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IoT-Based Prepaid Water Meter System with Digital Token for PDAM Customers

Halil Nustadia[#], Edwar Rosman[#], Fitri Nova[#], Hidra Amnur[#]

[#] *Department of Information Technology, Politenik Negeri Padang, LimauManis, Padang, 25164, Indonesia*
E-mail: edwar[at]pnp.ac.id, fitrinova[at]pnp.ac.id, hidraamnur[at]gmail.com

ABSTRACTS

Conventional PDAM water meter systems, which often employ post-paid techniques, frequently lead to payment delinquencies, challenges in consumption regulation, and delayed leak detection. This study creates a prototype of an IoT-enabled prepaid water meter system utilizing the ESP32 microcontroller, YF-S201 flow meter sensor, TDS sensor for water quantity assessment, and a relay-operated solenoid valve, combined with a PHP/MySQL website hosted on AWS Academy for digital token transactions and remote monitoring. The technique employs a Research and Development (R&D) framework including analysis, design, implementation, and testing phases. The test findings indicate that the system efficiently conducts real-time monitoring of water consumption and quantity while successfully addressing payment arrears. Nevertheless, a significant constraint is present in the solenoid valve, which produces an insufficient water flow, failing to meet typical home flow rate requirements. The prototype has significant promise for updating PDAM water distribution by offering transparency and comprehensive control to consumers; however, enhancements to the solenoid valve components are necessary before practical adoption.

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CORRESPONDING AUTHOR

Edwar Rosman
Department of Information Technology, Politenik Negeri Padang, LimauManis, Padang, 25164, Indonesia
Email: edwar[at]pnp.ac.id

1. Introduction

Water is a vital resource in everyday life, necessitating effective and transparent distribution management to deliver optimal service to the population. The advancement of Internet of Things (IoT) technology has brought about transformative changes in various aspects of society, particularly in water management and distribution systems. Traditional water payment systems using post-paid methods often present several challenges for PDAM, including significant payment arrears, billing administration complications, and unpredictability in the company's cash flow. This often leads to unforeseen expenses that are beyond the customer's financial capacity.

Alongside payment system challenges, water leakage, and water quantity in residential installations are significant problems that commonly arise. Field research reveals that several consumers have experienced significantly inflated water bills due to concealed leaks in pipes located under floors or inside walls. Homeowners often discover these leaks only after several months, resulting in substantial water wastage and considerable financial losses. The typical duration for manual leak identification is 1-2 months, resulting in water bills that are 3-5 times higher than the standard monthly charge. The primary issues identified are the lack of transparency in the water payment system and consumers' inability to check usage and water quantity in real-time. Customers lack comprehensive control over their water use and are only informed of the quantity utilized upon receipt of the monthly invoice. Moreover, there exists no method to restrict consumption based on financial capacity or to identify usage abnormalities that suggest leakage. Conventional water meter systems exhibit deficiencies in operating efficiency, necessitating manual readings that are labor-intensive and expensive, and are susceptible to inaccuracies. Moreover, traditional post-paid methods often result in arrears issues that adversely affect PDAM and diminish service quality. In response to these challenges, including leaks, difficulties with water quantity monitoring, and ineffective post-paid systems, a concept was developed to provide a technical solution that addresses all three issues concurrently. The selection of the ESP32 as an IoT platform was based on its proficiency in continuous monitoring, token-based digital payment systems, anomaly detection, and water quantity assessment, all of which are accessible via a website.

The webpage for token acquisition and system oversight for the IoT-based prepayment water meter system is hosted on AWS Academy. AWS Academy is a cloud computing platform offered by Amazon Web Services that delivers dependable and secure hosting infrastructure for system development. The decision of AWS Academy is based on its ability to facilitate interaction between IoT systems and websites, provide cloud databases for storing transactional and monitoring data, and deliver robust scalability for future expansion. By using AWS Academy for hosting, clients can visit the website to obtain digital tokens and monitor water consumption in real-time from any location. Data from the ESP32 is securely stored and processed within a reliable cloud architecture.

This study aims to develop a prototype of an IoT-enabled prepaid water meter system utilizing ESP32, designed to assist PDAM users in monitoring water consumption and quantity through a digital token mechanism. This system incorporates a website for the acquisition and generation of digital tokens used in water meter operations. The device can also identify irregular water use patterns that suggest leaks and assess water quantity in real-time. This technology aims to enhance transparency, reduce payment arrears, empower consumers to regulate their water use based on their financial capacity, and provide early alerts about potential leaks and deterioration of water quantity.

2. Research Methodology

The methodology used in this research is the Research and Development (R&D) approach. This method combines basic research to understand existing problems with the development of practical solutions that can be implemented.

2.1. Analysis and Design

The initial stage involved analyzing system requirements based on problems found during field practice. The design includes:

- Hardware Design: Schematic design using ESP32, YF-S201 flow meter sensor, TDS sensor, and solenoid valve.
- Software Design: Database design for customer data and tokens, and website interface design for token purchases and monitoring
- Architecture System: Integration between the website and IoT meter using a digital token system with encryption.

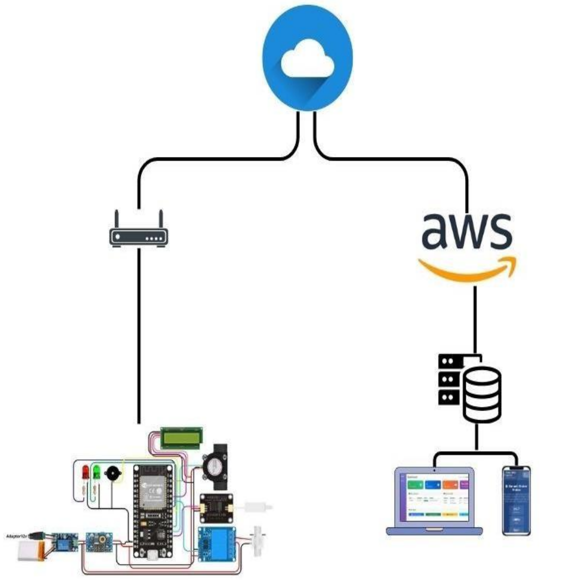

Fig 1. Architecture System

A topology design is a network architecture diagram that illustrates how the system's components are physically and logically connected to one another. The topology of the IoT prepaid water meter system describes the connections between hardware (ESP32, sensors, actuators), communication networks (WiFi, internet), application servers, databases, and user interfaces.

Design of an IoT-based prepaid water meter system hosting plan using AWS cloud computing services with Amazon EC2 as the main server platform. AWS EC2 Server Specifications:

1. Instance Type t3.micro for development, upgradable as needed
2. Operating System Ubuntu Server 20.04 LTS
3. Storage 20GB SSD with EBS (Elastic Block Store)
4. Network VPC with SSL certificate for communication security
5. Software Stack Apache/Nginx web server, PHP/Node.js backend, MySQL database.

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The ESP32 system communicates with the AWS EC2 server via the HTTPS protocol using a RESTful API. Sensor data from the water meter is sent to the API endpoint in real-time, while digital token validation and water relay control are performed thru responses from the server. The web dashboard hosted on EC2 displays monitoring data in real-time and allows users to purchase digital tokens securely

2.2. Hardware Specifications

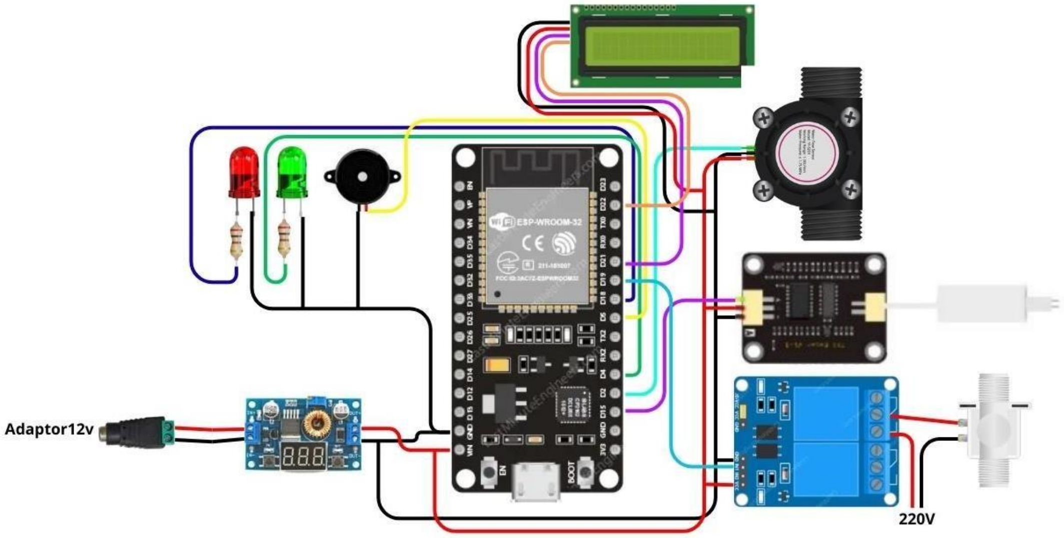

FIG 2. electronic system circuit

The prototype utilizes the following components:

- Microcontroller: ESP32 (Dual-core, Wi-Fi/Bluetooth).
- Sensors: Flow Meter YF-S201 (1-30 L/min) and TDS Sensor (0-1000 ppm).
- Actuators: Solenoid Valve (12V) and Relay Module (5V).
- Interface: LCD I2C 16x2 and Buzzer.
- Power: 12V 2A Adaptor with Step-Down Converter (12V to 5V).

2.3. System Flowchart

System operation begins with the user purchasing a token through the website. The flowchart process is as follows:

- Start: User buys a token on the website.
- Input: The user enters the token into the system.
- Validation: The server validates the token (active, used, or expired).
- Action: If valid, the balance increases, and the relay activates the solenoid valve, allowing water flow.
- Monitoring: The system continuously monitors the flow and TDS levels. If the balance reaches zero, the relay automatically closes the valve

3. RESULTS AND DISCUSSION

3.1. Hardware Implementation

The complete system circuit places the ESP32 as the main control center. It connects to the 12V adapter and step-down converter for power. The LCD displays local information, the flow meter measures water volume, and the TDS sensor monitors quantity. The relay module controls the solenoid valve based on the digital token balance.

TABLE 1. Hardware Configuration

No	Component	Pin Configuration	Function
1.	Mikrokontroler ESP32	a. GPIO21 (SDA) connects to the LCD I2C SDA b. GPIO22 (SCL) connects to the LCD I2C SCL c. GPIO2 connects to the Flow Meter Signal d. GPIO19 connects to the Relay Control Signal e. GPIO18 connects to the Status LED (Green) f.	The ESP32 serves as the main control center, connecting all system components. The ESP32 was chosen for its integrated WiFi

		GPIO5 connects to the Status LED (Red) g. GPIO5 connects to the Buzzer Control	capabilities, which support communication with cloud servers for digital token validation and monitoring data transmission.
2.	Sensor Flow Meter	a. VCC connects to the 5V pin on the ESP32. b. GND connects to the GND pin on the ESP32. c. Signal connects to the GPIO2 pin on the ESP32.	Measure water flow signal
3	Sensor TDS (Total Dissolved Solids)	a. Connect VCC to the 5V pin on the ESP32. b. Connect GND to the GND pin on the ESP32. c. Connect Analog Out to the GPIO35 (ADC) pin on the ESP32.	Measure analog water quantity
4	Relay Module and Solenoid Valve	a. Connect VCC to the 5V pin on the ESP32. b. Connect GND to the GND pin on the ESP32. c. Connect IN to the GPIO19 pin on the ESP32. d. The COM and NO relays are connected to the 12V solenoid valve.	Control Solenoid Valve
5	LCD I2C 16x2	a. Connect the VCC pin to the 5V pin on the ESP32. b. Connect to the GND pin on the ESP32. c. Connect to the GPIO21 pin on the ESP32. d. Connect to the GPIO22 pin on the ESP32.	Display visual data
6	LED Indikator dan Buzzer	a. Connecting the Green LED to the system indicator pin (GPIO18) for normal operation and WiFi connection. b. Connecting the Red LED to the error or low balance indicator pin (GPIO5). c. Connecting the Buzzer to the audio notification pin (GPIO17) for various system conditions.	Notification

3.2. Website and Hosting Implementation

The website was developed using PHP and MySQL, hosted on AWS Academy using an EC2 instance (Ubuntu Server 20.04). User Dashboard: Displays water balance, active meter status, token purchase history, and a quick buy button. Admin Dashboard: Provides overall system statistics, customer management, meter registration, and manual payment verification.

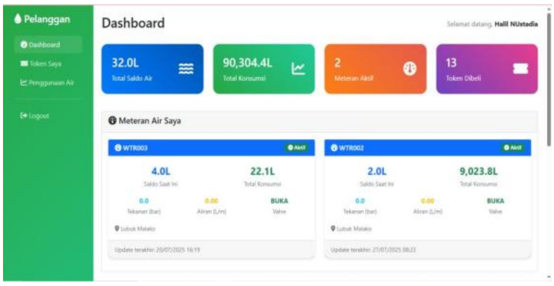

FIG 3. User Dashboard

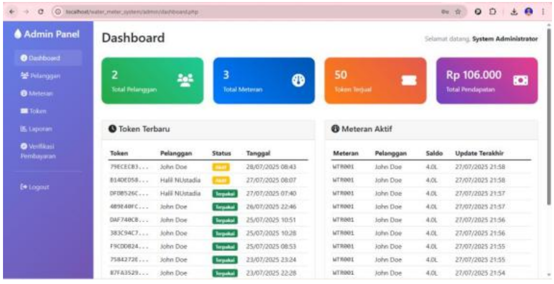

FIG 4. Admin Dashboard

3.3. Testing Results

Testing was conducted to verify the functionality of sensors and the control logic.

a. Flow Sensor Testing Testing involved flowing a measured volume of water (1 liter) and recording the pulses generated by the YF-S201 sensor to calculate accuracy. The sensor successfully provided data readable by the ESP32.
b. TDS Sensor Testing The TDS sensor was calibrated using a standard solution (890 ppm). The readings were compared with a reference TDS meter to ensure valid water quantity monitoring.
c. Relay and Valve Control Testing The relay switching was tested against various balance conditions. The system successfully cut off the water flow (Solenoid Valve closed) when the token balance was exhausted and opened it when a valid token was input.

The implementation results show that the prepaid system with digital tokens effectively eliminates payment arrears, a major issue in the traditional system. The real-time monitoring feature functions well, displaying flow rates and TDS values on both the local LCD and the website dashboard.

However, a significant limitation was identified during testing. The specific solenoid valve used in this prototype allows for only a very small volume of water flow. This flow rate does not meet the normal requirements for daily household water usage. While the electronic control logic works perfectly, the mechanical component (valve) requires an upgrade for practical application..

4. Conclusions

Based on the implementation and testing of the IoT-based prepaid water meter system using ESP32, the following conclusions are drawn:

1. The system was successfully developed integrating ESP32, flow sensors, TDS sensors, and a solenoid valve with a cloud-based web interface.
2. Real-time monitoring of water quantity and quantity (TDS) is functional and accessible via LCD and the web dashboard.
3. The digital token prepaid mechanism effectively eliminates arrears and provides customers with full control over their usage.
4. The primary limitation is the solenoid valve's low flow rate, which is insufficient for household needs. It is recommended to replace the solenoid valve with a model that supports higher pressure and flow volume for future implementation

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