MediTag: An RFID and ESP8266-Powered Smart Medication Inventory System with Real-Time Adherence Notifications

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***Abstract*— Elderly individuals often forget to take their medications, which can result in potential health risks. MediTag: Medicine Inventory (Smart Drawer) using RFID Scanner is a smart solution that promotes medication adherence by providing automated tracking and reminders. This system integrates RFID technology, Analog circuits, and Microcontroller automation to monitor medication inventory and send email notifications for both scenarios—when the medicine is taken and when it is missed. We have utilized the ESP8266 microcontroller to facilitate communication and control the functioning of the RFID scanner, acting as a bridge between the spreadsheet software and the RFID scanner. Additionally, the system uses an energy-efficient push-button switch to optimize power consumption. MediTag simplifies medication management and helps patients take their medications on time.**

***Keywords*— RFID (Radio Frequency Identification), ESP8266, Medication adherence, Smart drawer, Microcontroller, Analog circuits, Inventory management, Energy efficiency.**

I. Introduction

Patients often forget their medications, leading to health risks. MediTag solves this by sending real-time email updates when a dose is taken and alerts for missed doses, ensuring adherence to the schedule. By combining analog circuits with microcontroller automation, MediTag effectively monitors medication intake and manages inventory.

MediTag helps patients manage their medications by sending real-time notifications when a dose is taken and alerts if a dose is missed, ensuring adherence to prescribed schedules. It uses RFID technology to track medications, tagging each container with a unique identifier that communicates wirelessly with the RFID reader. The system incorporates the ESP8266, a low-cost Wi-Fi microcontroller, enabling devices to connect to the internet for data transmission. A push-button switch optimizes power consumption by conserving energy during inactive periods.

MediTag stores medication data in a spreadsheet, giving users a complete record of their intake and inventory. This allows for easy sharing of data with healthcare providers and helps track usage trends over time. By integrating analog circuits, RFID technology, and data management, MediTag offers reliable solution for monitoring medication adherence, managing inventory, and promoting energy efficiency.

II. Literature Review

R.K.A.R. Kariapper et al. (2020) [1] have examined various RFID healthcare systems to identify the best one and suggest improvements. The study analyzed ten systems against eight functionalities: patient monitoring and security. Only one system met the criteria, albeit with some shortcomings. A hybrid framework was proposed to enhance overall performance by combining features from multiple systems. RFID technology is vital for real-time monitoring, secure data transfer, and efficient emergency responses. Cesar Munoz-Ausecha et al. (2021) [2] offer an overview of RFID technology's applications across healthcare, supply chain management, and retail. The paper highlights RFID's role in enhancing operational efficiency, item tracking, and real-time data visibility. Additionally, the authors discuss critical security issues, such as unauthorized access, data interception, and tag cloning, which threaten the integrity and privacy of RFID systems. Mutammimul Ula et al. (2021) [3] have provided an analysis of a student attendance monitoring system using RFID technology. Each student is assigned an RFID tag, which is scanned upon classroom entry, automating attendance logging and reducing human error. The system offers real-time tracking, enhancing transparency and accountability for teachers and administrators. While the model improves efficiency over traditional methods, the paper also highlights challenges such as implementation costs and infrastructure requirements. Ridita Garg et al. (2022) [4] explored the implementation of an RFID-based clinical medicine dispenser to enhance medication management. The study demonstrated that integrating RFID technology significantly reduces medication retrieval time and minimizes errors, thus improving patient safety. The authors highlighted the system's accuracy and user-friendliness while proposing future enhancements for scalability and security in clinical applications. Ahmed Jobair et al. (2023) [5] designed a Smart Medicart system for patient monitoring, specifically targeting contagious diseases. The study highlighted that real-time data transmission and wireless communication enhance patient management and safety. The authors emphasized the system's effectiveness in securely tracking patient health and recommended improvements in data security and interoperability for future applications. Alice Buff et al. (2018) [6] investigated RSSI measurements for

RFID tag classification in smart storage systems. The study demonstrated that RSSI is an effective method for distinguishing between different RFID tags based on signal strength variations. The authors noted that environmental factors significantly influence RSSI accuracy and proposed strategies to mitigate these challenges. They emphasized the potential for integrating RSSI with machine learning algorithms to enhance classification accuracy and optimize inventory management processes in smart storage environments. We referred to the work of Pallavi Deshpande et al. (2019) & (2021) to guide the structure, format, and flow of this paper for conference publication. While their studies informed our organizational approach, no direct content or references were used, ensuring the originality of this work [7] [8] [9]. S. A. Ishak et al., (2016) [10]proposed the Smart Medicine Cabinet Monitoring System that was made to persuade patients to take their medications using RFID technology. The device monitors the retrieval of medicines and sends notifications to remind about doses and frequency in a real-time manner. It is aimed to make medication adherence better by providing alarms for missed or incorrect doses, thus enhancing the overall compliance and health of the patients. The article presents the combination of RFID tags with a surveillance system to improve simplification and thus transmission of data between the provider and the monitor, who is located in the home-based care setting. H.A. Khan et al. (2021) [11] developed an IoT healthcare system using RFID and steganography to enhance data security and real-time monitoring. The system employs sensors to track health metrics like heart rate and air quality, securely transmitting data via Blynk. Steganography conceals sensitive information to protect privacy, while a two-tier security model addresses patient data security and system latency.

III. PROPOSED SYSTEM

In Figure 1, the project flow is shown: the circuit activates only when the drawer is open to conserve energy. When closed, the circuit powers the ESP module, which connects to Wi-Fi. The RFID scanner then reads the medicine case's sticker, followed by a buzzer beep signalling a successful scan. An email is sent to notify the user of the medicine taken.

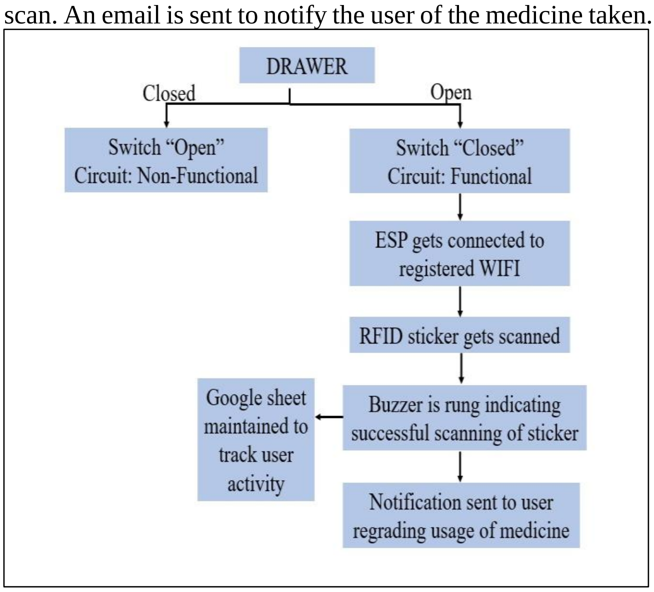


Figure 1 Working in Block Diagram

IV. HARDWARE SPECIFICATIONS

A. Hardware Requirement

The MediTag: RFID-based Medicine Inventory (Smart Drawer) System is designed with a focus on low-power operation, seamless data tracking, and automated reminders. Figure 2 shows the core components including the RC522 RFID Scanner, ESP8266 Node MCU, a 9V battery, a buzzer, and a push-button switch. The system architecture follows a modular approach:

1. **RFID Tags:** RFID tags, attached to medicine bottles, store patient email and medication details. They follow ISO 14443A standards and operate at a 30-300 KHz frequency.
2. **RFID Scanner Module:** The RC522 scanner, mounted at the drawer entrance, communicates with the ESP8266 via SPI to read tags as medicines enter or leave.
3. **ESP8266 Node MCU**: Acting as the system's central processing unit, the ESP8266 handles multiple operations, including reading data from RFID tags, establishing Wi-Fi connections, and sending notifications. Powered by a 9V battery, it uses HTTP requests to log data on Google Sheets and send notifications to users, ensuring up-to-date tracking of medication intake. Additionally, the ESP8266 powers down via a push-button switch at the back of the drawer to enhance energy efficiency.
4. **9V Battery:** To provide power supply to NODE MCU.
5. **Push-button Switch:** To control the power supply between the NODE MCU and the battery based on the status of the drawer.

B. Design Schematics

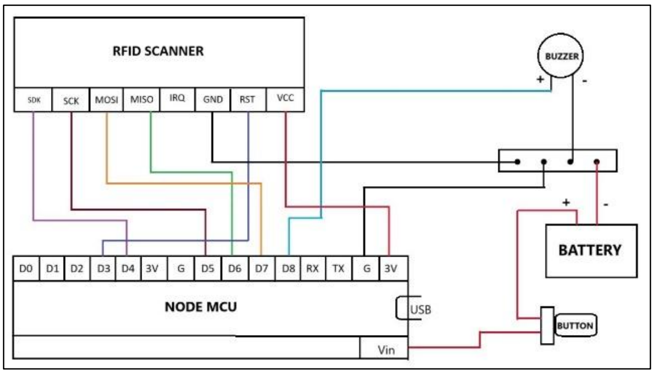


Figure 2 Circuit Diagram

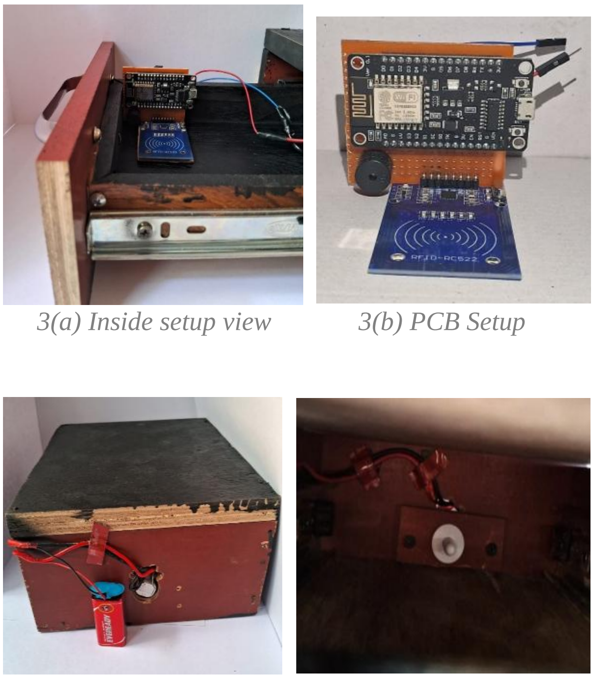
C. Hardware Implementation

The MediTag System integrates various hardware components for real-time medication tracking and management:

1. **RC522 RFID Scanner:** This module reads RFID tags and connects to the ESP8266 via the SPI protocol, using MISO, MOSI, SCK, SDA, and RST pins. It identifies patient- or medication-specific information from the tags.

2. **RFID Tags:** Operating at 30-300 KHz, these tags are attached to medication bottles, acting as unique identifiers for logging medication details.
3. **ESP8266 Node MCU:** The ESP8266 facilitates core functionalities—communicating with RFID tags, connecting to Wi-Fi for remote data logging, and sending HTTP requests to Google Sheets. This device also runs the code to handle incoming RFID data and matches it with patient entries, thereby ensuring an automated inventory system. The ESP8266 Node MCU is an excellent choice for the MediTag system because of the built-in Wi-Fi capabilities of components that make easy data transmission to cloud-level platforms as well as email notifications without adding extra modules instead, thus decreasing complexity and costs. It has low power consumption, especially in sleep modes. The controller's SPI compatibility ensures reliable communication with the RC522 RFID scanner for real-time medication tracking. Additionally, the ESP8266 is cost-effective and has strong community support, providing resources that simplify development and maintenance.
4. **Buzzer:** Activated by the ESP8266 upon successful scanning, the buzzer provides audio feedback to confirm tag recognition.
5. **Push Button:** Located in the drawer, it cuts power to the ESP8266 when the drawer is closed to conserve energy.

The entire hardware setup is installed in the drawer as depicted in Figure 3:



3(a) Inside setup view *3(b) PCB Setup*

3(c) Back View *3(d) Push-button at back.*

Figure 3 Hardware Setup

V. Software Implementation

1. **Arduino IDE:** The ESP8266 is programmed using the Arduino IDE. The code facilitates the reading of RFID tags, Wi-Fi connection to the Google Sheet, and sending HTTP requests.

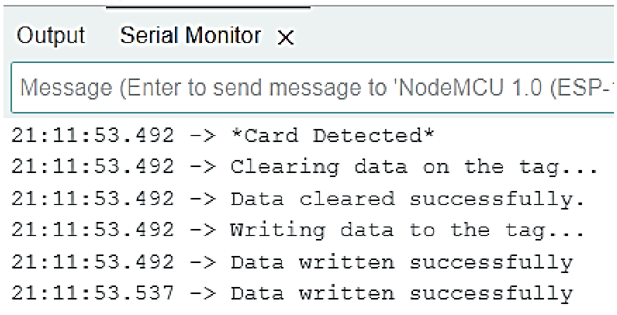
2. **Google Sheets Integration:** Two sub-sheets are used: 'Form Responses 1' stores patient-submitted information, while 'Sheet2' logs the RFID scan details.

3. **Google App Scripts:** Four Google Apps Scripts are implemented:

- StoreDetails.gs: Saves the RFID data (tag ID, medicine name, patient email) to 'Sheet2' in Google Sheets.
- EmailConfirmation.gs: Sends an email confirmation when the system detects that the patient has taken their medicine.
- Formatting.gs: Turns cells green when the medicine name in 'Form Responses 1' matches the name in 'Sheet 2' as shown in Figure 6
- EmailReminder.gs: Automates daily reminders, ensuring patients are notified at their specified dosage times

4. **Data Handling and Synchronization:**

- As shown in Figure 4(b), the ESP8266 fetches data from the RFID tags and posts it to Google Sheets using HTTP requests. This data is then cross-checked with the patient's input from the Google Form to ensure consistency.
- When a tag is scanned, the system compares the medication name with the patient's entry and updates the status in real-time. By leveraging both hardware and cloud-based software solutions, the MediTag System ensures a comprehensive and reliable medicine inventory management solution for patients.



4(a) Data stored in RFID

Output   Serial Monitor ×

Message (Enter to send message to 'NodeMCU 1.0 (ESP-12E Module)' on 'COM9')

```
21:08:23.483 ->
21:08:23.939 -> .........
21:08:28.798 -> Connected to WiFi
21:08:28.798 -> Scan an RFID card or NFC tag...
21:08:36.887 -> Card type: MIFARE Ultralight or Ultralight C
21:08:36.887 -> Blocks 4-5 (Medicine Name): Rabix
21:08:36.924 -> Blocks 6-10 (Email): rajlakshmidesai78@gmail.com
21:08:37.011 -> Medicine Name: Rabix
21:08:37.011 -> Email: rajlakshmidesai78@gmail.com
21:08:37.054 -> Requesting URL: https://script.google.com/macros/s/
21:08:40.951 -> [HTTPS] GET... code: 302
```

4(b) Data scanned from RFID

Figure 4 Output of Arduino IDE

VI. Methodology

A. System Working

In our proposed system, we will utilize NFC Type 2 stickers to store specific medicine and email data for each corresponding bottle or strip. We have developed two sets of Arduino codes to facilitate this process. The first code is designed to store data onto the NFC Type 2 stickers, which will be affixed to the medicine bottles or strips.

For power supply, a 9V battery is connected to the Vin pin of the NodeMCU. A push button is placed between the battery and the Vin pin to control the power supply. When the drawer is closed, the push button is activated, opening the circuit and halting the power from the battery. Conversely, when the drawer is opened, power is supplied to the NodeMCU and the RFID scanner, making the scanner ready to scan the NFC stickers from a maximum distance of 30 mm. The second code will be uploaded to the NodeMCU, which is connected to an RFID RC522 scanner. To enhance functionality, we have integrated a buzzer that activates when the sticker is scanned by the RFID scanner during the retrieval of a medicine bottle. This alert serves to indicate that the patient has taken their medication, prompting an email notification to be sent to the patient's relative.

The data collected from the stickers by the RFID scanner is subsequently transmitted to Google Sheets via the NodeMCU.

B. Functionality and Operation of System

The **MediTag System** operates as a smart, automated medicine management solution for patients. It is designed to streamline medication tracking and ensure patients take their medicine on time. Here's how it works:

1. **Patient Information Entry:** Patients first fill out a Google form with essential details, including their name, email, mobile number, medication name, dosage time, and dose end date. This data is stored in the 'Form Responses 1' sheet in Google Sheets as shown in Figure 6(a).

2. **Medicine Scanning and Logging:** Each time a medicine bottle or strip with an RFID tag is placed in the drawer, the RC522 RFID Scanner reads the tag and sends the tag information to the ESP8266 Node MCU. This data is processed and logged into a separate sub-sheet (Sheet2) in Google Sheets as shown in Figure 6(b), storing the patient's email, medicine name, and the exact timestamp of the scan.

3. **Data Matching and Visual Indicators:** As shown in Figure 6(a) and Figure 6(b) if the medication name in both 'Form Responses 1' and 'Sheet2' matches, the system automatically turns the corresponding cell in Sheet2 green, signalling that the correct medication has been taken.

4. **Email Confirmation:** Once a match is detected, the system sends an email to the patient confirming that the specified medication has been taken at the noted time, as shown in Figure 7(a).

5. **Automated Reminders:** Based on the dosage time provided in the Google form, App Scripts triggers an email reminder to the patient daily, reminding them to take their medication. If no RFID scan is recorded, the system sends follow-up reminders as needed, as shown in Figure 7(b).

The combination of automated reminders, real-time logging, and email confirmations ensures that patients are informed and compliant with their prescribed medication schedules.

VII. Performance Evaluation

The **MediTag RFID-based Medicine Inventory** System was assessed based on key performance criteria, including automated processes, RFID scanner range, and system responsiveness. Here's a detailed evaluation:

1) Trigger-Based Task Performance:

Google Apps Script time-based triggers are used to automate essential tasks such as email notifications, dosage reminders, and Google Sheets updates. Precision in these tasks is crucial for ensuring that medications are tracked and managed accurately:

- Email Confirmation Trigger: Sends confirmation emails once the medication is logged, with a 0.14% error rate as shown in Figure 5(a) ensuring nearly all emails are successfully sent.
- Email Reminder Trigger: Sends reminders based on dosage times entered in a Google form, with an error rate of 0.06%, confirming over 99.94% success in timely notifications.
- Highlighting Matching Cells Trigger: Highlights the corresponding cell in Google Sheets when a medication match is detected, with a 0.29% error rate as shown in Figure 5(a), ensuring minimal inaccuracies.

Reliability Assurance: These automated processes minimize human intervention and are monitored continuously, with error logs maintained to track failures. By leveraging Google Apps Script triggers, the system achieves consistency and high reliability in notification and alert functionalities.

Precision Enhancement: The automated triggering mechanisms reduce human error and ensure that every task is performed with high accuracy, minimizing delays and achieving consistency in notifications and alerts.

2) RFID Scanner Range:

The RC522 RFID scanner has an effective range of approximately 30 mm. This limited range ensures that RFID tags are only read when medicines are properly positioned near the drawer entrance, reducing the chances of erroneous scans and providing reliable inventory tracking.

3) Power Management Efficiency:

The ESP8266 Node MCU operates on a 9V battery (also works on DC 3.3V). A push-button switch at the back of the drawer as shown in Figure 3(d) disconnects power when closed, significantly reducing power consumption during idle periods and prolonging battery life.

4) System Responsiveness:

Although the system has a 90-second delay due to trigger intervals, its responsiveness remains adequate for non-urgent inventory management. The overall response time, which includes scanning, logging, sending confirmations, and highlighting cells, averages around 90-120 seconds, depending on the timing of scans.

5) Error Recovery Mechanism:

The MediTag System incorporates several layers of error detection and recovery*:*

- Error Logging for Debugging: The system logs errors during critical tasks, helping identify failed operations for troubleshooting.
- Status Columns in Google Sheets: These columns track the success or failure of email tasks, allowing administrators to monitor email delivery status and take corrective actions if necessary.
- Manual Error Handling: Administrators can manually verify and resend failed emails, ensuring minimal risk of data loss or missed notifications.

6) Performance Optimization:

Using a different range or frequency RFID reader will assist in improving MediTag. Faster triggers can also be used, allowing fast Google Apps script responses that result in less system delay; therefore, all of these steps ensure exact medication tracking as well as quick data syncing.

By integrating automated processes, controlled hardware range, effective power management, and robust error handling, the MediTag system achieves high reliability in medication tracking and notification functions. These performance criteria ensure that patients are consistently informed and that inventory management remains precise.

Table 1 shows the comparison with the project done in reference no. [10]

9V DC battery ratings:

Power=500mAh
Voltage=9V
The battery can discharge 500mA current in 1 hour
Assuming 8 pins are connected for both ESP and Arduino

ESP8266 NodeMCU ratings:
Output current per I/O pin=12mA(max)
Operating voltage=3.6V(max)

$$\text{Hence for ESP8266, time for battery to discharge} = \frac{500mAh}{12mA * 8} = 5.2083\ hours$$

Arduino UNO ratings:
Output current per I/O pin=40mA(max)
Operating voltage=5.5V

$$\text{Hence for Arduino, time for battery to discharge} = \frac{500mAh}{40mA * 8} = 1.5625\ hours$$

Table 1 Comparison Table

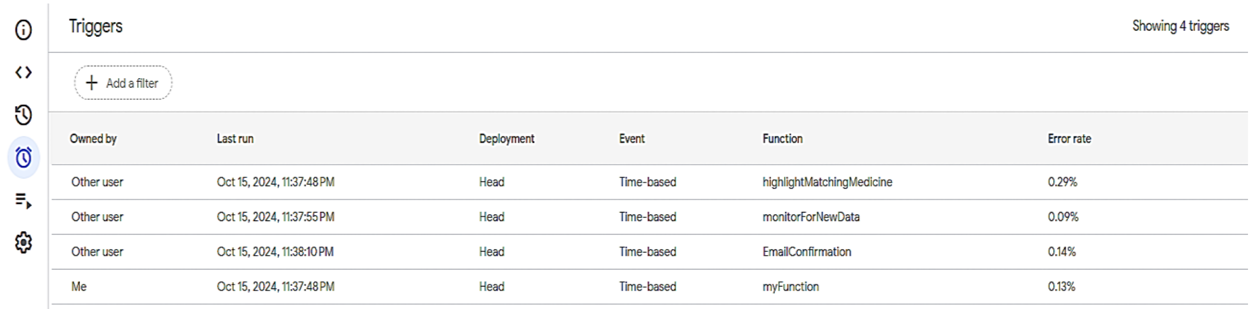
	ESP8266	Arduino Uno
Operating voltage(max)[in V]	3.6	5.5
Operating current(max for 1 pin)[in A]	0.012	0.040
Operating current(max for 8 pins)[in A]	0.096	0.320
Power supplied by DC Battery[in Ah]	0.5	0.5
Time taken for battery to discharge[in hrs]	5.2083	1.5625

If we implement a similar circuit using Arduino, it would consume the same power in 1.5625 hours and ESP8266 consumes in 5.2083 hrs. Therefore, the ESP8266 module is more energy-efficient

If there was no switch in the circuit, we would have to change the 9V DC battery every 5.2083 hrs. However, due to the introduction of a switch, the circuit doesn't consume power from the battery when the drawer is closed. Therefore, we save on power which we don't need to frequently keep replacing the battery. The circuit will be closed only when the drawer is opened thereby enhancing the efficiency of the circuit.

VIII. RESULT

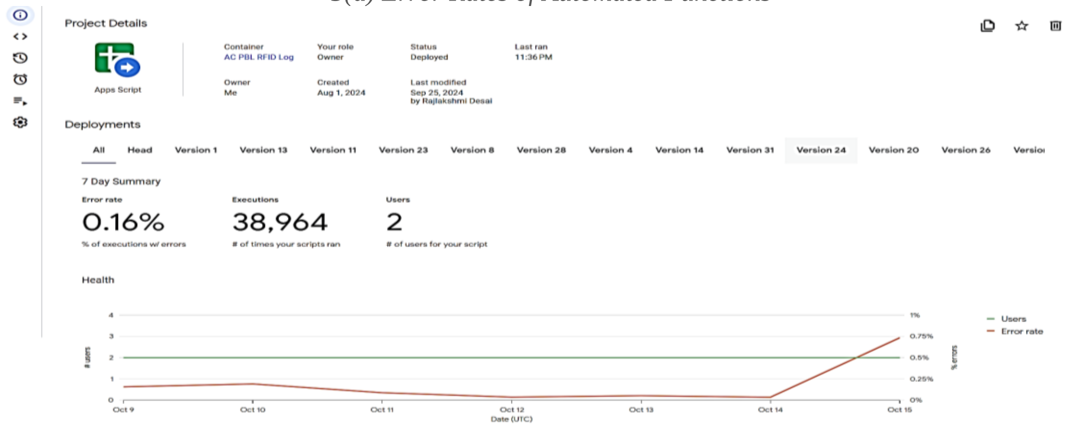
The **MediTag** system demonstrated high reliability and efficiency in medication management, with minimal errors across automated functions. As shown in Figure 5(a)it achieved **99.98% accuracy for email confirmations** and **99.94% accuracy for email reminders**, ensuring patients receive timely notifications for medication adherence. As shown in Figure 7, it consistently sent successful medication reminders and notifications when medicines were taken, ensuring patients remained informed and on schedule with their prescriptions. Power efficiency was further optimized through a drawer switch mechanism that conserves energy during idle times. MediTag is a reliable tool, that supports patient health management with timely, accurate notifications that enhance medication adherence.



Triggers | Showing 4 triggers

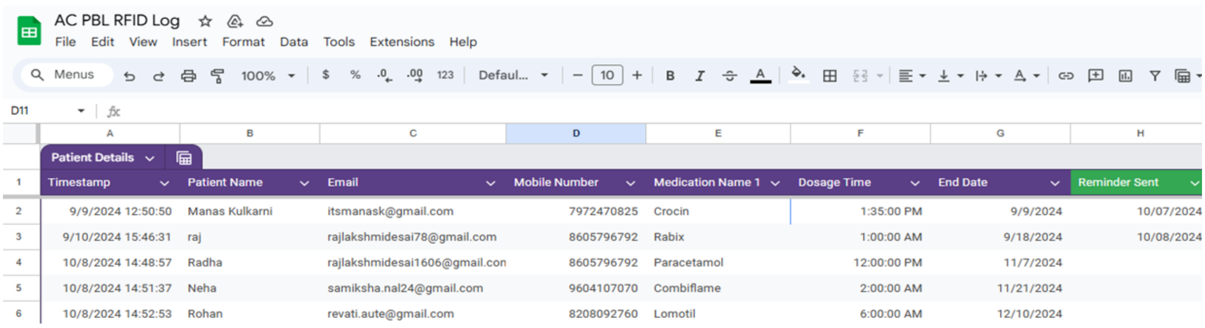
Owned by	Last run	Deployment	Event	Function	Error rate
Other user	Oct 15, 2024, 11:37:48 PM	Head	Time-based	highlightMatchingMedicine	0.29%
Other user	Oct 15, 2024, 11:37:55 PM	Head	Time-based	monitorForNewData	0.09%
Other user	Oct 15, 2024, 11:38:10 PM	Head	Time-based	EmailConfirmation	0.14%
Me	Oct 15, 2024, 11:37:48 PM	Head	Time-based	myFunction	0.13%

5(a) Error Rates of Automated Functions



5(b) Graph Representation

Figure 5 Performance Metrics

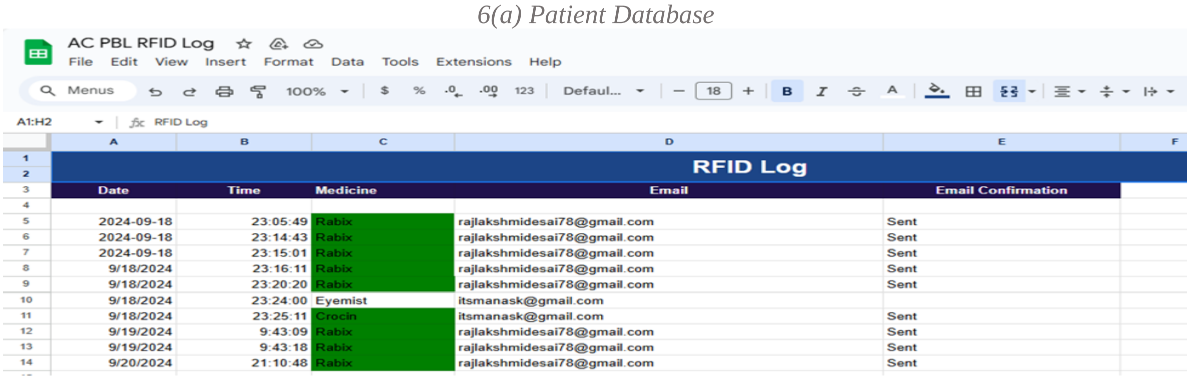


AC PBL RFID Log

Patient Details

Timestamp	Patient Name	Email	Mobile Number	Medication Name 1	Dosage Time	End Date	Reminder Sent
9/9/2024 12:50:50	Manas Kulkarni	itsmanask@gmail.com	7972470825	Crocin	1:35:00 PM	9/9/2024	10/07/2024
9/10/2024 15:46:31	raj	rajlakshmidesai78@gmail.com	8605796792	Rabix	1:00:00 AM	9/18/2024	10/08/2024
10/8/2024 14:48:57	Radha	rajlakshmidesai1606@gmail.con	8605796792	Paracetamol	12:00:00 PM	11/7/2024	
10/8/2024 14:51:37	Neha	samiksha.nal24@gmail.com	9604107070	Combiflame	2:00:00 AM	11/21/2024	
10/8/2024 14:52:53	Rohan	revati.aute@gmail.com	8208092760	Lomotil	6:00:00 AM	12/10/2024	

6(a) Patient Database



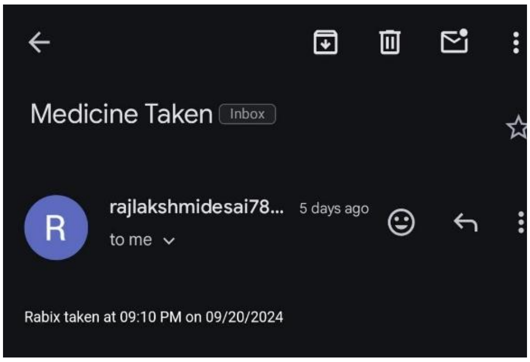
AC PBL RFID Log

RFID Log

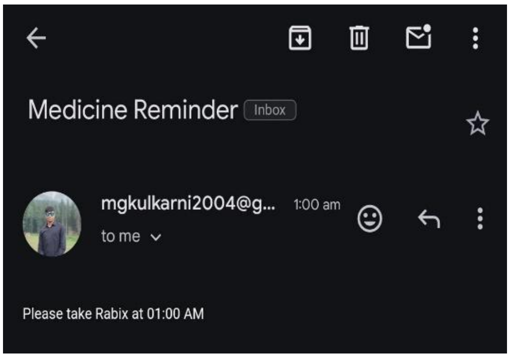
Date	Time	Medicine	Email	Email Confirmation
2024-09-18	23:05:49	Rabix	rajlakshmidesai78@gmail.com	Sent
2024-09-18	23:14:43	Rabix	rajlakshmidesai78@gmail.com	Sent
2024-09-18	23:15:01	Rabix	rajlakshmidesai78@gmail.com	Sent
9/18/2024	23:16:11	Rabix	rajlakshmidesai78@gmail.com	Sent
9/18/2024	23:20:20	Rabix	rajlakshmidesai78@gmail.com	Sent
9/18/2024	23:24:00	Eyemist	itsmanask@gmail.com	
9/18/2024	23:25:11	Crocin	itsmanask@gmail.com	Sent
9/19/2024	9:43:09	Rabix	rajlakshmidesai78@gmail.com	Sent
9/19/2024	9:43:18	Rabix	rajlakshmidesai78@gmail.com	Sent
9/20/2024	21:10:48	Rabix	rajlakshmidesai78@gmail.com	Sent

6(b) RFID Log Database

Figure 6 Database



7(a) Confirmation through Email



7(b) Reminder through Email

Figure 7 Email Notifications

IX. LIMITATIONS

1. There is uncertainty regarding whether the patient has taken the medicine after removing the bottle from the drawer.
2. The RFID tags have limited data storage capacity.
3. Storing medicine data on the tags is done manually through code, which is not user-friendly.
4. The RFID tag may inadvertently be scanned when the bottle is placed back into the drawer, potentially triggering the NodeMCU to send a false message indicating the medicine was taken, even if it was not.
5. The user may need to replace the battery periodically.

X. CONCLUSION

MediTag: Smart Drawer Medication Inventory using an RFID Scanner offers a sustainable and effective solution in medication adherence since it successfully integrated RFID technology with Analog circuitry and automation of the microcontroller, tracking inventory in real-time and offering timely dose reminders and refill alerts. In this system, the energy-efficient fridge door switch integrates into its design to optimize power usage and enhance its long-term reliability. Such enhancements in things in the future would include rechargeable lithium-ion cells to improve battery life and refinement of accuracy with the addition of environmental filters and higher-quality RFID or NFC tags. Increased RFID scanner range using high-frequency scanners and further hardening the tags would widen their functionality, reducing most interference issues, even in challenging environmental conditions. Implementation of sleep modes for microcontrollers such as ESP8266, coupled with effective power management intelligence, would achieve further extensions in battery life; precision-optimized RFID readers might be able to build on that with improved tag detection over various orientations. With such new and improved features, MediTag's friendly and energy-efficient design offers an eco-aware approach to enhanced medication adherence and patient care, further bolstering its prospects as a prized asset in smart healthcare.

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