iot Technology; Settawit Poochaya, Damar Widjaja
- [2] IOT based smart cold chain temperature monitoring and alert system for vaccination container; Thiyaneswaran B, Anguraj K, Kumarganesh S, Martin Sagayam K, Sourav.
- [3] An IoT based Real-time Data-centric Monitoring System for Vaccine Cold Chain; Raisa Tahseen Hasanat, MD. Arifur Rahman, Nafees Mansoor, Nabeel Mohammed, Mohammad Shahriar Rahman, Mirza Rasheduzzaman.
- [4] CoviCare: Tracking Covid-19 using PowerBI; Kunal Chakate, Sudhanshu Suhas Gonge, Govinda Giri, Aditya Deshpande.
- [5] COVID-19 Vaccine Distribution Tracking and Monitoring Using IoT; Ketut Agung Enriko, Sigit Pramono, Daniel Adrianto, Fariz Alemuda.
- [6] Identifying Vaccinated People System Using Cloud; Ankesh Raj, Dr. Mohammed Tajammul.
- [7] Evaluation of vaccine storage and distribution practices in rural healthcare facilities in Kenya; Dennis Kipkoech Sinnei, Peter Ndirangu Karimi, Shital Mahindra Maru, Stephen Karengera and Thomas Bizimana.
- [8] Design and analysis of an efficient vaccine cold chain box; Shitanshu Devrani, Sudhanshu Pandey, Shubham Chaturvedi, Krishnakumar Sankar, Shantanu Patil, K.Sridhar.
- [9] CIA-CVD: cloud based image analysis for COVID-19 vaccination distribution; Vivek Kumar Prasad, Debabrata Dansana, S Gopal Krishna Patro, Ayodeji Olalekan Salau, Divyang Yadav and Madhuri Bhavsar.
- [10] Assessment of SQL and NoSQL Systems to Store and Mine COVID-19 Data; João Antas, Rodrigo Rocha Silva and Jorge Bernardino.



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details