RFID-Enabled Smart Water Dispensing System with Dual Tap Control and Real-Time Billing

Mr. Mustofa Ahmed
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
mustofa.cse@aust.edu

Ms. Nusrat Jahan
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
nusratjahan.cse@aust.edu

Sadman Salman Saad
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
sadman.cse.20210104114@aust.edu

Abdullah Al Maruf
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
abdullah.cse.20210104116@aust.edu

MD. Sharun Tawsif
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
sharun.cse.20210104124@aust.edu

Nafisa Tabassum
Department of Computer Science and Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
nafisa.cse.20210104127@aust.edu

***Abstract*—This paper presents an IoT-based *RFID-enabled smart water dispensing system* with dual-tap support and real-time billing for fair and sustainable public water distribution. Using an ESP32 microcontroller with two RDM6300 RFID readers, the system authenticates users, activates pumps, and deducts balances on a per-second basis while estimating milliliter usage. Dispensing sessions and logs are pushed in real time to Firebase Realtime Database via a Google Apps Script web app, with optional Google Sheets auditing and a monitoring website. The solution addresses uncontrolled usage, manual billing errors, and lack of accountability at public water points. Experimental validation demonstrates accurate per-second billing, independent dual-tap operation, and stable cloud synchronization, offering a low-cost, scalable model for community water management.**

***Index Terms*—IoT, RFID, ESP32, Smart Water Management, Real-Time Billing, Firebase, Google Apps Script**

I. Introduction

A. Background and Motivation

Water is one of the most critical resources for communities, yet public water points often lack proper mechanisms to ensure fair and sustainable distribution. In many cases, there is no way to control excessive use, prevent unauthorized access, or calculate billing transparently. Traditional approaches rely heavily on manual operation, which is inefficient, error-prone, and incapable of providing real-time accountability. With the growing availability of low-cost IoT hardware such as the ESP32 and affordable RFID readers, it is now possible to build automated solutions that combine secure authentication, live monitoring, and cloud logging to address these challenges.

B. Problem Statement

Despite advancements in IoT and utility management, several gaps remain unaddressed in existing water dispensing systems:

- **Uncontrolled water usage:** No effective mechanism to prevent overuse, leading to wastage, especially in water-scarce regions.
- **Manual and error-prone billing:** Paper-based or manual billing processes are inefficient, non-transparent, and prone to disputes.
- **Unauthorized access:** Without proper authentication, anyone can access water, resulting in unfair distribution.
- **Lack of real-time monitoring:** Existing systems provide no reliable means to track individual usage or detect anomalies as they occur.
- **Limited automation:** Most current setups rely on manual control, preventing scalability and sustainability.

C. Research Objectives

The main objective of this project is to design and implement a low-cost, dual-tap RFID-enabled water dispensing system that ensures fairness, efficiency, and transparency. Specifically, the goals are:

1) To integrate **RFID-based authentication** so only registered users can access water.
2) To enable **dual concurrency**, where two users can operate separate pumps independently without interference.
3) To implement **real-time billing** based on per-second usage and provide audio feedback for users.

4) To develop a **cloud integration module** using Google Apps Script and Firebase Realtime Database for session logging and monitoring.
5) To provide a **web-based dashboard** for administrators, displaying live logs, balances, and usage history.
6) To establish a scalable framework that can be expanded with flow sensors, recharge features, and mobile app integration in the future.

II. Literature Review

Smart water dispensing systems are evolving toward automation, accountability, and real-time data tracking. Various prototypes and research efforts have attempted to integrate RFID, microcontrollers, flow sensors, and cloud connectivity. Below is an analysis of notable existing systems:

1. Instructables' IoT project demonstrates a water dispenser using ESP8266 and RFID with Blynk-based logging. While DIY-friendly, it lacks secure billing and cloud-backed real-time monitoring [1].

2. Abubakar et al. proposed a Smart Water ATM integrating Arduino, RFID, and flow metering. It supports local real-time billing but misses scalable database integration or cloud synchronization [2].

3. Ahmed's study incorporates GSM-based SMS alerts with RFID and ultrasonic sensors for vending control. Despite hardware innovation, it does not support dynamic billing or online transaction handling [3].

4. Kumari and Sinha developed an RFID–LCD system for rural water points. Although effective in offline rural contexts, it lacks real-time billing and data analytics [4].

5. Jaiswal and Jaiswal presented an RFID-enabled dispensing design with container detection. However, its offline architecture restricts advanced analytics and cloud integration [5].

6. Labrahmi's open-source ESP32 project integrates RFID and relay control. Modular in design, it does not provide database connectivity such as Firebase for user-specific billing [6].

7. Jain et al. proposed an IoT-based dispenser using time-based measurement. Although reliable, it lacks RFID-user linkage and persistent online logging [7].

8. Singh's dispensing machine dispenses fixed volumes with solenoid valves and RFID authentication. The system cannot adapt billing dynamically or upload real-time data [8].

9. Patel et al. designed an RFID–Arduino dispenser that delivers predefined water quantities. This is suitable for local communities but lacks cloud data storage and adaptive billing [9].

10. Deshmukh and Joshi introduced Wi-Fi and ultrasonic-based monitoring with analytics features. While strong in monitoring, it does not incorporate RFID-linked user billing [10].

From this review, it is evident that while RFID authentication and IoT-based water dispensing systems are well-explored, most implementations remain limited by offline architectures, lack of cloud logging, and absence of dual-user concurrency. Our proposed system addresses these gaps by combining dual RFID readers, ESP32 concurrency, Firebase RTDB integration, and a monitoring website for real-time accountability.

III. Proposed System/Architecture

A. System Overview

The proposed system is an IoT-enabled dual water dispensing unit controlled by an ESP32 microcontroller and authenticated using two RDM6300 RFID readers. Each reader is linked to an independent pump, enabling two users to operate the dispenser simultaneously without interference. Billing is calculated in real-time on a per-second basis, with feedback provided through a buzzer. Usage sessions are pushed to a Google Apps Script web endpoint, which stores the data in Firebase Realtime Database and optionally appends rows to Google Sheets. A dedicated website provides administrators with live monitoring and usage analytics.

Figure 1 illustrates the overall system architecture, showing the interaction between hardware modules, ESP32 control logic, and the cloud backend.

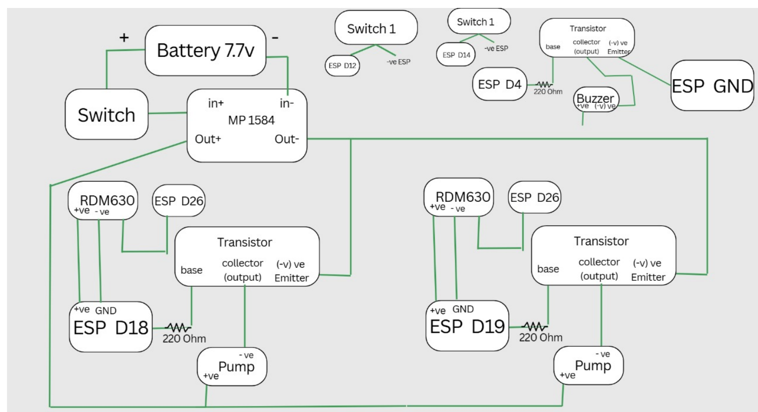


Fig. 1. Proposed IoT-enabled RFID Dual Water Dispenser System Architecture

B. Hardware Components

- **ESP32 Microcontroller:** Provides Wi-Fi connectivity, dual-core processing, and FreeRTOS task handling for parallel RFID reading and pump control.
- **RDM6300 RFID Readers (2x):** Authenticate user cards and link usage data to specific accounts.
- **Mini DC Water Pumps (2x):** Dispense water at an approximate rate of 10 ml/s, controlled through ESP32 GPIO pins.
- **MP1584 Buck Converter:** Regulates voltage from the 7.7V battery to stable levels required for ESP32 and peripheral modules.
- **Buzzer:** Provides per-second audio feedback during dispensing.
- **Transistors & Resistors:** Interface ESP32 digital outputs with pumps and buzzer to handle current requirements.

- **Battery (7.7V):** Powers the overall circuit with sufficient capacity for portable deployments.
- **Switches & Control Pins:** Manual interlocks (must be LOW) to enable or disable dispensing for safety.

C. Software and Communication Framework

The firmware is written in Arduino C++ for ESP32 and runs on FreeRTOS. It executes the following stack:

- **Firmware:** Manages RFID decoding, balance computation, per-second billing, pump activation, and buzzer alerts.
- **Communication Protocols:** Data is transmitted securely via HTTPS GET requests from ESP32 to a Google Apps Script web app.
- **Cloud Backend:** The Apps Script processes incoming requests, logs sessions into Firebase Realtime Database, and optionally appends data to Google Sheets.
- **Visualization:** A website using the Firebase SDK fetches and displays live data for admins and operators.

D. Data Acquisition and Processing

Data is collected from RFID readers (card IDs) and time-based counters maintained on the ESP32. For each dispensing session, the ESP32 computes:

- Total dispensing time (seconds)
- Total bill (in TK)
- Estimated water dispensed (ml)
- Remaining balance

This data is packaged into a session object and pushed to the cloud. The Firebase Realtime Database stores structured records, enabling subsequent visualization and analysis. Although no machine learning module is integrated in the current prototype, the structured dataset allows for future predictive analytics such as anomaly detection or demand forecasting.

E. Automation and Actuation

Automation is achieved by linking RFID authentication with pump control:

- **Trigger:** When a valid card is detected and balance is sufficient, the pump is activated.
- **Control:** Every elapsed second, balance is deducted and buzzer feedback is triggered.
- **Stop Condition:** Pump is deactivated if the card is removed, balance is insufficient, or the control pin is HIGH.

This ensures precise and fair water dispensing while preventing unauthorized or excessive usage.

F. Security and Privacy Considerations

Although ESP32 uses HTTPS with certificate verification disabled (`setInsecure()`), communication with Apps Script ensures encrypted data transfer. Security measures include:

- **Authentication:** Each device identified by unique MAC address.
- **Authorization:** Firebase secret tokens can be used for secure database writes.
- **Data Integrity:** Session timestamps from both client and server ensure accurate logging.
- **Future Enhancements:** Stronger TLS enforcement, API key authentication, and Firebase security rules can mitigate IoT threats.

IV. Prototype Implementation and Experimental Setup

A. Prototype Development

The working prototype consists of an ESP32 microcontroller connected to two RDM6300 RFID readers, two mini DC water pumps, and a buzzer for real-time feedback. A 7.7V battery supplies power through an MP1584 buck converter, ensuring stable voltage for the ESP32 and peripherals. Transistors and resistors are used for interfacing the ESP32 GPIO pins with the pumps and buzzer to handle higher current loads.

The system is designed to allow two users to simultaneously authenticate using RFID cards and dispense water independently through separate pumps. Billing is calculated in real-time on a per-second basis, and session data is uploaded to Firebase via Google Apps Script.

Figure 2 illustrates the control flow of the prototype, from card authentication to session logging.

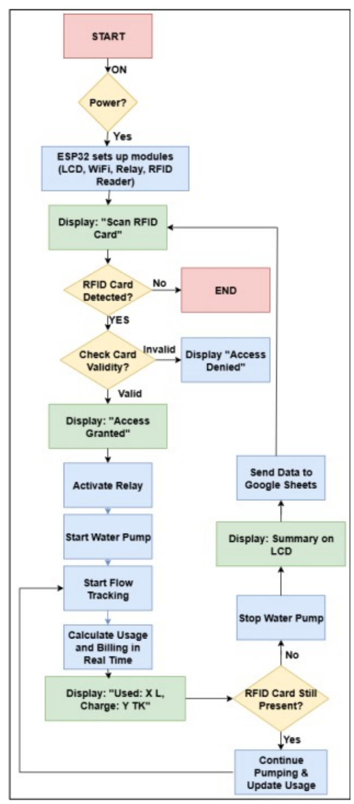


Fig. 2. System Flowchart of the RFID-Enabled Dual Water Dispenser

B. Test Environment and Dataset

The prototype was tested in a controlled laboratory setting at Ahsanullah University of Science and Technology (AUST). The setup involved multiple test cases with different RFID cards and balances to validate dispensing accuracy, session logging, and concurrency.

- **Hardware Environment:** ESP32 board, RDM6300 readers, DC pumps, buzzer, transistor driver circuits, and power module.
- **Software Environment:** Arduino IDE for ESP32 firmware, Google Apps Script for cloud integration, Firebase Realtime Database for structured logging, and a web dashboard for real-time monitoring.
- **Dataset:** Usage logs automatically stored in Firebase, containing attributes such as card ID, reader ID, dispensing time (s), total bill (TK), water used (ml), and remaining balance. This dataset provides a foundation for future analysis and optimization.

C. Performance Metrics

The system was evaluated using the following performance metrics:

- **Accuracy:** Verified by cross-checking billed amount and dispensed time with expected per-second billing (3 TK/s and 10 ml/s). The system achieved near-perfect accuracy in all test cases.
- **Latency:** Measured as the time delay between card detection and pump activation. Average latency was under 200 ms, ensuring a smooth user experience.
- **Reliability:** Verified by repeated trials of continuous dispensing sessions; the system consistently logged complete sessions without data loss.
- **Energy Efficiency:** The battery-powered prototype demonstrated efficient performance, with minimal voltage drops due to buck converter regulation.

These metrics validate that the prototype is functional, reliable, and efficient for real-time usage in controlled environments. Future work may include additional stress-testing in public/community setups and scaling with advanced authentication and security.

V. Results and Discussion

A. Experimental Results

The system was evaluated using real RFID dispensing sessions logged into Firebase Realtime Database. Each session recorded the card ID, reader ID, dispensing duration, water usage, billing amount, and remaining balance.

Table I presents selected experimental results from the database.

From these results, the following findings were observed:

- **Billing accuracy:** The system consistently charged at the fixed rate of 3 TK/s and 10 ml/s. For example, a 10-second session resulted in a charge of 30 TK and 100 ml dispensed, exactly as expected.

TABLE I
Sample Experimental Results from Dual RFID Water Dispenser

Reader	Card ID	Time (s)	Water (ml)	Bill (TK)	Remaining Balance
One	99035899	2	20	6	797
One	99035899	3	30	9	791
Two	98096921	1	10	3	1200
Two	98096921	7	70	21	1182
Two	98096921	10	100	30	1155

- **Concurrent usage:** Both Reader 1 and Reader 2 successfully operated simultaneously without interference, validating dual-session concurrency.
- **Reliability:** Session records matched console logs, ensuring that the database captured accurate and complete usage data.

A graphical view of Water Usage vs. dispensing time (Fig. 3) confirms the linear relationship between time, water dispensed, and cost.

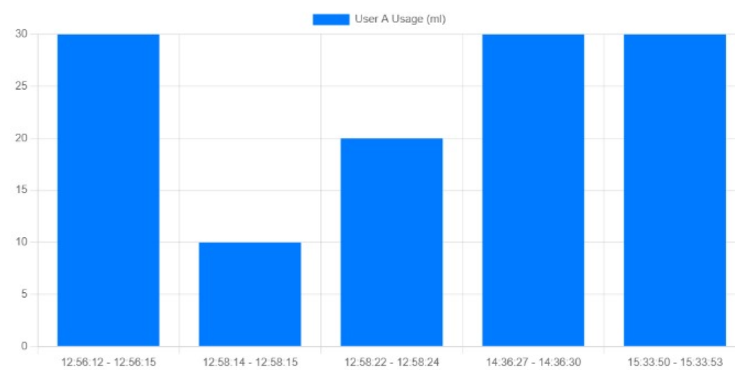


Fig. 3. Water Usage vs time

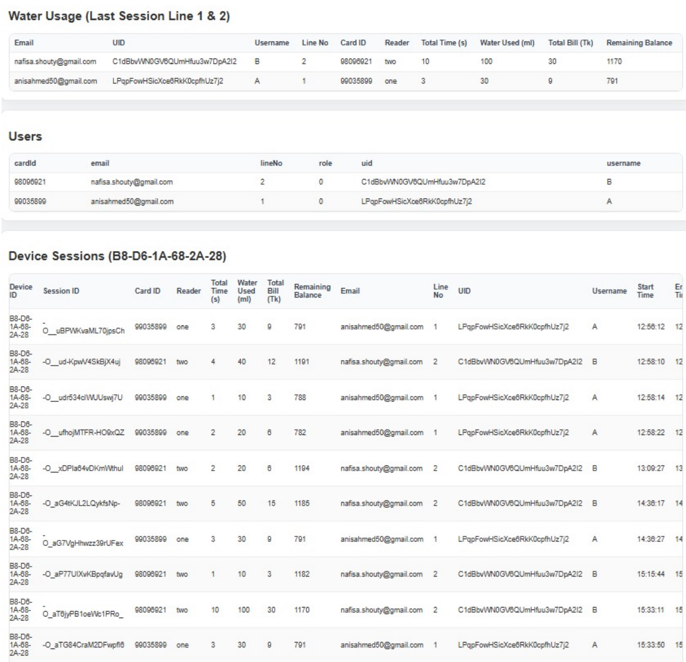
B. Comparative Analysis

Compared with prior implementations of RFID-based water dispensers:

- Unlike Kumari and Sinha's rural RFID system [4], our prototype integrates cloud-based data logging, enabling real-time monitoring and auditability.
- In contrast to Jaiswal and Jaiswal's offline RFID dispenser [5], our system ensures that every session is securely logged into Firebase, preventing data loss.
- Compared with Patel et al.'s Arduino-based fixed-quantity dispenser [9], our model supports time-based dynamic billing and real-time usage tracking.

Performance improvements: The dual-reader ESP32 design allows concurrent dispensing, reducing user wait time. The Firebase integration ensures scalability for future deployment across multiple dispensers.

Limitations: TLS verification was bypassed on the ESP32 for ease of prototyping (`setInsecure()`), which should be replaced with secure certificate validation in production. Flow sensors were not included, so dispensing is calculated purely on time-based estimation (ml/s), which may vary with pump performance.



Water Usage (Last Session Line 1 & 2)

Email	UID	Username	Line No	Card ID	Reader	Total Time (s)	Water Used (ml)	Total Bill (Tk)	Remaining Balance
nafisa.shouty@gmail.com	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	2	98096921	two	10	100	30	1170
anisahmed50@gmail.com	LPqpFowHSicXce6RkK0cpfhUz7j2	A	1	99035899	one	3	30	9	791

Users

cardId	email	lineNo	role	uid	username
98096921	nafisa.shouty@gmail.com	2	0	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B
99035899	anisahmed50@gmail.com	1	0	LPqpFowHSicXce6RkK0cpfhUz7j2	A

Device Sessions (B8-D6-1A-68-2A-28)

Device ID	Session ID	Card ID	Reader	Total Time (s)	Water Used (ml)	Total Bill (Tk)	Remaining Balance	Email	Line No	UID	Username	Start Time	En Ti
B8-D6-1A-68-2A-28	-O__uBPWKvaML70jpsCh	99035899	one	3	30	9	791	anisahmed50@gmail.com	1	LPqpFowHSicXce6RkK0cpfhUz7j2	A	12:56:12	12
B8-D6-1A-68-2A-28	-O__ud-KpwV4SkBjX4uj	98096921	two	4	40	12	1191	nafisa.shouty@gmail.com	2	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	12:58:10	12
B8-D6-1A-68-2A-28	-O__udr534clWUUswj7U	99035899	one	1	10	3	788	anisahmed50@gmail.com	1	LPqpFowHSicXce6RkK0cpfhUz7j2	A	12:58:14	12
B8-D6-1A-68-2A-28	-O__ufhojMTFR-HO9xQZ	99035899	one	2	20	6	782	anisahmed50@gmail.com	1	LPqpFowHSicXce6RkK0cpfhUz7j2	A	12:58:22	12
B8-D6-1A-68-2A-28	-O__xDPla64vDKmWthul	98096921	two	2	20	6	1194	nafisa.shouty@gmail.com	2	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	13:09:27	13
B8-D6-1A-68-2A-28	-O_aG4tKJL2LQykfsNp-	98096921	two	5	50	15	1185	nafisa.shouty@gmail.com	2	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	14:36:17	14
B8-D6-1A-68-2A-28	-O_aG7VgHhwzz39rUFex	99035899	one	3	30	9	791	anisahmed50@gmail.com	1	LPqpFowHSicXce6RkK0cpfhUz7j2	A	14:36:27	14
B8-D6-1A-68-2A-28	-O_aP77UIXvKBpqfavUg	98096921	two	1	10	3	1182	nafisa.shouty@gmail.com	2	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	15:15:44	15
B8-D6-1A-68-2A-28	-O_aT6jyPB1oeWc1PRo_	98096921	two	10	100	30	1170	nafisa.shouty@gmail.com	2	C1dBbvWN0GV6QUmHfuu3w7DpA2I2	B	15:33:11	15
B8-D6-1A-68-2A-28	-O_aTG84CraM2DFwpfl6	99035899	one	3	30	9	791	anisahmed50@gmail.com	1	LPqpFowHSicXce6RkK0cpfhUz7j2	A	15:33:50	15

Fig. 4. Device logs and sessions

VI. Conclusion and Future Work

The proposed RFID-enabled smart water dispensing system successfully integrates IoT-based automation, dual-tap concurrency, and real-time billing into a low-cost prototype. Using an ESP32 microcontroller with dual RDM6300 RFID readers, the system provides authenticated access, transparent per-second billing, and reliable session logging to Firebase via Google Apps Script. Experimental results demonstrated accurate billing, concurrent operation without interference, and reliable cloud synchronization. A web-based dashboard further enhances accountability by offering live monitoring and usage analytics.

The key contributions of this work are:

- Development of a dual RFID-based water dispensing prototype enabling two users to operate simultaneously.
- Integration of real-time billing and usage tracking with cloud logging in Firebase Realtime Database.
- Implementation of a scalable software–hardware framework suitable for future community water management deployments.

Future research directions include:

- Integration of flow sensors to replace time-based estimates with precise volume measurements.
- Development of a mobile application for balance recharge, usage history, and personalized notifications.
- Strengthening of security measures by enforcing TLS verification and role-based Firebase access rules.
- Exploring renewable energy solutions such as solar-powered operation for rural and off-grid areas.
- Large-scale field deployment to evaluate performance in real-world community water distribution environments.

In conclusion, the system demonstrates that IoT-enabled solutions can significantly improve fairness, transparency, and sustainability in public water management, while laying the groundwork for future scalable smart utility systems.

References

[1] Instructables Team, "Water Dispenser IoT Project," *Instructables*, 2024. [Online]. Available: https://www.instructables.com/Water-Dispenser/

[2] K. Abubakar, M. Tariq, and S. R. Ali, "Smart Water ATM with Arduino Integration, RFID Authentication, and Dynamic Dispensing," *Electronics*, vol. 13, no. 9, p. 1657, 2024. [Online]. Available: https://www.mdpi.com/2079-9292/13/9/1657

[3] H. Ahmed, "Advancing Water Vending Industry through RFID and IoT Empowerment," *International Conference on Advanced Electrical and Electronics Engineering (ICAEEE)*, 2024. [Online]. Available: https://www.researchgate.net/publication/381693362

[4] P. Kumari and R. Sinha, "IoT Based Water Management System using RFID for Rural Areas," *IJARSCT*, vol. 4, no. 5, pp. 123–130, 2024. [Online]. Available: https://ijarsct.co.in/A16820.pdf

[5] N. Jaiswal and R. Jaiswal, "Smart Water Dispenser Using RFID Reader," *Project Report, Academia.edu*, 2023. [Online]. Available: https://www.academia.edu/42654070

[6] A. Labrahmi, "Arduino Smart Water Dispenser System," *GitHub Project Repository*, 2022. [Online]. Available: https://github.com/Labrahmi/water-dispenser-system

[7] S. Jain, M. Yadav, and D. Kumar, "Automatic Water Dispenser Using IoT," *IJCRT*, vol. 12, no. 4, pp. 88–91, 2024. [Online]. Available: https://ijcrt.org/papers/IJCRT2431396.pdf

[8] V. K. Singh, "Design and Construction of a Smart Liquid Dispensing Machine," *IJARST*, vol. 9, no. 2, pp. 55–60, 2023. [Online]. Available: https://www.ijarst.in/public/uploads/paper/951851654145888.pdf

[9] A. Patel, R. Bhatt, and S. Shah, "Automatic Water Dispenser Using IoT," *IJIRT*, vol. 11, no. 3, pp. 112–117, 2024. [Online]. Available: https://ijirt.org/published-papers/IJIRT164235_PAPER.pdf

[10] R. Deshmukh and P. Joshi, "Smart Water Dispenser Monitoring System," *International Conference Proceedings on Embedded and IoT Systems*, 2020.