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Smart UPI Enabled Embedded Water Vending Machine with Integrated Filtration and Waste Water Management System

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***Abstract*—The Smart UPI Enabled Embedded Water Vending Machine with Integrated Filtration and Waste Water Management System an innovative solution to ensure clean and accessible drinking water in public areas. Access to safe drinking water is essential for health, yet many existing vending machines rely on outdated coin and cash systems. This project enhances the water distribution experience by integrating Unified Payments Interface (UPI) technology, allowing for seamless digital payments through popular apps like PhonePe, Google Pay, and Paytm. By shifting to a cashless model, we not only align with the "Digital India" initiative but also eliminate the maintenance challenges associated with traditional coin-operated machines.**

At its core, the machine operates through an advanced embedded system powered by a microcontroller, such as an ESP32. The user experience begins when a UPI QR code either dynamic or static is displayed on the machine's interface for payment. After the user scans the code and the payment is confirmed via the ESP32 Wi-Fi module, the system activates the dispensing mechanism. A solenoid valve or water pump is then engaged to deliver a precise volume of water, monitored by a flow sensor to guarantee accurate dispensing for each transaction.

This paper goes beyond payment advancements by prioritizing hygiene and environmental sustainability with its integrated filtration and wastewater management system. The raw water is purified using RO and UV filtration technologies, effectively removing impurities and harmful bacteria before reaching consumers. Acknowledging the environmental issues linked with traditional RO systems, which generate substantial "reject water," our design includes a dedicated wastewater management unit. This unit ensures that any excess or reject water is efficiently collected and managed, allowing for potential reuse in non-potable applications like cleaning or irrigation.

The Smart UPI Enabled Water Vending Machine offers a range of benefits over conventional systems, including minimal human intervention, low maintenance needs, and a completely contactless user experience. Its automated design makes it ideal for various settings—schools, colleges, hospitals, factories, and even remote villages where access to purified water is critical. Ultimately, this system presents a safe, hygienic, and technologically sophisticated means of water distribution, ensuring that clean drinking water is just a digital scan away.

***Index Terms*—Internet of Things (IoT), Smart Water Dispenser, Vending machine, Real-time monitoring, ESP-32 microcontroller, Digital payment, QR Code, Embedded System, Watwe Flow Sensor, solenoid valve, RO/UV Filtration, Waste Water Management, Digital India, Grey Water Treatment.**

I. INTRODUCTION

A fundamental human need is having access to clean, safe drinking water. Hygienically and effectively supplying drinking water in public areas like train and bus stops, offices, and schools presents many difficulties. Conventional coin-operated drinking water dispensers frequently have problems with sanitation, maintenance, and handling currency, particularly in congested or remote areas. The need for intelligent, touchless, and user-friendly water distribution systems is rising as a result of the development of online payment methods and Internet of Things (IoT) technologies. This paper suggests an Internet of Things (IoT)-enabled cashless drinking water system that uses the ESP32, a potent microcontroller with built-in Wi-Fi, to manage the water supply in real-time and accepts payments via

QR code scanning. The user is taken to a UPI-based payment page as soon as they scan the QR code. Following a successful payment, the ESP32 receives a request from a cloud server (like Firebase) to begin the dispensing procedure. A water flow sensor (YF-S201) detects the amount dispensed, ensuring that users receive a correct volume of water in accordance with the payment. The relay module controls the water flow through a solenoid valve. The system has several benefits, including contactless operation, real-time monitoring, little maintenance, and data recording. It is especially relevant in the context of existing initiatives like Digital India and Smart Cities, which aim to improve public infrastructure and services using digitization. This proposed model is cost-effective, easy to implement, and flexible, which makes it suitable for both rural and urban settings [6].

To further enhance the utility and sustainability of this system, the model integrates a sophisticated multi-stage filtration unit and a dedicated waste water management framework. The purification process utilizes RO and UV filtration to effectively eliminate bacteria and impurities, ensuring the water meets safety standards for consumption. A critical feature of this implementation is the focus on environmental responsibility; the system is designed to collect and manage reject water separately, allowing for the reuse of grey water in secondary applications such as cleaning or irrigation. By combining advanced purification with automated waste management, the machine operates efficiently while minimizing water waste.

II. LITERATURE REVIEW

The convergence of IoT and digital payment technologies has led to the development of numerous smart public utility systems, including vending machines, ticketing kiosks, and water dispensers. Several studies and projects have explored similar systems, focusing on automation, payment integration, and real-time monitoring.

In the paper “Implementing and monitoring water consumption using IoT Based Smart Dispenser” (2024), the authors implemented an ESP8266-based dispenser that allowed users to select predefined quantities of water using push buttons [12]. While the system provided automation and flow control using a flow sensor, it lacked any form of cashless or remote payment mechanism, limiting its real-world usability in public scenarios.

A study published in 2021 titled “Internet of Things based smart vending machine using digital payment system” discussed the incorporation of UPI and QR code-based payment systems into IoT applications [11]. The authors highlighted the dependability of UPI systems, instantaneous transaction verification, and the potential for integrating these with microcontrollers via cloud-driven triggers like Firebase or REST APIs. Another research project examined a Smart Water Dispensing System Even though many of the systems reviewed provide either automation or digital payment solutions, there is a notable gap in integrating real-time flow monitoring, cloud-enabled control, and cashless transactions into a single unified system. The proposed system in this paper addresses these concerns by combining all three elements using affordable and readily available components such as ESP32, YF-S201 flow sensors, and UPI-focused QR payment systems. Recent research has further expanded these concepts to include mobile-controlled convenience and advanced filtration.

For instance, Pindoriya et al. (2024) developed app-controlled vending machines to enhance user convenience, though such systems require consistent maintenance to ensure operational stability. In the realm of purification, Sharma et al. (2022) demonstrated the efficacy of Smart RO-based systems using UV filtration to eliminate bacteria, although their model was noted for producing high levels of reject water without a reuse mechanism. Addressing this environmental gap, Verma et al. (2022) explored grey water treatment and reuse systems using sedimentation and filtration methods, allowing treated water to be repurposed for irrigation and cleaning. Furthermore, while RFID solutions proposed by S. Rehman et al. (2022) offer a cashless alternative, they lack the flexibility and modern convenience of mobile UPI systems and often involve higher initial infrastructure costs. These studies collectively underscore the necessity of a system that balances digital transaction ease with sustainable water management practices.

III. SYSTEM ARCHITECTURE

The proposed system amalgamates hardware and software elements to enable a cashless, IoT-powered water dispensing solution. It operates using an ESP32 microcontroller as the core unit, which connects with a cloud-based server to authenticate payments and manage water dispensing through a relay and flow sensor arrangement [10]. The structure is segmented into three principal components: user interface (QR code payment), cloud communication, and hardware management.

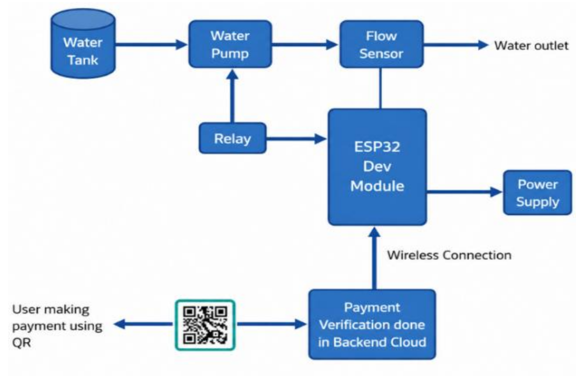

Fig. 1 System Architecture of the system

A. Hardware Components

Table 1. Hardware Components

ESP32	A microcontroller with Wi-Fi capability that executes commands, communicates with the cloud server, and manages the water dispensing system.
Relay Module	Acts as a switch to control the solenoid valve or water pump based on ESP32 instructions.
YF-S201 Water Flow Sensor	Tracks the volume of water circulating within the system. It transmits pulse signals to the ESP32 for volume calculation.
Solenoid Valve / Water Pump	Allows or restricts the water flow when triggered by the relay.
Power Supply	Provides the necessary voltage (5V or 12V) to power the ESP32 and other components.
Water Tank/Source	Reservoir connected to the output nozzle where water is dispensed.
RO Filter	Remove impurities, dissolved salts and harmful contaminants from water to make it safe for drinking.
LCD Display	Display alphanumeric character to show output

B. Software Components

Arduino IDE	Used to program the ESP32 and define the control logic.
Firebase Realtime Database / API Server	Maintains the payment verification status and serves as a link between the mobile payment system and the ESP32.
UPI/QR Payment Gateway	QR code linked to a UPI ID (via apps like Razor pay, Google Pay, Phone Pay, etc.) that initiates the transaction.
Internet Connectivity (Wi-Fi)	Enables ESP32 to send/receive data from the cloud.

C. System Workflow

- User scans a static QR code displayed on the dispenser using a UPI-compatible payment app.
- Payment is processed via the app and verified through a backend server or manually updated in Firebase/API upon confirmation.
- The ESP32 listens to the Firebase database for any change in payment status.
- Once the payment is confirmed, the ESP32 activates the relay, which powers the solenoid valve to allow water flow.
- RO Water first passes through RO filtration stages:
- membrane removes dissolved impurities (TDS)
- (Optional) UV/UF filter kills bacteria

- Purified water flows to the outlet.
- The flow sensor continuously measures the water dispensed.
- Upon reaching the predefined volume, the ESP32 turns off the relay, stopping the water supply.
- The system resets and waits for the next user.

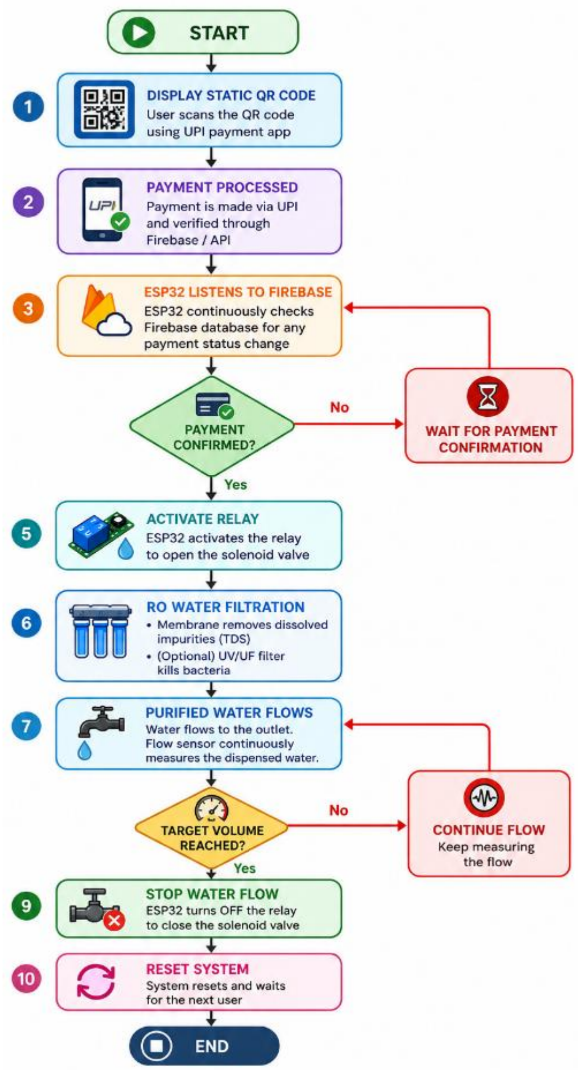

Fig. 2 Flow of System working

IV. WORKING METHODOLOGY

The envisioned IoT-driven system facilitates touchless water dispensing by merging a QR code payment solution with an automated hardware apparatus managed by an ESP32 microcontroller. The complete procedure is segmented into various essential phases, encompassing both user engagement and automated control mechanisms.

- QR Code Payment Initiation

A static QR code linked to a UPI payment gateway (e.g., Google Pay, Phone Pay, Paytm, or Razor pay) is displayed on the front of the water dispenser. Users scan the QR code using their mobile devices and make a payment for a predefined amount corresponding to a specific quantity of water (e.g., ₹1 for 500ml).

- Payment Confirmation and Server Update

Once the payment is completed, the backend server or Firebase Real-time Database receives and stores the transaction status. This can be implemented either manually or automatically using a payment gateway's API to update the database in real time.

- ESP32 Communication and Control

The ESP32 microcontroller, connected to the internet via Wi-Fi, continuously monitors the cloud server or Firebase database for any status change. Upon detecting a valid payment entry, the ESP32 activates the relay module to open the solenoid valve or turn on the water pump.

- RO Filtration Process

Before dispensing, water passes through multiple purification stages: RO membrane removes dissolved salts and harmful substances (TDS) (Optional) UV/UF filter kills bacteria and microorganisms. This ensures only safe and purified drinking water is dispensed to the user.

- Water Flow Monitoring

The YF-S201 water flow sensor connected to the ESP32 monitors the amount of water being dispensed by generating pulse signals. The ESP32 calculates the real-time volume based on pulse count and flow rate (typically ~450 pulses per liter).

- Automatic Dispense Control

Once the desired volume of water is dispensed (based on the payment tier), the ESP32 deactivates the relay, stopping the water flow. The system then resets and waits for the next payment and dispensing cycle.

- System Feedback and Logging

The entire transaction can be logged (locally or on the cloud) for monitoring, analytics, and maintenance purposes. Optional features like status LEDs, LCD displays, or buzzer alerts can be added to notify the user of successful payments and dispensing.

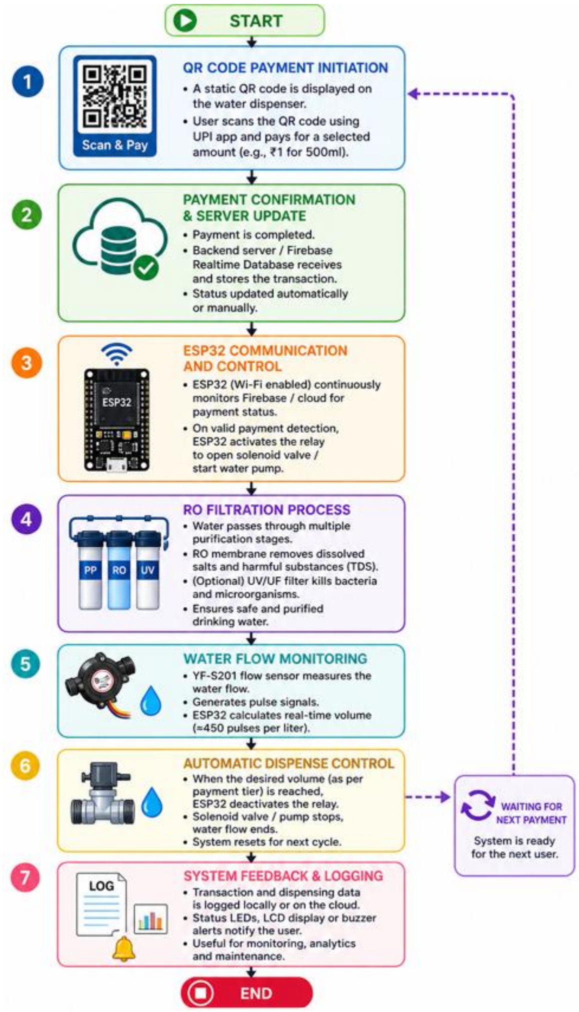

Fig. 3 Flow of Working Methodology

V. CONCLUSION

The development of an IoT-based cashless payment system for a drinking water dispenser marks an important advancement in smart and hygienic public utility services. By integrating technologies such as QR code-based UPI payments, ESP32 microcontroller, relay modules, Firebase cloud connectivity, and YF-S201 water flow sensors, the proposed system provides a contactless, automated, and user-friendly method for accessing safe drinking water. Users can conveniently make digital payments by scanning the QR code, after which the ESP32 verifies the transaction and initiates water dispensing. The flow sensor continuously measures the quantity of water delivered, ensuring users receive the exact amount paid for. Once the preset volume is reached, the system automatically stops the water flow, reducing wastage and improving efficiency. The system is cost-effective, scalable, and suitable for deployment in urban, semi-urban, and rural areas. It supports Digital India and Smart City initiatives by promoting cashless transactions, minimizing manual intervention, enhancing transparency, and improving public access to clean water services.

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