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IOT- Based Vaccine Management System

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Abstract: This user-friendly vaccine management system, equipped with Internet of Things (IoT) sensors, continuously monitors vaccine temperature during storage and distribution. This smart freezer box employs a waterproof temperature sensor to trigger multi-model alerts (SMS notifications through GSM module, red light indication, and an audible alarm) when temperature deviate from the safe range. Real-time location tracking is seamlessly integrated through a GPS module. A visual interface displays current temperature and stable conditions on a LCD panel. A Wi-Fi module transmits data to Google Sheets, enabling visualization on a Power BI dashboard accessible through our vaccine management website. This website provides a live temperature dashboard, historical temperature charts by region, vaccine details, and vaccination numbers by state. Utilizing role-based access control, caretakers have limited data visibility, while administrators have full access to support informed decision-making. This innovative system empowers healthcare professionals to effectively manage vaccines, safeguarding public health. We invite stakeholders to explore integrating this technology into their strategies.

Keywords: Vaccine storage, temperature monitoring, temperature sensor, Wi-Fi module, GSM notifications, Arduino Uno, Power BI, data visualization.

I. INTRODUCTION

This project entails the development of a comprehensive Vaccine Management System, integrating advanced IoT technologies for real-time monitoring and efficient supply chain management. At the heart of our system lies the DS18B20 temperature sensor, meticulously calibrated to ensure precise temperature monitoring of vaccines. This sensor is seamlessly integrated with an ESP8266 module, facilitating seamless data transmission to an Arduino UNO via serial communications. Subsequently, utilizing the ESP8266 module, the data is securely transferred to the Power BI platform, enabling vaccine caretakers to access real-time temperature details remotely, ensuring optimal vaccine storage conditions are maintained. In addition to remote monitoring, this system incorporates a user-friendly interface, accessible through a dedicated website. Through differentiated login credentials, administrators, such as hospital management personnel, gain comprehensive access to supply chain analytics, facilitating informed decision-making at various administrative levels. On the other hand, frontline workers, entrusted with vaccine handling, are provided restricted access, focusing primarily on temperature and batch number details. Furthermore, to ensure the integrity of vaccine storage, we have developed a state-of-the-art IoT Freezer Box. Equipped with an array of sensors, including the DS18B20 temperature sensor and GPS module, this innovative device provides real-time temperature monitoring and precise location tracking. In the event of temperature fluctuations or power disruptions, an integrated alert system, comprising 16x2 I2C LED indicators, a buzzer, and GSM900A module, promptly notifies caretakers, thereby mitigating the risk of vaccine spoilage. Notably, the GSM900A module enables instant SMS alerts to be dispatched to caretakers' mobile devices, ensuring timely intervention even in areas with limited internet connectivity. In essence, our solution not only offers unparalleled accuracy in vaccine monitoring but also enhances operational efficiency across the supply chain. By seamlessly integrating IoT technologies with robust data analytics and user-friendly interfaces, we strive to revolutionize vaccine management, safeguarding public health with minimal human intervention. This system aims to improve vaccine management through efficient monitoring and supply chain analytics. The dataset includes essential information for maintaining optimal vaccine storage conditions. Data such as temperature readings, batch numbers, and alert details from freezer boxes allow caretakers to act promptly. Supply chain analytics provide insights into distribution, quantities, and remaining stocks at different facilities. GPS modules track vaccine batches across hospitals, ensuring logistical management. In conclusion, This innovative approach to vaccine management combines IoT technologies with detailed analytics to streamline processes and ensure public health safety.

However, real-world challenges disrupt the cold chain. Power outages in rural clinics can render vaccines useless. Human error, like misplacing them in unsuitable freezers, can also disrupt it. Maintaining proper temperatures during transport, especially in regions with limited resources or

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extreme weather, presents significant logistical difficulties. These scenarios highlight the critical need for innovative solutions to safeguard vaccine potency throughout the cold chain journey.

II. METHODOLOGY

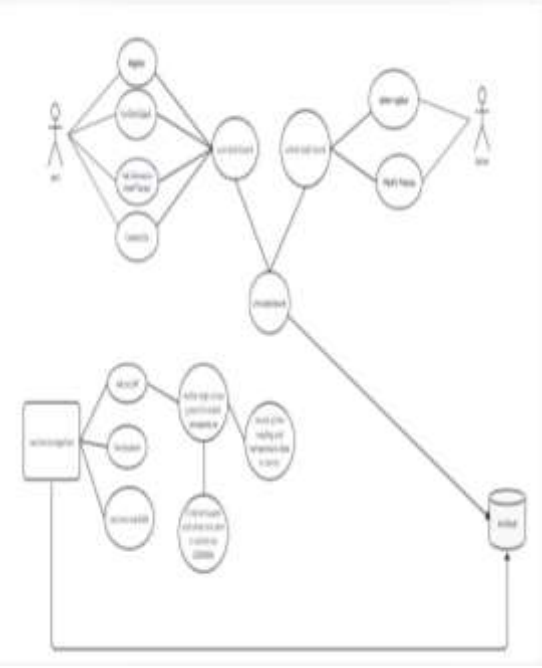
The core of the smart vaccine management system lies in its intricate interplay between meticulously chosen hardware components, software applications, and communication protocols. The ESP8266 microcontroller acts as the system's workhorse, collecting sensor data, performing essential processing tasks, and facilitating seamless communication with other components. This versatile chip boasts built-in Wi-Fi connectivity, enabling effortless data transmission to cloud platforms for remote monitoring. Precise temperature readings, crucial for safeguarding vaccine potency, are meticulously captured by the DS18B20 temperature sensor. This waterproof and highly accurate digital sensor features an embedded digital signal processor, further enhancing the reliability of temperature measurements. Several key advantages make the DS18B20 an ideal choice: its high accuracy (of ±0.5°C within the range of -10°C to +85°C) ensures highly reliable data, while it's wide temperature range (from -55°C to +125°C) effectively monitors vaccines requiring diverse storage and transportation needs. Additionally, the DS18B20 utilizes a digital interface, minimizing signal noise and ensuring data integrity during transmission.

Finally, a significant advantage is its low cost, making it a feasible option for wider implementation, even in resource-constrained settings.

Fig 1: Mapping the Choreography of Project Success

Optionally, the NEO-6M GPS sensor can be incorporated for tracking vaccine shipment routes and identifying potential cold chain disruptions during transport. The Arduino Uno microcontroller serves as a secondary processing unit, responsible for local data visualization and crucial alerting functionalities. Acting as a bridge between the ESP8266 and visual/audible alert mechanisms, the Arduino Uno receives temperature data and activates LED and buzzer alerts for pre-defined temperature deviations. Real-time notification and immediate intervention are ensured through the SIM900 GSM module, a cellular communication module that transmits SMS alerts to designated mobile numbers when temperature readings fall outside acceptable parameters. This empowers healthcare workers with prompt information to take swift corrective actions.

The software component plays an equally critical role, relying on a well-coordinated interplay between custom firmware, development environments, and cloud storage platforms. Custom firmware, meticulously developed and loaded onto the ESP8266 microcontroller, forms the brain of the system's software architecture. This firmware encompasses functionalities for sensor data acquisition, Wi-Fi communication, and data transmission protocols, ensuring seamless data flow throughout the system. The Arduino IDE



(Integrated Development Environment) serves as the software development platform for programming the Arduino Uno microcontroller. The code defines how the Arduino receives data from the ESP8266, interprets temperature readings, and activates LED and buzzer alerts, providing clear visual and auditory cues for temperature deviations.

Fig 2: Navigating System Interactions: A Use Case Perspective

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For secure and accessible data storage and visualization, Google Sheets serves as the designated cloud storage platform. The ESP8266 transmits data packets containing temperature readings and timestamps to a pre-defined Google Sheet, allowing for remote monitoring of vaccine temperature throughout the cold chain and historical analysis of temperature trends. The successful operation of the system hinges on the smooth exchange of data between its various components. This is achieved through a carefully chosen set of communication protocols. Wi-Fi protocols facilitate communication between the ESP8266 and the cloud platform (Google Sheets). Serial communication protocols facilitate data exchange between the ESP8266 and the Arduino Uno. Finally, SMS communication protocols empower the SIM900 GSM module to transmit critical temperature deviation alerts as SMS messages.

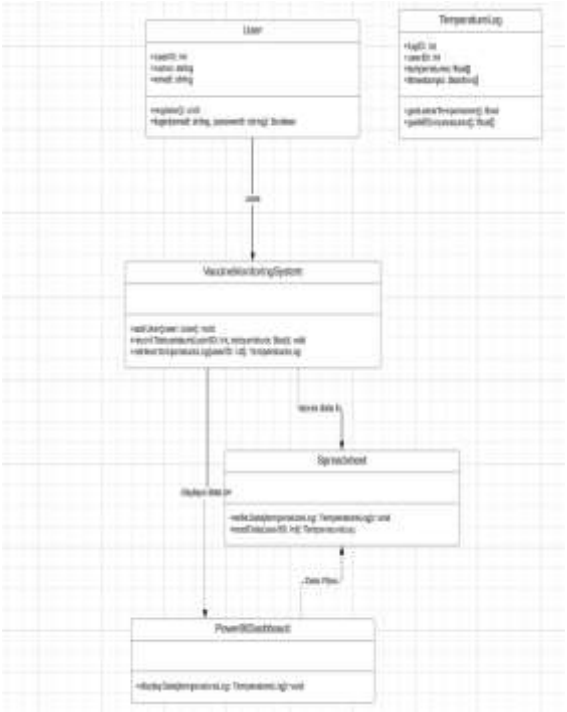
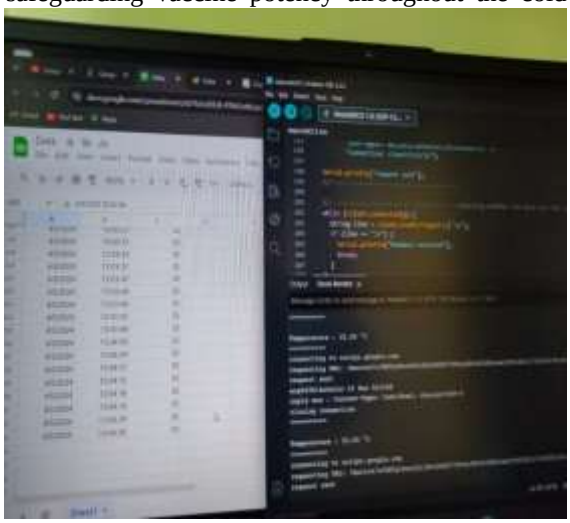


Fig 3: Architecting Stability: Unveiling System Structure through Class Diagrams

Prior to system deployment, meticulous calibration and validation steps are undertaken to guarantee accurate temperature readings and reliable system operation. The DS18B20 sensor undergoes a rigorous calibration process using a high-precision reference thermometer. All communication protocols between hardware components are thoroughly tested to eliminate potential transmission errors. The visual (LED) and auditory (buzzer) alert functionalities of the Arduino Uno are rigorously tested to confirm activation at pre-defined temperature thresholds. Test SMS messages are sent through the SIM900 GSM module to designated mobile numbers to verify the functionality of the cellular communication system for alert transmission. Finally, the entire system undergoes comprehensive integration testing, encompassing all hardware and software components. This comprehensive testing process ensures proper data flow, accurate temperature monitoring, and timely alert generation, laying the foundation for the system's reliability and trustworthiness in safeguarding vaccine potency throughout the cold chain.



III. RESULT ANALYSIS

The vaccine management system effectively displays real-time temperature data on a user-friendly dashboard. This data originates from the ESP8266 microcontroller and is categorized by location within Google Sheets which can be seen in fig4. The DS18B20 temperature sensor plays a crucial role by feeding readings to the ESP8266, which then transmits them to the Arduino Uno for processing via serial communication.

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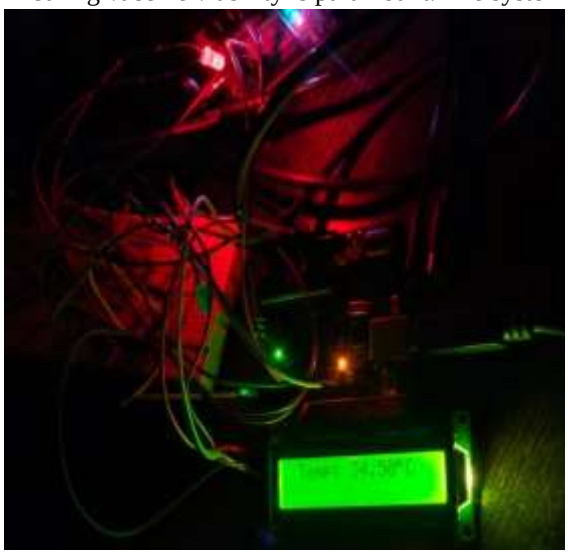
Fig 4: Data sending from ESP8266 to spreadsheet.

Fig 5: Green led indication when the freezer temperature is stable.

Ensuring vaccine viability is paramount. The system



maintains a strict temperature range between 2°C and 8°C. When temperatures deviate from this critical range, a red LED and buzzer activate, serving as a clear visual and audible alert for the caretaker.

Fig 6: Red led alert (tested under room conditions)

Furthermore, the system addresses potential caretaker absence by automatically sending SMS

notifications to a designated mobile number using the GSM SIM900A module. This eliminates the need for constant human monitoring and ensures timely intervention even when the caretaker is not physically present.

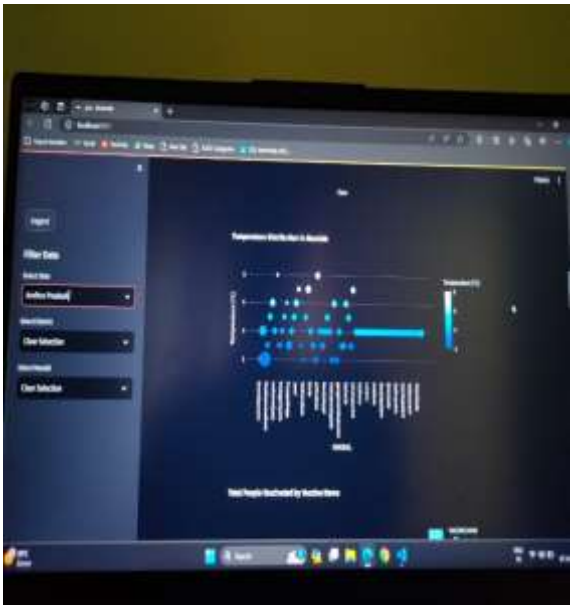
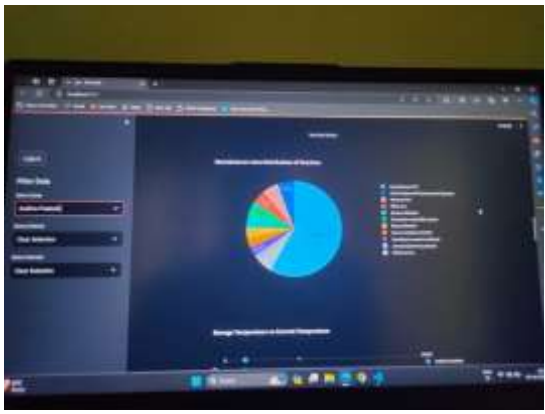


Fig 7: SMS notification sending to caretaker.



The ESP8266 not only transmits temperature readings but also collects location details, current date, and time. This comprehensive data is automatically stored in Google Sheets. This data repository serves a valuable purpose, allowing for historical analysis of temperature trends and identification of potential issues within the vaccine storage system. The

functionalities of the vaccine management system extend beyond temperature monitoring. The Google Sheet also serves as a central hub for tracking vaccine types, distribution details (state, district, and mandal levels), and vaccination statistics (number of people vaccinated in each mandal). This centralized data repository empowers hospital administrators with a holistic view of the entire vaccine supply chain across different regions.

Fig 8: Vaccine management system dashboard

The vaccine management system website dashboard caters specifically to caretakers. It provides a dedicated view of the specific vaccine they are handling, including real-time temperature data presented through clear charts and graphs. This visual representation empowers caretakers to make informed decisions regarding vaccine storage and handling practices.

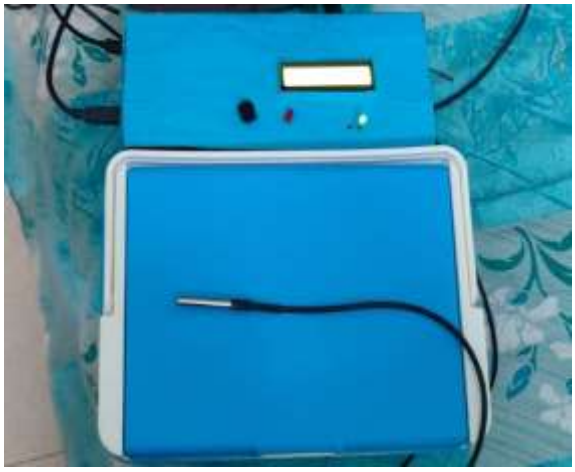
Fig 9: Dashboard showing about temperature and what type of vaccines distributed.

For hospital administrators, Power BI integration offers an additional layer of data analysis. This powerful tool allows visualization of average vaccine distribution rates in mandals with specific timestamps and geographical locations. By analyzing temperature data alongside vaccine distribution details, administrators can make strategic decisions regarding vaccine supply management and resource allocation.

Fig 10: Power BI dashboard for administrator.

The successful implementation of this vaccine management system demonstrates its significant potential to enhance vaccine storage and handling

practices. The system's core functionalities,



including real-time alerts, detailed data logging, and customizable data visualizations, empower both caretakers and administrators. Ultimately, this contributes to a more robust vaccine supply chain, ensuring vaccine potency throughout their journey.

Fig 11: live location in power BI dashboard

Fig 12: Final Hardware Implementation

IV. CONCLUSION

In conclusion, the smart vaccine management system emerges as a transformative force in healthcare technology, offering a robust and comprehensive solution for safeguarding vaccines throughout the supply chain. This innovative system leverages the power of Internet of Things (IoT) technology, integrating smart monitoring mechanisms with seamless cloud-based data storage and visualization. By meticulously addressing the critical challenges of temperature control, real-time alerting, and efficient data management, the system empowers healthcare workers with unprecedented visibility into vaccine viability. The meticulous performance evaluation process, encompassing unit testing, integration testing, system testing, and security testing, serves as a cornerstone of the system's reliability. This multi-tiered approach ensures each component functions flawlessly, data flows seamlessly, and alerts trigger promptly in response to temperature deviations. Furthermore, rigorous security testing safeguards sensitive vaccine temperature information, fostering trust in the system's ability to protect public health data.

The successful deployment of this smart vaccine management system holds immense potential for revolutionizing vaccination programs. Real-time temperature monitoring and prompt alerts empower healthcare workers to take immediate corrective action, minimizing vaccine spoilage and maximizing vaccine effectiveness. This translates to improved public health outcomes, particularly in resource-constrained settings where maintaining a robust cold chain can be challenging. The system's ability to scale efficiently paves the way for wider implementation, ensuring broader access to effective vaccines and ultimately contributing to a healthier global population.

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