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IoT based Cargo Monitoring System using Thingspeak

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***Abstract*— In modern logistics, ensuring the safe and efficient transport of cargo is critical, particularly for perishable goods like food. This project proposes a real-time cargo monitoring system that tracks both the environmental conditions and location of cargo during transport by truck, ship, or plane. The system utilizes an ESP32 microcontroller, a GSM module, and a GPS module for long-range communication and location tracking. It integrates sensors such as the DS18B20 temperature sensor to monitor temperature, the DHT11 sensor for humidity, and a tilt sensor to detect cargo displacement. Data from these sensors, along with GPS location information, is transmitted via the GSM module to cloud platforms such as ThingSpeak, allowing real-time monitoring over long distances. Power is supplied by a 1-cell battery pack. The project ensures that critical factors like temperature and humidity are maintained within safe limits for food cargo, and that cargo remains securely in place, providing a comprehensive solution for remote cargo management. This system offers practical applications in food logistics and other industries where environmental conditions and cargo safety are essential.**

***Index Terms*—ESP32 microcontroller, GSM module, GPS module, DS18B20 temperature sensor, DHT11 sensor, tilt sensor ,1-cell battery.**

I. INTRODUCTION

The logistics and transportation industry plays a critical role in the global supply chain, particularly in the safe and efficient delivery of perishable goods like food. Monitoring the environmental conditions of cargo during transportation is essential to maintaining the quality of these goods. In recent years, the development of real-time monitoring systems has become more important due to the increasing demand for transparency and safety in food logistics [1].

This research paper presents the design and implementation of a Cargo Monitoring System, which uses various sensors and communication technologies to track the environmental conditions and location of cargo in transit. The system is particularly useful for perishable goods, where temperature and humidity control are critical. By integrating a GPS module, GSM module, and sensors such as DS18B20 (temperature), DHT22 (humidity), and a tilt sensor, the system provides real-time data on cargo conditions. This data is transmitted to cloud platforms like Blynk, where it can be accessed remotely by logistics operators or consumers through a graphical interface [2]. The system aims to enhance the reliability of the transportation process, ensuring that food cargo remains safe, secure, and within specified environmental parameters throughout its journey. It addresses key challenges in food logistics, such as environmental monitoring, cargo safety, and real-time tracking, thereby contributing to the growing trend of digital transformation in supply chain management [1][2].

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II. LITERATURE SURVEY

Varsha Dange et al [1] proposed that IoT-based smart bag is a multipurpose product that uses various technologies to enhance functionality and security. Key components include Wi-Fi (ESP288), GPS (NEO 6M), and GSM modules, which provide real-time location tracking and communication via SMS if the bag moves outside a designated area. A microcontroller coordinates all the components, ensuring smooth operation.

Motor drivers and sensors allow the bag to move autonomously, avoiding obstacles. Bluetooth is used for short-range communication with a mobile app, and RFID tags help in tag detection. Solar panels can be used to power the system, and LCD screens display the bag's status.

Advanced features include GPS-triggered alarms, weight sensors to monitor the load, smart locks, and hand gesture control for bag movement. Some systems use voice recognition for hands-free control. In other cases, the smart bag can track its location using a GSM module that sends messages with GPS coordinates to the user's phone, displaying the bag's location on a map. Additionally, systems often include automatic security measures like alarms when the bag is moved beyond a set distance, making the bag more secure and user-friendly[3].

Mangaldeep Chakraborty et al [2] proposed that evolution of tracking technologies, particularly GPS, GSM, RFID, and mobile apps. Initially, RFID was used for attendance systems and employee tracking, but mobile-based solutions became more popular due to the widespread use of smartphones, offering real-time monitoring and enhanced efficiency. GPS remains the dominant technology for tracking, particularly for vehicles and employees, providing real-time location data often sent via GSM. The research also addresses challenges like battery life and privacy concerns in tracking systems.

Other applications include healthcare, where RFID helps reduce costs by tracking medical items and patients, and workplace efficiency improvements using technologies like RFID, GPS, and cameras. Overall, the survey underscores the growing importance of these technologies in tracking and monitoring systems, highlighting their practical uses and ethical considerations[4].

III. METHODOLOGY

The cargo monitoring system was designed to ensure continuous environmental monitoring of temperature, humidity, tilt, and location during transportation. The system is embedded with an ESP32 microcontroller to collect data from multiple sensors and transmit this data via a GSM module to a cloud-based application for remote monitoring. The sensors selected for the project provide real-time data on critical cargo conditions, and the system architecture is modular to accommodate various types of cargo.

A. Microcontroller

The ESP32 microcontroller was selected due to its dual-core capability, integrated Wi-Fi, and Bluetooth functionality. It serves as the central unit for data acquisition and communication. The ESP32 microcontroller operates at a clock frequency of 80 MHz and provides two independent UART interfaces, which are essential for establishing serial communication. To integrate both a GSM module and a GPS module, each device can be connected to a separate UART port, ensuring simultaneous and efficient data exchange.

B. Communication Modules

The system integrates a GSM module (SIM800/900) for long-range communication and a GPS module (NEO-6M) to track real-time location. Both uses UART protocol for communication.

C. Sensors

The system uses three sensors

DS18B20 temperature sensor for precise monitoring of cargo temperature.

DHT22 humidity sensor for measuring the relative humidity and temperature.

Tilt sensor to detect any abnormal movement or tilting of the cargo.

D. Hardware Setup

The system was assembled using a breadboard for initial prototyping, and the sensors were connected to the ESP32 using the following pin configuration:

DS18B20: Connected to GPIO pin 15 with a 4.7kΩ pull-up resistor on the data line.

GPS MODULE : communicates via UART and connects to satellites to provide real-time coordinate data.

It is interfaced with the ESP32 by connecting its TX (transmit) and RX (receive) pins to the corresponding RX and TX pins of the microcontroller, enabling seamless data transmission.

The ESP32 was powered using a 1-cell battery pack, providing 3.7V Nominal Voltage through a Vin pin and Gnd pin of the ESP32. Vin pin convert this unregulated power supply to regulated power supply and power the ESP 32. Each sensor and module was tested individually before final integration to ensure functionality and compatibility with the microcontroller.
DHT22: Connected to GPIO pin 4 with the required timing configuration for accurate data acquisition.

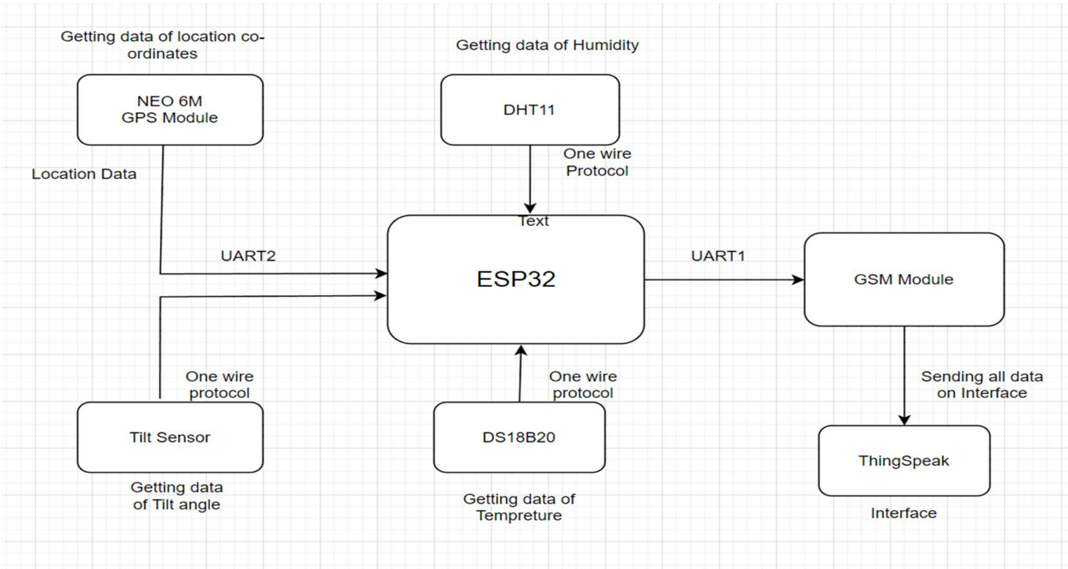

Figure 1. General Flow Diagram of System

IV. Implementation

Hardware Integration: The system was built using the ESP32 microcontroller as the core component, connected to several peripheral modules and sensors:

A. ESP32 Microcontroller

The ESP32 was selected for its integrated Wi-Fi and Bluetooth capabilities, in addition to its sufficient number of GPIO pins and UART protocols for connecting multiple sensors. The ESP32 is responsible for reading sensor data, processing GPS signals, and managing communication with the GSM module.

B. GPS Module (NEO-6M)

The GPS module provides real-time location tracking, which is transmitted to the ThingSpeak platform for visualization. The GPS module is connected to the ESP32 via UART, and the GPS coordinates are processed using the TinyGPS++ library. We get the real time coordinates of the latitude and longitude.

C. GPS Module (NEO-6M)

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D. Temperature Sensor (DS18B20)

The DS18B20 digital temperature sensor was connected to a digital pin on the ESP32 and used to monitor the temperature of the cargo. This sensor is well-suited for food cargo monitoring, providing precise temperature readings. It was interfaced with the ESP32 using the DallasTemperature library, which ensures accurate temperature data collection.

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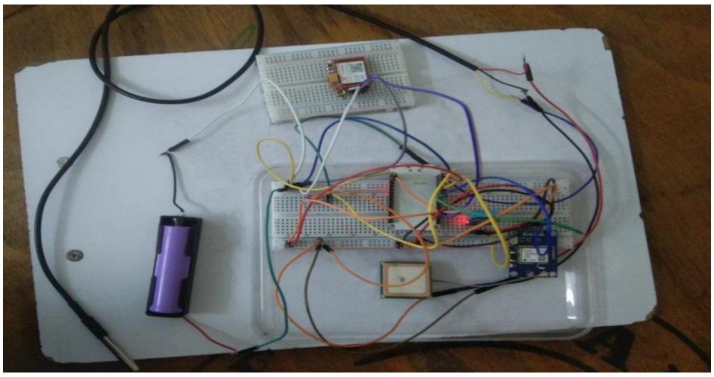

Figure 2. Screenshot of the Implemented System

V. FLOW CHART OF IMPLEMENTED CIRCUIT

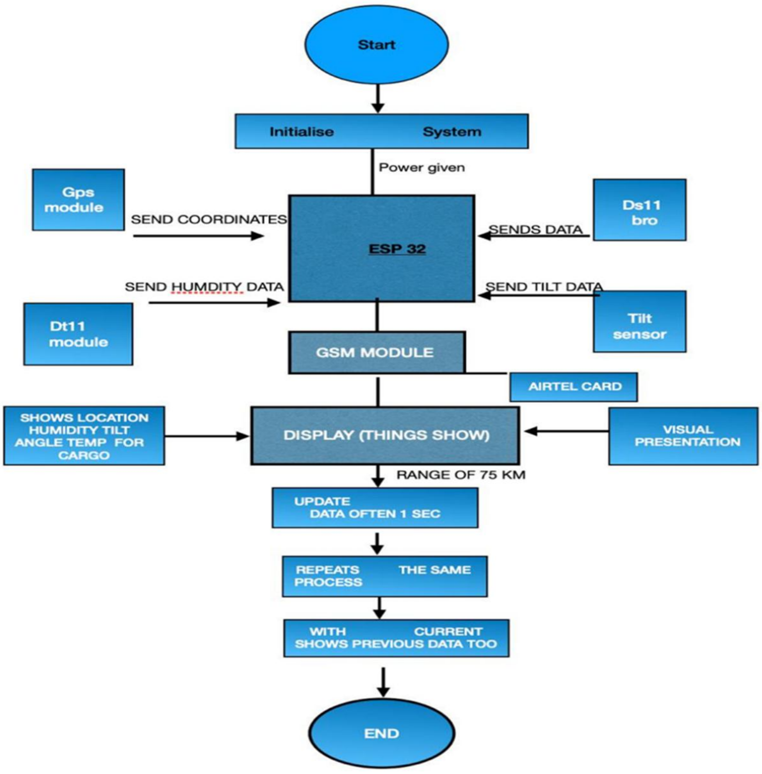

Figure 3

VI. RESULTS AND DISCUSSION

A. Location Tracking (NEO 6M GPS Module)

The GPS module accurately tracked the cargo's location, providing updates every 15 seconds. The location data was sent to the ThingSpeak interface, allowing real-time monitoring. When tested in open spaces, the GPS module had an accuracy of around ±5 meters.

B. Temperature Monitoring (DS18B20 Sensor)

The DS18B20 sensor measured the temperature inside the cargo. It provided reliable temperature readings with an accuracy of ±0.5°C. The temperature data was continuously sent to the ThingSpeak, making real-time tracking possible. The sensor was effective in capturing changes in temperature during different conditions. Data update Interval: After 5 Seconds.

C. Humidity Monitoring (DHT22 Sensor)

The DHT22 sensor measured the humidity levels inside the cargo. It delivered accurate readings, with a margin of error of ±2%. The humidity data was sent to the cloud interface, allowing users to monitor changes in moisture levels inside the cargo in real time. The sensor worked well, detecting variations in humidity during the testing period.

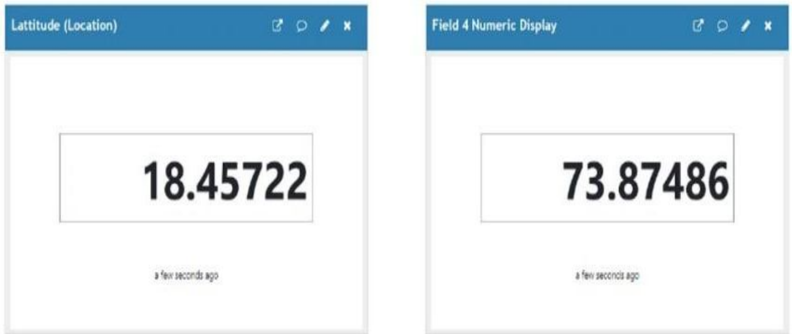

Figure 3. Location Data (Latitude and longitude)

Figure 4. Visualisation Of Location

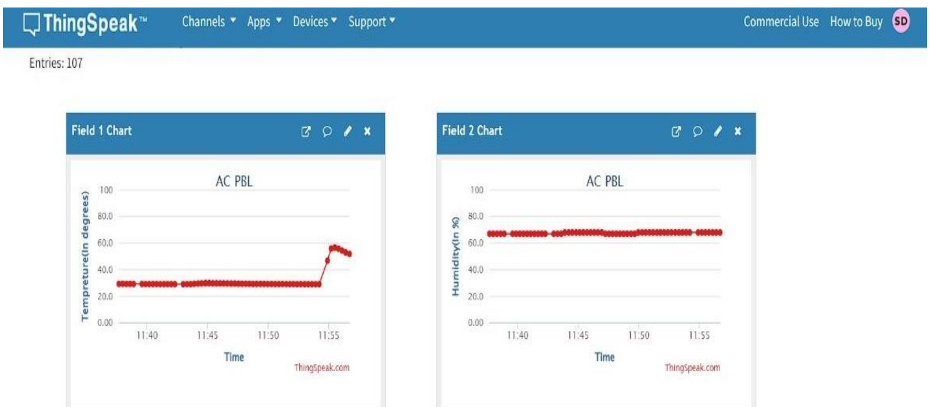

Figure 5. Temperature and Humidity Graph (After putting in Hot Water)

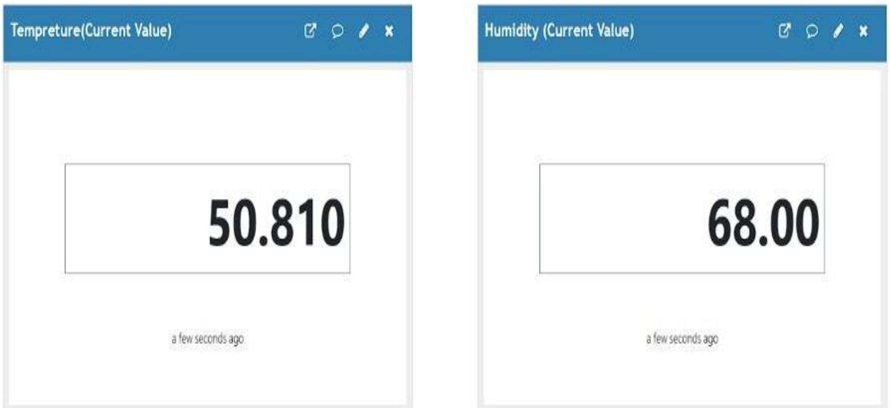

Figure 6. Temperature and Humidity (Current Values after putting in Hot Water)

Discussion of Results

The cargo tracking system we developed proved to be highly effective in monitoring key factors like temperature, humidity, tilt, and location during transport. When testing the DS18B20 temperature sensor, we found that it accurately tracked temperature changes in both cold and hot water, consistently providing readings within ±0.5°C. This level of precision is vital for protecting temperature-sensitive goods. Similarly, the DHT22 sensor offered reliable humidity readings, ensuring that the conditions remained optimal throughout the journey. The NEO 6M GPS module did an excellent job of providing accurate latitude and longitude data, achieving about ±3 meters accuracy in open spaces, though it occasionally dropped to around ±5 meters in urban areas where tall buildings could interfere with the signal.

The tilt detection feature added an important layer of security, alerting users immediately if the cargo experienced any significant shifts that could indicate mishandling. Data was transmitted through the SIM800L GSM module, which performed well overall, delivering real-time updates; however, we did notice some delays in areas with weaker signals. Overall, these results demonstrate the system's strong potential to enhance cargo safety and management. This project lays a solid groundwork for future enhancements and the ability to adapt to various shipping needs.

VII. Conclusion and Future Scope

A. Conclusion

This project successfully built a real-time cargo tracking system that keeps tabs on important factors like location, temperature, humidity, and tilt. By using the DS18B20 sensor for precise temperature readings and the DHT22 for monitoring humidity, the system delivered accurate and dependable data. The GPS module ensured reliable tracking, while the integration with the ThingSpeak made it easy for users to access information from anywhere. The tilt detection feature added an extra layer of security, providing alerts whenever there were unexpected shifts in the cargo’s position. While the SIM800L GSM module occasionally experienced delays in areas with weaker network signals, it generally performed well, offering consistent data transmission throughout the journey.

B. Future Scope

Better Alert Systems: The system could be enhanced with more customizable alerts. For example, it could send notifications via SMS or email when temperature, humidity, or tilt levels go beyond safe limits. This would allow users to react more quickly to any potential problems.

Solar-Powered Design: Making the system solar-powered could improve its efficiency and reduce the need for frequent battery replacements. This would be especially useful for long-distance shipments or for use in outdoor environments, where solar energy could help keep the system running smoothly.

Addition of More Sensors: Future versions of the system could include extra sensors to monitor air pressure, light levels, or shocks during transit. This would give a more complete picture of the conditions that the cargo faces, making the system suitable for even more types of sensitive goods.

AI-Based Anomaly Detection: Using AI to detect unusual patterns in sensor data could help spot issues like unexpected temperature spikes or abnormal tilts. This would enable quicker responses to potential problems, making the system safer and more reliable.

Upgraded GPS Technology: Adopting advanced GPS technology, such as multi-band GNSS, could improve location accuracy, especially in challenging environments like dense urban areas or forests. This would ensure more precise tracking no matter where the cargo travels.

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