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Design and Development of an IoT-Based PDAM Water Bill Monitoring System for Private Homes

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Abstract— **This project focuses on developing an IoT-based water bill monitoring system for private homes using a NodeMCU ESP8266 microcontroller, a water flow sensor, and cloud integration via ThingSpeak. The system enables real-time monitoring of water usage, allowing users to control and reduce excessive consumption.Testing showed that the water flow sensor operated with high accuracy, despite minor discrepancies. Comparisons between the sensor's output and actual measured water volumes revealed error rates ranging from 0.75% to 1.80% across different flow rates. The system also accurately calculated water bills using a predefined rate of IDR 7,000 per liter. For example, a water usage of 3 liters resulted in a bill of IDR 21,000, matching the expected amount. The system successfully provided real-time billing through the ThingSpeak platform and a custom mobile app developed with MIT App Inventor. Additionally, the built-in buzzer effectively alerted users when water usage exceeded predefined limits. While the system performed efficiently, occasional network instability affected IoT performance. Future improvements could focus on enhancing sensor accuracy and improving the user interface for better functionality.**

Keywords: PDAM, Waterflow, NodeMCUESP8266, Thingspeak, MIT App Inventor.

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I. Introduction

Water is a fundamental necessity in human life, playing a crucial role in nearly every aspect of daily activities, from household use to sanitation. The efficient management of water consumption is paramount, especially in urban settings where overuse can lead to inflated water bills and unnecessary waste of resources. Traditionally, water usage monitoring has been conducted manually, using PDAM (Perusahaan Daerah Air Minum) water meters, which often lack the precision and immediacy required for real-time tracking. This process is not only inefficient but also makes it difficult for customers to monitor their water consumption regularly, leading to unanticipated spikes in monthly water bills.

To address these issues, the integration of the **Internet of Things (IoT)** technology offers a promising solution. IoT facilitates the connection of various devices to the internet, enabling real-time monitoring and data analysis. In this project, the design and development of an IoT-based water bill monitoring system for private homes aim to provide a practical solution for consumers to track their water usage and control their bills more effectively.

The system employs a **NodeMCU ESP8266** microcontroller connected to a **Waterflow sensor** that measures the volume of water used. This data is then sent to the **Thingspeak** platform, where users can monitor their water usage remotely via the **MIT App Inventor** application on their smartphones. Additionally, the system includes a **buzzer** that triggers an alert when water usage exceeds a predetermined monthly limit, helping users avoid excessive billing.

Purpose and Benefits

The primary goal of this project is to develop a real-time water monitoring system that helps users track their water usage effectively, reduce wastage, and keep their bills in check. By leveraging IoT technology, the system ensures that users have access to their consumption data anytime, anywhere. Moreover, the integration of an alert mechanism notifies users before they reach their usage limits, thus preventing unexpectedly high bills. The system is designed with scalability in mind, making it adaptable for different residential setups and easy to manage through a user-friendly interface.

This IoT-based solution represents a significant improvement over traditional water meters, making water usage monitoring more efficient, accurate, and convenient for everyday users.

II. Materials and Methods

1. System Design and Components

The design and development of the PDAM water bill monitoring system based on the Internet of Things (IoT) was conducted using a variety of hardware and software components. The system integrates a NodeMCU ESP8266 microcontroller, a Waterflow sensor, a buzzer, and various peripheral devices for monitoring and controlling the water usage in real-time.

1.1 Block Diagram

The system's block diagram is shown in Figure 1. The system consists of the NodeMCU ESP8266 microcontroller, which serves as the core processing unit, connected to the Waterflow sensor for measuring water discharge. The data from the sensor is processed and transmitted via the WiFi module of the ESP8266 to the Thingspeak platform for real-time monitoring. A buzzer is used as an alert mechanism when water usage reaches a predefined limit. The data is also displayed on an LCD I2C for local monitoring.

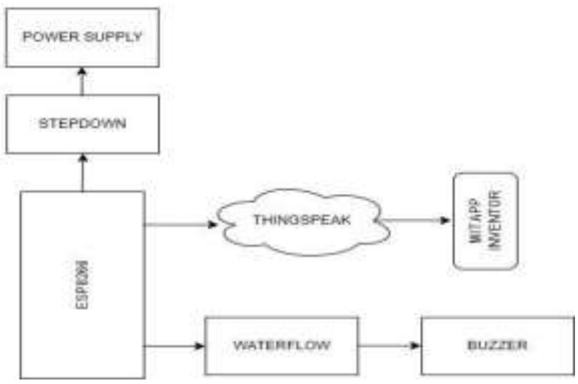

Figure 1: System Block Diagram

1.2 Flowchart

The flowchart in Figure 2 illustrates the logical flow of the system operation. It starts with initializing the components, including the WiFi connection and sensors. When water flow is detected, the system measures the discharge and calculates the total volume. If the water usage exceeds the preset limit, the buzzer is activated. The data is continuously sent to the Thingspeak cloud platform and displayed on the LCD and the MIT App Inventor interface.

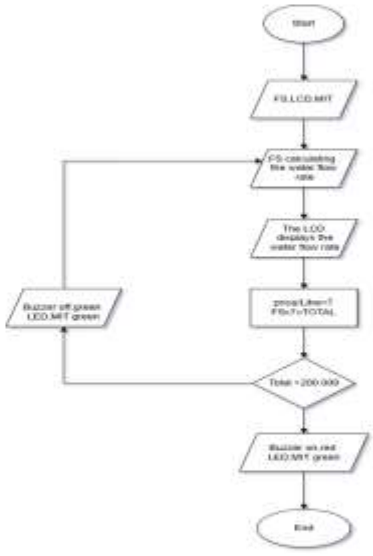

Figure 2: System Flowchart

2. Internet Of Things (IoT)

IoT refers to all commands that are programmed or executed as long as there is an internet connection, enabling the creation of an object. With the advancement of technology in today's era, where everything can be accessed through the internet, millions, even billions, of people are using the internet. With the emergence of the IoT system, not only communication devices and computers can be connected to the internet, but all electronic devices will be controlled via the internet. The Internet of Things (IoT) describes a network of physical objects—things embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet[3].

3. Hardware Components

The following hardware components were used to build the system:

3.1 NodeMCU ESP8266

The NodeMCU ESP8266 microcontroller is the main processing unit for the system. It is an open-source IoT platform that integrates a WiFi module, allowing data transmission to the cloud (Thingspeak) for real-time monitoring. The microcontroller operates at a voltage of 3.3V and is compatible with Arduino IDE, making it easy to program[5].

Figure 3: NodeMCU ESP8266

3.2 Waterflow Sensor

A Waterflow sensor is used to measure the flow of water in the pipe. The sensor generates pulses when water flows through it, and these pulses are counted by the NodeMCU to calculate the flow rate and total water usage. The data from the sensor is sent to the Thingspeak platform for remote monitoring[11].

Figure 4: Waterflow Sensor

3.3 Buzzer

A buzzer is included in the system to alert users when the water usage exceeds a preset limit. The buzzer is triggered by the NodeMCU when the total water usage reaches the predefined threshold, notifying the user of excessive water consumption[8].

Figure 5: Buzzer

3.4 LCD I2C

An LCD I2C is used to locally display the real-time water usage data. The display shows the current flow rate, total volume of water used, and the calculated cost. This provides immediate feedback to the user without needing to access the cloud interface[9].

Figure 6: LCD I2C Display

4. Software Components

The system utilizes several software platforms for data processing, monitoring, and control:

4.1 Arduino IDE

The Arduino IDE is used to write and upload code to the NodeMCU. The code controls the Waterflow sensor, buzzer, and LCD I2C, and handles data transmission to Thingspeak. The IDE also includes libraries to facilitate communication between the hardware components[8].

Figure 7: Arduino IDE Interface

4.2 Thingspeak

Thingspeak is an IoT analytics platform that allows for the visualization and analysis of real-time data. It is used to collect, store, and display water usage data transmitted by the NodeMCU. The platform provides a user-friendly interface where users can monitor water usage remotely[12].

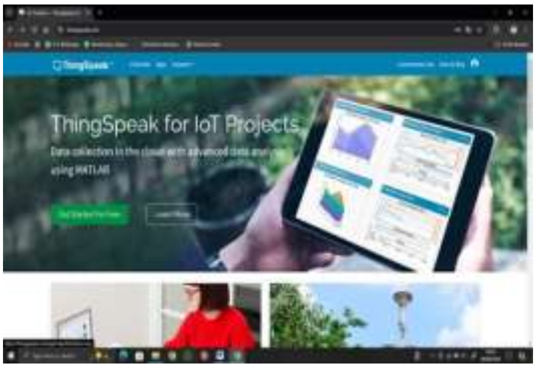

Figure 8: Thingspeak Interface

4.3 MIT App Inventor

MIT App Inventor is used to create a custom Android application for monitoring water usage on a smartphone. The app communicates with the Thingspeak platform and displays the data on the user's phone, allowing for easy monitoring and control of water consumption.

Figure 9: MIT App Inventor Interface

5. System Integration

The system integrates both hardware and software to provide a comprehensive solution for monitoring water usage. The NodeMCU continuously reads the water flow data from the sensor and calculates the total volume and cost. This information is displayed on the LCD, and an alert is triggered via the buzzer if the usage exceeds the limit. All data is transmitted to the Thingspeak platform for remote access, and users can monitor the data through the custom Android app built with MIT App Inventor.

III. Results and Discussion

Results

The development of the water bill monitoring system based on the Internet of Things (IoT) involved testing various components to ensure accuracy, functionality, and real-time data transmission. The results of the tests show the system's capability to monitor water usage efficiently and provide relevant notifications when water consumption reaches predefined thresholds. Below are the test results along with relevant images for

1. Waterflow Sensor Testing

The waterflow sensor is a crucial part of the system as it monitors the volume of water flowing through the pipes. To verify its accuracy, several tests were conducted by comparing the sensor's readings with measured water volumes in milliliters (ml). The results of the sensor tests are shown in Table 1.

TABLE I
Waterflow Sensor Test Results

No	flow rate (L/m)	Water volume			
		Output Water (L)	Sensor (L)	Difference (L)	Error (%)
1	24,67	1	0,82	0,18	18,0
2	23,97	2	1,89	0,11	5,5
3	24,89	3	3,12	0,12	4,0
4	23,94	4	3,97	0,03	0,75

2. PDAM Water Bill Calculation

The system is designed to calculate the water bill based on the actual usage. The test was performed by flowing different volumes of water through the system and comparing the calculated cost with the predefined rate of IDR 7,000 per liter. The results are presented in Table 2.

TABLE II
PDAM Water Bill Calculation Test Results

No	Water volume (L)	PDAM Rate (IDR)	Calculated Bill (IDR)
1	1 Liter	7.000	7.000
2	2 Liter	7.000	14.000
3	3 Liter	7.000	21.000
4	4 Liter	7.000	28.000
5	5 Liter	7.000	35.000

The system accurately calculates the water usage and displays the total water bill in real-time through the MIT App Inventor interface and the Thingspeak platform.

Figure 10 shows the Thingspeak interface displaying the water consumption and the total bill. The results show that the system correctly calculates the total bill based on water consumption, ensuring users receive accurate and real-time billing information.

3. System Monitoring and User Interface Testing

The monitoring system was tested through multiple platforms, including an LCD display, the Thingspeak cloud interface, and the MIT App Inventor mobile application. The system successfully transmitted real-time data from the sensor to these interfaces, allowing users to monitor water usage remotely.

Figure 3 shows the LCD displaying real-time water flow rates and total consumption.

Figure 4 shows the MIT App Inventor interface, which provides an overview of water usage, including the flow rate and total volume used.

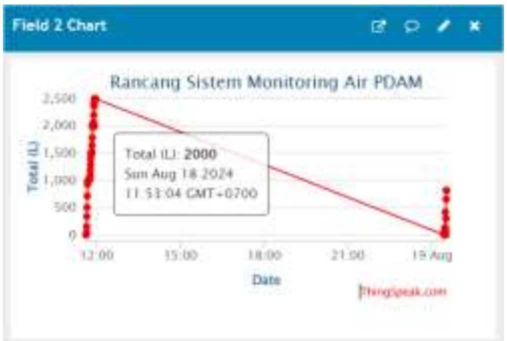

Figure 11 shows the Thingspeak platform, where users can view the recorded data for water usage and billing history.

Discussion

System Efficiency: The system effectively tracks water usage and calculates costs, helping users understand consumption patterns. This feature is particularly useful for water conservation and financial planning. The integration of IoT technology enhanced the system's accessibility, providing real-time data monitoring from any location with internet connectivity.

Sensor Accuracy: Although the waterflow sensor performed well, there were minor discrepancies in accuracy, likely due to the mechanical limitations of the sensor and water flow dynamics. Nonetheless, these errors were minimal and did not significantly affect the overall performance of the system.

IoT Integration Challenges: The use of the NodeMCU ESP8266 for data transmission through Thingspeak was efficient; however, network stability can impact the system's performance. Future enhancements may include redundant communication protocols to ensure reliable data transmission, even during network failures.

User Interface Experience: The mobile application developed using MIT App Inventor offered an intuitive interface for monitoring water usage and costs. However, the interface could benefit from additional features such as historical data tracking, notifications for water usage trends, and more customization options for setting thresholds.

IV. Conclusion

After designing and creating the system for monitoring PDAM water bills in private homes using the Internet of Things (IoT), several key outcomes were identified:

1.Accurate Water Usage Monitoring
The device successfully measures and transmits water volume data from the flow sensor through the NodeMCU ESP8266 microcontroller over IoT to the Thingspeak platform via a Wi-Fi connection. This allows for real-time monitoring of water usage.

2.Real-time Water Monitoring
The system can monitor water usage in liters and calculate the cost per liter for PDAM water in private homes. The information is accessible in real-time through both the Thingspeak platform and the MIT App Inventor application on a smartphone.

3.Alert System for Overuse
The system features an alert mechanism that activates a buzzer when water usage reaches a predefined limit. This feature helps users avoid exceeding their monthly water allowance.

4.Convenient Monitoring via Mobile Devices
Users can monitor water usage through both the MIT App Inventor on smartphones and the Thingspeak interface on the web. This dual platform functionality makes it easier for users to track their water consumption from anywhere in real-time.

5.Overall System Functionality
The water usage monitoring system is efficient and effective. It automates the process of tracking water consumption and calculating the associated costs, making it easier for households to manage their water usage.

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