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Design of IOT Based Smart Water Consumption Monitoring and Billing System for Apartments

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Abstract— *In apartment complexes, shared water resources often lead to challenges in accurate water billing and effective data management. To tackle these issues, this paper proposes an electronic water system tailored for apartment residents. The system continuously monitors individual water consumption using water flow sensors and employs an ESP8266 microcontroller to calculate and alert users of excess water consumption. Additionally, the system utilizes cloud storage via a Wi-Fi module to securely store consumption data and facilitate convenient access from anywhere in the world. The data, like the quantity of extra water consumed and charges for that extra water, is stored in a cloud using the Wi-Fi module. Additionally, residents may track their individual water consumption, set usage targets, receive alerts about aberrant usage, and access personalized recommendations for water conservation via the system's user-friendly web- based interface or mobile-application.*

Keywords— *Internet of Things (IOT),Water Consumption Monitoring,Water Flow Sensor, Solenoid Valve, GSM Module, Automation*

I. INTRODUCTION

The management of water resources is a critical concern in urban environments, particularly in the context of apartment complexes where large populations reside in close proximity. With the rising demand for water due to population growth, their individual water usage, receive personalized recommendations for conservation, and set goals for reducing consumption, while apartment managers can track overall usage, detect leaks or abnormal patterns, and optimize resource allocation accordingly.

This study centers on developing and executing a water consumption monitoring and management system based on IoT technology, specifically designed for apartment buildings. Traditional water billing systems often rely on manual meter readings and periodic inspections, which are labor-intensive, prone to errors, and do not provide real-time insights into water usage patterns. In contrast, the proposed IoT system leverages advanced sensor technologies, wireless communication protocols, and data analytics to enable real-time monitoring, analysis, and optimization of water consumption within apartment complexes.

At the heart of the system are smart water meters equipped with sensors that capture detailed information about water usage, including flow rates, volumes, and timestamps. These smart meters are strategically deployed at various points throughout the apartment complex, such as individual units, common areas, and main water supply lines, to ensure comprehensive coverage and accurate monitoring of water usage.

[1] The collected data from the smart meters is

transmitted wirelessly to a central server or cloud-based platform, where it is processed, analyzed, and visualized in real-time. Advanced data analytics techniques, including machine learning algorithms, are employed to identify patterns, anomalies, and trends in water consumption, thereby enabling proactive management strategies and timely interventions.

Furthermore, the IoT system incorporates a user-friendly interface, such as a web-based dashboard or mobile application, which provides residents, apartment managers, and maintenance staff with access to relevant information and functionalities.

A. Literature Survey

The proposed design addresses the challenges related to overflow, excessive utilization, water acquisition, and ensures proper water distribution. [3]

A Smart Meter for Water Utilization using IoT has been introduced in this study to calculate the flow rate and amount of water consumed by households. The data is then sent to the cloud for monitoring water consumption. [4]

Furthermore, this research paper covers aspects such as demand management, asset management, and leakage management in the water management system.

[5]The Smart Water Monitoring System using IoT presents a cost-effective solution for real-time monitoring of water quality and quantity. The system consists of various sensors to measure the physical properties of water, with data being stored and analyzed on a cloud server for future research and development. A cloud server was configured as data saving and analysis. This data can be used in future research and development. [6]

In another study, the authors analyzed the transition to a water-metering based system to assess its impact on household consumers. Short-term effects were studied in a single urban area with available data, while long- term effects were examined using a dataset of water utility level observations. The results showed a significant decrease in water usage compared to the normative water consumption of 200–250 liters per person per day. Additionally, a general framework for the classification of residential water demand modeling was developed by the authors in a separate study.

IoT Applications in Water Management:

- [7]Numerous studies have highlighted the potential of IoT technology in revolutionizing water management practices. IoT-based solutions have been proposed for various applications, including water quality monitoring, leak detection, irrigation control, and water consumption management.

2. *Smart Water Metering Systems:*

-[8] Smart water metering systems have emerged as a key component of IoT-enabled water management solutions. These systems utilize sensors and communication technologies to collect real-time data on water usage, enabling more accurate billing, leak detection, and conservation efforts.

3. *Water Consumption Monitoring in Apartment Complexes:*

-[9] Several researchers have explored the challenges and opportunities associated with monitoring water consumption in apartment complexes. These studies emphasize the importance of accurate data collection, resident engagement, and proactive management strategies in achieving water conservation goals.

4. *Wireless Sensor Networks for Water Management:*

- [10]Wireless sensor networks (WSNs) have been widely adopted for monitoring and managing water resources. These networks consist of spatially distributed sensors that communicate wirelessly to collect data on various parameters such as water flow, quality, and temperature.

5. *Data Analytics and Machine Learning in Water Management:*

- Data analytics techniques, including machine learning algorithms, play a crucial role in extracting insights from the vast amounts of data generated by IoT- enabled water management systems.[11]These techniques can be used to identify patterns, anomalies, and correlations in water consumption data, thereby informing decision-making and optimization efforts.

6. *Case Studies and Implementations:*

- Several case studies and real-world implementations of IoT-based water management systems in apartment complexes have been documented in the literature.

[12]These studies provide valuable insights into the design, implementation challenges, and performance evaluation of such systems in diverse urban environments.

7. *Challenges and Opportunities:*

-[13] Despite the potential benefits of IoT-based water management systems, there are various challenges that need to be addressed, including data privacy concerns, interoperability issues, infrastructure limitations, and stakeholder engagement. Addressing these challenges requires interdisciplinary approaches and collaboration between researchers, policymakers, and industry stakeholders.

8. *Future Directions:*

- The literature suggests several avenues for future research in the field of IoT-based water management for apartment complexes. [13]These include the development of advanced sensor technologies, integration with smart building systems, optimization of data analytics algorithms, and evaluation of the socio-economic impacts of such systems.

In summary, the existing literature provides valuable insights into the potential of IoT technology for monitoring and managing water consumption in apartment complexes. By building upon the findings and methodologies presented in these studies, this research project aims to develop a comprehensive IoT- based water consumption monitoring and billing system tailored specifically for the needs of apartment residents and managers.

II. METHODOLOGY

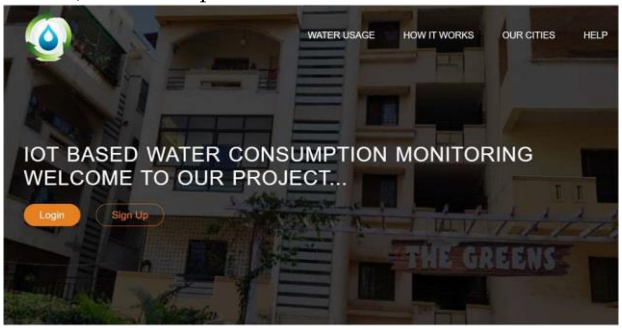
The setup is implemented within individual flats or houses in an apartment complex. The upper tank's solenoid valve is linked to a flow sensor, with the sensor's data pin connected to a Node-MCU for water flow monitoring. If water consumption exceeds 1000 liters, the solenoid valve shuts off, stopping the water flow. After 24 hours, the valve automatically reopens. Our project proposes a solution for efficient water usage using a water flow sensor and interfacing it with a Node MCU microcontroller, which runs Arduino code. The Arduino software calculates the water flow rate, displays the results on a serial monitor, and transmits the data to the cloud for customer monitoring. We will follow certain steps for successfully achieving required output.

1. User Requirements Gathering:

- Conduct interviews, surveys, or focus groups with stakeholders including apartment managers, residents, and maintenance staff to understand their requirements and preferences for the website.
- Identify key features and functionalities desired by users, such as real-time monitoring, usage analytics, leak detection alerts, and user-friendly interface.

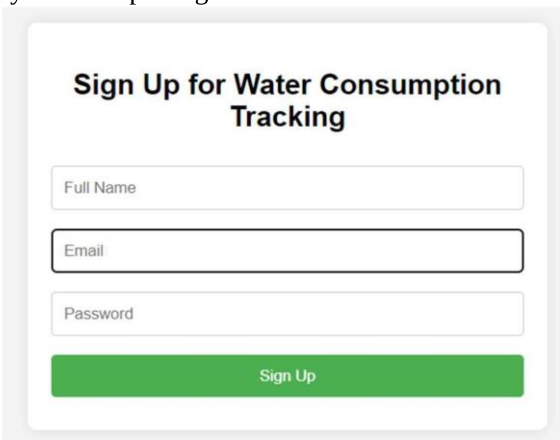
2. User Interface (UI) Design:

- Develop wireframes and mock-ups to visualize the layout, navigation, and design elements of the website.
- Design an intuitive and user-friendly interface that allows users to easily access and navigate through different sections of the website.
- Ensure responsiveness and compatibility with various devices, including desktops, laptops, tablets, and smartphones.



3. Database Design:

- Design the database schema to store relevant data related to water consumption, user accounts, apartment configurations, and historical usage records.Define appropriate tables, fields, and relationships to efficiently manage and retrieve data for analysis and reporting.



4. System Architecture:

- Define the overall architecture of the website, including server-side components, client-side scripting, and integration with IoT devices.

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- Determine the technologies and frameworks to be used for front-end development (e.g., HTML, CSS, JavaScript) and back-end development (e.g., Node.js, Python, PHP).
- Consider cloud-based solutions for hosting the website and managing data storage and processing.

5. Integration with IoT Devices:

- Establish communication protocols and APIs for integrating the website with IoT devices, such as smart water meters and sensors.
- Implement data collection mechanisms to receive real-time updates and readings from IoT devices regarding water usage, flow rates, and anomalies.
- Ensure secure and reliable transmission of data between the website and IoT devices, considering factors such as encryption, authentication, and error handling.

***6.** Feature Implementation:*

- Develop the core features of the website, including:
- Dashboard: Displaying real-time water consumption metrics, usage trends, and alerts.
- User Profiles: Allowing users to create accounts, customize settings, and view their individual usage statistics.
- Notifications: Sending notifications and alerts to users regarding abnormal usage patterns, leaks, or maintenance issues.
- Analytics: Providing data visualization tools and reports to analyze water consumption patterns and identify areas for optimization.

By following this design methodology, we can systematically design and develop a user-friendly website to control and monitor water consumption in apartments, leveraging IoT technology to promote efficient water management practices and enhance sustainability.

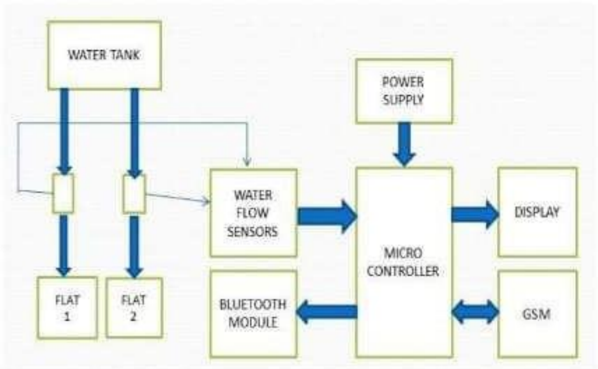

Figure 1: Block diagram of water metering system

III. SCHEMATICS ANALYSIS

The schematic diagram of the proposed work is as shown in fig. 2.

The entire work consisted of two parts, one is hardware & another is software.

The hardware part has 3 ESP8266(Node-MCU) which helps on demonstrating for three different apartments comparing each one at the same time.

One GSM module for continuously sending message alert on mobile phone about the consumption of water. The water consumption parameters are checked one by one and updated in the cloud server as well as the values are displayed in the website.

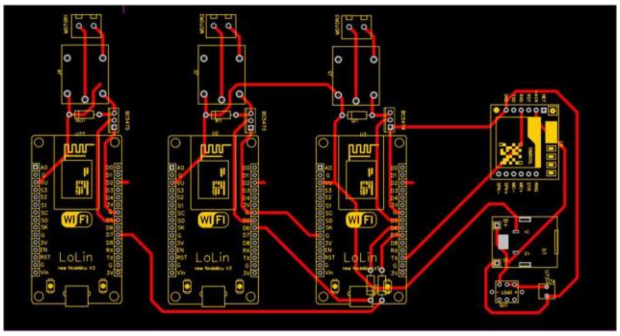

Fig. 2. Schematics

A. Discussion

Due to the limited drinking water resources, intensive money requirements, growing population, urban change in rural areas, and the excessive use of sea resources for salt extraction has significantly worsened the water available to people. A smart water consumption monitoring system is an essential device which monitors the consumption and wastage of water continuously. Fig.3 shows the working of smart water consumption monitoring system.

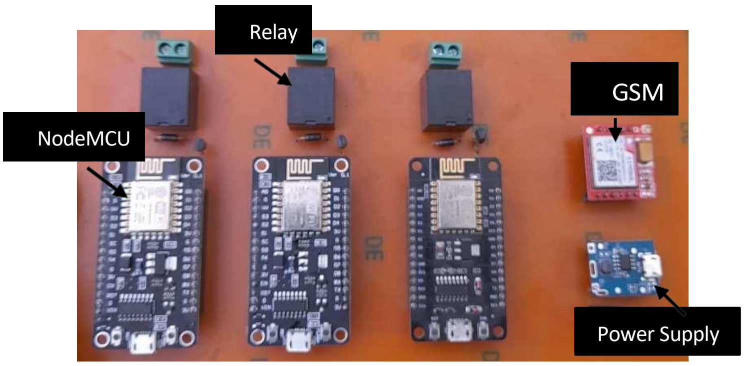

Fig. 4 Actual PCB designed

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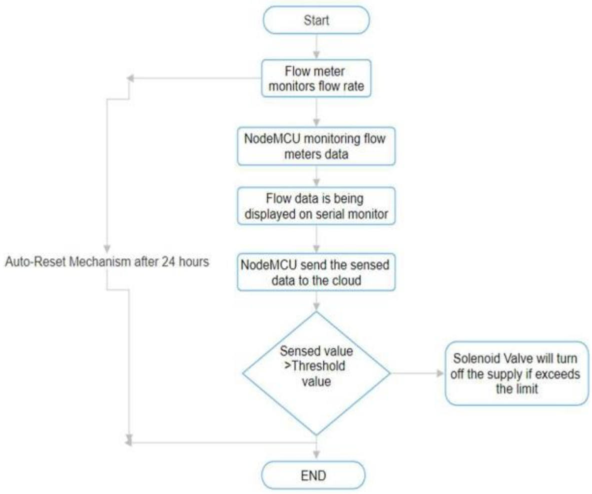


Fig.3 Working of Smart Water Consumption monitoring system

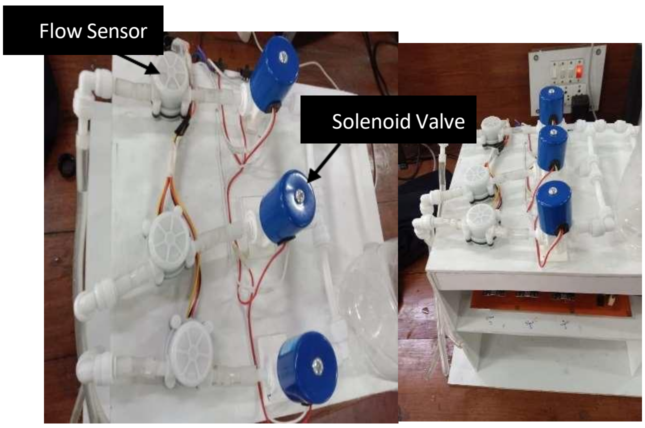


Fig. 5. Developed model of smart water quality monitoring system

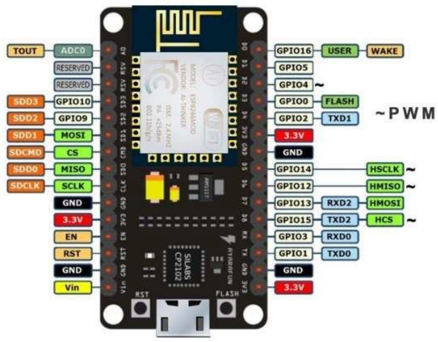
IV. COMPONENTS USED

1. **Water Flow Sensor:** The water flow sensor is positioned within the pipeline that links to theUpper tank, accurately gauging the water's flow rate.

This sensor aligns with the water line and incorporates a pinwheel sensor to quantify the liquid's movement. Additionally, it features an integrated magnetic hall effect sensor, generating an electrical pulse for each revolution. Flow sensors utilize acoustic waves and electromagnetic fields to assess the flow within a specific area based on physical parameters like acceleration, frequency, pressure, and volume. These sensors are robustly built, delivering a digital pulse whenever water traverses through the pipe.

2. Microcontroller ESP8266(Node-MCU):

The device we're utilizing is referred to as "Node-MCU," equipped with an ESP8266 module, which we'll program for our purposes. It comes pre-installed with the latest version of MicroPython and includes all the necessary drivers we'll require.



Espressif's ESP8266EX offers a fully integrated Wi-Fi System-on-Chip (SoC) solution designed to meet the ongoing requirements of users in the Internet of Things (IoT) industry, prioritizing efficient power usage, compact design, and dependable performance. Equipped with comprehensive Wi-Fi networking capabilities, the ESP8266EX can function independently or as a subordinate to a host MCU. In standalone mode, the ESP8266EX swiftly boots up from flash memory. Moreover, its integrated high speed cache enhances system performance and optimizes memory usage.

3. GSM MODULE :

Regarding the GSM module, it is a miniature GSM/GPRS breakout board built around the SIM800L module. It supports quad-band GSM/GPRS networks and facilitates remote transmission of GPRS and SMS

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message data.

The device boasts a compact design and minimal power consumption. Through efficient power-saving techniques, its current usage can drop to as little as 1mA when in sleep mode. It communicates with a microcontroller via a UART port and supports various commands, including 3GPP TS 27.007, 27.005, and SIMCOM enhanced AT Commands.

A. Features

- Quad-band 850/900/1800/1900MHz
- Connect onto any global GSM network with any 2G SIM (in the USA, T- Mobile is suggested)
- Make and receive voice calls using a headset or an external 8 speaker and electret microphone.
- Send and receive SMS messages Send and receive GPRS data (TCP/IP, HTTP, etc.) Scan and receive FM radio broadcasts.

4. SOLENOID VALVE:

A solenoid valve is a valve that operates using electromechanical principles. Solenoid valves vary in terms of the electric current they employ, the strength of the magnetic field they produce, the method they utilize to control fluid flow, and the type of fluid they manage. The valve's mechanism ranges from linear action, such as plunger-type or pivoted-armature actuators, to rocker actuators. It can employ a two-port design to regulate flow or a three or more port design to switch flows between different ports. Multiple solenoid valves can be grouped together on a manifold for coordinated Control.

V. RESEARCH GAP

Based on the analysis of other research papers, we have noticed that very few are thinking about IOT based smart water management and monitoring. As there many researches had conducted on how to monitor the quality of water.

In 2024 we are facing huge water crisis in the well-developed metro cities like Bangalore and many more, continuing in this speed we will definitely left with no pure water.

Our research specifically focuses on integrating IoT devices like Node-MCU ESP8266 and relays to automate the process of monitoring consumption of water for all apartments and buildings through our website. This emphasis on IoT integration for real-time monitoring and control of water supply through our website represents a significant research gap addressed in our paper.

There are several areas where potential research gaps can be identified:

1. **Limited Focus on IoT Integration for Water Management in Apartments:** While there is existing literature on IoT applications in water management, there is a gap in research specifically addressing the integration of IoT devices for real-time monitoring and control of water consumption within apartment complexes. Our research paper fills this gap by proposing a system that utilizes IoT technology to monitor water usage in individual apartments and optimize overall consumption at the building level.

2. **Scalability and Adaptability of IoT Solutions:** Many existing studies on IoT-based water management focus on individual homes or small-scale implementations. However, there is a lack of research addressing the scalability and adaptability of such systems for larger residential complexes like apartment buildings. Our research paper contributes to this gap by proposing a scalable solution that can be implemented across multiple apartments within a single building, potentially paving the way for broader adoption in densely populated urban areas.

3. **Evaluation of User Engagement and Behaviour Change:** While our paper mentions the provision of a user-friendly interface for residents to monitor their water consumption and receive personalized recommendations, there is a research gap in evaluating the effectiveness of such features in promoting behaviour change and fostering sustainable water usage habits. Future research could focus on conducting user studies or surveys to assess the impact of the proposed system on residents' awareness and attitudes towards water conservation.

4. Security and Privacy Concerns in IoT-enabled Water Management: With the increasing reliance on IoT devices for monitoring critical infrastructure like water supply systems, there is a growing concern regarding the security and privacy risks associated with these technologies. Further research could investigate methods for enhancing the cybersecurity of IoT-enabled water management systems, ensuring data integrity, confidentiality, and protection against potential cyber threats.

5. Integration with Existing Building Infrastructure: Our research paper outlines the hardware components and system architecture for implementing the proposed IoT-based water management system. However, there is a research gap in exploring the challenges and opportunities associated with integrating such systems with existing building infrastructure, including plumbing systems, water distribution networks, and building management systems. Future research could address these integration challenges to facilitate seamless deployment and operation of IoT-enabled water management solutions in apartment buildings.

By addressing these research gaps, future studies can further advance the field of IoT-based smart water consumption monitoring and billing systems, ultimately contributing to more sustainable and efficient use of water resources in urban environments.

VI. RESULT

- Reduced Water Consumption: By providing real-time data on water usage and personalized recommendations, the system can encourage residents to adopt water-saving habits. Analyze data from our pilot implementation to quantify the percentage reduction in water consumption achieved compared to traditional meter reading systems.
- Leak Detection Accuracy: The system's ability to detect leaks promptly can significantly reduce water wastage. Evaluate the effectiveness of our leak detection algorithms in identifying leaks of different sizes and at various locations within the apartment complex.
- User Engagement and Satisfaction: A user-friendly interface is crucial for resident adoption. Conduct surveys or user studies to assess resident satisfaction with the systems usability, information accessibility, and perceived impact on their water conservation efforts.

VII. CONCLUSION

The proposed electronic water consumption monitoring system offers an efficient solution to address water billing challenges in apartment complexes. By providing real-time monitoring, alerts for excessive consumption, and secure cloud storage, the system enhances data accuracy, transparency, and accessibility. Future enhancements may include integration with billing systems and predictive analytics for proactive water management. Reiterate the importance of water conservation and the limitations of traditional water management systems. Highlight the key features and functionalities of our proposed IoT-based system. Summarize the potential results discussed earlier, emphasizing the positive impact on water conservation, leak detection, and user engagement.

Conclude by acknowledging the research gaps we

identified and propose future research directions. This could include exploring advanced data analytics for more granular insights into water usage patterns, investigating cost-effective methods for wider system adoption, or researching strategies for integrating the system with smart building technologies for a more holistic approach to resource management. By providing a clear and well-supported conclusion, we can leave a lasting impression on our readers and emphasize the potential of our research to contribute to sustainable water management practices in apartment buildings.

VIII. ACKNOWLEDGEMENT

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We extend our gratitude to the authors and researchers whose work has been referenced in this paper. Their contributions to the field of IoT-based water management have provided valuable insights and served as a foundation for our research.

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