Pharma Secure - An IoT-Based Smart Medicine Transport System

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Abstract:
The safe transportation of temperature-sensitive pharmaceutical products such as vaccines, insulin, and biological medicines is critical to maintaining their efficacy and preventing spoilage. This paper presents the design and implementation of a Smart Medicine Monitoring and Secure Transportation System that ensures environmental control, real-time tracking, and authenticated delivery during transit. A DHT11 sensor continuously monitors temperature and humidity inside the medicine container. When the temperature exceeds a predefined threshold, a Peltier-based thermoelectric cooling module is automatically activated to maintain the required storage conditions. A GPS module provides real-time location tracking, while a GSM module enables remote communication through SMS alerts. The system incorporates two switches to indicate the start and end of the transportation process. Upon reaching the destination, an automated SMS notification is sent to the customer. The electronic lock mechanism is released only after receiving an authorized reply or one-time password (OTP) from the customer, ensuring secure and verified delivery. Additionally, all operational parameters, including temperature, location, trip status, and lock status, are updated to an IoT platform and displayed on an LCD for local monitoring. The proposed system enhances pharmaceutical supply chain reliability, improves security, and ensures compliance with temperature-controlled transportation standards.

Key words: Safe transportation of temperature-sensitive pharmaceutical products, One-time password, DHT11 sensor, GPS module.

1. INTRODUCTION

The transportation of temperature-sensitive pharmaceutical products such as vaccines, insulin, blood samples, and biological medicines requires strict environmental control to maintain their effectiveness and safety. Many medicines must be stored within a specific temperature range, typically between 2°C and 8°C, to prevent degradation. Any deviation during transportation may result in reduced potency, financial loss, and serious health risks. Maintaining an uninterrupted cold chain during transit is therefore a critical requirement in modern healthcare logistics.

Traditional medicine transportation systems rely on passive cooling methods such as ice packs and insulated containers. However, these systems lack real-time monitoring, automated temperature regulation, and secure delivery verification mechanisms. In many cases, temperature excursions go undetected until delivery, compromising the quality of the medicine. Additionally, conventional delivery systems do not provide authentication-based access control, increasing the risk of tampering or unauthorized access.

To address these challenges, this paper proposes a Smart Medicine Monitoring and Secure Transportation System that integrates environmental sensing, active cooling, real-time location tracking, communication, and electronic access control. A DHT11 sensor is used to continuously monitor temperature and humidity inside the container. When the temperature exceeds the predefined threshold, a Peltier-based thermoelectric cooling module is automatically activated to maintain safe storage conditions. A GPS module provides continuous location tracking, while a GSM module enables SMS-based communication for alerts and delivery confirmation.

The system includes start and end control switches to define the transportation cycle. Upon reaching the destination, an automated SMS notification is sent to the customer. The electronic lock mechanism is released only after receiving authorized confirmation, such as a one-time password (OTP), ensuring secure and authenticated delivery. Additionally, real-time data is updated to an IoT platform and displayed locally on an LCD for monitoring purposes.The proposed system enhances cold chain reliability, improves security, and provides real-time visibility throughout the transportation process. By combining monitoring, automation, and authentication mechanisms, the system offers a comprehensive solution for safe pharmaceutical logistics.

Objectives

The specific objectives of the system are as follows:

1. To continuously monitor temperature and humidity inside the medicine container using a DHT11 sensor to maintain proper storage conditions.
2. To automatically regulate temperature by activating a Peltier-based cooling system when the temperature exceeds the predefined safe threshold.
3. To provide real-time location tracking of the transportation vehicle using a GPS module for enhanced visibility and monitoring.
4. To enable remote communication through a GSM module for sending SMS alerts regarding trip status, temperature conditions, and delivery confirmation.
5. To implement secure delivery authentication by integrating an electronic locking mechanism that unlocks only after receiving authorized confirmation such as OTP from the customer.To incorporate start and end control switches to manage and record the transportation cycle effectively.
6. To update real-time data to an IoT platform, including temperature, location, trip status, and lock status for remote monitoring.
7. To display system parameters locally on an LCD for immediate on-site monitoring by the transporter.

2. LITERATURE SURVEY

2.1 K. S. J. Prakash et al. (2020)

"IoT Based Smart Cold Chain Management System for Pharmaceutical Products"

- **Journal:** 2020 International Conference on System, Computation, Automation and Networking (ICSCAN) - IEEE Xplore.
- **What they proposed:** They proposed a system for monitoring temperature and humidity using DHT sensors and an Arduino-based architecture.
- **Key Detail:** Similar to your abstract, they focused on the automated cooling intervention. They proposed that when the sensor detects a breach, a cooling unit is triggered, and a GSM module sends an immediate "Alert SMS" to the administrator with the exact GPS coordinates of the vehicle.

2.2. S. Gopinath et al. (2023)

"Smart Secure Delivery System using IoT and GSM"

- **Journal:** 2023 International Conference on Signal Processing, Computation and Control (ISPCC) - IEEE Xplore.
- **What they proposed:** They proposed a hardware-secured box for high-value goods that remains locked until a specific condition is met.
- **Key Detail:** This paper specifically covers your OTP/Secure Lock requirement. They proposed that the recipient receives a unique code via SMS (GSM). Only when the keypad on the container receives the correct code does the solenoid lock release. This mirrors your "authorized reply" mechanism for secure delivery.

2.3. P. Singh et al. (2021)
"Real-Time Cold Chain Monitoring System for Vaccine Distribution"

- **Journal:** 2021 5th International Conference on Computing Methodologies and Communication (ICCMC) - IEEE Xplore.
- **What they proposed:** They proposed a portable vaccine carrier utilizing a Peltier (Thermoelectric) module for active temperature regulation.
- **Key Detail:** Their proposal includes the use of IoT (Thingspeak) to plot real-time graphs of temperature. They specifically detailed the automatic switching logic for the Peltier module based on threshold values, ensuring that the medicine never leaves the required to range.

2.4. M. Adil et al. (2020)
"A Smart IoT Based System for Monitoring and Tracking of Pharmaceutical Products"

- **Journal:** 2020 IEEE International Conference on Smart Cloud (SmartCloud).
- **What they proposed:** They proposed a "Decision Support System" for logistics.
- **Key Detail:** They focused on the Trip Status indicators (Start/End switches). They proposed that the system should log the "Time of Departure" and "Time of Arrival" automatically. Their system utilized an LCD display on the box to show the driver the current internal status, similar to your local monitoring requirement.

2.5 R. Kumar & A. Selvakumar (2022)
"Anti-Theft and Environment Sensing Smart Box for Logistics using IoT"

- **Journal:** 2022 IEEE 7th International Conference on Recent Advances and Innovations in Engineering (ICRAIE).
- **What they proposed:** They proposed an integrated smart box that combines environmental sensors with anti-theft security.
- **Key Detail:** They proposed the use of GPS geofencing. If the box is opened (detected by the lock status) outside of the intended GPS destination, an emergency SMS is sent. This supports your proposal for authenticated delivery only upon reaching the destination.

2.6 Existing system

In the current pharmaceutical transportation system, temperature-sensitive medicines are typically transported using insulated containers with ice packs or passive cooling methods. These systems do not actively control temperature and depend on initial cooling conditions. As a result, temperature fluctuations during long-distance travel or unexpected delays may compromise medicine quality.Most existing systems lack continuous real-time monitoring. Temperature data is usually checked manually at specific intervals, which may delay the detection of temperature deviations. Although GPS tracking is used in logistics, it is generally not integrated with temperature monitoring or automated alert systems.Delivery verification in conventional systems relies on manual signatures or receipts, which do not ensure secure or authenticated access to the medicine container. Furthermore, many systems do not provide automated SMS communication or IoT-based real-time updates.Due to these limitations, existing systems are insufficient in ensuring continuous temperature control, secure delivery authentication, and integrated monitoring throughout the transportation process.

3. PROPOSED BLOCK DIAGRAM

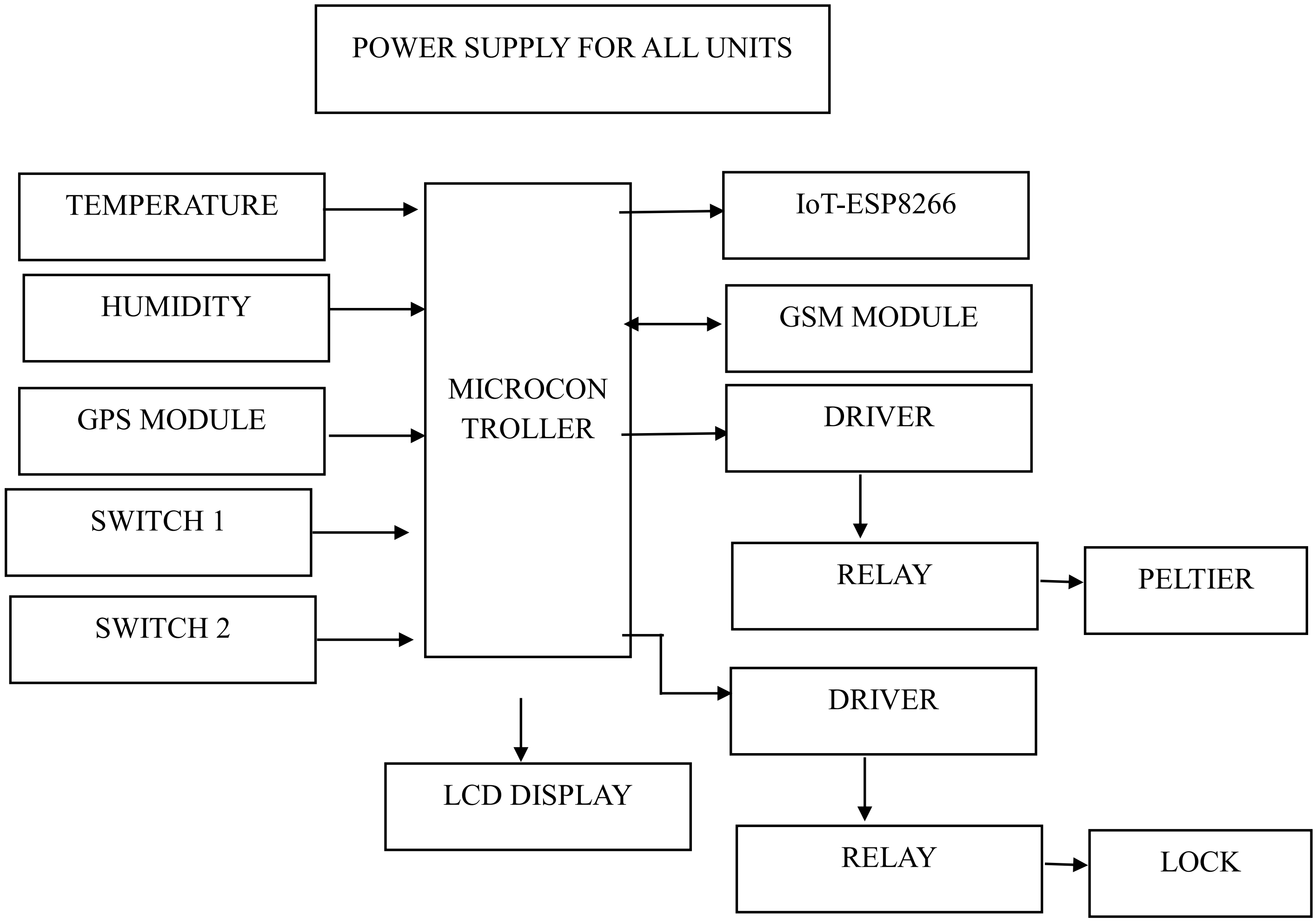

FIG. 3.1 BLOCK DIAGRAM

4. HARDWARE DESCRIPTION

4.1) Arduino Uno (ATmega328P)

Arduino Uno is the main controller that reads sensors (DHT11, GPS), controls actuators (relay, Peltier, electronic lock), updates LCD, and coordinates communication modules. It provides simple interfacing through digital/analog pins and serial communication, making it suitable for prototype-level embedded monitoring systems.

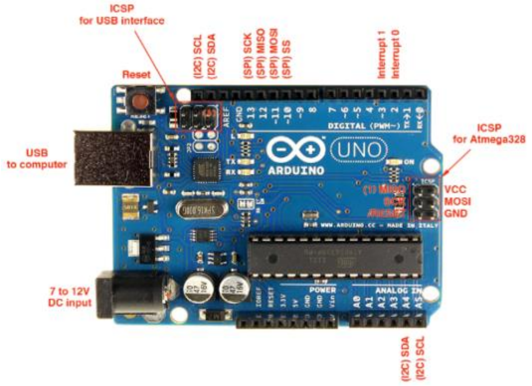

Fig 4.1 **Arduino Uno (ATmega328P)**

4.2) DHT11 Temperature and Humidity Sensor

DHT11 is used to measure the temperature and relative **humidity** inside the medicine box. The sensor output is digital, and the controller compares the measured temperature with a threshold. If temperature rises above the safe limit, cooling control is activated.

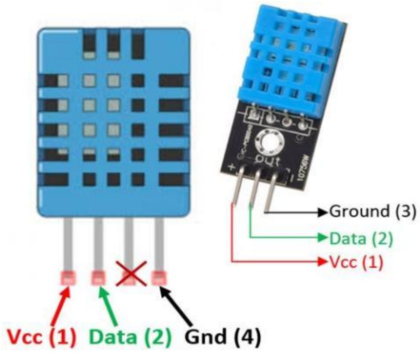

Fig.4.2 **Temperature and Humidity Sensor**

4.3) GPS Module (Neo-6M)

The GPS module provides real-time latitude and longitude of the transport vehicle. The Arduino reads NMEA data through serial communication and extracts coordinates to show on LCD and upload to IoT. Location can also be sent to the customer as a Google Maps link via GSM SMS.

Fig.4.4 **GPS Module**

4.4) GSM Module (SIM800L)

The GSM module enables SMS communication between the system and customer/owner. It is used to:

- Send delivery alert SMS when destination is reached
- Receive customer reply/OTP message
- Trigger electronic lock release after verification

GSM is preferred because it works without Wi-Fi and is reliable in remote areas.

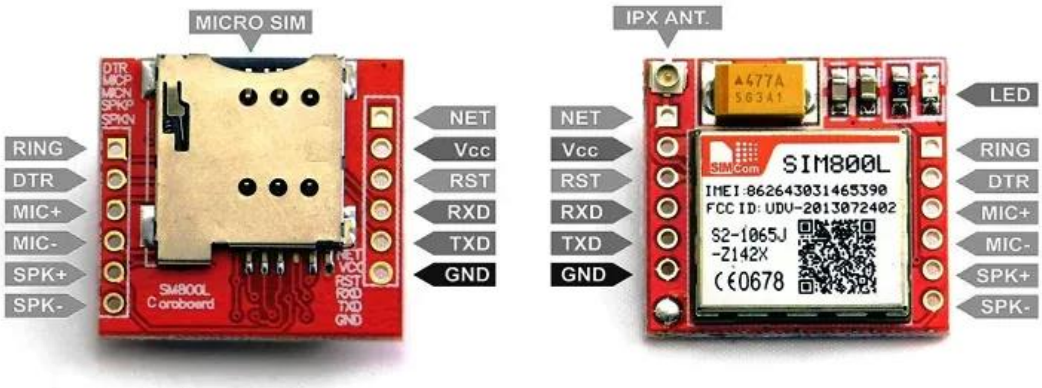

Fig.4.4 **GSM Module**

4.5) ESP8266 Wi-Fi Module (IoT)

ESP8266 is used to connect the system to the internet and update an IoT platform (such as Blynk server). It uploads parameters like temperature, humidity, GPS location, trip status, cooling status, and lock status for remote monitoring.

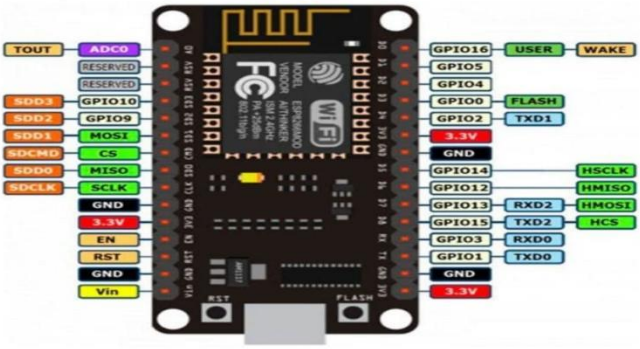

Fig.4.5 **ESP8266 Wi-Fi Module**

4.6) Relay Module

The relay acts as an electrical switch controlled by Arduino. It provides isolation and allows Arduino to safely control high-current loads such as:

- Peltier cooling unit power line
- Electronic lock (if using higher voltage solenoid)

A relay is essential because Arduino pins cannot directly drive heavy loads.

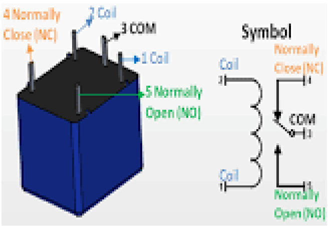

Fig 4.6 **Relay Module**

4.7) Peltier Thermoelectric Cooling Module

A Peltier module is used for active cooling inside the medicine container. When powered, one side becomes cold and the other side becomes hot. A heat sink and fan are required on the hot side to remove heat effectively. The system turns ON the Peltier when temperature exceeds the threshold and turns it OFF when temperature returns to a safe range.

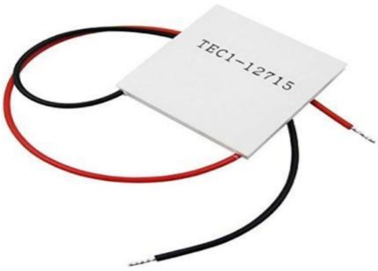

Fig 4.7 **Peltier Thermoelectric Cooling Module**

4.8) Electronic Lock (Solenoid Lock / Magnetic Lock)

The electronic lock ensures secure access control of the medicine box. By default, the lock remains in LOCK state during transport. After the destination is reached and a valid SMS confirmation/OTP is received, Arduino activates the lock driver/relay to unlock the container for the customer.

Fig **4.8 Electronic Lock**

4.9) 16×2 LCD Display

The 16×2 LCD provides local real-time display for the transporter. It shows important information such as:

- Temperature and humidity
- GPS status / coordinates (or simplified location)
- Cooling ON/OFF
- Trip status (Start/Transit/Reached)
- Lock status (Locked/Unlocked

The proposed system is a Smart Medicine Monitoring and Secure Transportation System designed to ensure the safe delivery of temperature-sensitive pharmaceutical products by integrating sensing, cooling, tracking, communication, and security mechanisms.

The system consists of a DHT11 temperature and humidity sensor, a Peltier cooling module, GPS and GSM modules, an electronic locking mechanism, an LCD display, and a microcontroller (Arduino/ESP-based system).

During transportation, the DHT11 sensor continuously monitors the internal environmental conditions of the medicine container. If the temperature rises above the predefined safe limit, the microcontroller automatically activates the Peltier cooling module to maintain optimal storage conditions. This ensures that sensitive medicines such as vaccines and insulin remain within the required temperature range.

For real-time tracking, the GPS module continuously acquires the location of the container, and the GSM module sends this information to the user via SMS or uploads it to an IoT platform. In case of abnormal temperature or any system fault, immediate alert messages are sent to the concerned authority.

The system includes two switches to indicate the start and end of transportation. When the delivery reaches its destination, the system automatically sends an SMS notification to the customer. The electronic lock attached to the container will remain locked until the customer provides an authorized reply or a One-Time Password (OTP). Upon verification, the lock is released, ensuring secure and authenticated delivery.

5.SOFTWARE DESCRIPTION

5.1 ARDUINO IDE

The Arduino IDE (Integrated Development Environment) is the official, free, and open-source software used to program Arduino microcontrollers. It provides a streamlined workflow for writing, compiling, and uploading code to Arduino boards, making it a foundational tool for both beginners and professionals in the world of electronics and embedded systems.

Results and Analysis

The proposed Smart Medicine Monitoring and Secure Transportation System was successfully designed and tested under different environmental and operational conditions. The system demonstrated reliable performance in monitoring, control, tracking, and security functionalities.

1. Temperature Monitoring and Control

The DHT11 sensor continuously measured temperature and humidity inside the container. During testing, when the temperature exceeded the predefined threshold (e.g., 35°C), the Peltier cooling module was automatically activated. The system effectively reduced the temperature back to the safe range within a short duration, ensuring proper storage conditions for temperature-sensitive medicines.

2. Real-Time Location Tracking

The GPS module accurately provided real-time location data throughout the transportation process. The location coordinates were successfully transmitted via the GSM module and could be monitored remotely. This ensured continuous visibility of the shipment.

3. Alert and Communication System

The GSM module successfully sent SMS alerts under different conditions:

- When temperature exceeded the threshold
- At the start of transportation
- Upon reaching the destination

The alerts were received without significant delay, confirming reliable communication.

4. Secure Delivery Mechanism

The electronic lock system functioned as intended. The container remained locked during transit and was only opened after receiving the correct OTP or authorized reply from the customer. Unauthorized access attempts did not trigger unlocking, ensuring delivery security.

5. 2 LCD AND IOT MONITORING

All parameters such as temperature, humidity, location status, and lock condition were displayed clearly on the LCD. Additionally, the IoT platform successfully logged and displayed real-time data, enabling remote monitoring and data analysis.

Analysis

The system shows significant improvement over traditional medicine transportation methods by integrating automation and security features. The following observations were made:

- **High Reliability:** Continuous monitoring and automatic cooling ensured stable environmental conditions.
- **Improved Safety:** Real-time alerts helped in quick response to abnormal conditions.
- **Enhanced Security:** OTP-based locking mechanism prevented unauthorized access.
- **Better Traceability:** GPS tracking provided complete visibility of the transport process.
- **Scalability:** The system can be extended with advanced sensors and cloud analytics.

However, some limitations were observed:

- The DHT11 sensor has moderate accuracy compared to advanced sensors.
- Cooling efficiency depends on external environmental conditions.
- GSM network dependency may affect communication in remote areas.

6.CONCLUSION

The proposed Smart Medicine Monitoring and Secure Transportation System provides an integrated solution for maintaining the safety and integrity of temperature-sensitive pharmaceutical products during transit. By combining real-time environmental monitoring, active temperature control using a Peltier module, GPS-based location tracking, GSM-based communication, IoT updates, and secure electronic lock authentication, the system ensures reliable and secure delivery. The use of a DHT11 sensor enables continuous monitoring of temperature and humidity, while automatic cooling control prevents temperature deviations that may affect medicine quality. The GPS and GSM modules enhance transparency by providing real-time tracking and automated customer notifications. The electronic lock mechanism, activated only after authorized confirmation, ensures secure and authenticated delivery. Additionally, IoT integration allows remote monitoring of system parameters, improving visibility and accountability throughout the transportation process.

Overall, the proposed system strengthens cold chain management, reduces the risk of medicine spoilage, enhances delivery security, and improves reliability in pharmaceutical logistics. It offers a cost-effective and scalable solution suitable for modern healthcare supply chain applications.

Future Scope

The proposed system can be further enhanced with the following improvements:

- **Advanced Sensors:** Replace the DHT11 with more accurate sensors like DHT22 or industrial-grade temperature sensors for better precision.
- **Mobile Application Integration:** Develop a dedicated mobile app for real-time monitoring, notifications, and control instead of relying only on SMS.
- **Cloud Data Analytics:** Integrate cloud platforms to store and analyze historical data for better decision-making and predictive maintenance.
- **Battery Backup System:** Add a reliable power backup to ensure uninterrupted operation during long-distance transportation.
- **AI-Based Prediction:** Use Artificial Intelligence to predict temperature fluctuations and optimize cooling performance.
- **Improved Security:** Incorporate biometric authentication or RFID-based access control for enhanced delivery security.
- **Energy Optimization:** Improve the efficiency of the Peltier module or replace it with more energy-efficient cooling technologies.

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