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Water Leakage, Unathorized Connection and Prevent Illegal Water Siphoning

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Abstract: *Water distribution systems face significant challenges due to leakage, unauthorized connections, and illegal water siphoning, leading to resource wastage and financial losses. This paper presents an IoT-enabled system that integrates flow, pressure, acoustic, and current sensors with cloud-based machine learning analytics for real-time detection and monitoring. The system uses ESP32 microcontrollers for sensor interfacing, MQTT for efficient data transmission, and Things Board for visualization. A Random Forest-based model is employed to analyze sensor data, enabling accurate detection of anomalies such as leaks, illegal motor siphoning, and unauthorized connections. The system also monitors pressure levels at the tail end of the distribution network to prevent supply inefficiencies. Experimental results demonstrate high detection accuracy and real-time anomaly alerts, making this solution cost-effective and scalable.*

Keywords: Water distribution

I. INTRODUCTION

Water distribution networks worldwide face significant challenges due to leakage, unauthorized connections, and illegal siphoning, leading to substantial losses in both resources and revenue. Non-revenue water (NRW), which includes water lost due to leaks and theft, poses operational inefficiencies, increases maintenance costs, and reduces the availability of clean water for consumers. Traditional leakage detection methods, such as manual inspections and periodic meter readings, are inefficient, labor-intensive, and often fail to provide real-time insights. Additionally, unauthorized connections and illegal water siphoning using motors further strain the distribution system, causing pressure imbalances that affect supply reliability.

To address these challenges, this paper proposes a smart IoT-based system integrating flow, pressure, acoustic, and current sensors for real-time monitoring of the water distribution network. The system uses ESP32 microcontrollers for sensor interfacing, MQTT for efficient data transmission, and Things Board for cloud-based data visualization. A machine learning-based anomaly detection model, specifically Random Forest, is implemented to analyze sensor data and identify irregularities indicative of leaks, unauthorized connections, and illegal siphoning. The proposed system enables early fault detection, proactive maintenance, and optimized water distribution. By leveraging IoT and AI-driven analytics, this solution aims to enhance operational efficiency, reduce water losses, and improve overall network sustainability.

II. RELATED WORK

Various techniques have been developed to detect water leakage, unauthorized connections, and illegal siphoning in distribution networks. This section reviews advanced methods, including pressure-based detection, flow anomaly analysis, current monitoring, IoT-based solutions, and machine learning for anomaly detection.

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1. Pressure-Based Detection

Pressure-based detection methods utilize pressure sensors to monitor fluctuations in the water supply network. A sudden pressure drop can indicate leakages, while unexpected spikes may point to unauthorized connections. Techniques such as Pressure Transient Analysis and District Metered Areas (DMAs) help identify problem zones. Integration with microcontrollers like Arduino Uno and IoT platforms enhances real-time monitoring, enabling early detection and reduced water loss.

2. Flow Anomaly Detection

Flow anomaly detection involves analyzing real-time water usage through flow sensors. By comparing current readings to historical usage patterns, systems can detect unexpected flow behaviors, including leaks and bursts. Arduino Uno can be programmed to read flow sensor data and transmit it via Wi-Fi modules, enabling real-time decision-making and alerts.

3. Current Sensor-Based Siphoning Detection

Illegal water siphoning using motor pumps often results in abnormal current usage. Current sensors detect these anomalies by monitoring power consumption trends. When connected to Arduino Uno, the data can be processed locally or sent to the cloud via modules like ESP8266. With proper threshold calibration, unauthorized motor use can be effectively detected.

4. Ultrasonic Sensor for Level and Pressure Estimation

Ultrasonic sensors, commonly used with Arduino Uno, measure the distance between the sensor and the water surface, allowing indirect monitoring of water levels and pressure, especially at the tail end of the distribution line. These readings help detect pressure drops due to leakage or supply issues. The non-contact nature of ultrasonic sensors makes them suitable for harsh environments and sealed systems.

5. IoT-Based Remote Monitoring

IoT integration enables remote monitoring of flow, pressure, water levels, and electrical consumption using platforms like Blynk, ThingsBoard, or ThingSpeak. Microcontrollers like Arduino Uno collect sensor data and transmit it via Wi-Fi modules for centralized analysis. This improves efficiency, reduces manual checks, and supports real-time notifications for abnormal activities such as leaks or unauthorized usage.

6. Machine Learning for Anomaly Detection

Machine learning models can analyze sensor data collected from Arduino-based systems to identify patterns associated with faults like leaks, unauthorized connections, or motor siphoning. Algorithms such as decision trees and neural networks classify anomalies with higher precision, aiding in predictive maintenance and timely responses

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TABLE: Analysis of Water Supply Monitoring and Security Systems

Platform/Study	Methodology/Technology	Features	Limitations
IoT-based Smart Water Leakage Detection System	IoT sensors, Machine Learning, Cloud-based monitoring	Real-time leakage detection, automatic alerts, remote monitoring	High initial setup cost, sensor calibration issues
Unauthorized Water Usage Detection using Flow Meters and AI	Smart flow meters, AI-based anomaly detection	Identifies unusual water consumption, detects illegal connections	False positives in detection, requires high computational power
Water Theft Prevention System using Smart Valves	IoT-enabled smart valves, RFID authentication	Prevents unauthorized siphoning, remote control of valves	Possible hacking vulnerabilities, requires stable internet connectivity
Pressure Monitoring and Leakage Identification in Water Pipelines	Wireless sensor networks (WSN), Data analytics	Monitors pressure at tail end, early leakage detection	Battery life issues in sensors, data transmission delays

Efficient water supply management is essential for ensuring proper distribution, minimizing wastage, and preventing unauthorized usage. Various technological approaches have been developed to address challenges such as leakage detection, illegal water siphoning, unauthorized connections, and pressure monitoring at the tail end of pipelines. Table 1 provides a comparative analysis of existing water monitoring and security systems based on their methodology, features, and limitations.

One of the widely used solutions is the **IoT-based Smart Water Leakage Detection System**, which utilizes IoT sensors, machine learning, and cloud-based monitoring to detect leaks in real-time and send automatic alerts. However, these systems require high initial investments and frequent sensor calibration. Another approach is **Unauthorized Water Usage Detection using Flow Meters and AI**, which employs smart flow meters and AI-based anomaly detection techniques to identify unusual water consumption patterns and detect illegal connections. Despite its efficiency, this method may generate false positives and demands high computational power.

To combat water theft, **Water Theft Prevention Systems using Smart Valves** have been developed, integrating IoT-enabled smart valves with RFID authentication to restrict unauthorized siphoning. While these systems offer remote control features, they are susceptible to hacking and rely on stable internet connectivity. Additionally, **Pressure Monitoring and Leakage Identification in Water Pipelines** using Wireless Sensor Networks (WSN) and data analytics is another effective technique. This system helps in detecting leaks and monitoring pressure fluctuations, especially at the tail end of pipelines. However, it faces challenges such as sensor battery life issues and potential data transmission delays.

A more secure and transparent approach is the **Blockchain-based Water Distribution Monitoring System**, which leverages blockchain technology, IoT, and smart contracts to ensure tamper-proof data and transparency in billing and monitoring.

III. EXISTING SYSTEM

Water distribution networks currently rely on traditional methods to detect water leakage, unauthorized connections, and illegal water siphoning. These conventional approaches include manual inspections, meter readings, pressure-based monitoring, and basic flow tracking. While these systems provide some level of monitoring, they lack real-time detection capabilities, automation, and efficiency.

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In many regions, water utilities depend on manual inspections and periodic meter readings to identify leaks or unauthorized usage. Field workers check for visible leaks and illegal tapping points, while meter readings are compared over time to detect anomalies. However, these methods are labor-intensive and inefficient, often leading to delayed responses. Since small leaks and hidden unauthorized connections do not always produce noticeable changes in consumption, they can go undetected for extended periods, resulting in significant water losses.

Pressure-based monitoring is another common approach used in water distribution networks. Utilities install pressure sensors at strategic locations to track pressure fluctuations. A sudden drop in pressure may indicate a leak, while an unexpected increase can suggest unauthorized siphoning. While this method provides better automation than manual inspections, it has limitations in detecting small leaks, especially in low-pressure zones. Additionally, pressure-based monitoring requires optimal sensor placement to ensure comprehensive coverage, which is not always feasible in large or complex distribution networks.

Flow monitoring systems offer another approach to detecting leaks and unauthorized usage. By tracking water consumption at various points in the distribution system, abnormal flow patterns can indicate potential issues. However, this method often relies on historical data comparisons, making real-time detection challenging. Small or slow leaks may not cause significant deviations in flow rates, leading to delayed detection. Moreover, flow monitoring alone cannot distinguish between leaks and unauthorized siphoning without additional sensor integration.

A major limitation of existing systems is their isolated operation. Most detection methods focus on a single aspect of water loss rather than integrating multiple sensor inputs for a more comprehensive analysis. The absence of real-time, IoT-enabled monitoring and data-driven decision-making further restricts proactive maintenance and predictive analytics.

IV. PROPOSED SYSTEM

To address the limitations of existing methods for detecting water leakage, unauthorized connections, and illegal water siphoning, an advanced IoT-based system is proposed. This system integrates multiple sensors, machine learning algorithms, and cloud-based analytics to provide real-time monitoring and intelligent decision-making. By combining flow sensors, Ultrasonic Sensor, Arduino UNO with IoT technology, the proposed system ensures accurate anomaly detection and automated response mechanisms.

The system incorporates flow sensors at key points in the water distribution network to continuously measure flow rates. By analyzing deviations from expected flow patterns, the system can identify irregularities caused by leaks or unauthorized water withdrawals. Flow data is transmitted to a central cloud platform, where machine learning algorithms analyze historical and real-time readings to detect anomalies. This approach enhances the detection of even minor leaks that might otherwise go unnoticed.

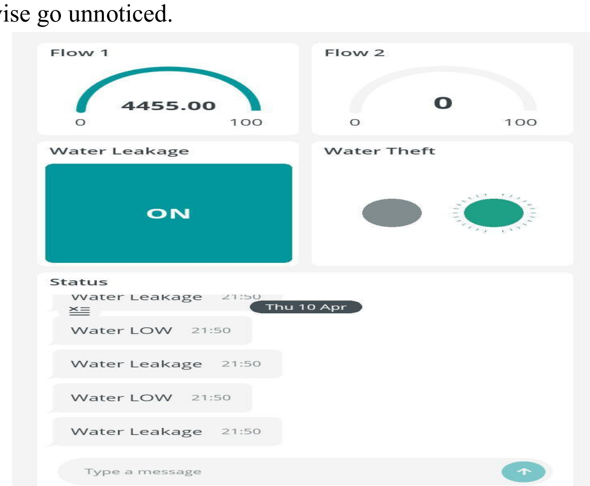

Figure 1: System measures flow rate

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A machine learning-based anomaly detection model, specifically using a Random Forest algorithm, is integrated into the system to improve detection accuracy. The model is trained on historical sensor data, enabling it to identify patterns associated with normal and abnormal water usage. By continuously learning from new data, the model enhances its ability to detect leaks, unauthorized connections, and illegal siphoning more accurately over time. This predictive capability allows for proactive maintenance, reducing water losses and preventing infrastructure damage

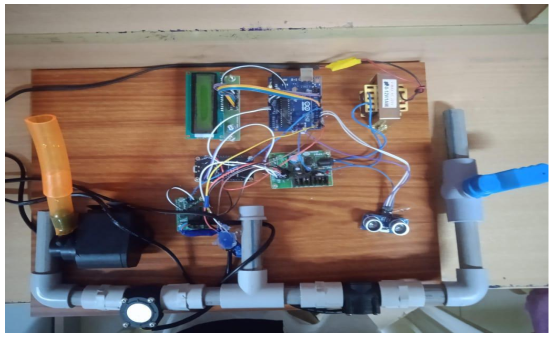

Figure 2: Prototype for Water Leakage Detection

Additionally, the system can be configured to automatically shut off affected pipeline sections to prevent excessive water loss in case of major leaks.

The proposed system significantly enhances water distribution management by integrating multiple sensor technologies with IoT and machine learning capabilities. It provides a real-time, scalable, and cost-effective solution for identifying leaks, preventing illegal water siphoning, and ensuring efficient resource utilization. By enabling proactive maintenance and automated response mechanisms, the system reduces non-revenue water losses and enhances the sustainability of water distribution networks.

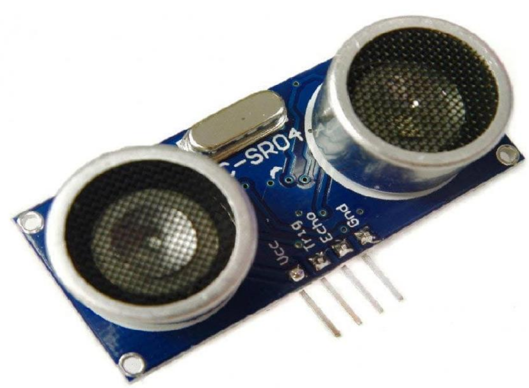

Figure 3:UltrasonicSensor(HC-SR04)

In the development of a smart water distribution monitoring system, the ultrasonic sensor (HC-SR04) plays a vital role in accurately detecting water levels and flow irregularities. This sensor works by emitting ultrasonic waves and measuring the time it takes for the echo to return after hitting a surface, which allows it to calculate the distance between the sensor and the water surface. When installed at strategic points such as overhead tanks, underground reservoirs, or tail-end locations of the water distribution line, it helps monitor real-time water levels and detect anomalies. By analyzing sudden drops or irregular changes in water level, the system can identify potential leakage points in the pipeline.

Additionally, if water levels drop at an unusual rate without corresponding usage, it may indicate unauthorized connections or illegal siphoning using motors. The ultrasonic sensor helps detect such suspicious activities by

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monitoring inconsistent flow rates or rapid water withdrawal. These readings can be fed into a central microcontroller or IoT platform for continuous analysis. If abnormal patterns are detected, alerts can be automatically sent to the concerned authorities. The data collected by the sensor also helps in understanding consumption patterns and pressure variations in the system, especially at the tail end, where pressure is usually lower.

Using this sensor reduces the need for manual inspections and enables remote monitoring, making the system more efficient and responsive. The HC-SR04 sensor is cost-effective, easy to integrate with microcontrollers like Arduino or NodeMCU, and provides reliable distance measurement with high precision. It operates at low power and can be installed in confined spaces, making it suitable for distributed water systems. Its real-time feedback allows the system to take corrective actions such as shutting off valves or notifying maintenance teams. Thus, the ultrasonic sensor is a key component in building an intelligent and automated water distribution monitoring system that ensures water conservation and operational safety. It not only prevents loss of water but also ensures fair and legal usage of the resource.

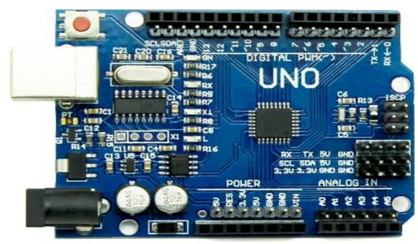

Figure 4: Arduino UNO

The **Arduino UNO** is a powerful microcontroller board that serves as the central processing unit in our smart water distribution monitoring system. It acts as the brain of the system, receiving data from multiple sensors, processing the input, and making real-time decisions. To identify water leakage, the Arduino UNO collects readings from ultrasonic sensors placed in tanks or pipelines. By continuously measuring water levels and flow rates, the system can detect sudden drops that may indicate leakage or pipe damage. Similarly, if there is unauthorized tapping of the pipeline, the abnormal flow pattern is detected, and the Arduino triggers an alert.

For preventing illegal water siphoning using motors, the system relies on detecting rapid and unusual drops in water levels, which the Arduino can identify by comparing real-time data with predefined thresholds. When such activity is found, it can activate a buzzer or send a notification through a communication module like GSM or Wi-Fi. Moreover, pressure sensors connected to the Arduino UNO can monitor the pressure levels at the tail end of the distribution line. If the pressure falls below normal, it may indicate blockages, leakage, or misuse. These sensor values are analyzed and compared using simple programming logic on the Arduino platform.

The board is ideal for this application because it supports multiple digital and analog inputs, has low power consumption, and is compatible with various sensors and modules. It also allows for automation of processes like valve control, thereby enhancing the efficiency of water usage. The Arduino UNO supports easy coding through the Arduino IDE and can be programmed to perform multiple checks at once. Overall, the Arduino UNO makes the system cost-effective, reliable, and adaptable, playing a crucial role in smart water management and ensuring transparency and accountability in distribution.

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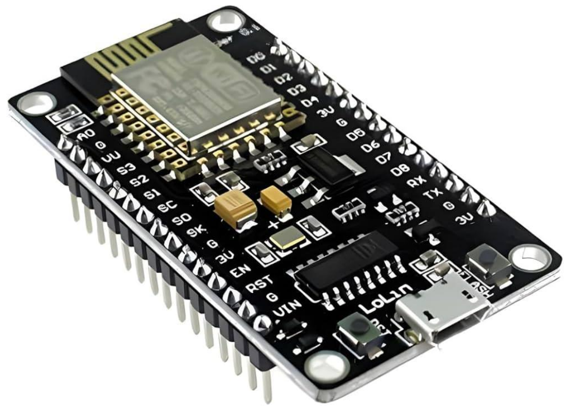

Figure 5: ESP 32 Node MCU Module

NodeMCU is an open-source IoT platform widely used in water leakage detection systems. Based on the ESP8266 Wi-Fi system-on-chip, this microcontroller offers seamless wireless connectivity for real-time monitoring applications. It enables continuous data transmission from remote sensors, ensuring efficient water management. The board features multiple GPIO pins for interfacing with various sensors, such as water flow, pressure, and vibration sensors. Its compatibility with the Lua scripting language allows for flexible programming, while users can also program it using the Arduino IDE.

In water leakage detection systems, NodeMCU collects data from integrated sensors and continuously monitors sensor inputs to establish normal water flow patterns. By comparing current readings against predefined threshold values, it can detect significant deviations that may indicate potential leaks. Upon detecting an anomaly, the system immediately processes the alert and initiates a warning procedure, which may include sending SMS or email notifications.

Additionally, NodeMCU can update web dashboards with real-time data, enabling remote monitoring from any location.The platform's low-cost, compact design makes it ideal for widespread deployment, while its energy efficiency ensures reliable operation in continuous monitoring systems. It supports multiple sensor inputs simultaneously without compromising performance and processes sensor data quickly and accurately

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