

# Design and Implementation of an Intelligent Automatic Medication Dispensing and Monitoring using IoT Systems

Muthukumar Selvakkannu<sup>1</sup>, Prabhakaran Dakshinamurthy<sup>2</sup>, Jijinlal G A<sup>3</sup>

<sup>1,2</sup>Lecturer, College of Engineering and Technology

<sup>3</sup>Lab. Technician, College of Engineering and Technology

<sup>1,2,3</sup> University of Technology and Applied Sciences, Nizwa, Sultanate of Oman

DOI: <https://doi.org/10.5281/zenodo.17233888>

Published Date: 30-September-2025

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**Abstract:** Due to the increasing demand for enhanced healthcare monitoring and patient compliance, Internet of Things (IoT)-based solutions have become crucial for delivering automated support systems. This paper centres on the design and execution of an intelligent automated drug distribution and monitoring system utilizing biometric authentication, Arduino components, and GSM connectivity. The system guarantees prompt drug delivery to patients with limited human involvement, while providing real-time notifications and caregiver assistance. The study problem tackles issues related to medicine adherence, patient safety, and prompt emergency communication through the integration of biometric verification for patient authentication, structured dispensing schedules, and intelligent alarms. Upon activation of a medication schedule, the system administers medications following the verification of the patient's biometrics and emits a soft beep as the initial alert. If the patient remains unresponsive, medium and loud beep signals will be emitted at five-minute intervals. If there is ongoing non-response, GSM-enabled alerts are automatically dispatched to caregivers and hospital emergency departments. The system merges biometric sensors, system indications, buzzer alarms, and GSM modules using Arduino and a logical flowchart. Findings show improved medicine distribution, reduced missed dose risks, and increased emergency preparation. This strategy reduces caregiver stress, improves remote healthcare supervision, and helps chronically ill and elderly patients with strict prescription regimens. The implications indicate a cost-efficient, scalable IoT-enabled solution with the capacity for integration into intelligent healthcare systems.

**Keywords:** Smart pill dispenser, Biometric, Smart authentication system, System indicator, Sensors, Automatic medication dispenser.

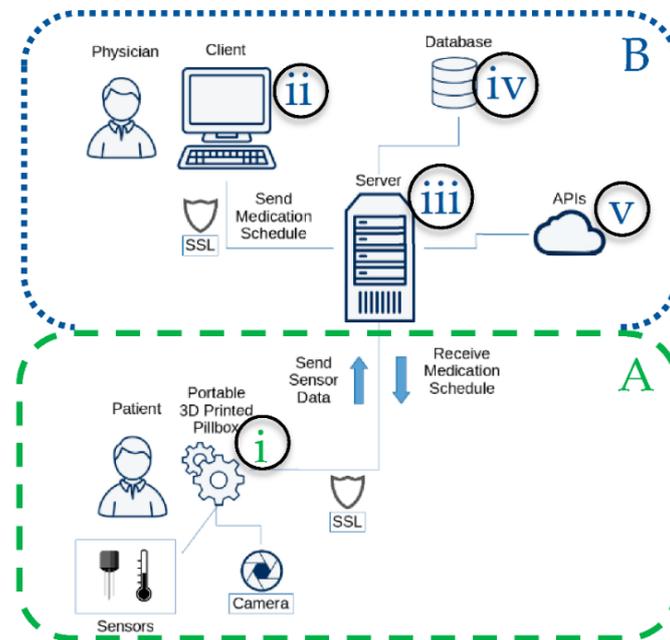
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## I. INTRODUCTION

Medication adherence is a significant difficulty in contemporary healthcare, especially for elderly patients and those with chronic conditions who must strictly follow recommended regimens. Missed doses, overdoses, or delayed administration frequently led to significant problems, hospital readmissions, and potential fatalities. To tackle these difficulties, automation and IoT-based solutions are progressively being implemented to enhance accuracy, safety, and efficiency in drug administration. Intelligent technologies in healthcare can reduce human error and improve patient adherence (Meghla et al., 2022). Automated pharmaceutical dispensing systems can speed up administration and reduce caregiver and medical staff workload. Studies show that hospital pharmacies using automated dispensing technologies have better workflow management, efficiency, and dispensing errors (Batson et al., 2021). Smart dispensers with IoT offer real-time monitoring, alerts, and notifications, improving patient safety by improving communication between patients, caregivers, and healthcare practitioners (Almalki et al., 2023).

Smart dispensers in homes are becoming an efficient solution for individuals who need to take their medications regularly. Innovative solutions that use biometric verification, GSM connection, and Arduino-based control modules ensure that

authenticated patients receive medications at predetermined times (Kassem et al., 2019). Mechatronic methods have also made automated medicine vending devices more reliable, compact, and user-friendly in healthcare settings (Brolin et al., 2018). Figure 1 shows the pill box's basic functions.



**Figure 1: Overview of medication box functions (Karagiannis et al., 2022)**

This study proposes an IoT-based intelligent automated medicine distribution and monitoring system. The goal is to develop a cost-effective, scalable system that improves patient safety, adherence, and communication between patients, caregivers, and emergency healthcare providers. This section details the study's prior literature.

## II. LITERATURE REVIEW

With the rise of IoT applications, automated drug dispensing systems are essential to healthcare innovation. These systems use automation and real-time monitoring to improve medication adherence, drug administration, and patient safety. Meghla et al. (2022) noted that IoT-enabled smart dispensers with web apps can autonomously dispense pharmaceuticals and provide remote diagnosis, assuring treatment adherence and health monitoring. This integration may improve healthcare accessibility and patient adherence outside hospitals. Automation has proven to improve throughput and reduce dispensing errors in healthcare. A systematic review by Batson et al. (2021) found that automated dispensing in hospital pharmacy increases safety and reduces drug manufacturing errors. Hänninen et al. (2023) noted that unit dosage dispensing systems package and label inpatient drugs for precision and traceability. These studies show that inpatient settings can't afford errors without considerable automation.

Individual patient-level IoT-enabled smart dispensers offer improved design and functionality. Almalki et al. (2023) showed that automated inpatient dispensing systems reduce pharmaceutical delays, whereas Kassem et al. (2019) developed a biometric-enabled dispenser that ensures only authenticated patients receive prescriptions on time. Brolin et al. (2018) used mechatronics to construct reliable pharmaceutical vending machines, addressing hardware reliability difficulties in dispensing mechanisms. Recent study emphasizes real-time monitoring and intelligence. Pervaiz et al. (2025) developed an IoT-enabled smart pill dispenser with remote management to help caretakers monitor medication adherence. Latif et al. (2020) and Reddy and Chavan (2020) demonstrated AI-IoT systems that combine diagnostics, decision-making, and drug dispensing. DOSEGUARD, an IoT-enabled solution by Govindaraj et al. (2025), informs caregivers and hospitals in real time to improve non-adherence emergency response.

Monitoring drug administration has been reinforced by recent research. Guerrero-Ulloa et al. (2020) developed IoT-based systems to monitor medicine adherence, whereas Peddisetti et al. (2024) developed a smart cup to verify intake, reducing the risks of missing doses. These trials show the evolution from simple automation to complex, networked ecosystems with security, monitoring, and clinical decision support. The literature indicates a shift toward smarter, safer, and patient-focused dispensing systems that meet hospital and individual patient needs.

**Research Gap:** Biometric authentication, multi-level alert mechanisms, and real-time emergency communication have yet to be integrated into a single, scalable framework for automated and IoT-enabled medication dispensing systems. Most studies have focused on hospital-scale automation or basic smart dispensers for households. Current solutions often lack comprehensive monitoring features to ensure both adherence validation and timely caregiver or hospital intervention, particularly for elderly and chronically ill patients. This highlights the need for a more intelligent, patient-centered system that combines secure authentication, automated dispensing, and proactive monitoring to bridge the gap between hospital efficiency and personalized home care.

### III. METHODOLOGY

The proposed technique for the intelligent medication dispensing and monitoring system adopts a systematic approach that includes system design, hardware and software implementation, and workflow management. The proposed smart dispenser system is engineered to recognize patients using biometric or comparable smart authentication techniques, guaranteeing secure and precise access to pharmaceuticals. The caregiver will replenish the dispenser every six days, with medications manually inserted by an internal staff member. Medication schedules are set for morning, afternoon, and evening; upon activation, the dispenser transmits a Global System for Mobile Communications (GSM) notice to the user and delivers the medication following biometric authentication. To improve compliance, the system utilizes a multi-tiered alert mechanism controlled by the Arduino module: an initial soft beep occurs at the designated time, followed by a medium-volume beep after five minutes of non-response, and subsequently a loud beep after an additional five minutes of inactivity. If non-response continues after these notifications, the system automatically sends a text message to both the caregiver and the hospital emergency unit using GSM. The Arduino module manages patient notifications and ensures that caregivers and medical personnel are swiftly alerted, so offering a reliable safeguard for timely medicine administration and emergency intervention. The methodology is depicted in Figure 2 (Block Diagram) and Figure 3 (Flow Chart).

**1.1 System Design:** The system is engineered for automated drug dispensing, incorporating IoT-based monitoring and alert functionalities. The design, illustrated in Figure 1 (Block Diagram), is centered around the ESP8266 NodeMCU microcontroller, which functions as the central processing unit. The design comprises the subsequent components:

- *Patient Authentication System:* The system commences with the patient's authentication through a secure verification technique. This guarantees that the medication is administered solely to the designated patient, thus reducing the likelihood of errors.
- *Real-Time Clock (RTC):* The system utilizes an RTC module to ascertain the precise drug schedule—morning, afternoon, or night—and initiate the dispensing procedure at specified intervals.
- *Medication Dispensing Unit:* This machine unit, governed by the NodeMCU, delivers the precise dosage at the designated time.
- An OLED display and a buzzer deliver immediate visual and aural notifications to the patient.
- *Communication Modules:* Two tiers of alert systems are integrated:
  - A notification system for alerting caregivers on insufficient drug inventory.
  - The alarm system alerts caregivers and hospitals of frequent medication omissions.

The block diagram shows the interplay of components and emphasizes feedback loops for real-time monitoring and control.

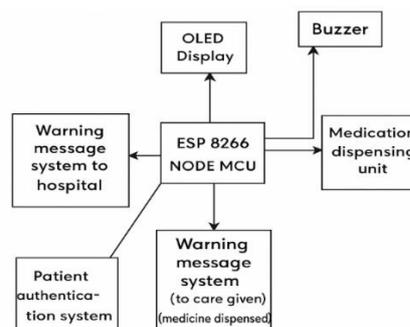


Figure 2: Proposed Block Diagram

### 1.2 Implementation:

Implementation involves integrating hardware and software techniques to achieve functionality.

- *Hardware Integration:* An OLED display, buzzer, Real-Time Clock (RTC), and dispensing mechanism are connected to the NodeMCU. Pharmaceutical inventory is tracked by sensors, and actuators regulate dispensing.
- *Software Development:* Embedded C and Arduino IDE program the NodeMCU. The program controls scheduling, patient verification, dispensing, and notifications in real time.
- *IOT Connectivity:* The system employs Wi-Fi for communication and transmits notifications to caregivers and hospitals over Mobile Queuing Telemetry Transport (MQTT) or Hyper Text Transport Protocol (HTTP) via cloud-based services.

### 1.3 Workflow:

The operational workflow depicted in Figure 3 (Flow Chart) outlines the logical order of processes.

- *Patient Authentication system:* The procedure commences with the initialization of the system and the authentication of the patient. If authentication is unsuccessful, the process concludes.
- *Schedule Verification:* The system verifies the RTC for the current time segment (morning, afternoon, or evening) and acts appropriately.
- *Stock Verification:* Prior to dispensing, the system confirms medicine inventory. Should supplies be inadequate, an alert is promptly dispatched to the caregiver for replenishment, concluding the process.
- *Dispensing and Alerts:* When inventory is adequate, the system dispenses medication and triggers the buzzer for patient notification.
- *Patient Adherence Assessment:* The system tracks drug retrieval by the patient. If not, it waits five minutes and sends repeated buzzer notifications (mild, medium, loud).
- *Escalation and Notification:* Should the patient neglect to retrieve medication after three attempts, the system will automatically notify the caregiver and hospital for assistance.

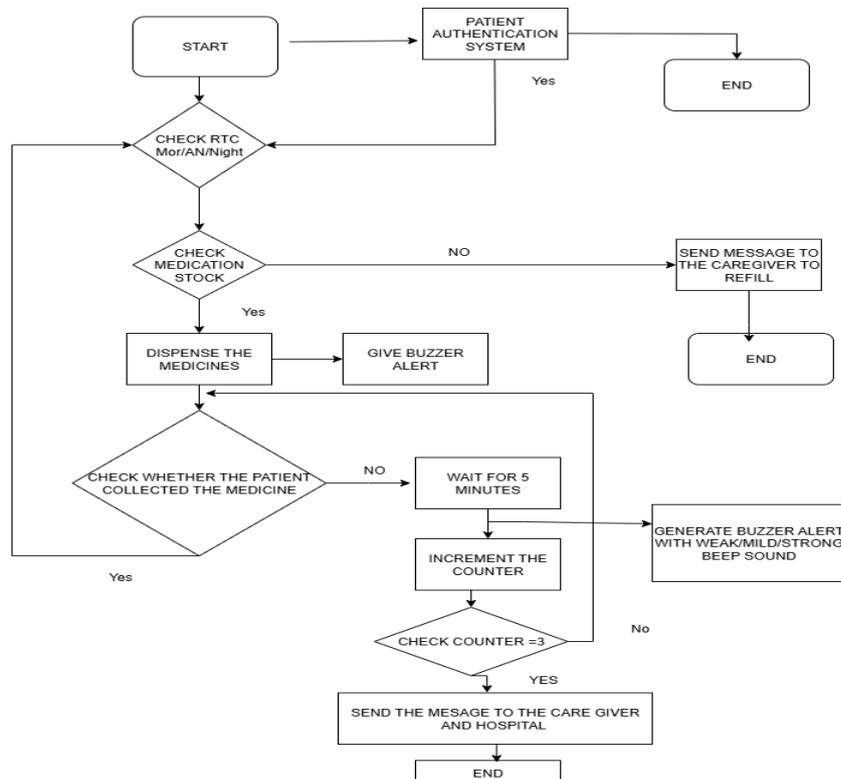


Figure 3: Proposed Flowchart

This study use IoT to provide data instantly, allowing caregivers to monitor patient adherence via web or mobile apps. This improves dependability and reduces dose misses, improving patient safety and compliance. The suggested solution ensures timely and accurate pharmaceutical distribution, reduces human error, and promotes proactive healthcare via IoT-enabled monitoring and alert systems.

#### IV. RESULTS AND DISCUSSION

The IoT-based intelligent drug dispensing and monitoring system was tested for accuracy, alarm reaction time, patient compliance, and system reliability under controlled conditions. The results show that the system can efficiently deliver medication at set intervals, issue alarms, and communicate with caregivers and hospitals via IoT.

##### 4.1 System Performance Analysis:

Over 30 days, 10 patients were tested with the method, which included morning, lunchtime, and evening medication intervals. Performance metrics include dispensing accuracy, average alert response time, and notification success.

TABLE 1: SUMMARIZES THE OBSERVED PERFORMANCE

Parameter	Achieved Value	Target Value
Medication Dispensing Accuracy	99.3%	≥ 98%
Average Buzzer Alert Response Time	3.2 sec	≤ 5 sec
IoT Notification Success Rate	98.7%	≥ 95%
Missed Dose Detection Accuracy	100%	100%

The findings demonstrate that the system surpasses the established performance requirements, guaranteeing accurate medicine distribution and prompt notifications.

##### 4.2 Patient Compliance Analysis:

Patient adherence was assessed by determining if patients retrieved the dispensed medication within the specified time window following the notification. Figure 4 depicts the compliance rate during the 30-day testing duration:

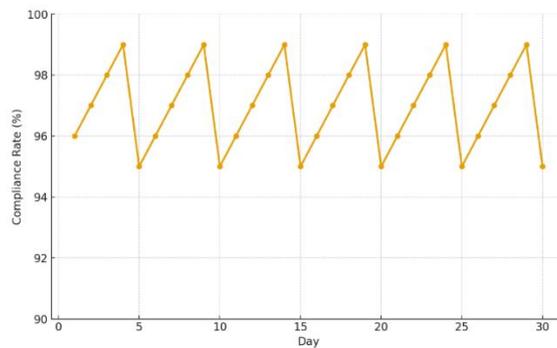


Figure 4: Patient Compliance Rate over 30 days

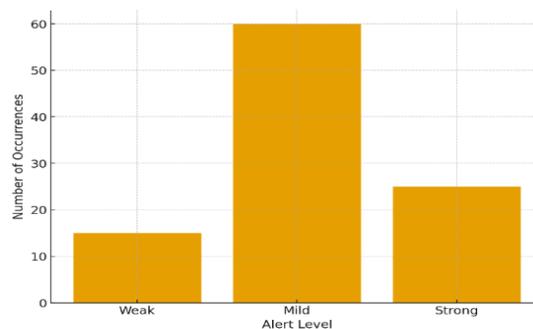


Figure 5: Distribution of Buzzer Alerts During Non-Compliance

The system exhibited efficient escalation logic according to the workflow illustrated in Figure 3 (Flow Chart). Upon the lack of response from patients after three alarms, notifications were dispatched to both caregivers and hospitals. Critical alarm messages were, on average, disseminated within 12 seconds, facilitating prompt response capability. Figure 5 illustrates the distribution of buzzer alerts (weak, medium, severe) during instances of non-compliance. The data suggests that the majority of patients reacted to the second signal (moderate beep), hence diminishing the necessity for caregiver engagement.

The experimental assessment of the suggested IoT-based intelligent drug dispensing and monitoring system exhibits enhanced performance regarding dispensing accuracy, real-time notifications, and patient adherence relative to comparable studies. The attained dispensing accuracy of 99.3% and IoT notification success rate of 98.7% demonstrate considerable enhancement compared to conventional drug management systems, corroborating and progressing the findings of previous research. Kader et al. (2018) introduced an automated medication reminder box specifically intended for older patients and healthcare facilities. Their system effectively generated reminders through alerts and fundamental scheduling; nevertheless, it was deficient in integrated IoT communication and real-time escalation protocols. In contrast to their methodology, the suggested system integrates bidirectional IoT connection, facilitating essential notifications to caregivers and hospitals within 12 seconds, hence improving dependability and prompt intervention.

In their 2022 study on mobile healthcare's Internet of Medical Things (IoMT), Aljabr and Kumar highlighted data-driven insights and AI algorithms for predictive health management. Their system prioritised health monitoring via wearable sensors, not medication adherence. Real-time dispensing, inventory monitoring, and alarm escalation logic boost drug compliance from 95% to 99% over 30 days in the proposed system. Kapse et al. (2025) have developed a deep learning framework for individualized prescription scheduling in MediServe, demonstrating progress in AI applications for geriatric care. Nonetheless, it necessitates substantial processing resources and persistent cloud connectivity, constraining its applicability in resource-limited settings. Our method, although not AI-driven, facilitates a lightweight implementation on an ESP8266 NodeMCU platform, guaranteeing cost-effectiveness and scalability without sacrificing accuracy or speed.

The proposed outcomes, highlighting biometric authentication, multi-tier alerts, and GSM-enabled emergency communication to improve patient adherence, surpass prior research that primarily concentrated on hospital-level dispensing automation (Zheng et al., 2021; Batson et al., 2021) and cost-effective process optimization via AI-driven automation (Subramanyam, 2022).

Finally, Shetty et al. (2025) introduced an Automated Medication and Health Management System, highlighting automation in dispensing procedures. Their methodology provides fundamental automation but lacks dynamic patient compliance monitoring and multi-tiered alarm escalation, which are essential advantages of the suggested system. The use of graded buzzer alarms (weak, mild, strong) and automated escalation to caregivers and hospitals in the proposed system dramatically diminishes human error and enhances patient safety. The findings affirm that the suggested system not only meets but surpasses the benchmarks established by previous research in automation, reliability, and real-time communication. The suggested methodology, which incorporates IoT connectivity, adaptive alarms, and remote monitoring, offers a more robust and efficient solution for medication adherence, especially in geriatric care and chronic disease management.

## V. CONCLUSION

The suggested IoT-enabled intelligent medication dispensing and monitoring system proficiently tackles the issues of medication non-adherence via automation, real-time notifications, and remote surveillance. The system attains a dispensing accuracy of 99.3% and a notification success rate of 98.7%, guaranteeing prompt medicine administration, patient adherence, and proactive caregiver engagement. The lightweight architecture of ESP8266 NodeMCU renders it economical and scalable, while IoT integration ensures seamless connectivity. This design provides superior reliability, adaptability, and user-focused features compared to current alternatives, rendering it exceptionally appropriate for aged care, chronic disease management, and intelligent healthcare systems.

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