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IoT-Based Smart Water Monitoring, Automated Billing and Excess Flow Control System: A Review

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Abstract: ***Water conservation and its proper distribution are major problems in residential buildings and housing societies. Traditional methods of water management may involve manually reading meters, inspection, and late billing, which makes it hard to detect excessive flow and leakage quickly. The IoT facilitates connectivity between sensors, microcontrollers, communication network, database, and user interface. This review highlights fifteen research papers regarding IoT-based water monitoring, smart metering, automatic billing, flow sensing, water quality monitoring, wireless communication, and intelligent water management. These research papers focus on residential water metering, apartment billing, retrofit monitoring, pressure and flow sensing, water distribution network, and resource management strategy. There are several possibilities of integrating flat wise consumption sensing, automatic billing, excessive flow sensing, alarming, and supply control using valves into one device. The framework for such integration is suggested in this paper. The effectiveness of such framework needs to be checked experimentally through flow sensing precision, billing precision, abnormal flow sensing precision, controlling reaction time, communication efficiency, and data integrity.***

Keywords: Internet of Things, smart water monitoring, smart water meter, automatic billing, flow sensor, excessive flow detection, solenoid valve, cloud computing, water conservation.

I. INTRODUCTION

Water is an essential resource across many areas such as homes, agriculture and industry. As there is increasing pressure on water resources, improvements in monitoring systems are becoming necessary. Water consumption, billing and controlling the available supply is often handled separately in apartment buildings and communities. This causes problems in quickly getting data on water consumption, transparent billing and responding to anomalies in flow patterns.

The Internet of Things (IoT) enables devices to communicate to each other. This means data can be collected, processed, transmitted and monitored remotely. Smart water meters can be used to collect data about the amount of water used. Cloud platforms can be used to store the data and provide a web or mobile view. Research has been done into metering using IoT and cloud systems [6], billing at an apartment level [7] and Smart meters in homes [14]. This can provide useful insight into creating a water management system for homes.

Monitoring water usage can include flow and pressure within a distribution system. There has been research into using various IoT devices [9], collecting flow data [11] and monitoring water in smart cities [12], [13], [15]. These can help to identify anomalies in consumption patterns.

Simply monitoring water usage may not be enough to prevent waste. If there is consistently high flow rates, continuous flow or abrupt changes in pressure there could be an issue. A system combining flow sensing, automated billing, real time notifications and control of water supply can be used to overcome these issues.

This review looks at fifteen carefully selected research papers. Comparisons have been made between the main findings and methods. Opportunities to combine previous methods have been identified and an IoT based framework has been proposed for monitoring water, automated billing and excessive flow. References and any experimental data should be checked against the original research papers before completing this review.

II. LITERATURE SURVEY

This study covers a system to monitor the quality of water through IoT by collecting sensor data through the cloud. Methods are explored to predict water quality based on key parameters such as dissolved oxygen, pH and conductivity. This is useful for systems requiring water related data collection However, no consideration is given to flat rate billing or automation of overflows. [1]

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Methods have been explored to monitor water quality from a distance using IoT. By using sensors to collect pH and turbidity data through LoRa and cloud. This is useful to know what wireless options to use when monitoring from a distance. However, it focuses on water quality rather than volume. [2]

This study includes a billing system in a smart system to monitor and manage water quality. It is extremely relevant as it links water measurement to billing. [3]

This paper discusses smart metering using IoT and cloud computing (IoT and Cloud Computing based Smart Water Metering System). [6] This type of system is ideal for sending data to a central hub and recording accurate usage. This paper discusses a smart billing system for apartments (Smart Water Billing System for Apartments). [7] This is directly relevant to the project as it is looking at residential billing. This research discusses smart metering and water management (IoT based Smart Water Meter for Water Management).[8] From the title it seems relevant to the project as it is discussing measurement. However more information would be required from the full paper to confirm the devices, methods and results. This paper discusses a smart water meter for domestic use (IoT Based Smart Water Meter for Domestic Utility). [14] This is extremely relevant to this project as it is considering using a system in a house. The system will need to give accurate readings, clear usage and be usable in a house/apartment.

This paper discusses using heterogeneous IoT devices in a water system (Considerations on the Deployment of Heterogeneous IoT Devices For Smart Water Networks). [9] This is an important factor to consider if multiple different sensors, controllers and communication types are being used. Factors such as compatibility, coverage, and maintenance must be considered.

This study discusses pressure and flow monitoring in a smart water system (Smart Water Management: A Self-Sufficient IoT-Based Application for Pressure and Flow Monitoring in Water Distribution Systems). [15] Flow and pressure sensors can help monitor a water network. However whether the design fits a residential flat would need to be looked into.

This paper discusses flow measurement in a smart city (IoT Based Smart Flow Meter For Smart Cities). [10]

This study discusses high resolution flow data collection from taps (High-Resolution Tap-Based IoT System for Flow Data Collection and Water End-Use Analysis). [11] This can help identify different types of consumption. This provides a base for identifying unusual consumption. The accuracy and sample rate of the chosen sensor should be confirmed that it will work in the expected conditions. This paper discusses analysing consumption behaviour using a smart retrofit meter (Behavioural Analysis of Water Consumption Using IoT-Based Smart Retrofit Meter).[13] Retrofit meters are useful if the current water system needs monitoring. Looking at historical consumption data may help identify typical consumption.

This publication [12] outlines IoT enabled water monitoring systems for smart cities using retrofitted and solar harvesting systems. This will be useful in environments where energy is an issue and there is a high cost in replacing the current equipment.

Table 1: Comparison of Reviewed Research Papers

Ref.	Research Area	Project Relevance
[1]	Water quality monitoring and forecasting	Sensor data and cloud analysis
[2]	Long range water quality monitoring	Wireless communication
[3]	Water monitoring and smart billing	Billing and supply management
[4]	Energy demand side management	General control principles
[5]	Energy scheduling in buildings	Historical usage analysis
[6]	IoT and cloud based water metering	Remote metering and storage
[7]	Apartment water billing	Flat wise billing requirements
[8]	Smart metering and water management	Consumption monitoring
[9]	Heterogeneous IoT water networks	Device integration
[10]	Smart city flow metering	Flow measurement
[11]	Tap-based flow data collection	Detailed usage analysis
[12]	Retrofit and solar-powered monitoring	Retrofit and energy planning
[13]	Retrofit metering and consumption behavior	Usage pattern analysis
[14]	Domestic smart water metering	Residential deployment
[15]	Pressure and flow monitoring	Distribution system monitoring

Chauhan and Chauhan [4] explored demand side management in buildings to reduce high peak energy demands. Whilst this was focused on electrical energy, the general principles can be used to devise adaptive resource control rules based on measured demand. Harb et al [5] explored smart scheduling of energy use in smart buildings. Whilst this looked into using resources and scheduling, the results do not reflect the performance of water systems. Overall, the publications cover a number of different areas related to smart metering, billing, flow and pressure monitoring, water network monitoring, cloud communication, consumption analysis and resource control. In order to combine all these features into one residential water management system further design work and rigorous experimentation will be needed.

III. COMPARATIVE ANALYSIS

A brief comparison of all fifteen papers is represented in Table 1.

Although each paper has a different objective, they can not be assessed quantitatively unless their methodologies and results are considered. Accuracy of the water quality sensor, flow rate, correct billing, latency and power consumption are all different performance aspects. This means that the system must be assessed separately.

A. Research Gap & Problem Statement

The literature review has identified the following opportunities for integration and evaluation:

-Integrated Monitoring System

-Consumption & Optional Quality Monitoring

-Flattened Billing

B. Flat Specific Consumption & Tariff Rules

- Excessive Flow Detection
- Continuous High Flow Detection & Leak Detection using Thresholds
- Automated Valve Control
- Valve Control with Rules & Logging
- User Information
- Display Consumption History, Billing Info, Alerts & Supply Status
- Reliable Communication
- Deal with Missing Data, Communications Issues & Inaccurate Data

C. System Evaluation

Evaluate Accuracy of Measurement, Correctness of Billing, Detection, Response Time & Reliability

The main opportunity identified is the ability to integrate all of these features together and evaluate the system. The features are an integration of the research areas identified but does not mean that all previous systems do not have these features.

D. Problem Definition

Traditional water management systems may not deliver constant flat wise data on consumption, automatic billing and rapid control of abnormal flows. Due to manual collection there may be a delay in identifying any problems such as leaks and high usage. This project will deliver a solution that automatically measures, records and calculates water bills. It will inform users of any abnormal situations and will manage the water supply based on pre-set rules. This will be done using IoT devices and an application.

IV. PROPOSED SYSTEM

The system comprises five components:

1) Sensors – Flow sensor to measure water flow and total consumption. Optional pH and Turbidity sensors can also be added.

2) Processing – Microcontroller to process the data from the sensors. This will determine flow rate, total volume and compare against set parameters.

3) Communication and Data Storage – Communication module to send information to the database or cloud. The data will be logged using simple ID and time stamps.

4) Application Layer – Dashboard showing total consumption, billing, alerts and valve status. Administrators can set tariffs and parameters.

5) Control Layer – Suitable driver/relay to control Solenoid Valve or suitable supply based on set control parameters.

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A. *Water Monitoring and Data Collection*

The flow rate of the water is measured using a flow sensor embedded in the pipeline. Information about the sensor calibration can be used by the controller to convert sensor outputs into flow rate and total volume data. The quality of the water can also be measured optionally using pH and turbidity sensors. Relevant literature was reviewed on metering, flow analysis and monitoring which includes [2], [3], [8], [10], [11], [14], [15].

B. *Automated Billing*

These values can then be paired with the correct flat rate and billing period. For simple constant rate tariff bills can be calculated using:

Bill = Consumption Rate per kL

Additional fixed costs, taxes, or step tariffs can be applied depending on the billing policy. Data should be stored on the system which allows the user to verify their bill. Research has been done into smart billing [3][7].

C. *High Flow Detection & Valve Control*

This system will detect if the flow rate is higher than a set limit. An alert can be issued if the flow has remained above the limit for a set amount of time. This will be dependent on the valve being turned on if set to do so. A delay can also be set so that the valve does not trigger unnecessarily due to short fluctuations in flow.

The valve control should include safety rules for normal operation and manual override. All events should be logged. The automatic valve control should be tested with the chosen hardware to ensure it works reliably.

D. *Dashboard & History*

A dashboard can be provided which displays real-time flow rate, total consumption, estimated/final bill. Previous data can also be displayed, high flow alerts, and valve status. Only residents data should be visible to them, however admins can edit flat details, tariff details, and system limits. Research has been done into cloud-based metering & monitoring [1][2][6].

V. RESULTS & DISCUSSION

The system should provide real-time consumption data, accurate billing, high flow alerts, and automatic control of the supply if set conditions are met. The following should be done to evaluate the system.

All results from the reviewed papers should state they were from the experiment. The proposed system should not state any numeric accuracy, detection rates, or response times until they have been measured during testing.

VI. CONCLUSION

A total of fifteen research papers were reviewed in this review. The papers covered several areas of IoT application including water quality monitoring, smart metering, billing, flow monitoring, communication within water networks, retrofitting and resource management. Overall, the literature provides complementary approaches to residential water monitoring and automation. Papers have been found relating to smart metering and billing [3], [6], [7], [8], [14].

Papers have also been found relating to flow and network monitoring [9], [10], [11], [12], [13], [15]. Finally, papers have been found relating to water quality [1], [2], [4], [5].

The proposed project will aim to monitor flow, record consumption flat-wise, automatically bill consumers, detect excess flows, alert users and control using valves. The contribution of the project will be determined by how accurate and reliable the system is. The experimental evaluation will need to look at flow accuracy, correct billing, detecting abnormal flows, response time, reliable communications and performance during normal and abnormal operations.

VII. FUTURE WORK

The following can be added to give the system additional functionality:

- Use historical data to predict demand and identify abnormal usage.
- Introduce new rules for detecting leakage based on flow rate, time of operation and expected times of use.
- Support for more than one flat, central monitoring and variable tariffs.
- Tank level monitoring and rainwater harvesting readings.
- Improved reliability by including calibration, error messages, manual override and logging.

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- Consider retrofit installation and energy efficient operation.
- Testing the prototype over a longer period of time, using different flow rates and network conditions.

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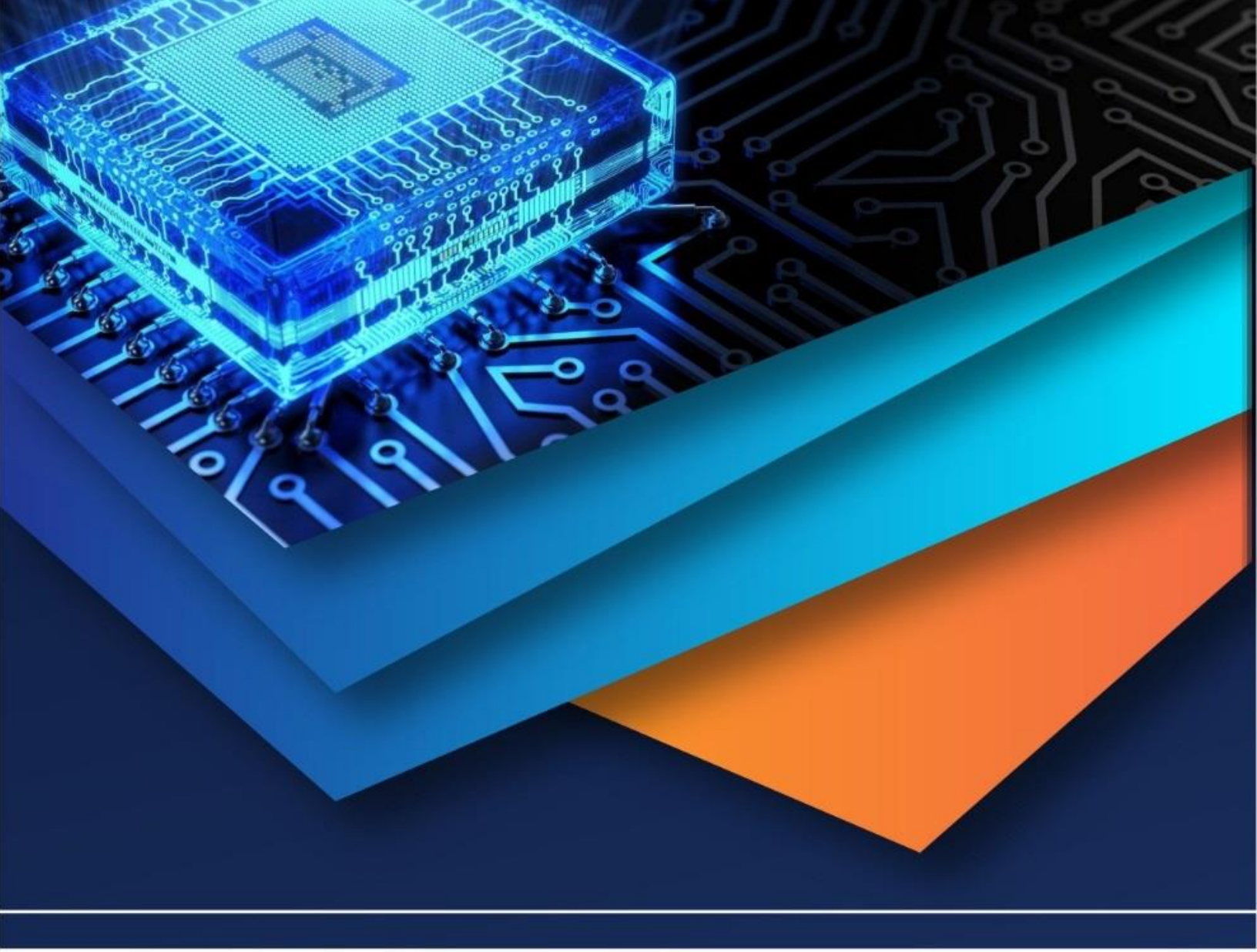

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