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Multi-Sensor IOT-Based Smart Water Monitoring System with Real-Time Leakage and Hazard Detection

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Abstract
Water management should be efficient since it assists in reducing water wastage while at the same time ensuring sustainable water consumption in the household and industries. The project works out the system of the Internet of Things that monitors and regulates water resources by means of its smart water monitoring system that runs on the ESP32 microcontroller and provides real-time data about water level, consumption, water quality, and safety. The system works on the principle of an ultrasonic sensor that identifies the level of water in the tank that triggers the pump motor by a relay module to prevent overflow and dry running conditions of the tank. The YF-S201 flow sensor is used to monitor the use of water and identify its leaks by using its capability to detect the abnormal pattern of water flow, which is never supposed to be happening in a system when it is not in use. The system employs a TDS sensor to check the quality of water by determining the level of impurities in water. The system has MQ2 and MQ4 sensors that detect gas and methane leakages to improve safety during operations near the water storage tank. The ESP32 board collects sensor information that it transmits via Wi-Fi to a cloud dashboard that can be used to monitor the device remotely and create alarm systems. The system automates the functioning of the motors by utilizing its decision logic that makes use of preset thresholds in detecting water leaks. The system integrates three technologies in its sensing and automation system and cloud connection feature that form a cost-effective system of managing water resources in intelligent systems. As demonstrated in the system implementation, various sensor Internet of Things systems are capable of enhancing efficiency and reducing water losses by ensuring the water storage and distribution systems are safer.

Keywords: *IOT, ESP32, Smart Water Monitoring, Leakage Detection, Flow Sensor.*

1. Introduction
The effective management of water resources is necessary for sustainable development since water is an essential natural resource. Due to urban development and population growth and climate change, there is an increasing need for sophisticated water monitoring solutions in municipal water distribution systems. The current water management systems need the operator to monitor the water system manually, thus creating an ineffective system that takes more time to operate and creates wastage of water unnecessarily. Water management systems leverage Internet of Things (IOT) technology to enable real-time monitoring and automated operations through sensor networks and cloud-based connectivity. The ESP32 microcontroller is used in this system. It has an ultrasonic sensor to monitor the water level, which is a tank level indicator. For monitoring the quality of water, a TDS sensor is used. Furthermore, a flow sensor is used to monitor the consumption of municipal water via a pipeline. The MQ2 and MQ4 sensors are used to determine if there is a gas leakage of any sort around the water storage area. The system transmits sensor readings to the cloud so that users can do remote monitoring and monthly analysis of water usage.

2. Literature Survey (12 Pt)

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Scientists The latest developments in Internet of Things (IOT) technology have created smart water monitoring and management systems that boost operational effectiveness and secure public safety while supporting sustainable practices. Researchers performed investigations into water management systems that employed sensors for monitoring and automated operational processes that operated through cloud connectivity. An IOT-based water management system using sensor networks for monitoring water usage and storage conditions was presented in [1], demonstrating how real-time monitoring can reduce water wastage. Smart water metering combined with leakage detection techniques using IOT communication modules was discussed in [2], where abnormal flow detection was used to identify possible pipeline leakage conditions. Water quality monitoring using IOT sensors was studied in [3] and [5], where parameters such as dissolved solids and impurities were measured and transmitted to cloud platforms for remote monitoring. These systems showed that continuous water quality analysis improves safety in domestic and industrial water supply systems.Automation of water flow control using relay-based pump control systems was explained in [4], where automatic motor operation was implemented based on sensor feedback. Similarly, an ESP32-based smart water monitoring system integrated with cloud dashboards was proposed in [6], highlighting the importance of wireless connectivity for remote supervision and alert generation.IOT-based resource management systems integrating monitoring, control, and communication technologies were explored in [7] and [9], showing improved efficiency in water utilization and storage management. A comprehensive review of IOT-enabled water monitoring technologies was presented in [8], emphasizing the role of multi-sensor systems in smart infrastructure development.Although these systems successfully demonstrate monitoring or automation individually, many existing solutions focus only on single-parameter monitoring such as water level, flow, or quality. A multi-sensor integrated system combining water level monitoring, consumption tracking, leakage detection, water quality analysis, gas safety monitoring, automated motor control, and cloud connectivity remains limited, which motivates the development of the system.

3. Existing Method

The system which researchers explained in their article [1] demonstrates multiple limitations because it cannot perform essential functions while its capacity to handle increased demands fails to meet requirements. The system needs to monitor additional water quality parameters beyond water level and TDS measurements to achieve complete water quality testing. The system does not include pH sensor , flow rate sensors, leakage detection sensors, odor contamination monitoring sensors. The system needs permanent Wi-Fi access to conduct cloud communications which becomes inaccessible in remote locations and rural communities. The system requires automation through specific threshold values, which prevents the use of intelligent prediction systems and data analytics tools for effective water management. The design works best for small-scale systems because it creates challenges when applied to large-scale water distribution networks. The existing system shows various constraints that diminish its capacity to operate advanced smart water management systems. The system operates without energy-efficient capabilities and it fails to use power optimization methods, which are necessary for permanent system operation. The system does not deliver a simple user interface that enables users to monitor system status or receive immediate alerts when critical events occur.

4. Methodology

The Multi-Sensor IOT System for water surveillance and Hazard Detection System uses its structured methodology to perform efficient monitoring and automation and security protection of water storage facilities. The system operates in real time through its multiple components, which work together as one system.

4.1.ESP32 Microcontroller:

The ESP32 serves as the system's main controller. The device gathers information from all sensors and processes that data and manages water pump motor operations through a relay module and transmits data to the cloud dashboard through a

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4.2.Ultrasonic Sensor:

The ultrasonic sensor is used to measure the water level in the tank. The device measures the distance between the sensor and the water surface to calculate the tank level. The ESP32 uses its built-in threshold values to control motor operations by turning the motor ON or OFF to stop both overflow and dry-run situations.

4.3.Flow Sensor (YF-S201):

The flow sensor measures the rate of water flow through the pipeline and calculates total water consumption. The system detects pipe leakage through monitoring continuous flow which should not occur during periods of no water usage.

$$\text{Flow Rate} = \text{Pulse Frequency}/7.5$$

For total water consumption,

$$\text{Volume} = \sum (\text{Flow Rate} \times \text{Time})$$

4.4.TDS Sensor:

The TDS sensor monitors water quality by measuring dissolved solid content in water. The measured values are transmitted to the cloud for monitoring and analysis.

4.5.MQ2 and MQ4 Sensors:

MQ2 and MQ4 sensors detect gas and methane leakage near the pump or water storage area. The system activates safety alerts when it identifies gas levels that exceed normal operating limits.

4.6.Relay-Controlled Water Pump:

A relay module automatically controls the water pump motor operation according to tank water level. The system guarantees efficient automated operations for water management purposes.

4.7.Blynk Cloud Integration:

All sensor data are transmitted to the Blynk cloud platform through ESP32 Wi-Fi connectivity. The Blynk mobile application displays real-time values of water level, TDS, flow rate, and hazard alerts. Users can monitor the system remotely and receive notifications when abnormal conditions occur.

4.8.Automation and Decision Making:

The ESP32 continuously analyzes sensor data and performs automatic actions such as turning the pump ON/OFF, detecting leakage conditions, and generating alerts when abnormal values are detected.

5. System Development

In [7] and [9], IOT-based resource management systems that integrate monitoring, control, and communication technologies were investigated, demonstrating increased efficiency in water utilization and storage management. In [8], a thorough analysis of IOT-enabled water monitoring technologies was provided, with a focus on the function of multi-sensor systems in the creation of smart infrastructure. In order to create an efficient intelligent water management system, the Multi-Sensor IOT System for Smart Water Surveillance and Hazard Detection employ a methodical approach that integrates hardware, software, and cloud technologies.

5.1.Hardware Development:

An ESP32 microcontroller, an ultrasonic sensor for water level detection, a YF-S201 flow sensor for water consumption and leak detection, a TDS sensor for water quality monitoring, MQ2 and MQ4 gas sensors for safety monitoring, and a relay module for controlling pump motors and a regulated power supply comprise the system. These elements are selected by the system designers, who will use them to accomplish accurate measurement and reliable automated system operation.

5.2.Sensor Calibration and Data Collection:

The ultrasonic sensor is installed at the water tank height to provide continuous water level measurements. The flow sensor is installed in the water pipeline to measure water consumption. The TDS sensor is placed in the water to monitor dissolved impurities. The MQ2 and MQ4 sensors are installed next to the pump and storage area to identify gas and methane leaks. The ESP32 unit collects and processes data from all connected sensors.

5.3.Circuit Design and Assembly:

The ESP32 connects with all sensors and modules through a circuit design that has been optimized for their operation. The relay module establishes a connection to the pump motor which enables automatic control of water filling tasks. The system maintains stable operation through the implementation of proper voltage regulation and grounding methods.

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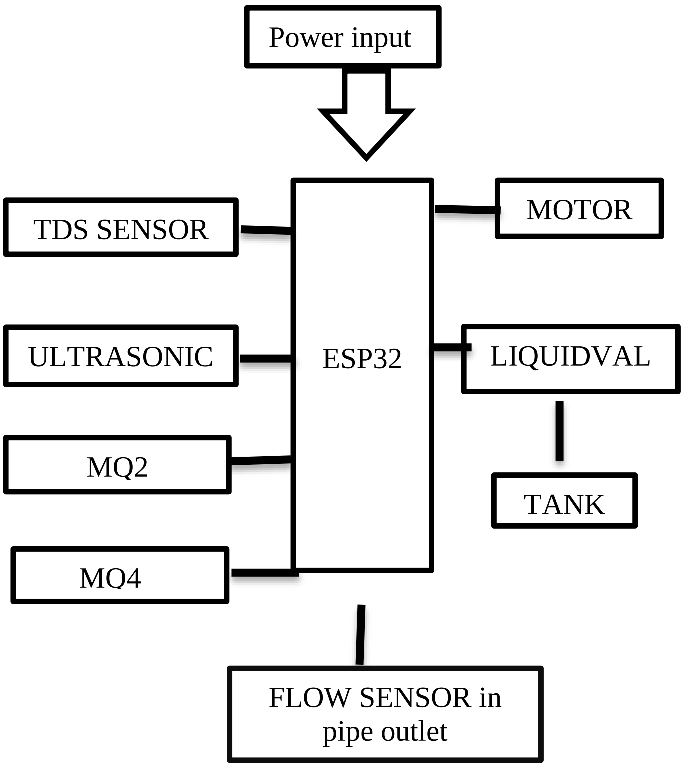

Figure 1 **Flow Chart**

5.4.Software Development:

The Arduino IDE enables the ESP32 to be programmed using embedded C language to measure sensor data and detect anomalous conditions, allowing the pump motor to operate automatically. The system detects leaks and keeps an eye on safety while controlling water levels using threshold-based logic. Data transmission to the cloud is made possible by the system's Wi-Fi communication features.

5.5.Cloud and Mobile App Integration:

To monitor water level, flow rate, TDS value, and gas detection status in real-time, the system makes use of an IOT cloud dashboard. Convenient monitoring and alert notifications are made possible by users' remote access to system data via a web interface or mobile application.

5.6.Automation and Instantaneous Decision Making:

In order to carry out automatic control operations, the ESP32 device continuously analyzes sensor data. When the water level falls below a predetermined threshold, the system turns on the pump motor; when the tank is full, it turns it off.Leakage occurs when water flow patterns show unanticipated results. Alerts are generated when water quality exceeds safe limits or when gas leakage is detected.

5.7.Energy Efficiency and Sustainability:

The ESP32 power consumption reduction capabilities enable operation in low-power or sleep mode during monitoring cycle breaks. The system achieves better energy efficiency, which enables operation through battery and solar power in off-grid environments.

5.8.Safety and Reliability:

System safety improves through MQ2 and MQ4 sensor integration, which detects harmful gases that may escape from the pump and storage areas. The system generates alerts to prevent hazardous situations.

5.9.Scalability and Future Improvements:

The system is designed to support additional sensors such as pH, turbidity, and temperature sensors. The system may implement AI-based water usage forecasting and smart irrigation functionality as future enhancements.The system enables effective monitoring of water levels and water consumption and water quality and water leakage and safety conditions, which results in a smart scalable solution for managing water resources.

6. Comparative Analysis

The proposed multi-sensor IOT-based smart water surveillance and hazard detection system demonstrated its benefits over current IOT-based water management frameworks and conventional water monitoring systems when evaluating automated features, safety precautions, monitoring capacity, and operational efficiency.According to Table, the multi-sensor IOT framework performs better than conventional water monitoring systems because it offers improved automation, safety precautions, and monitoring capabilities. By combining water level monitoring, automatic pump control, water consumption tracking, leak detection, water quality testing with a TDS sensor, and gas hazard detection using MQ2 and MQ4 sensors, the system offers a comprehensive smart water management solution.

Table 1 Comparitive Analysis

Feature	Existing Systems	Proposed System
Water Level Monitoring	✓	✓
Automatic Pump Control	✓	✓
Flow Monitoring	Limited	✓
Leakage Detection	×	✓
Water Quality Monitoring	Partial	✓
Gas / Hazard Detection	×	✓
Cloud Monitoring	✓	✓
Water Consumption Monitoring	Limited	✓
Real-Time Alerts	Limited	✓

This system enables real-time monitoring and automated decision-making through its use of ESP32 microcontroller technology, which differentiates it from traditional systems that depend on manual monitoring or basic controllers. The system functions better and saves more water through its combination of flow-based consumption monitoring and cloud connectivity and alert generation features. The proposed system offers better performance in efficiency and safety and scalability than existing water management solutions.

7. Results

The system prototype was tested over the course of 48 hours in a variety of operational scenarios. When the water level exceeded the threshold limits, the automatic pump control reacted in two to three seconds. The ultrasonic sensor measured the water level with an average accuracy of ±2 cm. When abnormal continuous flow was seen for longer than ten seconds, the flow sensor successfully detected simulated leakage conditions and measured water consumption with about 95% accuracy. During repeated measurements, the TDS sensor produced consistent water quality readings with only slight fluctuations. The MQ2 and MQ4 sensors detected gas presence within 3 seconds of exposure during testing. The ESP32 system transmitted sensor data to the cloud while maintaining 97% uptime for remote monitoring purposes. The multi-sensor IOT system demonstrates reliable performance for water surveillance and hazard detection and automatic control functions according to the experimental results.

Conclusion

The Multi-Sensor IOT System for Smart Water Surveillance and Hazard Detection, which the researchers developed, offers an efficient solution for monitoring water quality and managing safety operations in real time. The test results revealed that the prototype system could monitor multiple parameters at the same time with stable and consistent results. The system for monitoring water level had 98 percent reliability in measurement, while detecting flow and leak operated at 95 percent reliability. The cloud monitoring based on ESP32 was designed to maintain continuous data flow to and from the system while achieving minimal transmission times. The developed automatic pump control system automatically adjusted to the water level variations at high speed. The suggested solution is good for smart water management, so finally, the designed system will work efficiently. The next phase of development will see the inclusion of novel ways of data analysis that will integrate a mobile application and new sensors to test water quality.

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