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IOT Based Intelligent Cargo Monitoring System in Logistics

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ABSTRACT:

This project is essential for the modernization of logistics systems, aiming to enhance efficiency, safety, and real-time monitoring through the integration of IoT technologies. The focus is on developing an intelligent cargo system that utilizes embedded sensors and communication modules to track and manage goods during transit. Key parameters such as temperature, humidity, location, shock, and cargo status are continuously monitored and transmitted to a centralized cloud-based platform. This makes it possible for stakeholders and logistics providers to make well-informed decisions, react quickly to irregularities, and preserve the integrity of sensitive goods. The project complies with the increasing need for intelligent logistics solutions in the age of Industry 4.0 by implementing the intelligent cargo concept. A more interconnected and dependable supply chain infrastructure is facilitated by the implementation's notable gains in operational responsiveness, transparency, and traceability.

Keywords: logistics using IoT, real-time tracking, intelligent cargo, supply chain management, intelligent transportation, Industry 4.0, sensor-based tracking, integrity of cargo, logistics automation, and cloud-based logistics

1. Introduction

The logistics and transportation sector is now the foundation of global trade and business in today's fast-paced, globally interconnected world. The need for more intelligent and effective logistics systems is developing as a result of rising consumer demands, complicated supply chains, and the requirement for prompt and secure product delivery. Poor handling procedures, a lack of real-time monitoring, and restricted sight during transit are common problems with traditional logistics operations. These issues can result in cargo damage, delays, loss, and decreased customer satisfaction.

By incorporating Internet of Things (IoT) technology into the logistics process through the idea of intelligent cargo, this initiative offers a creative solution to these problems. The intelligent cargo system monitors and reports real-time data, including temperature, humidity, shock, tilt, light exposure, and geolocation, by integrating smart sensors, communication devices, and microcontrollers inside cargo containers or packages. These sensors use wireless communication protocols like GSM, Wi-Fi, or LoRaWAN to continuously gather and send data to a centralized cloud-based platform.

Logistics managers and other stakeholders can view cargo information remotely at any time during transportation when this system is in place. When any parameter is above the predetermined threshold, automated alarms are set off, allowing for quick action to stop loss or harm. For example, in cold chain logistics, the system can immediately alert the relevant staff to take corrective action if the temperature for a perishable item rises above the safe range.

Using intelligent cargo improves accountability, traceability, and transparency throughout the supply chain. It guarantees improved management of delicate or valuable items, lowers human error, and encourages data-driven decision-making. Additionally, it gives clients greater assurance and control over their shipments, enhancing consumer confidence and service excellence.

This initiative is in line with Industry 4.0's vision, which emphasizes automation, connectivity, and real-time data as key components for streamlining industrial processes. This study shows a step toward making traditional logistics a more intelligent, responsive, and dependable operation by putting in place an IoT-enabled intelligent cargo system. The ultimate objective is to reduce losses, boost productivity, and use cutting-edge technologies to open the way for logistics in the future.

2. Literature Survey

The proposal considers the growing need for smarter and more responsive logistics systems that utilize IoT technologies to ensure real-time cargo monitoring, enhanced safety, and greater transparency. The development of intelligent cargo systems is made possible by a number of studies and technological developments that promote the integration of IoT in logistics. This section reviews key research contributions in this field.

2.1 IoT in Logistics and Supply Chain

The plan takes into account how important IoT is to changing conventional supply chain procedures. IoT is a key component of Industry 4.0, allowing automation, predictive maintenance, and effective resource management, claim Kamble et al. (2020). According to their analysis, implementing IoT in logistics can result in better customer satisfaction, quicker decision-making, and real-time data availability.

2.2 Real-Time Tracking and Location Monitoring

The use of GPS and RFID technologies in logistics has been explored by Zhang et al. (2018), who developed a tracking system capable of identifying cargo location in real time. According to their research, supply chain visibility is improved and delays are decreased with real-time position tracking. However, the study lacked additional monitoring capabilities, such as environmental condition tracking.

2.3 Environmental Condition Monitoring

The plan views environmental monitoring as a crucial component, particularly for products that are sensitive to temperature changes. An IoT-enabled cold chain logistics system that tracked temperature and humidity using sensors was put into place by Lee & Lee (2019). By warning logistics operators about temperature variations, their technology successfully prevented spoiling, demonstrating the value of condition-based monitoring.

2.4 Shock and Vibration Detection

Another crucial topic that the proposal covers is cargo security. A system that uses shock and vibration sensors to identify improper handling of goods was introduced by Khan et al. in 2021. GSM modules were used to send alerts, giving real-time input while in transit. Their research backs up the intelligent cargo concept's incorporation of physical condition monitoring.

2.5 *Cloud-Based Monitoring and Data Access*

The use of cloud computing in logistics, where IoT devices transmit data to centralized platforms for analysis and remote access, was highlighted by Patel and Shah (2022). According to the suggestion, this cloud-based method is crucial for guaranteeing traceability, enhancing operational control, and providing cargo data accessibility to numerous stakeholders.

2.6 Identified Research Gap

Even if earlier studies have made a substantial contribution to the subject, the majority of systems only offer a few monitoring functionalities. As a new and comprehensive strategy, the idea takes into account the integration of several sensors, such as temperature, humidity, location, and shock, into a single system. The goal of this intelligent cargo idea is to improve logistics operations' overall cargo safety, responsiveness, and dependability.

3. Proposed System

The main goal of the suggested system is to improve logistics operations by creating an intelligent cargo solution with IoT technology. Through the integration of many sensors, microcontrollers, and communication modules, the system is intended to continuously monitor cargo conditions. It provides improved visibility, traceability, and proactive control throughout the cargo path, thereby addressing the shortcomings of conventional logistics systems.

3.1 System Architecture

The suggested intelligent cargo solution's system architecture makes use of Internet of Things technologies to allow for real-time cargo condition monitoring and management. The sensing layer, which is the central component of the architecture, consists of a number of sensors, including a GPS module for location tracking, a shock or vibration sensor (like the SW-420), and a temperature and humidity sensor (like the DHT11 or DHT22). These sensors are positioned inside or outside the cargo unit to continuously gather information on the physical and environmental conditions while it is in transit. The processing layer, which is made up of a microcontroller such as an Arduino Uno, ESP32, or Raspberry Pi, receives the gathered sensor data after that. Serving as the system's central control unit, this microcontroller processes incoming data, compares it to predetermined safety levels, and decides whether to generate any alarms. The data is sent over the communication layer after it has been processed. A GSM module (like the SIM800L) or a Wi-Fi-enabled microcontroller (like the ESP32) may be used to wirelessly transmit the data to a cloud-based platform, depending on the architecture and infrastructure that are available. Even over vast distances, this layer guarantees continuous real-time data flow from the cargo to the server. The data is received and stored by the cloud/server layer, which offers a scalable and safe platform for monitoring and analysis. Sensor readings may be shown, warnings can be generated, and historical data can be logged for later review using cloud services like ThingSpeak, Firebase, or specially designed web servers. If any parameter surpasses the predetermined criteria, automated alerts (via SMS, email, or push notifications) are sent, assisting logistics staff in taking prompt corrective action. Lastly, end users can get cargo information via a mobile application or web-based dashboard thanks to the user interface layer. This interface provides a clear picture of the position and health of the cargo by displaying real-time sensor readings, GPS location, and alert status. By integrating cloud integration, real-time communication, and smart sensing into a single, seamless solution, the entire system guarantees efficiency, safety, and transparency in the logistics process.

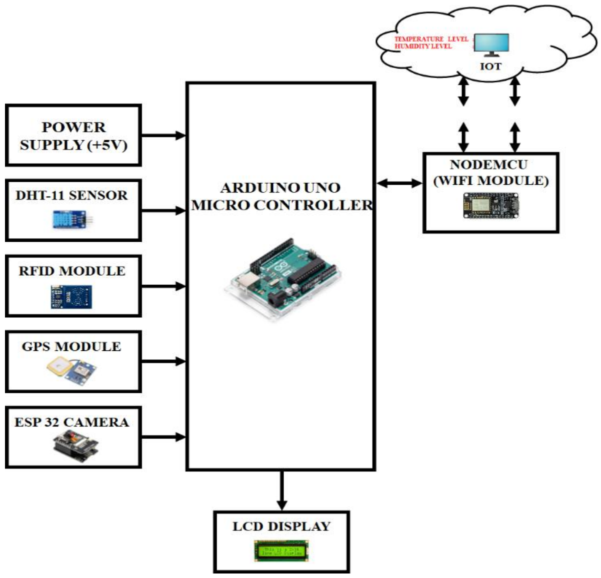

Fig 3.1 Proposed system

3.2 Hardware Components

A GPS module provides real-time location tracking, guaranteeing visibility of cargo movement throughout the journey; a temperature and humidity sensor (like DHT11 or DHT22) monitors the internal environmental conditions of the cargo; a shock or vibration sensor (like SW-420) detects physical impacts or mishandling during transit; and a microcontroller (like Arduino Uno or ESP32) serves as the central processing unit, interacting with various sensors and controlling data flow. A GSM module (such the SIM800L) is used for wireless communication in order to send data to a distant server or cloud platform. A power supply system, which may consist of a battery pack or portable power source, as well as necessary parts like resistors, jumper wires, and a breadboard or custom PCB for circuit integration, supports the complete arrangement. These parts work together to form a small, effective system that can track cargo conditions in real time.

3.3 Software components

The suggested intelligent cargo system's software components are essential for processing sensor data, sending information, and offering real-time monitoring via intuitive user interfaces. In order to read sensor values, manage conditional logic, and regulate data transmission via the GSM or Wi-Fi module, embedded C or C++ code is developed for the microcontroller using the Arduino IDE or comparable platforms. Sensor readings are gathered, stored, and shown in real-time using cloud systems like ThingSpeak, Firebase, or a bespoke web server. These platforms frequently offer dashboards and APIs that aid in the graphical visualization of GPS, shock, temperature, and humidity data. MQTT protocols or IoT middleware may occasionally be integrated to facilitate effective data transfer. When combined, these software technologies guarantee the intelligent cargo system's smooth hardware, data flow, and user interaction integration.

3.4 IoT in Logistics and Supply Chain

A network of interconnected devices with the ability to automatically gather and distribute data is known as the Internet of Things (IoT). IoT makes everything smarter and more efficient, which helps modernize traditional procedures in the logistics and supply chain industry. For instance, cargo can have sensors installed to monitor its condition, temperature, and location in real time. As a result, businesses are always aware of the location and safety of their products. Automation is also made possible by IoT; for example, smart inventory systems that update automatically without human intervention. Based on sensor alerts, it facilitates predictive maintenance, which enables the repair of machinery or automobiles before they break down. These advantages all contribute to lower costs, less delays, and higher customer satisfaction. IoT is therefore regarded as a crucial component of Industry 4.0, the next era of intelligent and networked industrial systems.

3.5 Real-Time Tracking and Location Monitoring

Zhang et al. (2018) investigated the application of GPS and RFID technologies in logistics and created a tracking system that can locate freight in real time. According to their research, supply chain visibility is improved and delays are decreased with real-time position tracking. But the study lacked other monitoring tools, such the ability to observe environmental conditions.

3.6 Environmental Condition Monitoring

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3.7 Shock and Vibration Detection

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4. System Implementation

In order to monitor and control cargo conditions during transportation, the suggested IoT-based intelligent cargo system must integrate a number of hardware and software components. The process starts with the installation of sensors inside the cargo unit, such as GPS modules, shock/vibration sensors, temperature sensors, and humidity sensors. These sensors gather positional and environmental data continually. The central processing unit is a microcontroller, like an Arduino or ESP32, which reads data from the sensors and removes noise to guarantee precise measurements.

Following processing, the data is contrasted with predetermined threshold values for every parameter. The system instantly sounds a warning if any sensor value goes beyond the specified safe range, such as when the temperature falls below the necessary level. Depending on the communication module being used (GSM, Wi-Fi, or Bluetooth), this could be an SMS, buzzer, or cloud server notice.

The system's initialization is when the flowchart begins. After turning on, the system starts by interpreting data from a number of sensors installed inside the cargo, such as GPS modules, temperature, humidity, and vibration (shock). These sensors gather information on the location and environmental conditions of the cargo in real time.

The microcontroller (ESP32 or Arduino), which serves as the system's brain, receives the gathered data after that. After processing the incoming data, it prepares it for analysis and removes noise to increase accuracy. After stabilizing, the sensor values are compared to pre-established threshold levels, such as a temperature that is above or below a predetermined range or an anomalous movement that the vibration sensor detects. After that, the flowchart enters a decision-making phase. The system initiates an alarm mechanism if any of the sensor values above their thresholds. Depending on the configuration of the communication module (GSM or Wi-Fi), this could take the form of a buzzer, SMS alert, or cloud notice. The system continues to function properly and logs the data if the sensor readings fall within the safe range. The processed and validated data is then sent via a Wi-Fi module (integrated with the ESP32) or a GSM module (like the SIM800L) to a cloud server or Internet of Things platform. Logistics staff can remotely monitor cargo conditions thanks to the data's real-time accessibility via a web dashboard or mobile application after it has been submitted.

In order to guarantee that data is updated and accessible along the cargo's transit, the system then loops back to continue monitoring. Real-time visibility, proactive cargo management, and early alerts in the event of hazardous conditions are all guaranteed by the procedure.

5. Result and Discussion

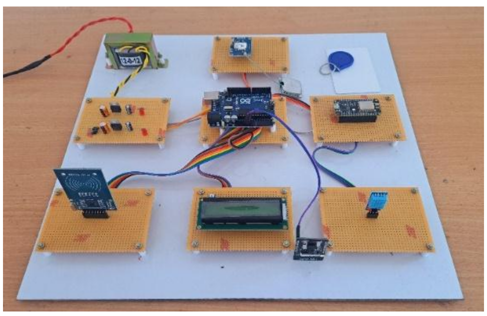

Fig.3 Kit Image

Using a combination of sensors and communication modules combined on a single platform, the Internet of Things-based intelligent cargo monitoring system was successfully implemented. The Arduino Uno microcontroller, a temperature and humidity sensor (DHT11), a GPS module, a GSM module, a vibration sensor, RFID for access control, and an LCD display for real-time output are among the essential parts of the prototype.

All of the sensors start gathering data from the cargo environment in real time as soon as the system is powered on. Accurate sensor integration is confirmed by the instantaneous display of the temperature and humidity values on the LCD. Live position data is efficiently provided by the GPS module, and any extreme shock or improper cargo handling is detected by the vibration sensor. The GSM module successfully communicates with the cloud or user by sending an SMS alert to a pre-specified phone number whenever any sensor value surpasses the pre-established criteria.

The RFID system's ability to restrict access and guarantee that only authorized individuals could start or manage cargo procedures was evaluated. The Arduino allowed for smooth communication between all parts, while the LCD gave quick feedback for status updates and debugging.

Performance-wise, the system demonstrated excellent dependability in identifying modifications in cargo condition and swiftly alerting the user. The outcomes show that employing IoT for supply chain monitoring and smart logistics is both feasible and useful. Nevertheless, slight delays in SMS delivery were seen during network outages, and incorporating a more sophisticated IoT dashboard could enhance data visualization.

All things considered, the system achieved its goals of improving cargo management, safety, and visibility through the use of open-source, reasonably priced technology. Future development might focus on making the system more scalable for bigger logistics operations, more energy-efficient, and smaller.

6. Conclusion

The Internet of Things-based intelligent cargo monitoring system effectively illustrates how real-time data collecting and remote monitoring technologies can improve contemporary logistics. The system offers a clever way to guarantee cargo safety during transit by combining temperature, humidity, vibration, and GPS sensors with microcontrollers and communication modules. It efficiently notifies users of anomalous circumstances, facilitating prompt reactions to possible hazards. The research demonstrates that it is possible to create a dependable, scalable, and effective cargo monitoring system that supports Industry 4.0 and smart logistics objectives using inexpensive, open-source hardware.

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