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## “Smart Water Management System”

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### ABSTRACT:

Water shortages, wasteful water usage, and water leaks pose several obstacles for efficient water management. In this paper, a Smart Water Management System based on the IoT will be proposed that can help monitor and manage water consumption of residential buildings. The system consists of ESP32 microcontrollers following a Master-Slave design and also utilizes YF-S201 Hall effect water flow sensors for detecting water flow and consumption. The proposed system detects abnormal water flow continuously and regulates the water supply through the relay operated solenoid valve. On-site data can be obtained from the local OLED screen whereas flow rate, water consumption, water bills estimation, water consumption limit, and leakage information can be monitored through the web dashboard.

**KEYWORD:** IoT, Smart Water Management, ESP32, Water Flow Sensor, YF-S201, Leak Detection, Solenoid Valve, Remote Monitoring, Water Usage, Smart Metering.

## I. INTRODUCTION

Water is the most vital resource used for all sorts of human activities, whereas increased use of water and its shortage has made water management an important issue. Traditional water metering is based on the human observation and periodic readings, which do not provide information on actual use and may cause delays in the detection of abnormal use and leakage of water [1], [2]. With the emergence of Internet of Things (IoT), the development of such technologies has offered new possibilities in monitoring of water use in real time through integration of various elements such as sensors, microcontrollers, wireless communication and data processing. There are a number of studies, in which the application of IoT technology was used to monitor water consumption and leakage, as well as automate water distribution [3]–[6].

This paper proposes an IoT-Based Smart Water Management System that will monitor and control water consumption in several residences in real-time. In the proposed system, the ESP32 microcontrollers are employed in a distributed Master-Slave arrangement, whereby the Slave devices measure water flow by means of YF-S201 Hall effect flow sensors, compute the flow rate and the overall consumption. In case of any abnormal flow rate continuously or reaching a certain water consumption limit, the automatic controlling of the water flow using a relay-driven solenoid valve takes place. The proposed Slave devices not only display information locally using OLED displays but also wirelessly transfer data to the Master ESP32. The Master device has a centralized local web interface that is used to view the water flow rate, total consumption, estimated bill, usage limits, and leakage. Various IoT-based residential water management systems have demonstrated the effectiveness of integration of flow sensing, wireless communications, and valve controlling in efficient use of water [9]–[15].

## II. LITERATURE SURVEY

A system that is IoT-based for measuring water consumption as well as detecting leakages was designed by Fuentes and Mauricio [1], which made use of flow sensors, local gateways, and cloud computing for monitoring. Communication topologies for smart water meter networks were analyzed by Marais et al. [2], whereas Alvisi et al. [3] provided wireless middleware solutions for smart water metering. Jai Ganesh et al. [4] have provided an IoT-based water management system for managing water in residential buildings.

Mohapatra et al. [6] conducted research on smart water taps to save water from being wasted, whereas Fabbiano, Vacca, and Dinardo [7] conducted research on leakage detection in smart water grids. Andric et al.

[8] pointed out the significance of smart water usage monitoring and awareness. Boudville et al. [9] presented a leakage detection system at home using ESP32, YF-S201, and solenoid valve. Jamadarkhani et al. [10] explored multi-sensor based solutions for better water metering. All the above researches

prove that IoT, wireless sensing, flow measurement, and automation control is effective for water management. The suggested solution builds upon the above-mentioned concept through a distributed system of ESP32 Master-Slave type.

**Table 1: Comparative Analysis of Existing Methods**

| Authors                          | Methods                                                           | Application Areas                                  |
|----------------------------------|-------------------------------------------------------------------|----------------------------------------------------|
| Fuentes & Mauricio [1]           | IoT flow sensing, cloud monitoring, and leakage detection         | Household water consumption and leakage monitoring |
| Marais et al. [2]                | Wireless communication and smart-meter network topologies         | Smart water-metering networks                      |
| Alvisi et al. [3]                | Wireless middleware and communication solutions                   | Wireless smart water-metering systems              |
| Jai Ganesh et al. [4]            | Flow measurement, wireless monitoring, and solenoid valve control | Residential building water management              |
| Narayanan & Sankaranarayanan [5] | IoT-based water distribution and underground pipe monitoring      | Smart-city water distribution systems              |
| Mohapatra et al. [6]             | ICT-enabled smart taps and automated water control                | Water conservation and smart water supply          |
| Fabbiano, Vacca & Dinardo [7]    | Smart water-grid monitoring and leakage detection                 | Water distribution networks and loss reduction     |
| Andrić et al. [8]                | Smart water-usage monitoring and consumption awareness            | Domestic water conservation                        |

|                          |                                                             |                                              |
|--------------------------|-------------------------------------------------------------|----------------------------------------------|
| Boudville et al. [9]     | ESP32, YF-S201 flow sensor, and solenoid valve              | Domestic water leakage detection and control |
| Jamadarkhani et al. [10] | Multi-sensor monitoring and machine-learning-based metering | Advanced water metering and monitoring       |

### III .PROBLEM DEFINITION

The conventional system used for water management mainly relies on manual readings of meters, making it impossible to get precise data on water consumption at any time. In case of residential houses, more precisely multi-residential houses, each house is not continuously monitored regarding water usage. This leads to high chances of water wastage due to either excess consumption or leakage/continuous water flow. It is difficult to have an immediate response for unusual water consumption as well as maintaining the consumption limits of individual users. There is thus a need for a simple yet efficient and automated system to continuously monitor water consumption as well as flow rate and to give immediate information to the user about his/her water consumption. Such a system must be capable of detecting unusual flow rate or any continuous flow rate and also must be able to monitor the consumption limit of individual users and control water supply accordingly. Besides, it must be able to provide a simple way of viewing water consumption as well as the system status of all the residential units.

### IV. METHODOLOGY

**Figure 1: Block Diagram**

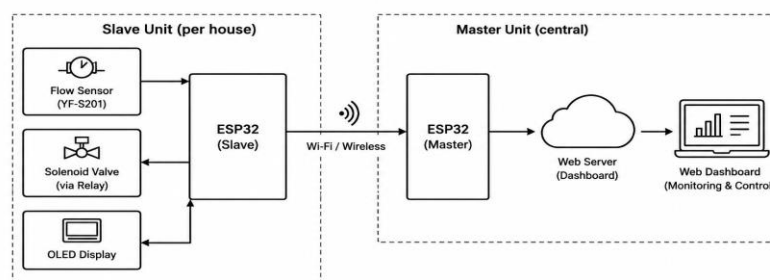


Figure 1: This project includes two primary components; the first is the Slave Unit and the second is the Master Unit. In the Slave Unit, the YF-S201 flow sensor detects the water flow rate and provides pulses to the Slave ESP32 that processes the pulses and calculates the water flow rate and consumption. Depending upon the continuous flow rate or predefined water consumption rate, the ESP32 will control the solenoid valve using the relay in order to control the water flow. The current water flow rate and water consumption data are also displayed on the OLED screen. The processed data by the Slave ESP32 is transferred through the local Wi-Fi network to the Master ESP32. The Master Unit will collect the data and provide the same in the form of the web-based dashboard where the user can view the water flow rate, water consumption rate, leakage status, and other details of the system.

Mathematical Equations Used:

#### 1. Flow Rate Calculation

$$Q = \frac{P}{7.5}$$

where QQ is the flow rate in L/min and PP is the number of pulses counted in one second.

**Purpose:** To calculate water flow rate from sensor pulses.

#### 2. Water Consumption

$$V = \frac{Q}{60}$$

where VV is the water consumed during a one-second interval in litres.

**Purpose:** To calculate water volume used per second from the flow rate.

#### 3. Total Water Consumption

$$Total\ Consumption = V_{total} + V_{current}$$

**Purpose:** To calculate the total water consumption.

#### 4. Estimated Bill

$$Bill = Rate \times V_t$$

where RR is the configured water rate per litre.

**Purpose:** To calculate the estimated water bill.

#### 5. Usage Percentage

$$Usage\ Percentage = \frac{V_{total}}{Water\ Limit} \times 100$$

**Purpose:** To calculate the percentage of water consumed against the set limit.

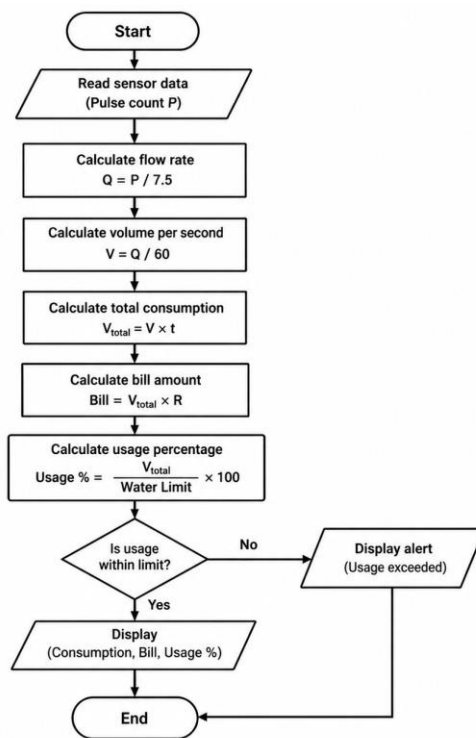


Figure 2 :Flowchart Of Model

This diagram shows the entire workflow of the smart water management system. The system begins with water flow sensing and information gathering process. Information is processed by the Slave ESP32. This information contains monitoring of the amount of water used and whether there is any exceedance of the water use limit. The required information is then transmitted to the Master ESP32. Information regarding consumption, billing and usage is then provided on the monitoring interface. Any abnormalities in the flow rate and the exceeding of the water limit would result in an alarm. There should also be centralized monitoring of the water flow in various residential units so as to be able to monitor water usage without having to visit each one individually. The collected information should include flow rate, amount of water consumed, estimated billing, limits of water usage, and status of the system. Having all this information on a centralized interface would make the water management much easier. Other factors include ensuring the economy of the system, ease of operation and scalability of the system to fit various applications. In this case, the solution integrates available technologies such as ESP32 controllers, flow sensors, wireless technology, relay boards, and solenoid valves. Integration of the system in the measurement and automatic control functions will help in achieving efficient use of water and reducing water wastage.

Table 2: Components Used in the System

| Sr .N o. | Component/ Module        | Function                                                               |
|----------|--------------------------|------------------------------------------------------------------------|
| 1        | ESP32 DevKit-V1          | Main controller for processing sensor data and controlling the system  |
| 2        | YF-S201 Flow Sensor      | Measures water flow and generates pulse signals                        |
| 3        | 0.96-inch OLED (SSD1306) | Displays flow rate, water consumption, and alerts                      |
| 4        | Relay Module             | Controls the solenoid valve according to ESP32 commands                |
| 5        | 12V Solenoid Valve       | Automatically controls the water supply                                |
| 6        | LM2596 Buck Converter    | Converts 12V input to approximately 5V for the electronic circuit      |
| 7        | Push Buttons             | Used for system reset and leakage/limit reset                          |
| 8        | 12V DC Power Supply      | Provides power to the solenoid valve and electronic system             |
| 9        | Wi-Fi Communication      | Transfers data between Slave ESP32 units and the Master ESP32          |
| 10       | Master ESP32             | Collects data from all Slave units and provides centralized monitoring |

Table below highlights the important hardware and communication modules that will be utilized in the designed IoT-based Smart Water Management System. The ESP32 module acts as the controller in the system that facilitates processing and control of the system, the YF-S201 is used to measure the flow rate of the water, the OLED module facilitates display of information locally, relay and 12v solenoid valve facilitate water supply control while the LM2596 acts as the buck converter that supplies the needed low voltage in the electronic circuit.

#### Algorithms Utilized

- Algorithm of Water Flow Measurement: The YF-S201 flow meter generates pulses depending on the water flowing through it. Pulses are counted by the Slave ESP32, and water flow is computed.
- Pulse Counting Algorithm: Pulses are counted by the ESP32 within a particular amount of time based on the flow sensor. These pulses will be utilized to compute water flow and consumption.
- Algorithm for Water Flow Calculation: Pulses are counted to calculate the water flow instantly to measure the water flow at the moment.
- Water Consumption Calculation Algorithm: Water flow is converted to water consumption, which is constantly updated. This value is stored separately for each house.
- Bill Calculation Algorithm: Water consumption is multiplied with the set water price to compute the bill of each house.
- Usage Percentage Algorithm: Here, there is comparison between the total consumption of water and the set limit of water usage. This is later expressed in terms of percentages to show the extent of water consumption.
- Leakage Detection Algorithm: Here, the water flow is monitored at all times to detect any kind of continuous running that might be caused by a water leak.
- Water Limit Algorithm: The ESP32 compares the total consumption of water to the set limit of water usage and triggers an action when this limit is attained.

#### OBJECTIVES

1. To design a system based on Internet of Things (IoT) for monitoring household water usage in real time.
2. To measure water flow rate and overall amount of water used by means of the YF-S201 flow sensor.
3. To identify persistent abnormal flow of water and possible leakage in the water supply pipe.
4. To enable automatic regulation of the water supply with the help of the relay-driven solenoid valve in case of leakage or exceeding the limit.
5. To perform centralized monitoring of multiple houses using Master ESP32 and web-based interface.

#### RESULT

The proposed IoT-Based Smart Water Management System successfully incorporated three Slave ESP32 devices with one Master ESP32 device for multi-resident monitoring of water consumption. The Slave devices have sensors for water flow estimation (YF-S201), consume calculation, and OLED display for local information. Additionally, the system has been designed for monitoring water consumption limit and estimated bill per household.

The system has successfully proven its capability to automate the water supply process by implementing the relay switch and 12V solenoid valve. The testing included continuous water flow to prove the ability to detect leakage and water consumption limits to prove automatic water supply shutdowns. The tests proved that interaction between flow sensor, ESP32, relay, and solenoid valve works as expected.

Wi-Fi communication from Slave ESP32 devices to Master ESP32 has been done through a common Wi-Fi network. Monitoring of the flow rate, total water consumption, estimated bill, water limit, usage percentage, leakage and limit status has been done via the Master dashboard for three connected homes.



Figure 3 :Prototype Implementation of the IoT-Based Smart Water Management System

**Figure 3:** Figure below depicts the hardware prototype design for the proposed smart water management system which is made up of several ESP32 devices along with the flow sensors, relay module, OLED screen, and the solenoid valves. Both the water flow sensing as well as control unit segments have been put together with all the necessary plumbing requirements in order to monitor the water flow and also control it automatically. The signal from the sensor is being processed using the ESP32 microcontroller, while the relay controls the operation of the solenoid valve according to the programmed logic.

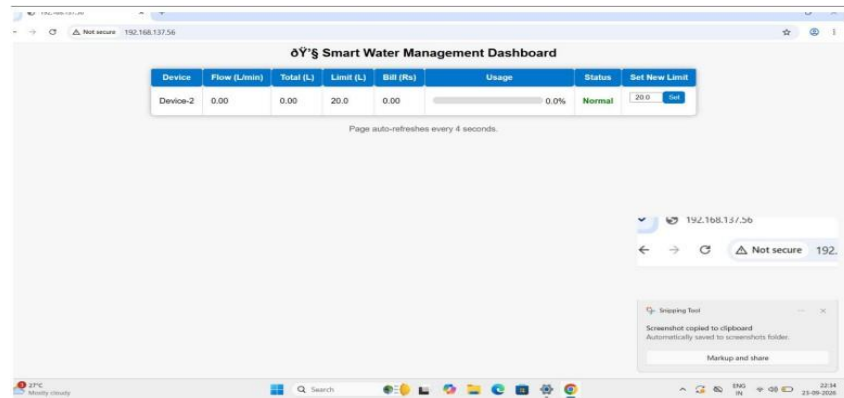


**Figure 4: Web-Based Smart Water Management Dashboard**

The above image highlights the web-based dashboard that has been designed to monitor the intelligent water management system. The information that is shown in the dashboard includes the device name, flow rate, water consumption, water limit, billing, usage percentage, and status of the system. The dashboard provides the user with an option of setting a new water consumption limit for the particular device.

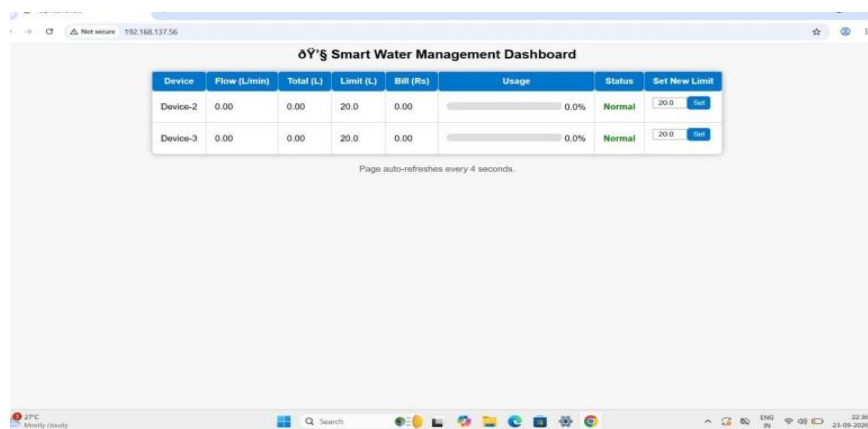


**Figure 5: Multi-Device Smart Water Management Dashboard**

Figure 5: As can be seen from the image below, the dashboard is centralized, and multiple devices are being monitored by this dashboard with each individual device having its own information regarding the flow rate, total water consumption, set limit, estimated bill, percentage of usage, and current status. The dashboard also gives the user the opportunity to change the water consumption limit of each individual device.

**Figure 6: Real-Time Multi-Device Water Monitoring and Alert Dashboard**

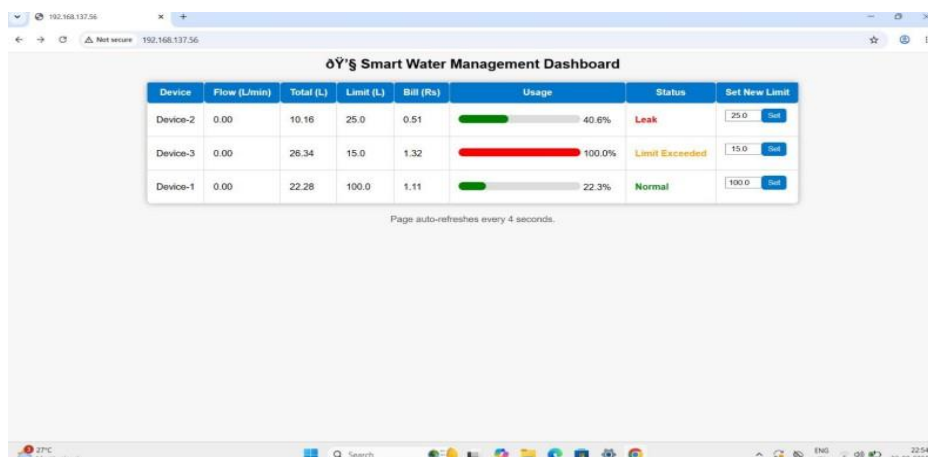


Figure 6 is the screen shot of real time monitoring of the three devices using the central web-based dashboard that displays flow rate, water usage, limit, estimated bill, percentage of usage, and system status. Device-2 has been marked with Leak condition having 40.6% usage, Device-3 has achieved the status of Limit Exceeded with 100% usage, whereas Device-1 has the Normal status with 22.3% usage. This dashboard allows the limits of the water to be updated and auto refreshes itself after every four seconds.

## CONCLUSION

Introduction of the IoT Based Smart Water Management System is an efficient technique for the real-time monitoring and automation of water consumption by the residents. It involves the use of the ESP32 controller, YF-S201 water-flow sensor, OLED display, relay, 12V solenoid valve for measuring water consumption, monitoring of set consumption limit, detecting abnormal continuous flow and automating water supply. Master-slave structure ensures the communication between several household units using Wi-Fi for the centralization of flow rate, water consumption, estimated billing, percentage of usage, leakage, and limit monitoring. All these are essential parts of smart water monitoring and water automation.[1], [4], [6], [9].

It can be seen that the developed prototype highlights the implementation of IoT technology to save water waste and raise awareness regarding the amount of water usage in households. The automatic control valves are another level of safety that comes into action in case of abnormal water flow or crossing the predefined limits of water usage, whereas the dashboard makes it easier to monitor different users simultaneously. This system can be further enhanced by adding some more features like large-scale implementation, sensing technologies, communication and data analysis. [3], [8], [10], [15].

## FUTURE SCOPE

Further enhancements can be made to this system by incorporating a monitoring system and application that run on the cloud. This will enable the user to get access to the consumption details, billing data, leakage information, and past usage details in real-time from remote locations. It can also include sending messages through SMS or WhatsApp regarding leakage or exceedance of the limit on consumption. [6], [9].

The system can also incorporate machine learning based predictions on water usage and leakage detection through the use of water usage trends, pressure sensors, and multiple flow sensors. Another enhancement that will make the system more functional is the incorporation of slab metering billing and water tank level sensing. In order to scale up the system for larger implementations, the system can be designed for apartment buildings and even smart cities. [2], [10].

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