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Smart IoT-Based Water Leakage and Quality Monitoring System with Automated Pump Control and Alert Mechanism

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ABSTARCT_ This project introduces an Internet of Things (IoT)-based Smart Irrigation and Monitoring System that incorporates automated motor control, water quality monitoring, and real-time water leak detection with voice and SMS notifications. Accurate pipe leak detection is made possible by the system's continuous comparison of inlet and output flow rates using dual water flow sensors. The controller instantly cuts off the motor to avoid wasting water when it detects any unusual flow disparity. It also sends an SMS alert and, utilizing Twilio services, starts a voice call notification to the owner. Water quality is monitored using a TDS (Total Dissolved Solids) sensor; if the water quality drops below a predetermined level, the system sends out a programmed audio message and sends out SMS notifications. The system also allows both manual and automatic modes of operation. In manual mode, the motor can be controlled directly through a web dashboard without relying on sensors, whereas in automatic mode, the motor's operation is dependent on the data from a soil moisture sensor. This integrated architecture is a scalable and economical solution for precision agriculture since it guarantees optimal water management, quick fault response, increased reliability, and remote monitoring capabilities.A high-performance microprocessor with Wi-Fi connectivity is used in the system's design to enable smooth cloud integration. For remote display and logging, real-time sensor data is synchronized to a Firebase Realtime Database. Farmers can keep an eye on motor status, system mode, flow rate, and TDS levels from anywhere via a dedicated web dashboard. The web interface allows for the dynamic configuration of threshold values for water quality and leak detection. The architecture ensures motor shutdown under unusual operating situations by adhering to the fail-safe design principle. TwiML-based automatic speech responses are used to implement voice alerts for unambiguous event communication. By intelligently automating tasks, the system minimizes human intervention and lowers operating expenses. Long-duration field deployment is supported by optimized power usage. Future additions of sensors like temperature, humidity, or rainfall modules can be integrated thanks to the modular design. All things considered, the solution improves farm safety, crop dependability, and resource conservation by creating a single IoT-enabled monitoring ecosystem..

1.INTRODUCTION

The Internet of Things' (IoT) quick development has made it possible to turn conventional irrigation systems into automated, intelligent, and remotely controllable infrastructures. The goal of the IoT-Based Smart Irrigation and Leakage Detection System with SMS and Voice Call Alerts project is to provide an autonomous farming environment with a primary focus on intelligent motor control, water leak detection, and water quality monitoring. The system guarantees effective water management and provides immediate owner notice during crucial situations by combining a number of sensors with an ESP32 microcontroller.

Automated fault response and real-time leak detection are key to the system's operation. A differential flow comparison technique is implemented by installing two water flow sensors at the inlet and exit sites. To avoid wasting water, the system instantly shuts off the engine if it detects a mismatch in flow rate, which could be a sign of a pipe rupture or leak. It simultaneously uses Twilio services to start a voice call and send an SMS alert to the owner. TwiML is used to configure the voice notification such that the leakage condition is clearly conveyed.

The system uses a TDS (Total Dissolved Solids) sensor to continuously check water quality in addition to detecting leaks. The device immediately notifies the owner by automated voice call and SMS notifications if the TDS value falls below a certain threshold, indicating poor water quality. By doing this, crops are shielded from potential harm and only appropriate water is used for irrigation.

Additionally, a dual-mode motor control architecture—Automatic Mode and Manual Mode—is introduced in this project. In Automatic Mode, irrigation is only possible when necessary because motor operation is entirely reliant on soil moisture sensor readings. Without relying on sensor data, the farmer can operate the motor directly (ON/OFF) in Manual Mode via a web dashboard. Operational flexibility depending on current needs is made possible by this adaptable control mechanism.

2.LITERATURE SURVEY

Singh et al. (2021) provide a comprehensive survey of IoT-based water management systems, outlining their core architecture and key components such as sensors, controllers, communication protocols, and application interfaces. They highlight how IoT solutions can simultaneously monitor water level and quality parameters like pH, salinity, and turbidity in real time, enabling remote monitoring and analytics for efficient water management. Their study emphasizes the scalability and low-cost nature of IoT platforms, while also suggesting the integration of machine learning techniques for improved prediction and anomaly detection (Singh et al., 2021).

Guezouli et al. (2024) introduced an IoT and AI-enhanced water monitoring system capable of detecting leaks using real-time sensor data. Their proposed model applies artificial intelligence techniques to identify anomalies in streaming sensor information, achieving improved detection accuracy compared to traditional pressure-based approaches. The study demonstrates that

integrating AI with IoT significantly enhances reliability and early detection of leakage events (Guezouli et al., 2024).

Boujelben et al. (2023) proposed an end-to-end IoT solution for leak detection and localization in water pipelines using lightweight convolutional neural networks deployed on sensor nodes. Their system integrates acoustic sensing and long-range communication technologies to detect and pinpoint leaks efficiently. The research highlights the importance of minimizing data transmission while maintaining detection accuracy, which is essential for scalable smart water infrastructure (Boujelben et al., 2023).

Motaz Daadoo et al. (2025) explored the implementation of wireless sensor networks for real-time leak detection in residential water distribution systems. Their work focuses on flow and pressure anomaly detection to trigger alerts and prevent water wastage. The study emphasizes energy efficiency and distributed monitoring capabilities, making IoT-based approaches suitable for both urban and rural environments (Daadoo et al., 2025).

Jan et al. (2022) reviewed IoT-based smart water systems that integrate water level monitoring, leakage detection, and pump control mechanisms. Their findings indicate that automated control systems improve resource conservation by reducing overflow and minimizing water loss. However, they observe that many existing systems focus on individual functions rather than providing an integrated solution that combines leakage detection, quality assessment, and automation (Jan et al., 2022).

Khairullah et al. (2025) investigated the use of LoRaWAN communication protocols for large-scale water monitoring and leakage detection in pipeline networks. Their research demonstrates that long-range wireless communication technologies enhance scalability and reliability in smart city deployments. The study confirms that IoT platforms combined with suitable communication infrastructure can effectively support real-time monitoring systems (Khairullah et al., 2025).

Huque et al. (2023) developed an IoT-based smart water tank level monitoring and motor pump control system to prevent water wastage. Their approach uses microcontrollers such as Arduino or NodeMCU along with water level sensors to automate pump operation based on predefined thresholds. Although primarily focused on tank level monitoring, their work establishes a strong foundation for integrating motor automation with additional features such as leakage detection and quality monitoring (Huque et al., 2023).

Ali et al. (2022) presented an IoT-based water management system addressing both distribution and leakage challenges. Their study emphasizes the limitations of conventional systems that lack real-time data analysis capabilities. By incorporating IoT sensors and real-time visualization dashboards, the proposed solution enhances monitoring efficiency and decision-making processes. The research supports the need for integrated, intelligent water management platforms (Ali et al., 2022)by Al-Ali et al. [7], but it lacked dual connection and local visualization capabilities.

Individual investigations have been conducted into other outdoor environmental characteristics. An Internet of Things-based ambient light monitoring system was created by Islam et al. [11] in order to optimize outdoor lighting. In order to support early warning systems, Singh and Tudu [12] suggested an Internet of Things-enabled rainfall and flood monitoring system that uses rain sensors. These studies do not combine several environmental elements into a single monitoring node, although emphasizing the significance of separate data.

3.PROPOSED SYSTEM

The suggested system is an Internet of Things (IoT)-based Smart Irrigation and Leakage Detection Ecosystem that offers automated motor control, real-time monitoring, and immediate voice and SMS notifications. As the central processing unit, the ESP32 microcontroller gathers information from all of the sensors that are attached, runs control logic, and oversees communication and cloud services.

Soil hydration levels are measured in real time using a soil moisture sensor. The motor works in Automatic Mode according to preset moisture criteria, guaranteeing watering only when required. In Manual Mode, sensor data is not necessary to directly operate the motor via a web dashboard.

The differential leakage detection mechanism of the system is its primary novelty. The pipeline's intake and output are equipped with two YF-S201 water flow sensors. The pulse outputs from the two sensors are continually compared by the ESP32. As a failsafe measure, the device instantly shuts off the motor if a noticeable change is found, suggesting a leak or ruptured pipe. With a pre-programmed voice message set up with TwiML, it simultaneously sends an SMS alert and uses Twilio to start a voice conversation with the owner.

A TDS sensor keeps an eye on the dissolved solids in the irrigation supply to guarantee water purity. The technology notifies the farmer of low water quality situations by sending out automated voice calls and SMS messages if the TDS measurement falls below a predetermined level.

All real-time characteristics, such as motor status, operation mode, TDS value, and flow rate, are synchronized to the Firebase Realtime Database for remote monitoring. Global access to manual motor control and monitoring is made possible using a web dashboard. Non-blocking logic is used in the firmware's implementation to guarantee continuous sensor gathering, cloud connectivity, and alert delivery.

All things considered, the suggested system provides a dependable, expandable, and reasonably priced smart irrigation solution that integrates cloud-based supervision, automated fail-safe mechanisms, water quality monitoring, and real-time SMS and voice call warnings for contemporary precision agriculture..

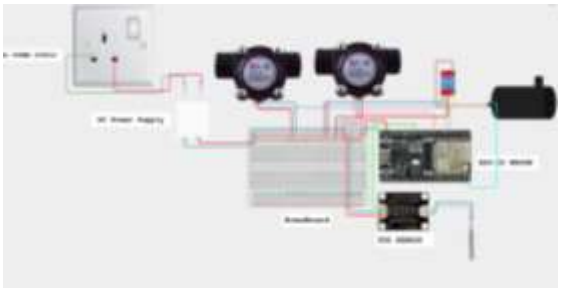


Fig: 1: System Architecture

4. Components Description

4.1. ESP32 Microcontroller

The system's central processor, the ESP32 microcontroller, controls all hardware modules. It processes data, reads sensors, handles WiFi, and controls the LED matrix display. The ESP32 is perfect for Internet of Things applications because it contains built-in WiFi and Bluetooth. In this project, it establishes an internet connection in order to communicate with the Telegram Bot and transfer data to Firebase. It polls sensors, synchronizes with the cloud, and manages warnings simultaneously. The ESP32's many GPIO pins, low power consumption, and high processing speed make it perfect for real-time weather monitoring systems..



Fig 2: ESP32 Microcontroller

4.2.YF-S201 Water Flow Sensors (Dual Setup)



Fig 3 Water Flow Sensors

Dual Water Flow Sensors are key to leak detection. These Hall Effect sensors generate electrical pulses as water goes through the valve and spins an internal rotor. The water source (Inlet) and field delivery point (Outlet) are sensor locations in this project. The ESP32 calculates flow rate in L/min from both sensors' pulse frequencies. A Differential Analysis (comparing Inlet vs. Outlet flow) can determine if a pipe break or loose junction is leaking water. To avoid water loss and soil erosion, the device shuts down the motor if the discrepancy exceeds a safety margin..

4.3. Soil Moisture Sensor



Fig 4 **Soil Moisture Sensor**

The Soil Moisture Sensor is the primary environmental input used to determine the volumetric water content of the soil. This sensor consists of two exposed copper probes that act as variable resistors. It operates on the principle of electrical conductivity: since water is a much better conductor of electricity than dry soil, the resistance between the probes decreases as the soil moisture increases.

4.4. TDS (Total Dissolved Solids) Sensor



Fig 5: Total Dissolved Solids

A TDS Sensor measures water quality and nutrient concentration. The concentration of dissolved inorganic salts and organic materials is closely connected to water electrical conductivity. This is crucial for Precision Agriculture because high salinity can cause "chemical drought," where plants cannot absorb water despite wet soil.The ESP32 converts the sensor's analog voltage into PPM. TDS levels above the crop's safe limit generate a "Water Quality Alert" via the Fast2SMS API, alerting the farmer to probable contamination or high salinity..

4.5. Relay Module

The system's main fire protection instrument is the 5V Relay Module, an electromagnetic switch. The low-power ESP32 can manage high-voltage electrical circuits, acting as an automated circuit breaker. The ESP32 opens the relay to isolate the building's electrical supply immediately if gas levels above the safety threshold or a flame is detected. This prevents gas leaks from sparking from appliances or light switches, which might cause a massive explosion. The relay's autonomous operation maintains property security even when no one is home..



Fig 6: Relay

4.6 Water Pump Motor

This is the mechanical actuator of the system, typically a submersible or centrifugal DC pump.

Role: Physically moves water from the reservoir to the irrigation lines based on commands from the relay.



Fig 7: Water Pump Motor

5.RESULTS AND DISCUSSION

Under real-time operational conditions, the Smart Irrigation and Leakage Detection System was successfully installed and tested. Dual flow sensors, a TDS sensor, relay-based motor control, Firebase cloud monitoring, ESP32 hardware, and Twilio-based SMS and voice call warnings are all integrated into the system. The outcomes below confirm that each subsystem is operating correctly.

The Smart Irrigation Web Dashboard (Demo Mode) displays real-time agricultural parameters including:

- Flow In (L/min)
- Flow Out (L/min)
- Soil Moisture (%)
- TDS (PPM)
- Automatic / Manual Mode Selection

- Motor ON/OFF Control (Manual Mode)
- System Status Indicator



Fig 8: Website

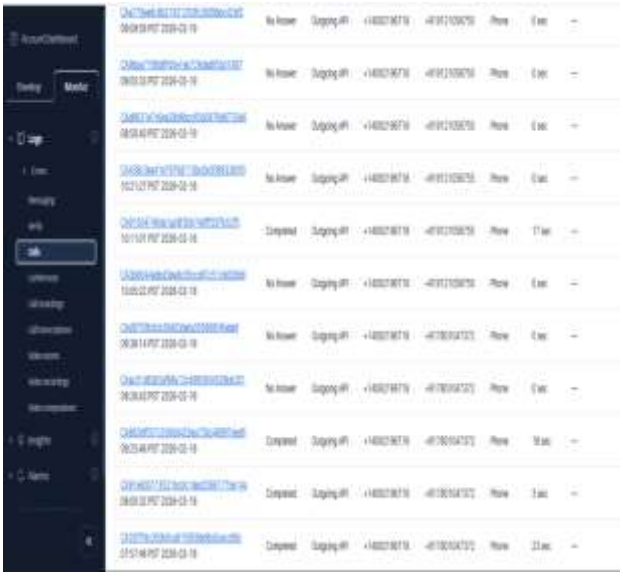


Fig 9: The dashboard successfully reflects sensor readings and motor status dynamically. In Automatic Mode, the motor responds to soil moisture thresholds. In Manual Mode, the user can override the motor state using web controls.

Result:
Real-time parameter visualization and remote motor control were successfully achieved

The Twilio Console "Calls" log confirms that voice calls were triggered during critical events such as:

- Water Leakage Detection
- Emergency Motor Shutdown



Call logs show:

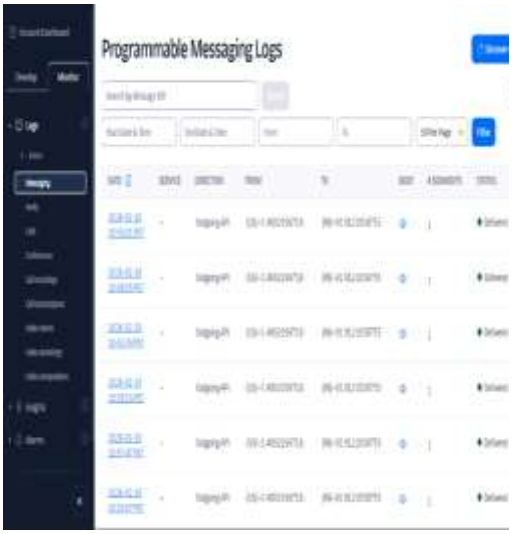
- Outgoing API calls initiated by ESP32
- Call status (Completed / No Answer)
- Call duration

Result:
Voice alert system is functioning correctly and emergency calls are generated when leakage conditions are detected.

Fig 10: Twilio Call Log – Voice Alert Verification

The Programmable Messaging Logs confirm that SMS alerts were successfully delivered for:

- Water Leak Alert
- Water Quality (TDS) Alert



The log displays:

- Date and time of SMS
- Destination number
- Delivery status (Delivered)
- API source

Result:
SMS notifications are delivered successfully with minimal latency

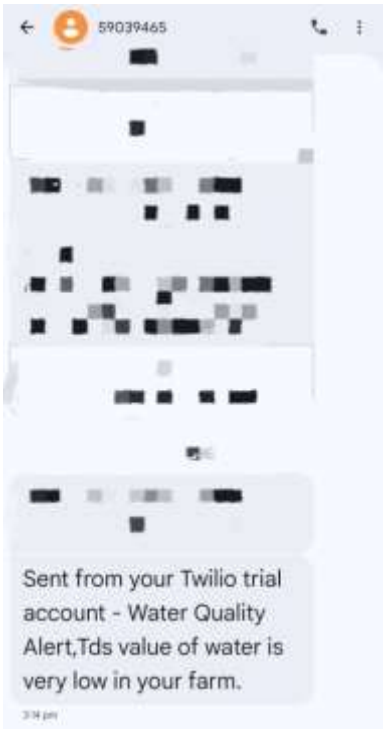
Fig 11: Twilio Messaging Log – SMS Alert Verification

The received SMS on the mobile device displays:

"Sent from your Twilio trial account – Water Quality Alert. TDS value of water is very low in your farm."

This confirms:

- Twilio API integration is successful.
- TDS threshold logic is correctly implemented.
- Real-time alert transmission works.



Result:
Water quality monitoring and SMS alert system validated successfully.

Fig 12:Mobile SMS Output – TDS Alert

The system successfully generated a Water Leak Alert message when:

Flow_In > Flow_Out + Threshold

Upon detection:

- Motor was automatically stopped.
- Relay was deactivated.
- SMS was sent instantly.



Result:
Leakage detection and automatic fail-safe motor cutoff mechanism works reliably.

Fig 13: Mobile SMS Output – Leakage **Alert**

6.CONCLUSION

The Smart Irrigation and Leakage Detection System proves precision agriculture can be reliable, scalable, and intelligent. The system integrates real-time environmental sensing, automatic motor control, cloud synchronization, and emergency alerts into a single IoT framework using the ESP32 microcontroller as the central processing unit.

Differential Flow Analysis with dual flow sensors effectively detected pipe leaks and prevented water waste. The automatic relay-based motor cutoff mechanism responds immediately to abnormal flow conditions, reducing resource loss and electrical damage. TDS sensor integration allows continuous water quality monitoring, ensuring irrigation water fulfills crop health standards.

The system becomes a remotely accessible digital platform with Firebase Realtime Database for real-time monitoring and secure dashboard control. Twilio SMS and Voice Call alerts improve system responsiveness by notifying users of crucial events like leakage or water quality. This proactive alert removes manual oversight. The system may be upgraded to include pH, NPK, and weather sensors due to its modular firmware architecture, non-blocking programming design, and scalable communication layer. The system is cost-effective, energy-efficient, and technically strong for sustainable water management and smart agricultural automation. The project proves that embedded systems, cloud computing, and telecommunication APIs can create an intelligent, autonomous irrigation control system for real-world use..

FUTURE SCOPE

Its goal is to turn the IoT Weather Ecosystem prototype into an autonomous, industrial-grade environmental monitoring platform. Complete energy independence through solar power integration is a huge improvement. The monitoring unit can work constantly in remote agricultural areas, smart city infrastructures, and rural locations without USB power thanks to high-efficiency PV panels and a lithium-ion battery management system (BMS). This solar-powered design runs 24/7 with no upkeep.

The system will be moved from breadboard-based prototyping to a bespoke PCB to improve physical reliability and deployment readiness. ESP32, sensor interfaces, power regulation modules, and communication circuits will be integrated

into a compact and durable PCB. This shift will simplify wiring, reduce electromagnetic interference, improve signal stability (particularly for sensitive sensors like BME680), and increase resilience to humidity, dust, and vibration.

AI and data analytics will advance the project. Machine learning algorithms can anticipate weather and find anomalies using Firebase environmental data. It offers greater value than typical weather applications by providing localized forecasts, crop advice insights, and environmental trend projections instead of just monitoring in real time. Future development must also include sensory enhancement. A precision agriculture ecosystem will be created by adding anemometers (wind speed), UV index sensors, rainfall gauges, and soil moisture probes. This multi-parameter sensing method will improve irrigation scheduling, crop health analysis, and climatic risk assessment.

Creating a mobile app will boost user interaction and accessibility. Push notifications, graphical analytics, device management, and real-time alarms are possible. Encrypting cloud communication (HTTPS with token-based authentication and database security rules) improves data privacy and cybersecurity.

These advances in autonomous power systems, hardware robustness, predictive intelligence, expanded sensing, and secure cloud architecture will transform the prototype monitoring node into a scalable, intelligent, and industrial-grade smart environmental monitoring network for large-scale agricultural and smart city deployments.

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