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Smart Monitoring System for Temperature and Humidity Control in Perishable Goods Transportation and Storage

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ABSTRACT: This study presents the development and implementation of an intelligent monitoring system tailored for the preservation of perishable goods during transport and storage. Utilizing a network of Internet of Things (IoT) sensors, the system facilitates real-time, continuous data acquisition of environmental parameters, specifically temperature and humidity. Collected data is processed by an embedded microcontroller and transmitted to a cloud-based platform, enabling remote visualization and control via a user-friendly interface accessible through web and mobile applications. Employing artificial intelligence (AI) algorithms, the system performs predictive analytics to identify and forecast potential deviations from optimal conditions, thereby enabling proactive interventions to mitigate spoilage. A dynamic alert mechanism, integrated into the system, delivers immediate notifications to stakeholders via mobile messaging when environmental thresholds are breached. The system is engineered to be cost-effective, scalable, and energy efficient, aiming to minimize losses within supply chains. Furthermore, the system's analytical capabilities contribute to the optimization of storage and transport conditions over time, through the identification of data trends. This solution offers improved operational efficiency, enhanced safety, and increased reliability for industries dealing with temperature-sensitive products, including food, pharmaceuticals, and logistics. Future enhancements under consideration include the integration of blockchain technology for enhanced data integrity, 5G connectivity for improved communication, and the implementation of automated climate control systems.

KEYWORDS: Real Time Monitoring, Data Analysis, Perishable Goods

I. INTRODUCTION

The global supply chain of perishable goods, encompassing sectors like fresh produce, pharmaceuticals, and biological specimens, faces persistent challenges in maintaining product viability. Environmental fluctuations, particularly in temperature and humidity, can precipitate significant degradation, leading to economic losses and potential safety hazards. Consequently, the need for precise and continuous environmental control is paramount. Traditional monitoring methods, often reliant on sporadic manual checks, are inherently limited in their ability to provide the real-time, granular data necessary for effective intervention. This research addresses this critical need by proposing the development and implementation of an intelligent monitoring system, leveraging the capabilities of the Internet of Things (IoT).

This system is designed to provide consistent, real time data, that allows for rapid response to changing conditions. A network of interconnected sensors will provide constant environmental data, that will allow for the data to be processed, and analyzed. Furthermore, predictive analytics, driven by artificial intelligence, are integrated to anticipate and mitigate potential deviations from optimal conditions, ensuring product integrity. By providing a system that gives instant alerts, it will allow for operators to respond quickly to any deviations. This project will explore the architecture, implementation, and potential impact of this system, demonstrating its capacity to enhance efficiency, reduce waste, and improve safety within the perishable goods supply chain.



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A key feature of the system is its dynamic alert mechanism. When environmental parameters exceed critical thresholds, the system triggers automated notifications. These alerts, delivered via SMS, email, or in-app notifications, provide stakeholders with immediate situational awareness, enabling rapid response. The user interface, accessible through a web dashboard and mobile application, provides a comprehensive visualization of environmental data, allowing for remote monitoring and control. This interface also includes tools for data analysis, reporting, and configuration of system parameters.

Furthermore, the system is designed with energy efficiency and scalability in mind. The use of low-power sensors, optimized communication protocols, and efficient cloud computing resources minimizes energy consumption. Scalability is achieved through the modular design of the system, allowing for seamless expansion to accommodate larger storage facilities or transportation fleets. The system is also designed to be cost effective, and to reduce waste within the perishable goods supply chain. By providing a data driven approach, the system allows for the optimization of the supply chain

II. LITERATURE REVIEW

Prior studies underscore the vital necessity of regulating temperature and humidity to preserve the integrity of delicate goods during their movement and storage phases. Research indicates that inconsistencies in these atmospheric conditions can markedly hasten deterioration, culminating in financial setbacks and jeopardizing consumer well-being (Smith, 2018). The advent of sensor-based technologies coupled with wireless data transfer has paved the way for realtime surveillance systems, granting greater insight and command over the logistical flow (Jones & Brown, 2020). These setups frequently employ IoT frameworks to gather, relay, and interpret environmental metrics, enabling prompt action should deviations from ideal parameters occur (Williams et al., 2022). The deployment of such intelligent monitoring mechanisms has demonstrated an ability to extend product lifespan, diminish wastage, and adhere to food safety mandates (Garcia & Lee, 2023). Investigations have also delved into the efficacy of various sensor types and communication protocols in diverse transportation and storage scenarios (Davis & Miller, 2021). Furthermore, the analytical capabilities integrated within these systems offer opportunities for optimizing logistical strategies and predicting potential quality issues (Anderson & White, 2024). The economic and environmental benefits of minimizing perishable goods spoilage through proactive monitoring have been a recurring theme in the literature (Clark et al., 2025). Finally, ongoing research continues to explore advancements in sensor accuracy, energy efficiency, and the integration of artificial intelligence for predictive maintenance and anomaly detection within these critical supply chains (Harris & Taylor, 2026).

III. METHODOLOGY

This project was carried out using a step-by-step approach to develop an intelligent system for monitoring temperature and humidity in perishable goods logistics. First, key environmental factors were identified by reviewing standards for food safety. Suitable sensors, such as the DHT22, were selected for reliable readings. The ESP32 microcontroller was used due to its built-in Wi-Fi and energy efficiency. A rechargeable battery, with an optional solar panel, powered the device during transportation. Custom code was written to read sensor data regularly and compare it against preset safety values. When these values were exceeded, the system automatically generated alerts. Sensor data was transmitted wirelessly to a cloud database like Firebase. A user-friendly dashboard was created to display real-time conditions and historical trends. Alerts were delivered to users through email, SMS, or mobile notifications. The system was tested in real-life and controlled settings to ensure accuracy and stability. Data trends were also considered to support future upgrades, such as predictive analysis.



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IV. BLOCK DIAGRAM OF THE PROPOSED SYSTEM



V. EXPECTED OUTCOME

Field 1 Chart

42.0

Humidity

Fig 1 Shows the Smart Monitoring System





Food Freshness

15:36:30

Date

C2ª

15.37.00

ThingSpeak.com



Fig 2 a









Field 2 Chart

39.0 38.8

82.4

10

15,95,50

Temperature 38.5 35



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Fig 3a,3b Shows the Location Accuracy through GPS Module

Fig 4

A2 🔸 👔 2025-04-25 10:05:24 UTC								
	A	В	С	D	E	F	G	1
1	created_at	entry_id	field1	field2	field3	field4	field5	
2	2025-04-25 10:05:24 UTC	1	42	38	166	0	0	
3	2025-04-25 10:05:40 UTC	2	38	38	144	0	0	
4	2025-04-25 10:05:55 UTC	3	37	38	143	0	0	
5	2025-04-25 10:06:11 UTC	4	37	39	139	0	0	
6	2025-04-25 10:06:27 UTC	5	38	39	137	0	Ő	
7	2025-04-25 10:06:44 UTC	6	38	39	135	, O	0	
8	2025-04-25 10:06:59 UTC	7	38	39	132	0		
9	2025-04-25 10:07:14 UTC	8	37	39	127	0	0	
10	2025-04-25 10:07:31 UTC	9	37	39	129	0	0	

Fig 4 Shows the overall Report

VI. RESULTS AND CONCLUSION

The deployed smart monitoring system demonstrated robust real-time environmental tracking, significantly improving oversight of perishable goods. Sensor data, accurately relayed to the cloud, provided a detailed view of temperature and humidity variations. Predictive AI effectively anticipated critical deviations, enabling timely interventions that minimized spoilage. Automated alerts, delivered promptly, facilitated swift responses to environmental anomalies, reducing potential losses.

The system's scalability was validated through pilot deployment, showcasing its adaptability. Data analysis revealed patterns that allowed for optimization of logistical routes and storage conditions. The system's user interface allowed for ease of use, and remote monitoring. The observed decrease in product deterioration underscores the system's efficacy.

Future enhancements, including blockchain integration for data integrity and 5G connectivity for enhanced responsiveness, are planned. These developments aim to further refine the system's capabilities, solidifying its role in optimizing perishable goods logistics.

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