Smart Irrigation System for Precision Farming

SUNDARAM SINGH
Department of Electronics and Telecommunication Engineering
JSPM's Bhivarabai Sawant Institute of Technology & Research , Pune, India
sundaramsingh1020@gmail.com

AVINASH GHALME
Department of Electronics and Telecommunication Engineering JSPM's Bhivarabai Sawant Institute of Technology & Research , Pune, India
avinashghalme8@gmail.com.

MAHESH ANKUSHE
Department of Electronics and Telecommunication Engineering
JSPM's Bhivarabai Sawant Institute of Technology & Research , Pune, India
maheshankushe003@gmail.com

Dr. Y.S ANGAL
Department of Electronics and Telecommunication Engineering
JSPM's Bhivarabai Sawant Institute of Technology & Research , Pune, India
ysangal_entc@jspmbsiotr.edu.in

Abstract- Water scarcity and inefficient irrigation methods challenge modern agriculture, necessitating of smart solutions for sustainable water management. This paper presents a Long Range(LoRa)-based smart irrigation system for precision farming, integrating soil moisture sensors, weather data, and IoT-based control mechanisms to optimize irrigation dynamically. LoRa technology enables long-range, low-power communication, making the system ideal for remote agricultural fields. Real-time data transmission ensures precise irrigation, reducing water wastage and enhancing crop yield. The proposed system is a cost-effective, scalable, and energy-efficient, addressing limitations of traditional irrigation. Experimental results demonstrate improved water utilization and reduced operational costs, contributing to sustainable and efficient agricultural practices.

Keywords: Smart Irrigation, LoRa Technology, Precision Farming, Water Management, IoT,THINGSPEAK.

I. Introduction

Water scarcity and inefficient irrigation techniques remain significant challenges in modern agriculture, particularly in arid regions where water resources are limited. Traditional irrigation systems often lead to overuse of water, resulting in wastage and uneven crop growth, which negatively impacts agricultural productivity. As global demand for food increases and climate change exacerbates water stress, there is an urgent need for more efficient and sustainable solutions in farming practices.Smart irrigation systems, powered by the Internet of Things (IoT), offer a promising solution by enabling real-time monitoring and automated control of irrigation.

These systems optimize water usage by integrating sensors that measure soil moisture levels, weather conditions, and other environmental factors. In this context, Long Range (LoRa) technology plays a key role by providing long-distance, low - power communication, making it suitable for large-scale agricultural areas where traditional communication systems might be impractical.This paper introduces a smart irrigation system based on LoRa technology for precision farming, aiming to improve water management efficiency. The system integrates IoT-based soil moisture sensors, weather data, and automated control mechanisms to dynamically adjust irrigation schedules. By reducing water consumption and ensuring the consistent crop growth, the proposed system not only conserves water but also enhances overall agricultural productivity. This paper explores the system's design, implementation, and performance, highlighting its potential to revolutionize water management practices in farming and contribute to sustainable agricultural development.

Smart irrigation systems have been extensively studied to improve water efficiency and enhance agricultural productivity. Researchers have explored the integration of IoT, wireless sensor networks (WSN), and automated control mechanisms for optimized irrigation. Alavi and Ahmadi [1] provided a comprehensive review of key technologies in smart irrigation, highlighting IoT and sensor network advancements. Sharma and Singh [2] introduced an IoT-based smart irrigation system using wireless communication, improving water conservation in precision farming. Jain and Yadav [3] developed a smart irrigation system utilizing WSN for real-time soil moisture monitoring and automated irrigation. Kumar and Singh [4] proposed a real-time soil moisture monitoring system aimed at optimizing water usage in agriculture. Chauhan and Kumar [5] designed an IoT-based smart irrigation system integrating wireless sensors to enhance water management efficiency. Despite these advancements, challenges such as sensor calibration, data transmission reliability, and large-scale implementation persist. This study aims to develop an optimized LoRa-based smart irrigation system to enhance water management, reduce operational costs, and improve sustainability in precision farming.

II. Methodology

Efficient water management is essential for sustainable agriculture, especially in regions facing water scarcity. The proposed smart irrigation system utilizes LoRa technology to enable real-time monitoring and automated control of irrigation processes, reducing water wastage and improving crop yield (Bose & Kumar, 2021)[6].This system integrates IoT-based soil moisture sensors, weather data, and wireless communication to optimize irrigation schedules dynamically(Chand & Kumar, 2021)[7].

The system employs soil moisture sensors to measure real-time soil conditions and weather sensors to track environmental parameters such as humidity, temperature, and rainfall(Yadav & Chaurasia, 2021)[8]. These sensors transmit data via Long Range Wide Area Network (LoRaWAN), ensuring long-range, low-power communication even in remote agricultural fields (Goyal & Sharma,2022)[9]. Based on the collected data, the system automatically regulates water flow using smart valves, preventing over-irrigation and ensuring optimal soil moisture levels.A cloud-based monitoring platform allows farmers to track soil conditions, receive alerts, and control irrigation remotely using a mobile or web application. This feature minimizes manual intervention, enabling precision farming with data-driven decision-making. The system also incorporates predictive analytics, using historical weather and soil moisture data to optimize irrigation schedules further. The system is powered by solar energy, making it an efficient and sustainable solution for precision farming.

A. Transmitter Node (Sensor Station)

Each transmitter node is equipped with multiple sensors and communication modules to monitor field conditions and send data wirelessly. The system is powered by solar energy, making it an efficient and sustainable solution for precision farming. The transmitter node is designed to collect real-time environmental data from the field and send it wirelessly to a central receiver. At its core is the NodeMCU, a microcontroller that processes input from two key sensors: the DHT11, which measures temperature and humidity, and the soil moisture sensor, which monitors the water content in the soil. These readings are essential for determining when and how much to irrigate.

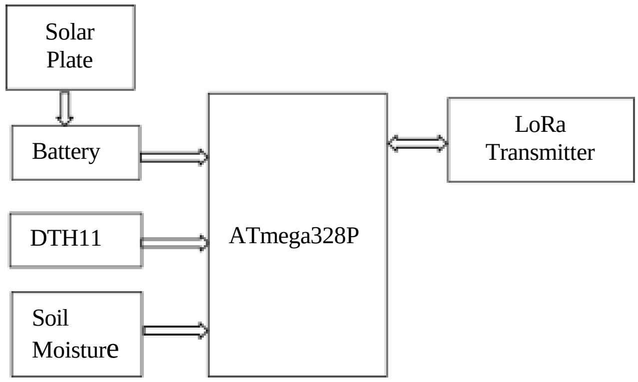

Fig 1. Block Diagram of Transmitter

[1] Digital Humidity and Temperature Sensor (DTH11): Measures temperature and humidity, helping optimize irrigation schedules based on environmental conditions.[2] Soil Moisture Sensor: Detects soil moisture levels, determining when irrigation is required to prevent overwatering or drought stress.[3] LoRa Transmitter: Enables long-range, low-power data transmission from the sensor nodes to the receiver station.[4] Microcontroller (ATMEGA328P): Acts as the processing unit, collecting sensor data and sending it to the LoRa transmitter.[5] Battery and Solar Plate: Ensures uninterrupted power supply to the sensor nodes, enabling autonomous operation in remote agricultural fields.

B. Receiver Node (Control & Monitoring Station)

The receiver node acts as the central hub, collecting data from multiple transmitter nodes deployed across the farm. It processes this data, displays real-time field conditions, and facilitates automated irrigation control. The LoRa receiver receives sensor data, including soil moisture levels, temperature, humidity, and water flow rates. This data is processed by the NodeMCU (ESP8266/ESP32), which determines whether irrigation is required and sends relevant commands.

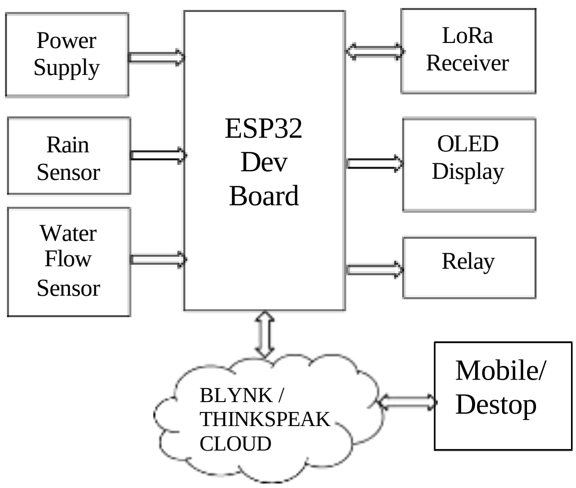

Fig 2. Block Diagram of Receiver

[1] **LoRa Receiver:** The receiver node is equipped with a LoRa module that receives data packets from multiple sensor nodes across the field. LoRa technology ensures long-range, low-power communication, allowing data collection over vast

agricultural areas without requiring an internet connection at the sensor nodes. [2] **Water Flow Sensor:** This sensor monitors water usage and detects irregularities in irrigation, such as leaks or overflows, ensuring optimal water distribution. By continuously tracking water flow rates, the system can prevent excess water loss and alert farmers in case of any anomalies. [3] **ESP32 :** Acting as the micro-controller, the ESP32 processes received data from the LoRa receiver and determines irrigation needs based on soil moisture levels, temperature, and humidity. It also facilitates communication with the cloud (ThingSpeak/Blynk) for remote access and automation. [4] **OLED Display:** The OLED screen provides local real-time visualization of key sensor readings, including soil moisture levels, temperature, humidity, and water flow rates. This allows farmers or field operators to quickly check conditions without needing to access the cloud dashboard. [5] **Battery-Powered Operation:** The receiver node operates on a battery-powered system, ensuring continuous functionality even in areas with unreliable electricity. It can also be supplemented with solar power, making it a sustainable and energy-efficient solution for remote farming locations. [6] **Cloud Integration & Remote Monitoring:** The receiver node uploads sensor data to the cloud (ThingSpeak/Blynk), enabling real-time remote access via mobile and web applications. Farmers can monitor irrigation status, view historical data, and receive alerts or notifications if water levels drop below or exceed predefined thresholds.[7] **Servo Motor:** A servo motor is an electromechanical actuator used for precise control of position, speed, and acceleration. It consists of a DC motor, feedback device, and controller for accurate movement. The motor adjusts in real-time based on control signals and feedback. Servo motors are used in applications requiring high precision, such as robotics and CNC machines. They offer excellent torque, reliability, and fast response times.

C. Cloud-Based Data Processing and Monitoring

Fig 3. Blynk App Dashboard

The cloud-based monitoring system plays a crucial role in data storage, analysis, remote access, and automation. Once the receiver node collects data from multiple sensor nodes, it is uploaded to the cloud via the ESP32. The system utilizes ThingSpeak/Blynk Cloud for real-time monitoring, decision-making, and irrigation control. This cloud integration enhances precision farming by providing data-driven insights, predictive analysis, and remote management. Farmers can access live sensor readings via mobile and web applications, ensuring real-time monitoring of field conditions. The dashboard displays critical parameters such as soil moisture, temperature, humidity, and water flow rates, with customizable graphs and analytics that help farmers visualize trends and assess field conditions at a glance. The system uses predefined thresholds to determine when irrigation should be activated or stopped. If soil moisture falls below a critical level, the system automatically turns on irrigation and shuts it off once optimal moisture is reached. This minimizes manual intervention, prevents overwatering or under watering, and ensures efficient water usage.The cloud platform also stores past sensor readings, allowing farmers to analyze long-term trends in soil moisture, weather conditions, and water usage. Predictive analytics can help anticipate irrigation needs based on historical patterns and weather forecasts, providing valuable insights for decision-making. These data-driven insights enable farmers to make informed decisions about crop water requirements and irrigation planning, ultimately improving overall efficiency. Additionally, the system provides real-time alerts via mobile notifications emails when critical conditions arise, such as low soil moisture, excessive water usage, sensor malfunctions, or abnormal environmental changes. This ensures farmers can take immediate action, even when they are away from the farm. The cloud platform offers a user-friendly interface, enabling farmers to remotely monitor and manage the irrigation system from anywhere.

III. WORKING

A. Sensor Deployment

a) Soil Moisture Sensors: These sensors are placed in the soil to monitor the moisture level. They measure the volumetric water content in the soil.

b) Weather Sensors (DHT11): These measure ambient temperature and humidity. They help in understanding the environmental conditions that can influence water evaporation and crop water requirements.

c) Light Sensors: Sometimes, light sensors are added to monitor the amount of sunlight, which can also affect crop irrigation needs.

B. Data Collection and Transmission (Transmitter Node)

a) Sensor Data Collection: The data from soil moisture sensors, weather sensors, and other environmental sensors are collected by the ESP32 (microcontroller). The ESP32 processes the data and prepares it for transmission.

b) LoRa Communication: The LoRa Transmitter Module sends the data from the ESP32 to a receiver node located nearby, over a long range with minimal energy consumption.

C. Data Reception and Processing (Receiver Node)

a) LoRa Receiver: The LoRa Receiver Module receives the transmitted data from the transmitter node. This node typically resides on a central location or server that processes the incoming data.

b) Microcontroller (ESP32): The receiver node also uses a ESP32 to process the received data. It can display the received data on an OLED display for real-time monitoring or send it to a cloud platform.

D. Cloud Integration

a) Data Upload to Cloud: The receiver node sends the data to a cloud platform like ThingSpeak or Blynk, where the data is stored for further analysis and visualization.
b) Analysis and Monitoring: The cloud platform aggregates the data, creating insights and graphs based on soil moisture, temperature, humidity, etc.
c) Alerts and Recommendations: If the soil moisture level is below a threshold, the system can send alerts or recommendations for irrigation.

E. Automated Irrigation Control

a) Irrigation Decision: Based on the cloud analysis or locally embedded algorithms, the system determines whether irrigation is needed. This decision can be automated based on soil moisture levels, weather predictions, and crop needs.
b) Activation of Irrigation System: If irrigation is needed, a signal is sent to the irrigation system to open valves or activate sprinklers or drip lines.
c) Water Flow Measurement: A Water Flow Sensor might be used to ensure that the system is delivering the correct amount of water, helping to ensure optimal irrigation.

F. Remote Monitoring and Control

a) User Dashboard: The farmer can access a dashboard (web or mobile) to monitor real-time sensor data, irrigation status, and historical trends.
b) Manual Override: If necessary, the farmer can manually control irrigation through the app, even if the system is automated.

IV. Results

A. Overall System Setup

The below figure shows the system set-up which include various components such as sensors, microcontrollers, LoRa modules, and a cloud platform for data storage and analysis. The system comprises multiple sensor nodes placed across the farm, with each node equipped with environmental sensors like DHT11 (temperature and humidity) and soil moisture sensors. These sensors collect real-time data about the soil and environmental conditions.

The data is transmitted wirelessly from the sensor nodes to a central receiver node using LoRa technology. The receiver node then sends the data to the cloud platform, where it is stored and analyzed for irrigation decisions.

This system is designed to automatically activate irrigation based on the analyzed data. The system also allows for remote monitoring and control via a mobile app or web dashboard, enabling farmers to oversee and adjust the irrigation process from anywhere. The Overall system setup is shown in the above fig 4.

Fig 4. Overall System Setup

B. Blynk application/Cloud

This is the GUI of Blynk application which displays a Blynk Console dashboard for a Smart Agriculture system, which is used for real-time monitoring of various environmental parameters. The dashboard is currently inactive and belongs to an organization identified as "My organization - 34B7J4K." It presents live data readings of key agricultural factors, including temperature (29°C), humidity (95%), soil temperature (28°C), and soil moisture (84%).

Fig 5. Blynk Dsahboard

The temperature value is highlighted in red, possibly indicating a high level, whereas the humidity and soil moisture are shown in green, suggesting optimal conditions. Additionally, there is a motor control toggle switch, which is currently turned off, allowing remote operation of connected agricultural equipment. The bottom of the interface displays network speed information and support options, ensuring smooth operation and troubleshooting if needed. This dashboard serves as a critical tool for farmers and agricultural researchers to monitor and control environmental conditions using IoT technology through the Blynk Cloud platform.

C. ThingSpeak cloud

The image displays a ThingSpeak Cloud dashboard, which is used for real-time monitoring and visualization of sensor data in an IoT-based system. The dashboard is labeled "Channel Stats" and consists of four separate field charts, each representing different environmental parameters. The first chart shows Soil Moisture levels over time, indicating fluctuations in the recorded values. The second chart represents Soil Temperature, displaying relatively stable readings with a sudden drop at one point. The third chart monitors Air Temperature, which initially remains stable but experiences a sharp decline before recovering. The fourth chart tracks Humidity, showing an increasing trend followed by a significant drop. The dashboard includes options to add visualizations, widgets, and export data, making it a useful tool for analyzing trends and patterns in environmental conditions.

Fig 6. ThingSpeak Dashborad

D. Email alert

The image showcases notification alerts from the Blynk cloud platform, illustrating the real-time monitoring features of the smart irrigation system for precision farming. The "Inactive" alert indicates that the device has lost connection, potentially due to power issues or network instability. Email Notifications are like "LoRa_Disconnected" and "LoRa_Connected" reflect the status of the LoRa communication link, confirming both disconnection and successful reconnection events. This highlights the system's ability to detect and recover from connectivity interruptions, ensuring continuous data transmission.

Fig 7. Email Alert

The "low_moisture" alert signals a drop in soil moisture levels below the threshold, triggering a prompt to activate irrigation. These notifications demonstrate the system's automated alert mechanism, enabling quick responses to environmental changes and device status. This functionality reduces the need for manual monitoring, enhances water management efficiency, and supports sustainable agricultural practices. Overall, the results confirm the system's reliability in real-time monitoring and remote control.

V. CONCLUSION

The smart irrigation system for precision farming optimizes water usage by leveraging real-time data from various sensors such as soil moisture and weather sensors. The system uses LoRa technology for low-power, long-range communication between sensor nodes and a central receiver, transmitting data to the cloud for analysis. By automatically adjusting irrigation based on soil moisture levels and environmental conditions, it significantly reduces water wastage and ensures efficient water distribution.

The integration of remote monitoring via mobile or web apps allows farmers to manage irrigation from anywhere, providing flexibility and ease of use. The system promotes sustainability by conserving water resources, lowering operational costs, and improving crop yields. Ultimately, smart irrigation enhances the efficiency of farming operations, contributing to more sustainable agricultural practices. With future advancements in IoT and AI, such systems will continue to evolve, offering even greater precision and support for farmers worldwide.

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