

Aquareach: Lora Enabled Smart Irrigation System

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Abstract - This paper introduces AquaReach, a LoRa-enabled smart irrigation system for efficient, automated irrigation in rural areas. The system utilizes a Raspberry Pi, LoRa device, and solenoid valve to remotely control irrigation by receiving signal commands to manage water flow. The core aim is to enable efficient irrigation using low-power (Tx 40 mA, Rx 12 mA) and long-range (~7–8 km) wireless communication. AquaReach is designed to be an affordable and efficient solution for small and marginal farmers, optimizing water usage and reducing manual labor. The primary control is achieved via SMS commands, allowing farmers to monitor and manage water usage efficiently and promoting water conservation.

Index Terms - LoRa, Smart Irrigation, IoT, Rural Agriculture, Remote Control, ESP32, Raspberry Pi.

1. INTRODUCTION

In Section I, we introduce the significance of efficient irrigation and present the AquaReach system, which utilizes IoT and LoRa technology to optimize water use in agriculture. In Section II, a literature survey explores the evolution of IoT-based irrigation systems, highlighting challenges and the emergence of LPWAN technologies like LoRa as effective solutions. Section III details the methodology, describing the hardware architecture, software components, and overall functionality of the AquaReach system for smart irrigation. Section IV presents the results, applications, and limitations, showcasing the system's performance, practical uses, and challenges faced. Section V discusses future scope, outlining potential enhancements such as AI integration, additional sensors, and improved scalability. Finally, Section VI concludes by emphasizing AquaReach's impact as an affordable, sustainable innovation that bridges traditional farming with digital transformation to promote precision agriculture and improve rural livelihoods.

In this section, we introduce the significance of efficient irrigation practices and present the AquaReach, which leverages IoT and LoRa technology to optimize water usage in agriculture.

Agriculture accounts for nearly 70% of global freshwater consumption. However, conventional irrigation systems often rely on manual scheduling, leading to over-irrigation, water wastage, and reduced crop productivity. With the advent of the Internet of Things (IoT) and Low Power Wide Area Networks (LPWANs) such as LoRa (Long Range), farmers can now

deploy intelligent and remote-controlled irrigation systems at minimal cost.

The AquaReach aims to provide an efficient and scalable LoRa-enabled smart irrigation solution that allows farmers to monitor and control field irrigation from any location. By combining soil sensors, temperature-humidity sensors, and a gateway module, AquaReach establishes a reliable data-driven irrigation mechanism suitable for large and rural farmlands.

2. LITERATURE REVIEW

The rapid advancement of the Internet of Things (IoT) has significantly transformed modern agricultural practices, particularly in the domain of smart irrigation systems. IoT-based solutions enable real-time monitoring and automation, improving water efficiency and crop productivity. Several studies have explored different communication technologies and system architectures to address irrigation challenges.

Early research in smart irrigation primarily focused on GSM-based communication systems. In [1], a GSM-enabled irrigation system was proposed that allowed farmers to remotely control water pumps using SMS commands. While this approach improved accessibility, it suffered from high operational costs, increased power consumption, and limited network coverage, making it less suitable for rural and large-scale agricultural deployments.

Subsequently, Wi-Fi-based IoT systems were introduced to enhance real-time monitoring and cloud integration. Kumar et al. [2] developed a Wi-Fi-enabled smart irrigation system capable of collecting and transmitting environmental data to cloud platforms. Although this system provided accurate monitoring, its limited communication range and dependency on continuous internet connectivity restricted its applicability in remote agricultural areas.

To overcome these limitations, researchers explored Low Power Wide Area Network (LPWAN) technologies, particularly LoRa and LoRaWAN. Augustin et al. [6] conducted a comprehensive study on LoRa technology, highlighting its long-range communication capabilities and low power consumption, making it ideal for IoT applications. Similarly, Palattella et al. [7] discussed the role of IoT in next-generation communication systems, emphasizing scalable and energy-efficient architectures for smart applications.

Several practical implementations of LoRa-based smart agriculture systems have demonstrated its effectiveness. Verma et al. [3] showed that LoRa communication can achieve reliable data transmission over long distances with minimal packet loss.

Singh and Gupta [4] proposed a LoRaWAN-based precision agriculture system capable of monitoring multiple environmental parameters with extended battery life. Additionally, Qureshi [8] designed and implemented a LoRa-based smart agriculture system, validating its efficiency in real-time field monitoring.

Further advancements in smart irrigation include integration with cloud computing and artificial intelligence. Misra and Singh [9] proposed a cloud-based smart agriculture system using LoRa and AI for predictive irrigation and improved decision-making. Moreover, Valecce et al. [5] introduced an IoT-based fertigation system that combines irrigation and fertilization, demonstrating the potential of integrated smart farming solutions.

Despite these advancements, challenges such as network scalability, data rate limitations, and environmental interference still persist. However, LoRa-based systems continue to emerge as a promising solution for smart irrigation due to their long communication range, low power consumption, and cost-effectiveness, particularly in rural and resource-constrained environments.

3. METHODOLOGY

In this section, we provide a comprehensive overview of the proposed AquaReach system, detailing its hardware architecture, software components, and operational functionality designed for efficient smart irrigation.

A. System Overview

The proposed AquaReach system consists of three main units:

1. Sensor Node Unit
2. LoRa Gateway Unit
3. Cloud Monitoring Platform

i) Sensor Node Unit

Each node comprises a soil moisture sensor, DHT11 temperature-humidity sensor, Arduino Uno microcontroller, and a LoRa SX1278 transceiver module. The node continuously measures soil conditions and transmits data to the gateway every 15 minutes. The node is powered by a rechargeable lithium-ion battery supported by a small solar panel for off-grid operation.

ii) LoRa Gateway Unit

The gateway acts as a bridge between multiple sensor nodes and the cloud. It uses a Raspberry Pi integrated with a LoRa receiver and Wi-Fi/Ethernet connectivity to upload data to the cloud server or local dashboard. The gateway also sends control commands back to actuators such as solenoid valves or water pumps.

iii) Cloud Monitoring Platform

The collected data is visualized using a cloud-based IoT dashboard (e.g., ThingSpeak or Blynk) that displays real-time parameters and allows the farmer to set irrigation thresholds. When soil moisture drops below a predefined level, the system automatically triggers irrigation.

1. Hardware Implementation

The proposed AquaReach system is built using a combination of low-power and high-performance hardware modules. The Raspberry Pi 3B serves as the central gateway, featuring a 1.2 GHz processor and 1 GB RAM, responsible for data

aggregation, processing, and cloud communication. Each sensor node is powered by an ESP32 microcontroller, known for its low power consumption and integrated Wi-Fi and Bluetooth capabilities, enabling efficient local data handling. Long-range communication is established using the LoRa-02 (Ai-Thinker Ra-02) module, which ensures reliable data transmission over several kilometers with minimal energy usage. The SRD-05VDC-SL-C relay module is utilized to control irrigation actuators such as solenoid valves or pumps, interfacing safely between the microcontroller and high-voltage circuits.

A HiLink 5V power module (HLK-2M05) provides stable DC power conversion for all electronic components, while DG301 terminal blocks are employed for secure and modular wiring connections within the system. Together, these components create a cost-effective, energy-efficient, and scalable hardware architecture suitable for real-time smart irrigation applications.

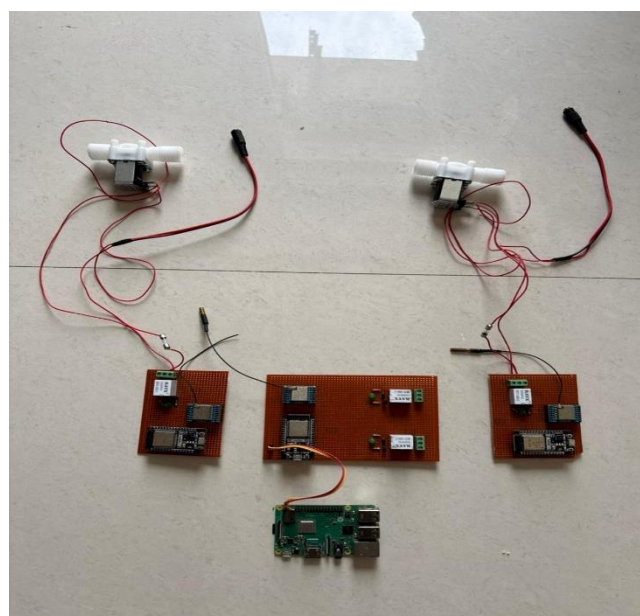


Fig. 1. Hardware Components

2. Software Components

The firmware for Arduino nodes was developed using the Arduino IDE, employing the LoRa.h library for data transmission. The gateway Python script handles data parsing and MQTT-based cloud communication. The dashboard interface allows users to visualize metrics and manually override irrigation when needed.

B. System Functionality

The AquaReach system operates by continuously monitoring soil and environmental parameters to automate irrigation based on real-time data. The ESP32 microcontroller at each sensor node collects readings from the soil moisture and temperature-humidity sensors. These values are processed locally and transmitted to the Raspberry Pi 3B gateway using the Ai-

Thinker Ra-02 (SX1278-based LoRa module) , which ensures long-range and low-power communication.

The gateway aggregates the received data and uploads it to a cloud-based IoT platform, where it is visualized through a user-friendly dashboard. When the soil moisture level drops below a predefined threshold, the system automatically activates the relay-controlled solenoid valve to start irrigation. Once the desired moisture level is restored, the valve is switched off to conserve water.

The HiLink 5V power module and DG301 terminal connections ensure stable and reliable operation, while the solar-powered supply enables continuous field deployment without manual intervention. Thus, the system provides a fully automated, energy-efficient, and scalable irrigation mechanism, minimizing water wastage and reducing the need for human supervision.



Fig. 2. Smart Irrigation System Model

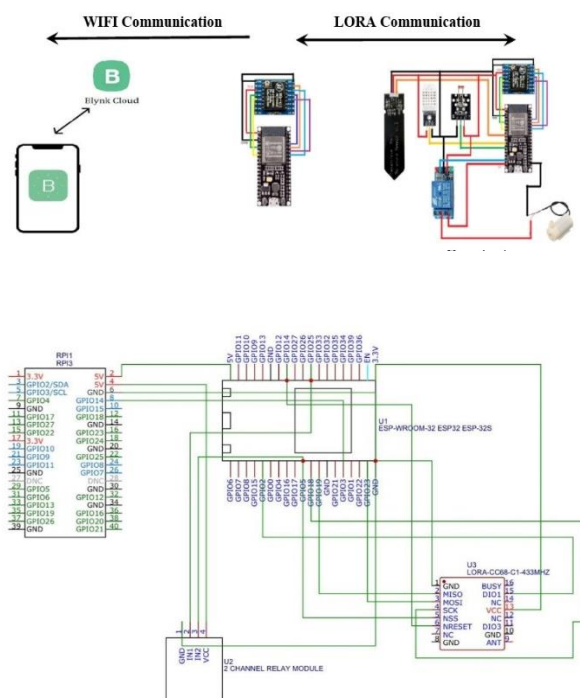


Fig. 3. System Architecture Block diagram

4. RESULT, APPLICATION & LIMITATIONS

In this section, we get to know the key outcomes, practical applications, and limitations of the proposed AquaReach system.

A. Result

The system enables successful remote irrigation control using SMS-based LoRa communication, making it highly practical for agricultural use. It is designed to consume low power, with a transmit current of around 40 mA and a receive current of about 12 mA, ensuring energy efficiency. The communication range is approximately 7–8 km, which makes it well-suited for large rural fields. Additionally, the system is cost-effective, making it accessible for small and marginal farmers. It also supports efficient automation, as the irrigation process is triggered automatically when sensor readings, such as soil moisture levels, fall below predefined threshold values.

B. Application

The system allows remote irrigation control through simple SMS commands, making it easy to operate even without advanced infrastructure. It uses long-range LoRa communication, which is ideal for covering large agricultural fields efficiently. By enabling optimized water management, the system helps reduce manual labor while conserving valuable resources like water. Moreover, it is especially suitable for rural agricultural areas where internet connectivity is limited or unreliable, ensuring consistent and dependable operation.

C. Limitations

The system has certain limitations, as the LoRa communication range can be affected by interference due to terrain variations and physical obstacles, leading to inconsistent performance in some environments. Additionally, it operates at a low data rate, which restricts the amount of sensor data that can be transmitted in real time, making it less suitable for applications requiring high-speed or large-volume data transfer.

5. FUTURE SCOPE

In this section, we get to know potential future enhancements for the AquaReach system aimed at improving its efficiency, scalability, and usability.

The AquaReach system can be further enhanced by integrating AI and machine learning for predictive irrigation and improved water management. Cloud connectivity can enable real-time monitoring and data analytics, while a mobile application can simplify user interaction. Incorporating additional sensors for pH, nutrients, and rainfall would provide more accurate environmental insights. Finally, using solar power and expanding the network for community-based irrigation systems can make AquaReach more sustainable and scalable in rural areas.

6. CONCLUSION

In this section, we get to know the overall significance and impact of the AquaReach system as a transformative solution for modern agriculture.

AquaReach stands as a scalable, affordable, and sustainable innovation that bridges the gap between traditional farming and digital transformation. It empowers farmers with accessible technology, reduces operational burden, and lays the groundwork for a smarter, more sustainable agricultural future in India and beyond. It highlights how simple yet powerful communication technologies like LoRa and GSM can create a major social impact when applied thoughtfully in rural contexts. By optimizing resource usage and enabling data-driven decisions, AquaReach encourages the adoption of precision agriculture practices among small and marginal farmers. Continued development and deployment of such systems can significantly enhance food security, improve rural livelihoods, and promote sustainable technological growth in the agricultural sector.

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