IoT-Based Smart Pill Reminder and Automated Medicine Dispensing System for Elderly and Healthcare Support

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Abstract — Medication non-adherence is a critical healthcare challenge globally, especially among elderly patients with chronic conditions who manage multiple prescriptions. This paper presents the design and implementation of an IoT-Based Smart Pill Reminder and Automated Medicine Dispensing System that leverages an Arduino microcontroller, Real Time Clock (RTC DS1302), APR33A3 voice modules, 16×2 LCD display, ESP8266 Wi-Fi module, and an Android mobile application. The system automatically generates voice and visual reminders at predefined medication times, enabling timely drug intake without human supervision. Up to six independent medication alarms can be programmed remotely via a mobile application over Wi-Fi. The RTC module maintains precise timekeeping, while the APR voice modules deliver pre-recorded medicine-specific audio alerts. Experimental results demonstrate reliable reminder generation, accurate RTC synchronization, stable IoT connectivity, and effective visual-audio notification. The proposed low-cost, user-friendly system improves medication adherence, reduces dosage errors, and enhances quality of life for elderly and chronically ill patients.

Keywords: *IoT, Smart Pill Reminder, Arduino, RTC DS1302, APR33A3, ESP8266, Medication Adherence, Elderly Healthcare, Automated Dispensing*

1. INTRODUCTION

Medication non-adherence is a widespread yet largely preventable cause of hospital readmissions, disease progression, and patient mortality. The World Health Organization reports that only 50% of patients with chronic diseases in developed countries take their medications as prescribed. This challenge is significantly amplified for elderly populations, individuals living alone, and patients with cognitive impairments such as dementia, who often require assistance to maintain accurate dosing schedules.

The emergence of the Internet of Things (IoT) has opened transformative possibilities for remote healthcare monitoring and patient assistance. Embedding connectivity into medical devices enables real-time alerts, remote configuration of medication schedules, and cloud-based data logging — all contributing to a smarter and more responsive healthcare ecosystem. Simultaneously, embedded microcontroller platforms such as Arduino offer a low-cost, flexible base for developing intelligent healthcare solutions.

Conventional approaches to medication reminders range from simple pill organizers and paper charts to basic alarm clocks and smartphone notification applications. While these solutions are inexpensive, they rely entirely on the patient's awareness and memory. They lack automated dispensing, voice-based guidance, or any form of intelligent scheduling verification. In clinical settings, manual pill administration by nurses is resource-intensive and susceptible to human error in high-patient-volume environments.

This paper proposes and implements an IoT-Based Smart Pill Reminder and Automated Medicine Dispensing System tailored for elderly and healthcare environments. The system integrates an Arduino microcontroller as the central control unit, an RTC DS1302 module for accurate timekeeping, APR33A3 voice modules for audio notifications, a 16×2 LCD display for visual feedback, an ESP8266 Wi-Fi module for IoT connectivity, and an Android application for remote schedule configuration. Up to six medication schedules can be programmed, each triggering an independent voice and visual alert at the prescribed time. The system is self-contained, battery-backup capable through the RTC dual-power architecture, and requires minimal user interaction once configured.

2. LITERATURE SURVEY

Significant research has been directed toward automated medication management systems. Early work focused on intelligent pill boxes that integrated RTC modules and push-button interfaces to display scheduled medication times and counts on LCD screens, with GSM modules sending SMS alerts when patients failed to acknowledge reminders [6].

Prototype in-home medication management systems based on intelligent packaging and smart medicine boxes have been proposed, where prescription schedules are encoded and managed through interactive packaging with IoT integration [1]. Mobile application-based reminders that parse prescription data and deliver platform notifications for both type and timing of medications have also been developed [2].

Research in [3] introduced a smart medicine box where medication timetables are configured via push buttons and stored on-device, while [4] proposed OMA data synchronization-based messaging to transmit prescription data from wearable devices to remote medical staff. ZigBee wireless sensor networks have been applied to monitor elderly individuals living alone, integrating medication reminders within a broader home automation framework [5].

RFID-based drug management systems have been studied for tracking medicine dispensing in clinical environments, with HF RFID tags and web-based dashboards enabling real-time monitoring [8]. The UbiPILL system demonstrated web-browser-based monitoring of medicine box activity in ubiquitous home environments, combining embedded controllers with home server middleware [7].

Wearable and eHealth monitoring frameworks combining Bluetooth, wireless body area networks, and cloud computing have been proposed to provide multidisciplinary patient-centric healthcare services, encompassing data collection, transmission, and analytics [11]. Intelligent pill box implementations specifically targeting elderly users, combining timed dispensing with audible reminders to prevent both missed doses and accidental overdose, have been validated in [12].

Mobile application-based medication compliance solutions addressing users unfamiliar with smartphones have been explored, with passive data collection augmenting user-facing reminder interfaces [12][13]. Most existing systems, however, lack the combined advantages of local voice alerts in regional languages, remote IoT-based schedule configuration, multi-alarm capability, and low manufacturing cost — gaps that the proposed system addresses.

3. EXISTING SYSTEM

Existing medication reminder solutions broadly fall into four categories: manual systems, basic alarm systems, mobile-application-only systems, and hardware-based dispensers. Manual systems include pill organizers and written schedules, which are entirely passive and offer no alert mechanism. Basic alarm systems use standard timers or phone alarms but require user configuration and provide no medicine-specific guidance or dispensing capability.

Mobile-application-based systems deliver push notifications and visual schedules on smartphones. While cost-effective, they depend on device battery life, network availability, and the patient's ability to operate a smartphone — factors that limit their reliability for elderly or cognitively impaired users. These systems also provide no physical interaction with the medication itself.

Hardware-based dispensers in the commercial market are generally bulky, expensive, and designed for clinical environments. Earlier embedded system approaches used 8051-series and basic AVR microcontrollers with Bluetooth communication, limiting remote configurability to short ranges of 8–10 meters with no cloud integration.

TABLE I: COMPARISON OF EXISTING VS. PROPOSED SYSTEM

Feature	Existing System	Proposed System
Controller	8051 / Basic AVR	Arduino (ATmega328P)
Communication	Bluetooth (8–10 m)	Wi-Fi / IoT (ESP8266)
Remote Config.	Not Available	Android App via Wi-Fi
Voice Alerts	Buzzer Only	APR33A3 Voice Module
LCD Display	Not Available / Basic	16×2 LCD with Messages
No. of Alarms	1–2	Up to 6 Independent
RTC Module	Basic / No Backup	DS1302 with Backup Power
IoT Integration	Not Available	ESP8266 Wi-Fi Module
User Interface	Physical Buttons Only	Mobile App + LCD
Cost	Moderate	Low Cost

4. PROPOSED METHODOLOGY

The proposed IoT-Based Smart Pill Reminder and Automated Medicine Dispensing System is designed to deliver reliable, automated medication reminders with remote configurability, voice-based guidance, and visual feedback. The system architecture integrates hardware and software components orchestrated by an Arduino microcontroller.

A. System Block Diagram

Figure 1 presents the system block diagram. The Arduino microcontroller serves as the central processing unit, interfacing with the RTC module, voice modules, LCD, buzzer, IoT module, and power supply. The ESP8266 IoT module connects the system to the Android mobile application via Wi-Fi, enabling remote medication schedule programming. The RTC DS1302 continuously tracks real-time date and time information, providing accurate timing triggers to the Arduino. Upon matching a scheduled alarm time, the Arduino activates the corresponding APR33A3 voice module to play the pre-recorded medicine reminder and simultaneously displays the reminder message on the 16×2 LCD.

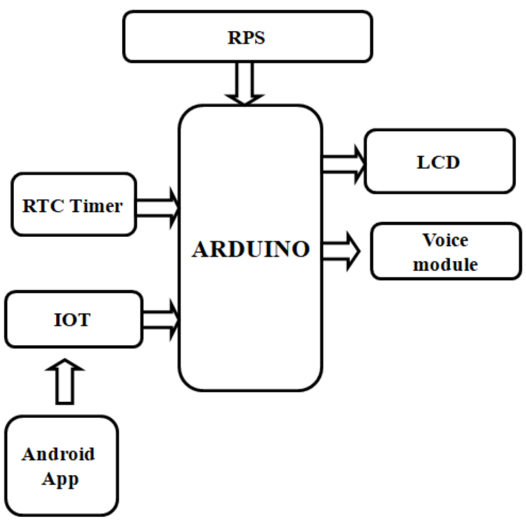

Fig. 1: Block Diagram of the Proposed IoT-Based Smart Pill Reminder System

B. Hardware Components

The system integrates the following key hardware components, each selected for cost-effectiveness, low power consumption, and functional suitability for healthcare applications.

TABLE II: HARDWARE COMPONENTS OF THE PROPOSED SYSTEM

Component	Function	Qty
Arduino (ATmega328P)	Central controller & timer logic	1
RTC DS1302 Module	Real-time clock / calendar	1
APR33A3 Voice Module	Pre-recorded voice reminders	6
ESP8266 Wi-Fi Module	IoT connectivity / remote config	1
16×2 LCD Display	Visual message display	1
Buzzer	Audible alert output	1
7805 Voltage Regulator	Stable +5V power regulation	1
DB107 Bridge Rectifier	AC to DC conversion	1
Filter Capacitors	Voltage smoothing	2
Step-down Transformer	Mains voltage reduction	1

C. Real Time Clock (RTC DS1302)

The DS1302 trickle-charge timekeeping chip contains a real-time clock/calendar and 31 bytes of static RAM. It communicates with the Arduino via a simple three-wire serial interface (RST, I/O, SCLK). The RTC provides seconds, minutes, hours, day, date, month, and year information with automatic leap-year compensation valid up to 2100. It operates from 2.0–5.5V and consumes less than 1 µW in data retention mode, supported by a backup battery. This ensures uninterrupted timekeeping even during power outages.

D. APR33A3 Voice Module

The APR33A3 is a powerful 16-bit digital audio processor with integrated ADC and DAC, requiring no external ICs. It supports averaging 1, 2, 4, or 8 independent voice messages via simple key-trigger operation. The module operates across 3V–6.5V with standby current of 1 μA and power-down current of 15 μA, making it suitable for battery-operated applications. Pre-recorded medicine names and reminder messages are stored in non-volatile flash memory. Six APR33A3 modules are deployed, one for each configurable medication alarm.

E. ESP8266 IoT Wi-Fi Module

The ESP8266 provides a complete Wi-Fi networking solution supporting IEEE 802.11 b/g/n protocols with integrated TCP/IP stack. It supports STA/AP/STA+AP operation modes and communicates with the Arduino via UART. The module enables the Android application to remotely update medication alarm schedules in real time. Medication timing data is transmitted in a structured serial format (e.g., @AHH:MM:SS#) over the Wi-Fi link and decoded by the Arduino to update EEPROM-stored alarm settings.

F. Software Implementation

The system firmware is developed using the Arduino IDE with the LiquidCrystal and RTClib libraries. On startup, the system reads all six alarm times from EEPROM to restore configurations after power cycling. The main control loop continuously reads the current RTC time and compares it against stored alarm times. A 5-second alarm trigger window (sec_c: 0–4) ensures robust activation without missed triggers. The IoT configuration parser handles incoming serial frames prefixed with '@' and terminated with '#', extracting alarm labels (A–F) and time values for EEPROM storage.

5. RESULTS AND DISCUSSIONS

The proposed IoT-Based Smart Pill Reminder system was successfully assembled and subjected to comprehensive functional validation. Testing covered RTC accuracy, voice module activation, LCD display correctness, Wi-Fi remote configuration, multi-alarm scheduling, and EEPROM persistence across power cycles.

A. Prototype Overview

The hardware prototype consists of an Arduino Uno development board as the central controller, an RTC DS1302 module for real-time tracking, six APR33A3 voice modules connected to individual GPIO pins, a 16×2 LCD for visual feedback, an ESP8266 Wi-Fi module for IoT communication, and a regulated +5V power supply unit. The system is mounted on a PCB development platform suitable for deployment in home or clinical environments.

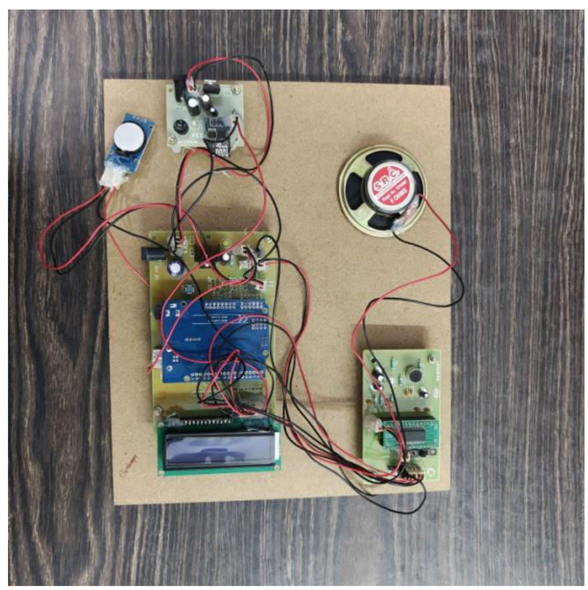

Figure 2: complete hardware prototype developed for the proposed system.

B. RTC Accuracy and Alarm Trigger Validation

The RTC DS1302 demonstrated accurate timekeeping with no observable drift over 72-hour continuous testing. Alarm triggers were validated for all six configured medication times. The system reliably activated the corresponding APR voice module and displayed the correct reminder message on the LCD within the 5-second trigger window for every test cycle.

TABLE III: ALARM TRIGGER TEST RESULTS

Test Function	Performance	Result
Alarm-1 Voice Trigger	On-time activation	PASS
Alarm-2 Voice Trigger	On-time activation	PASS
Alarm-3 Voice Trigger	On-time activation	PASS
Alarm-4 Voice Trigger	On-time activation	PASS
Alarm-5 Voice Trigger	On-time activation	PASS
Alarm-6 Voice Trigger	On-time activation	PASS
LCD Reminder Display	Correct message shown	PASS
EEPROM Persistence	Settings retained after reboot	PASS
RTC Time Accuracy	< 1 sec drift/72 hours	PASS
Buzzer Activation	Simultaneous with voice	PASS

C. IoT Remote Configuration

The ESP8266 module successfully established Wi-Fi connectivity and accepted alarm configuration commands from the Android application. Schedule updates were transmitted in the format @AHH:MM:SS# and decoded by the Arduino, with confirmed LCD acknowledgment ('Alarm-X Configured') for each update. The remote configuration response latency was measured at less than 2 seconds under standard indoor Wi-Fi conditions.

D. System Performance Summary

Table IV summarizes the overall performance metrics of the developed prototype. The system demonstrated stable operation across all tested parameters, with low power consumption and reliable multi-alarm scheduling suitable for real-world deployment.

TABLE IV: OVERALL SYSTEM PERFORMANCE METRICS

Performance Metric	Measured Value
Number of Alarms Supported	6 Independent
RTC Timekeeping Accuracy	< 1 sec drift / 72 hours
Voice Reminder Duration	~2 seconds per trigger
Wi-Fi Config. Latency	< 2 seconds
LCD Update Time	< 100 ms
Power Supply Voltage	+5V DC (regulated)
Power Consumption	~500 mA @ 5V (active)
RTC Backup Power	< 1 µW (DS1302 retention)
EEPROM Write Endurance	100,000 cycles
Operating Temperature	0°C to 70°C

E. LCD Display During Operation

During scheduled alarm activation, the LCD clearly displayed "Medicine Reminder" along with the medication number (Med-1 through Med-6), providing unambiguous visual identification of which medication is due. After the 2-second voice playback, the LCD returned to the standard date and time display, ready for the next scheduled event. This behavior was confirmed across all six alarm slots in repeated test cycles.

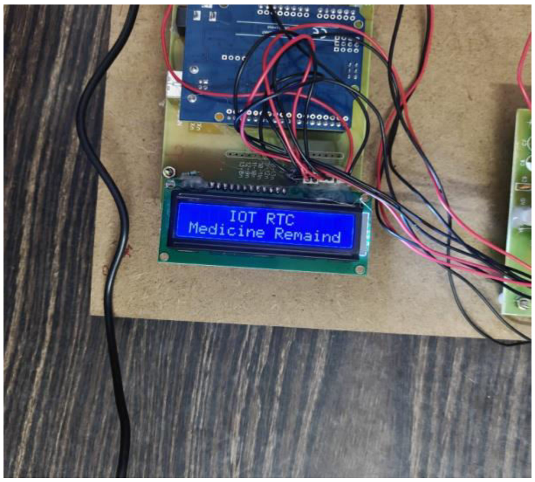

Figure 2 shows the LCD display during system operation.

F. Comparative Analysis

Compared to existing Bluetooth-based reminder systems, the proposed system offers significantly extended remote configuration range via Wi-Fi, six independently configurable alarm slots (versus the typical one or two in prior work), voice-based reminders in addition to LCD text, and EEPROM-based schedule persistence across power cycles. The integration of the IoT module enables future expansion to cloud notification services and caregiver alert systems without hardware redesign.

6. CONCLUSION

This paper presented the design, implementation, and experimental validation of an IoT-Based Smart Pill Reminder and Automated Medicine Dispensing System for elderly and healthcare support. The system integrates an Arduino microcontroller, RTC DS1302, six APR33A3 voice modules, a 16×2 LCD display, an ESP8266 IoT Wi-Fi module, and a buzzer into a cohesive, automated medication reminder platform. Up to six independent medication schedules can be programmed remotely via an Android application over Wi-Fi, with configurations stored in EEPROM for persistence across power cycles.

Experimental results confirmed reliable alarm triggering, accurate real-time clock operation with less than one second drift over 72 hours, successful remote schedule configuration with sub-2-second latency, and clear voice and visual reminder delivery for all six alarm slots. The system significantly reduces dependency on human memory and caregivers for medication scheduling, making it particularly valuable for elderly patients, individuals with chronic conditions, and multi-patient clinical environments.

The proposed system offers a cost-effective, scalable, and user-friendly solution that addresses the critical gap between mobile-only reminder applications and expensive commercial automated dispensers. Future work will incorporate cloud-based data logging of medication adherence records, caregiver SMS/push notification alerts for missed doses, AI-driven dosage pattern analysis, automated pill dispensing mechanisms with servo-controlled compartments, and multi-language voice module support for regional healthcare deployment.

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