Revolutionizing Cold-Chain Management: An Innovative Approach to Temperature Monitoring in Pharma/Food Industry using Node MCU Processors

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***Abstract*— The proper temperature control of sensitive products, such as pharmaceuticals and food, is crucial to maintain their quality and safety throughout the supply chain. Cold-chain logistics, which involve the transportation and storage of temperature-sensitive goods, present unique challenges that require advanced monitoring and control systems. In this paper, we propose a temperature monitoring and control system that utilizes Internet of Things (IoT) technology and a web-based interface to enable real-time monitoring and control of temperature in the cold-chain logistics of the pharma/food industry. The system incorporates NodeMCU controllers, temperature sensors, and a web-based dashboard for remote monitoring and control. The proposed system provides real-time temperature monitoring, data logging, and alerts for out-of-range temperature conditions, allowing timely intervention to prevent spoilage, contamination, and other temperature-related issues. The system also allows for remote control of temperature settings, ensuring that the desired temperature conditions are maintained throughout the supply chain. The system is scalable, cost-effective, and can be easily integrated into existing cold-chain logistics processes. We discuss the design, implementation, and evaluation of the proposed system, and highlight its potential applications in the pharma/food industry, cold-chain logistics, transportation of sensitive goods, storage facilities, and supply chain management.**

Index Terms*— Temperature monitoring, Cold-chain logistics, IoT, NodeMCU, Pharma/Food industry, Supply chain management.

I. INTRODUCTION

The paper's goal is to track the temperature in the pharmaceutical and food industries. The model will upload its data to a server, where customers can then remotely access the data. The information we provide is continuously checked around-the-clock, and customers may track the progress of their orders up until they arrive at their destination. In order to keep food fresh and edible and to reduce food waste, it is crucial to maintain food safety and hygiene. Maintaining adequate environmental conditions for the food that is being stored can help slow down the rate of decomposition. Food decomposition is influenced by a variety of elements, but temperature, humidity, and bacteria are the main ones that affect how quickly food breaks down.

When the storage is between 40 to 140 degrees Fahrenheit, it is in a danger zone because at that temperature, germs multiply quickly and double in number in just 20 minutes. According to this, to maintain the food's high quality for as long as feasible, the humidity in the storage space for food should be between 50 and 55 percent.

In the pharmaceutical and food industries, controlling the temperature of products is essential for assuring their efficacy, quality, and safety. To avoid deterioration, loss of effectiveness, or contamination, all of which could cause large financial losses or even jeopardize public health, a variety of items, including vaccines, pharmaceuticals, and perishable foods, must be stored and delivered at precise temperature conditions. As a result, it is crucial to regularly check the temperature of these products throughout every stage of their life—from manufacturing to storing to shipping.

A crucial component of quality control in the pharmaceutical and food sectors is temperature monitoring. To maintain their safety, effectiveness, and high quality, products including vaccinations, pharmaceuticals, and perishable foods must be stored and delivered under specific temperature requirements. Lack of proper temperature control can cause products to decay, lose their efficacy, or even get contaminated, which can be expensive in terms of product waste and legal repercussions. Systems for monitoring temperature are created to continuously track and document the temperature of products during every stage of their existence, from manufacturing to storing and shipping. These systems typically collect temperature measurements using temperature sensors and data loggers, which are subsequently sent to a central monitoring system for evaluation and storage. Manufacturers and distributors can verify that their products are maintained within the proper temperature range and, if necessary, take corrective action to avoid quality issues, by employing temperature monitoring systems. We want to create a temperature monitoring system exclusively for the pharmaceutical and food industries in this paper. To gather and send temperature data to a cloud-based server, we will employ temperature sensors and microcontrollers.

We will also provide a user interface that enables users to keep track of temperature data in real-time, set alert thresholds, and get alerts when temperature readings deviate from the predetermined range. Our objective is to develop a low-cost, simple-to-use temperature monitoring device that would aid in ensuring the security and caliber of pharmaceutical and food items.

By putting in place an effective temperature monitoring system, manufacturers and merchants can maintain the right temperature range for their products and, if necessary, take corrective action to minimize quality concerns. Additionally, we will give consumers access to a user interface that lets them set temperature thresholds, view real-time temperature data, and receive alerts when temperatures stray from the expected range.

We will consider a variety of factors when creating the system, including the ideal temperature range for various product types, the accuracy and coverage of the sensors, the processing speed and memory of the microcontroller, and the usability and visual appeal of the user interface. Due to the system's inexpensive price, easy installation process, and user-friendly interface, small and medium-sized businesses in the food and pharmaceutical industries will be able to benefit from continuous temperature monitoring.

II. METHODOLOGY

A. *Temperature monitoring system*

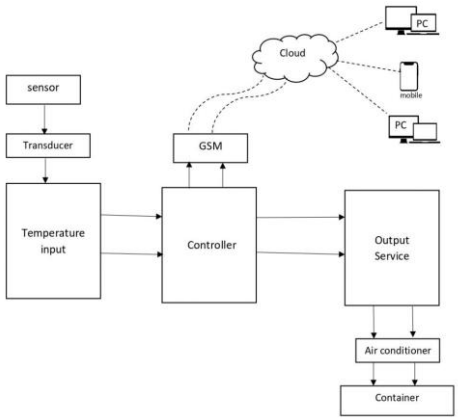

Fig. 1: The architecture of the proposed system.

The proposed temperature monitoring and control system utilizes Node MCU controllers, temperature sensors, and a web-based dashboard for remote monitoring and control. The Node MCU controllers, equipped with temperature sensors, are placed in the shipping containers, storage facilities, and other key locations in the cold-chain logistics process. These Node MCU controllers continuously monitor the temperature and send the data to a centralized web-based dashboard in real-time. The web-based dashboard provides a user-friendly interface for remote monitoring and control of temperature conditions. Users can access the dashboard through a website, allowing for real-time monitoring of temperature data, data logging, and alerts for out-of-range temperature conditions. The system is automated and can also be further integrated as remotely controlled.

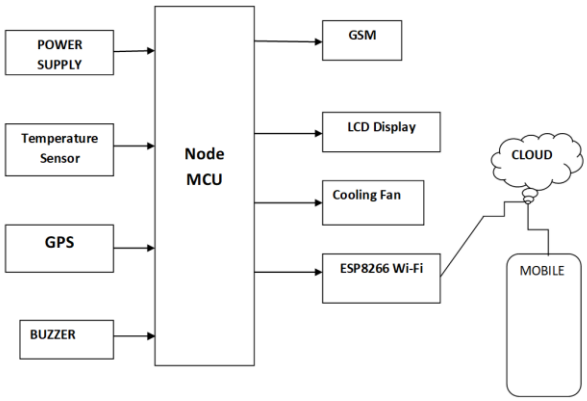

Fig. 2: Block diagram in detail.

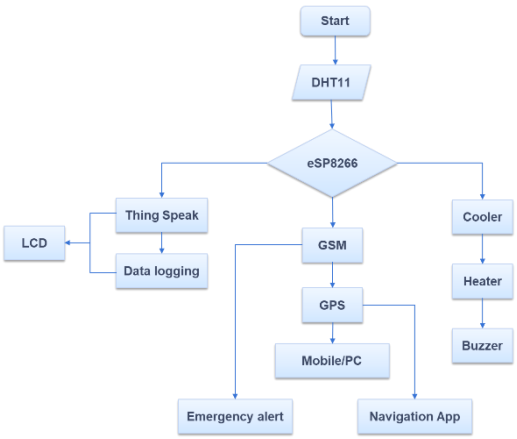

Fig. 3: Flowchart of system.

- Start: The process starts by initializing the temperature sensor, GPS module and GSM module.
- Read temperature: The temperature sensor reads the current temperature of the storage area or container where the food or pharmaceutical products are kept.
- Check temperature: The system then checks if the temperature is within the safe range. If the temperature is less than 31 degrees Celsius, an SMS alert is sent to the user, “Your food is not safe, and we are working on it.” The blub will on at this condition to maintain the temperature.
- If the temperature is 35 degrees Celsius or greater, the system sends an SMS alert, “Your food is safe, and we deliver you the freshness of food.” The cooler fan will on to maintain the temperature between 31 to 35 degrees Celsius.

- Log data: The temperature data is then logged and stored in the database.
- Update ThingSpeak: The system updates the ThingSpeak dashboard with the current temperature reading.
- GPS Location: The current location of vehicle will be sent to the host.
- Display on LCD: The temperature reading and humidity is also displayed on an LCD screen for quick monitoring.
- Sleep: The system then goes to sleep for a specified period before repeating the process.
- End: The process ends.

B. Implementation

An ESP8266 microcontroller with sensors, an internet-connected laptop, and a cloud platform (Thing Speak) were used to implement the temperature and humidity. For displaying the sensor data in certain ThingSpeak fields (Temperature and Humidity), a cloud-based dashboard has been set up. Fig.4 is an example of a graphical presentation.

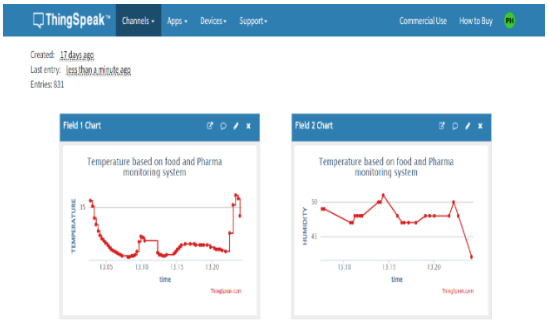

Fig. 4: Sensor data reading on a cloud platform - ThingSpeak.

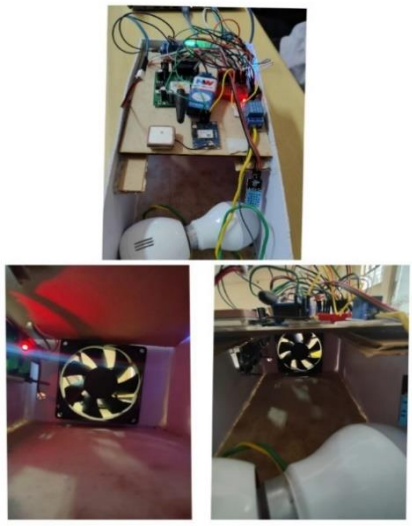

Fig. 5: Implementation on the real-time environment - college premises.

Additionally, a column for the phone message alerts has been added to the real-time database. These options enable it to deliver the text message and display the monitored sensors' data on a personal dashboard. The alert system will function in accordance with the established standards to initiate message notification over the GSM Module if the current environmental data exceed the predefined set-point. The project's cloud-based technology has been put into place and made available in a live setting at the college grounds of SVCE, Bangalore, as illustrated in Fig. 5.

III. EXPERIMENTAL RESULTS

A. Monitoring Sensor Data on Cloud Platform

Data from the measured sensors has been kept on the cloud platform Thing Speak on college grounds in a real-time setting. The prototype gadget was put into use in the middle of the scene. The entire system was being watched, and the laptop and mobile device receiving warnings through GSM module, together with the answers from the cloud platform (ThingSpeak), were all functioning flawlessly.

B. Configuring message notification.

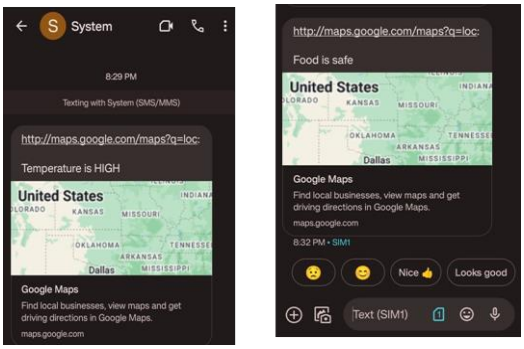

Fig. 6: Configuring message notification

The message alert notification operates as illustrated in Fig. 6, where it activates the message alert system and delivers a message that reads "temperature is HIGH" when the temperature rises over the predefined set-point. Additionally, the system notifies us that the food is safe when the temperature is maintained. This is a fantastic feature since it lets us know where the food is at all time.

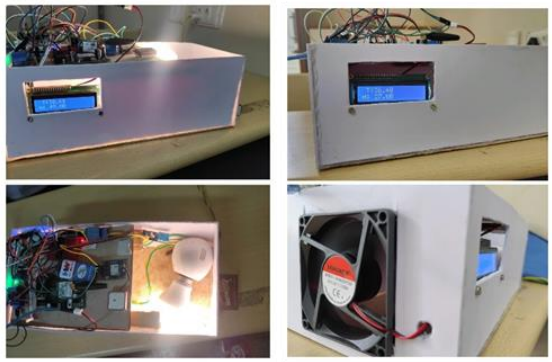

Fig. 7a: When temperature is low, Fig 7b: when the temperature HIGH.

Here above is the working as in fig 7a, the bulb will turn on when the temperature is low, accordingly the fan will turn on when the temperature is HIGH in fig 7b. Temperature is sensed via the sensors present in it.

C. Project Analysis

Fig. 8 displays the whole project module in portable form. Continuously detected environmental conditions for temperature and humidity. Periodically, the system used the internet to send data from the sensors to the cloud platform. The data from the incoming sensors was continually monitored by the cloud platform. The GSM module delivers the SMS notice if the temperature and humidity are outside of the predetermined range. The system's temperature, humidity, and messaging may all be customized.

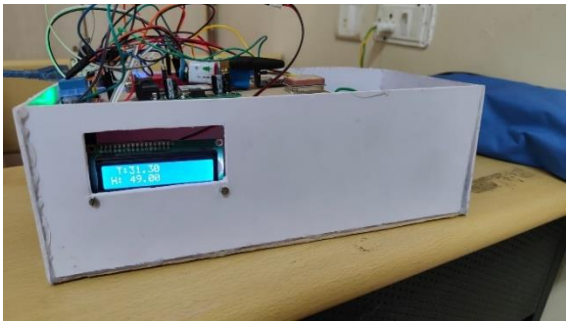

Fig. 8: Prototype of the implemented project module.

IV. CONCLUSION

The significance of temperature monitoring in the pharmaceutical and food industries cannot be emphasized, in my opinion. We can guarantee that goods are secure, of the highest caliber, and beneficial to everybody by utilizing cutting-edge technology to maintain the right temperature along the whole supply chain. The possibility of ever more sophisticated and precise temperature monitoring systems employing Node MCU processors makes the future of temperature monitoring appear promising. Let's keep innovating and give our goods' safety and quality top priority.

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