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IOT-BASED SMART IRRIGATION AND MONITORING SYSTEM

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ABSTRACT

Efficient irrigation management plays a critical role in sustainable agriculture and water conservation. This paper presents the design and implementation of a cloud-enabled smart irrigation system using the ESP32 microcontroller and the Blynk IoT platform. The system monitors soil moisture, temperature, and humidity in real time using an analog soil moisture sensor and a DHT22 environmental sensor. Based on threshold-based decision logic, a relay-controlled water pump is automatically activated when the soil becomes dry and deactivated when sufficient moisture is detected.

The system integrates cloud connectivity through the Blynk IoT platform, enabling remote monitoring and control via a mobile dashboard. It supports both automatic irrigation mode and manual override mode. A 16×2 LCD provides local real-time system feedback. The proposed solution demonstrates a low-cost, scalable, and hybrid edge-cloud IoT architecture suitable for smart agriculture and small-scale irrigation systems.

Keywords: Smart Irrigation, ESP32, Blynk IoT, Soil Moisture Monitoring, Cloud-Based Automation, Embedded Systems

1. INTRODUCTION

Water scarcity and inefficient irrigation systems are major challenges in modern agriculture. Traditional irrigation methods rely on manual supervision or fixed scheduling mechanisms, which often result in over-irrigation, under-irrigation, and resource wastage. The emergence of Internet of Things (IoT) technologies has enabled the development of intelligent agricultural systems that combine sensing, wireless communication, and automated control. By integrating environmental sensors with cloud platforms, irrigation systems can operate dynamically based on real-time soil conditions.

This research focuses on the design and development of a cloud-connected smart irrigation system using the ESP32 microcontroller. Unlike local-only systems, this implementation integrates real-time cloud monitoring using the Blynk IoT platform and provides both automatic and manual control modes for enhanced operational flexibility.

2. LITERATURE REVIEW

This section presents the contributions of various researchers in the field of IoT-based smart irrigation and agricultural monitoring systems using embedded systems and wireless communication technologies:

• Initially developed an automated irrigation system using wireless sensor networks (WSN) to monitor soil moisture and environmental parameters. The study demonstrated that sensor-based irrigation significantly reduces water consumption compared to traditional manual irrigation methods. Their work established the importance of integrating sensing technology with wireless communication in agricultural automation [1].

• The research is to design an IoT-based smart irrigation system using soil moisture sensors and microcontrollers connected through wireless communication. The system automatically controlled water flow based on soil conditions and showed improved efficiency in water resource management. Their research highlighted the effectiveness of real-time monitoring in precision agriculture [1].

• It explored the application of low-cost embedded systems for irrigation scheduling. The study emphasized the role of sensor-driven decision systems in reducing over-irrigation and enhancing crop yield. Their findings demonstrated that threshold-based automation can improve irrigation accuracy while minimizing operational costs [3].

• Finally implemented an IoT-based agricultural monitoring system using the ESP8266 WiFi module. The system allowed remote monitoring of soil parameters through a web interface. Their work demonstrated how integrating wireless connectivity into embedded systems enhances accessibility and real-time control [4].

3. PROBLEM STATEMENT

Efficient irrigation is essential for conserving water and improving agricultural productivity. Traditional irrigation methods rely on manual operation or fixed timers, which do not consider real-time soil conditions. This often leads to water wastage and inefficient crop growth.

The objective of this project is to design and implement a cloud-enabled smart irrigation system using the ESP32 microcontroller and Blynk IoT platform. The system monitors soil moisture, temperature, and humidity in real time and automatically controls a water pump based on a predefined moisture threshold.

The system also provides remote monitoring and manual override functionality through a mobile dashboard, while a 16×2 LCD ensures local system visibility. The proposed solution aims to deliver a low-cost, reliable, and scalable irrigation system suitable for small-scale agricultural applications [5].

4. METHODLGY

The proposed smart irrigation system is developed using the ESP32 microcontroller integrated with sensor-based monitoring and cloud communication. The soil moisture sensor and DHT22 sensor continuously collect environmental data and send it to the ESP32 for processing.

A predefined moisture threshold is used to determine soil dryness. If the soil becomes dry, the relay activates the water pump automatically; otherwise, the pump remains off. The system supports both automatic and manual modes through the Blynk IoT platform. Sensor readings and motor status are displayed locally on a 16×2 LCD and remotely on the cloud dashboard [6].

4.1 System Design

The proposed system consists of the following main components:

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• Soil Moisture Sensor – Measures soil water content and sends analog data to the ESP32.
• DHT22 Sensor – Measures ambient temperature and humidity for environmental monitoring.
• ESP32 Microcontroller – Acts as the central processing unit and WiFi communication module.
• Relay Module and Water Pump – Controls irrigation automatically based on soil conditions.
• 16×2 LCD Display – Displays real-time soil moisture values and motor status locally.

The ESP32 processes sensor data using threshold-based logic and connects to the Blynk IoT platform in WiFi station mode for remote monitoring and control.

4.2 Data Acquisition

The soil moisture sensor is connected to the analog input pin (GPIO 34) of the ESP32. The sensor continuously measures soil moisture levels and sends analog voltage signals to the microcontroller. The ESP32 reads these values using the analogRead() function.

4.3 Threshold-Based Decision Logic

A predefined threshold value is set in the program to determine soil dryness.

- If the soil moisture value exceeds the threshold (indicating dry soil), the ESP32 activates the relay module, turning the water pump ON.
- If the value falls below the threshold (indicating sufficient moisture), the relay is deactivated, and the water pump is turned OFF.

This logic ensures automatic irrigation based on real-time soil conditions.

4.4 Wireless Communication and Web Interface

The ESP32 operates in SoftAP mode and creates a local WiFi network. A built-in web server (port 80) handles HTTP requests. Users can connect via a mobile device or laptop to access a web page that provides LED control options.

The web interface allows:

- Turning the LED ON
- Turning the LED OFF

This demonstrates remote device control through wireless communication.

4.5 Local Monitoring

A 16x2 LCD display is interfaced with the ESP32 to provide real-time system feedback. The LCD displays:

- Soil moisture value
- Motor status (ON/OFF)

This ensures that the system can be monitored locally without requiring a mobile device.

4.6 System Operation Flow

1. The system initializes the ESP32, LCD display, WiFi connection, and GPIO pins.
2. The ESP32 connects to the Blynk IoT cloud platform.
3. Soil moisture, temperature, and humidity values are continuously read from the sensors.
4. The soil moisture value is compared with the predefined threshold.
5. Based on the operating mode (Auto/Manual), the relay controls the water pump accordingly.
6. Sensor readings and motor status are transmitted to the Blynk dashboard.
7. The LCD updates real-time system information locally.
8. The process repeats continuously using timer-based scheduling.

This methodology demonstrates a hybrid edge-cloud IoT implementation where sensing and decision-making occur locally within the ESP32 (edge computing), while monitoring and control are enabled remotely through cloud connectivity.

The proposed smart irrigation system operates using a hybrid edge-cloud architecture in which sensing and control decisions are performed locally, while monitoring and remote access are enabled through cloud connectivity. When the system is powered on, the ESP32 initializes all connected components, including the soil moisture sensor, DHT22, relay module, WiFi module, and 16×2 LCD display. The ESP32 then establishes a wireless connection and connects to the Blynk IoT platform for real-time remote monitoring and control [7].

During operation, the soil moisture sensor continuously measures the water content of the soil and sends analog signals to the ESP32 through GPIO 34. Simultaneously, the DHT22 sensor collects ambient temperature and humidity data. The ESP32 reads these sensor values at regular intervals and processes them using a predefined threshold-based decision algorithm. If the soil moisture level indicates dry soil (exceeds the set threshold), the ESP32 activates the relay module, which turns the water pump ON to irrigate the field. When sufficient moisture is detected (below the threshold), the relay is deactivated, and the pump is turned OFF. This automatic control mechanism ensures efficient water usage and prevents over-irrigation [8].

General Process of the Proposed Systems

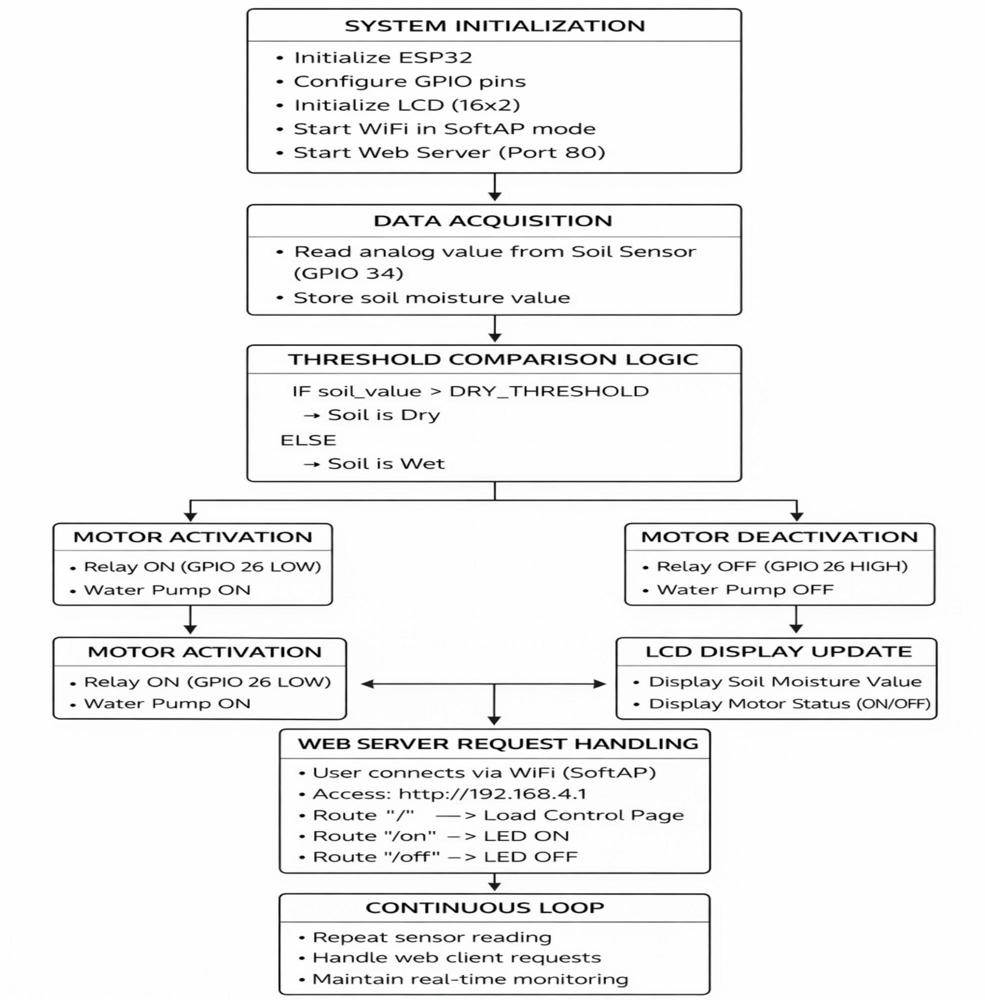

Fig 1. Research Working Progress

RESULT AND DISCUSSION:

The soil moisture sensor accurately detected variations in soil water content under different irrigation conditions. When the soil was dry, higher analog values were recorded, and when water was supplied, the values decreased significantly, indicating proper sensor responsiveness.

The ESP32 successfully processed analog data from GPIO 34 without signal instability. The DHT22 sensor provided consistent temperature and humidity readings, enabling environmental monitoring alongside soil analysis [9].

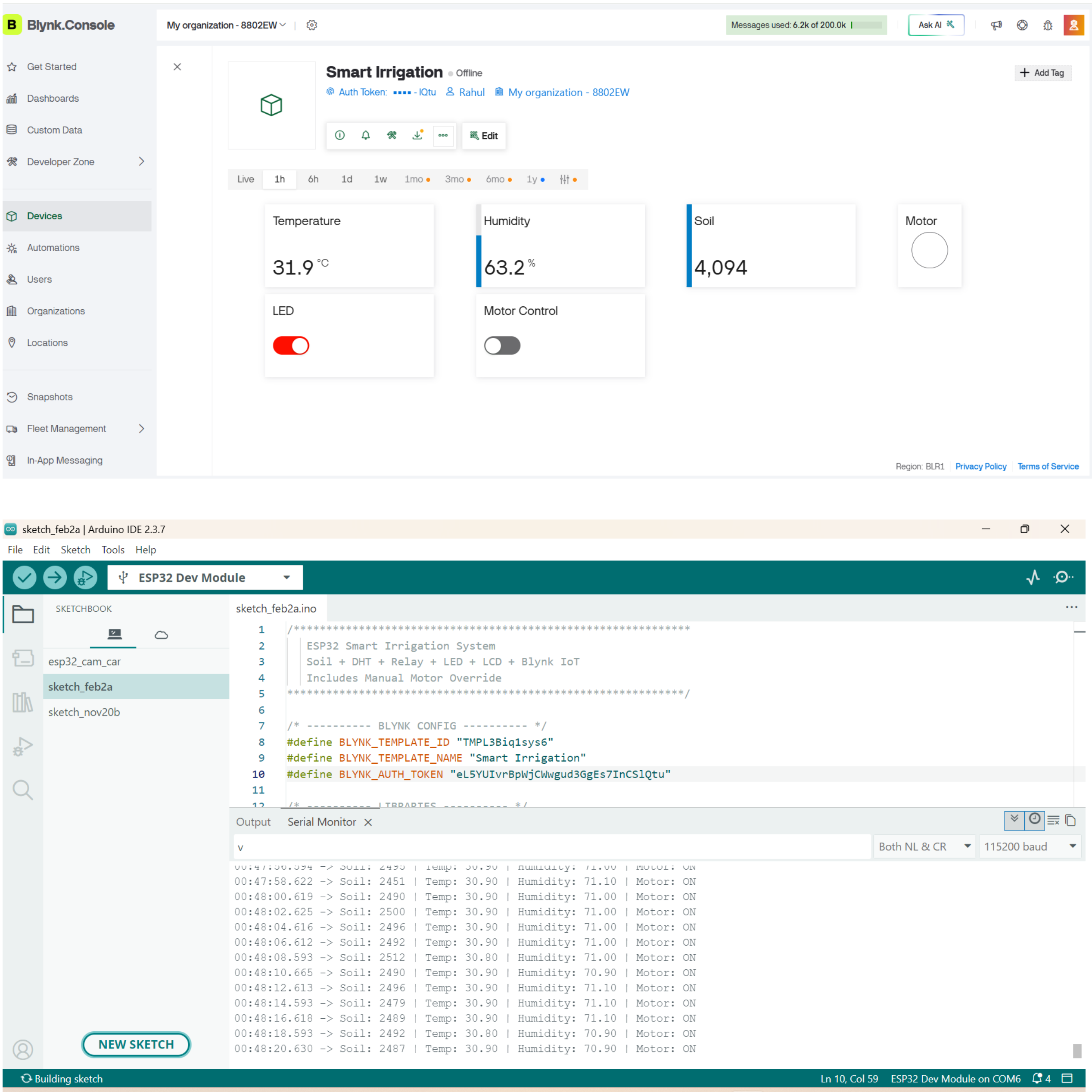

Fig. 2, 3. ESP32-Based Smart Soil Monitoring and Irrigation Control System Architecture

Automatic Irrigation Control

The threshold-based decision logic functioned effectively:

When soil moisture exceeded the predefined dry threshold, the relay module was activated automatically, turning the water pump ON. When soil moisture fell below the threshold (indicating adequate moisture), the pump was turned OFF.

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This automation reduced unnecessary water usage and ensured that irrigation occurred only when required. The relay switching response time was observed to be minimal, with near-instant activation upon threshold detection.

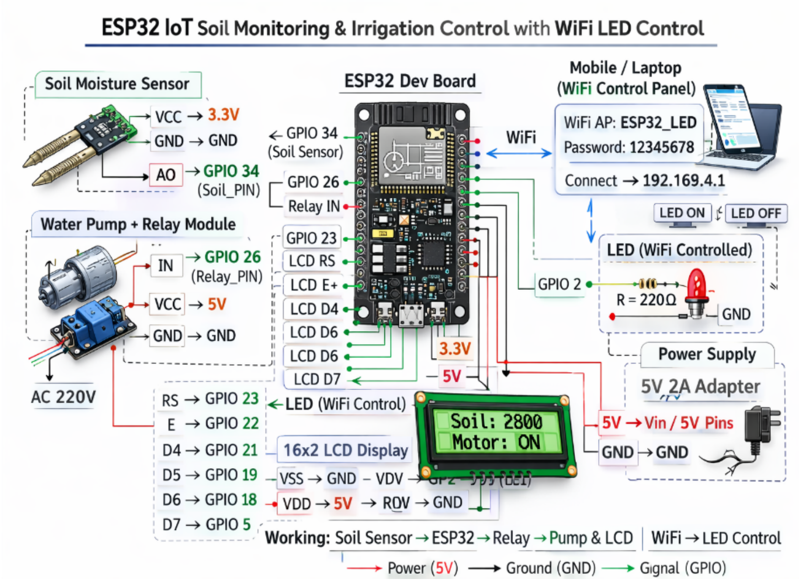

Fig 4. Overall Component Structure

The experimental results confirm that the proposed smart irrigation system, Efficiently automates irrigation based on real-time soil conditions. Reduces water wastage compared to manual irrigation methods. Enables remote monitoring and flexible control. Demonstrates scalability for future expansion. The results validate that the implemented system meets the objectives of sustainable irrigation management using IoT-based automation.

5. CONCLUSION

This paper presented the design and implementation of a cloud-enabled smart irrigation system using the ESP32 microcontroller and the Blynk IoT platform. The system integrates soil moisture sensing, environmental monitoring through the DHT22 sensor, automatic motor control using a relay module, and real-time cloud connectivity for remote supervision [10].

The threshold-based irrigation logic ensures efficient water usage by activating the water pump only when the soil becomes dry. The inclusion of both automatic and manual operating modes enhances system flexibility and reliability. Local monitoring through a 16×2 LCD display and remote visualization through the Blynk dashboard demonstrate the effectiveness of a hybrid edge-cloud architecture.

The developed system provides a low-cost, scalable, and energy-efficient solution suitable for small-scale agricultural and smart gardening applications. Overall, the implementation highlights the practical application of IoT technologies in improving irrigation efficiency and promoting sustainable water management.

FUTURE ENHANCEMENT:

1. Cloud Integration

The current system operates in local SoftAP mode without internet connectivity. In future, the system can be integrated with cloud platforms such as ThingSpeak, Firebase, or AWS IoT. This would allow real-time data storage, remote monitoring from any location, and historical data analysis for better irrigation planning.

2. Mobile Application Development

A dedicated mobile application can be developed for Android or iOS platforms to provide a more user-friendly interface. Instead of accessing the system through a web browser, users could monitor soil moisture levels, receive alerts, and control devices directly through a mobile app.

3. Integration of Additional Sensors

The system can be expanded by integrating additional environmental sensors such as:

- Temperature sensor
- Humidity sensor
- Rain sensor
- Water level sensor

This would enable more intelligent irrigation decisions based on multiple environmental parameters.

4. Automated Data Logging and Analytics

Future enhancement may include data logging and graphical visualization of soil moisture trends. By storing sensor readings over time, the system can analyze irrigation patterns and optimize water usage.

5. Solar Power Integration

To improve energy efficiency and sustainability, the system can be powered using a solar panel and rechargeable battery setup. This would make the system suitable for remote agricultural fields without reliable electricity access.

6. AI-Based Irrigation Optimization

Machine learning algorithms can be integrated to predict optimal irrigation schedules based on historical data, weather forecasts, and soil conditions. This would transform the system from simple threshold-based automation to intelligent predictive irrigation.

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