



Design and Implementation of LoRa Based Wireless Sensor Network for Long Range Data Communication

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Abstract: The Design and Implementation of LoRa Based Wireless Sensor Network for Long Range Data Communication is developed to provide reliable and long-distance wireless monitoring of agricultural and environmental conditions. The system uses sensors such as a soil moisture sensor, DHT11, and MQ-135 to measure soil moisture, temperature, humidity, and air quality. An Arduino Nano collects and processes the sensor readings and sends the information through a LoRa wireless module. At the receiving end, an ESP32 receives the transmitted data and displays the sensor values on a display. The system can also generate alerts through a buzzer when the measured values cross predefined limits and can control a water pump using a relay according to soil moisture conditions. LoRa communication allows the system to transmit data over a long distance with low power consumption, making it useful for farm monitoring and other remote sensing applications.

Index Terms - LoRa, Wireless Sensor Network, Arduino Nano, ESP32, Soil Moisture, DHT11, MQ-135, Long-Range Communication, Smart Agriculture, Remote Monitoring.

I. INTRODUCTION

Wireless sensor networks are becoming increasingly useful for monitoring farms and other remote areas where wired need to be monitored regularly for better crop management. The proposed system uses LoRa (Long Range) communication to collect and transfer this information over a long distance with low power consumption.

In this system, different sensors are connected to an Arduino Nano at the farm-side transmitter. The soil moisture sensor measures the water content in the soil, the DHT11 measures temperature and humidity, and the MQ-135 monitors changes in air quality. The Arduino processes these readings and sends the collected information through a LoRa module. The readings can also be viewed locally on a display.

At the main station, an ESP32 receives the wireless data through another LoRa module. The received values are processed and displayed so that the user can easily monitor the condition of the farm. A buzzer can provide an alert when any measured value reaches an unwanted level. The system can also operate a water pump through a relay when irrigation is required based on soil moisture conditions.

Overall, the proposed system provides a simple and economical way to monitor agricultural conditions from a distance. By combining sensors, Arduino, ESP32, LoRa communication, and automatic pump control, the system reduces the need for continuous manual monitoring and supports more efficient farm management.

II. AIM AND OBJECTIVES

Aim

The main aim of this project is to design and implement a LoRa-based wireless sensor network for long-distance monitoring of agricultural and environmental conditions. The system collects important sensor information such as soil moisture, temperature, humidity, and air quality, and transfers it wirelessly to a main station for monitoring, alerts, and basic control of farm devices.

Objectives

- To monitor soil moisture and determine when irrigation is required for the farm.

- To measure temperature and humidity using the DHT11 sensor for continuous environmental monitoring.
- To monitor air quality using the MQ-135 sensor and identify changes in surrounding air conditions.
- To transmit sensor data over a long distance using LoRa communication without requiring physical wires.
- To provide reliable and low-power communication between the farm-side transmitter and the main receiving station.
- To display the collected sensor information on a display at both the required monitoring points.
- To generate alerts through a buzzer when sensor values reach predefined limits.
- To control the water pump automatically or manually through a relay according to soil moisture conditions.

III. LITERATURE REVIEW

The development of wireless sensor networks has gradually improved the way agricultural and environmental data is collected and monitored. Earlier systems mainly used wired sensors and short-range wireless technologies, which worked well for nearby monitoring but were less suitable for large farms. With the development of low-power wireless communication, long-distance monitoring became more practical. The following points summarize the development from older systems to the proposed LoRa-based system:

[1] Design and Implementation of Long Range Wide Area Networks for Future Industrial IoT Applications .

R. Mariappan, "Design and Implementation of Long Range Wide Area Networks for Future Industrial IoT Applications," *International Journal of Sensors, Wireless Communications and Control*, vol. 14, no. 3, pp. 215–225, 2024, doi: 10.2174/0122103279297225240329042445.

R. Mariappan (2024) proposed the design and implementation of Long Range Wide Area Networks (LoRaWAN) for future Industrial Internet of Things (IIoT) applications. The study focuses on using long-range, low-power wireless communication to connect industrial devices and sensors efficiently. The work highlights LoRaWAN's suitability for industrial environments due to its long communication range, low power consumption, and scalability. The study is useful for developing reliable and energy-efficient communication systems for future IIoT applications.

[2] Energy Consumption Evaluation of LoRa Sensor Nodes in Wireless Sensor Network.

M. S. Philip and P. Singh, "Energy Consumption Evaluation of LoRa Sensor Nodes in Wireless Sensor Network," in 2021 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), Hyderabad, India, Dec. 2021, pp. 1–6, doi:10.1109/ANTS52648.2021.9708341.

M. S. Philip and P. Singh (2021) evaluated the energy consumption of LoRa sensor nodes in Wireless Sensor Networks (WSNs). The study analyzes the power requirements of LoRa-based sensor nodes and highlights their suitability for low-power and long-range communication. The findings are useful for designing energy-efficient sensor networks, especially in applications where battery life and reliable communication are important.

[3] On the Use of LoRaWAN for Indoor Industrial IoT Applications.

M. Luvisotto, F. Tramarin, L. Vangelista, and S. Vitturi, "On the Use of LoRaWAN for Indoor Industrial IoT Applications," *Wireless Communications and Mobile Computing*, vol.2018, no. 1, Art. no. 3982646, pp. 1-11, 2018, doi: 10.1155/2018/3982646.

M. Luvisotto et al. (2018) investigated the use of LoRaWAN for indoor Industrial IoT (IIoT) applications. The study evaluates the communication performance of LoRaWAN in industrial environments, focusing on factors such as coverage, reliability, and signal propagation. The authors showed that LoRaWAN can be a suitable solution for long-range and low-power industrial communication, although indoor environments can affect signal quality. The work provides a foundation for implementing LoRaWAN-based networks in industrial IoT systems.

[4] Internet of Things and LoRaWAN for Smart Cities Applications

IEEE Access, A. Lavric and V. Popa, "Internet of Things and LoRaWAN for Smart Cities Applications," *IEEE Access*, vol. 6, pp. 102–118, 2018.

Lavric and V. Popa (2018) studied the use of IoT and LoRaWAN for smart city applications. The study focuses on the capabilities of LoRaWAN for long-range, low-power, and reliable communication between IoT devices. The authors discussed applications such as smart monitoring, environmental sensing, and smart infrastructure. The work shows that LoRaWAN can be an effective communication technology for developing scalable and energy-efficient smart city systems.

[5] 5.Understanding the Limits of LoRaWAN

Sensors, F. Adelantado et al., "Understanding the Limits of LoRaWAN," *Sensors*, vol. 17, no. 3, pp. 1–27, 2017.

F. Adelantado et al. (2017) studied the limitations and performance of LoRaWAN for IoT applications. The study analyzes factors such as data rate, communication range, network capacity, latency, and energy consumption. The authors highlighted that LoRaWAN is suitable for long-range and low-power communication, but its performance can be limited by network traffic, interference, and duty-cycle restrictions. The work provides a better understanding of the practical limitations of LoRaWAN in IoT networks.

[6] Low Power Wide Area Networks: An Overview

IEEE Internet of Things Journal, U. Raza, P. Kulkarni, and M. Sooriyabandara, "Low Power Wide Area Networks: An Overview," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 2, pp. 855–873, 2017.

U. Raza, P. Kulkarni, and M. Sooriyabandara (2017) presented an overview of Low Power Wide Area Networks (LPWANs) for IoT applications. The study discusses major LPWAN technologies, their architecture, communication range, data rate, power consumption, and network performance. The authors compared different LPWAN solutions and highlighted their suitability for low-power, long-range IoT communication. The work provides a useful foundation for understanding LPWAN technologies such as LoRaWAN and their applications in IoT systems.

IV. METHODOLOGY

The proposed system is designed as a LoRa-based wireless sensor network with two main sections: a farm-side transmitter and a main-station receiver. The transmitter collects environmental and soil information using different sensors, while the receiver obtains the data wirelessly through LoRa and displays it for monitoring. A relay-controlled water pump is also included to support irrigation based on soil moisture conditions.

1. Power Supply and Regulation:

A 12 V DC adapter supplies power to the system. The 7805 voltage regulator converts the input voltage into a regulated 5 V supply for the Arduino Nano, sensors, relay, display, and other required components.

2. Sensor Data Collection:

The soil moisture sensor measures the amount of moisture present in the soil. The DHT11 sensor measures temperature and humidity, while the MQ-135 sensor detects changes in air quality and gas levels.

3. Data Processing:

The Arduino Nano receives the signals from all the sensors and processes the readings. The collected information can also be shown on the local display for quick observation.

4. Long-Range Wireless Transmission:

After processing the sensor readings, the Arduino sends the data to the LoRa module. The LoRa module wirelessly transmits the information over a long distance to the main station.

5. Receiving and Monitoring:

At the main station, another LoRa module receives the transmitted data and passes it to the ESP32. The ESP32 processes the received information and displays the sensor values on the LCD.

6. Alert and Pump Control:

If any monitored value crosses a predefined limit, the ESP32 can activate a buzzer to provide a warning. Based on soil moisture conditions, the Arduino can operate the relay to switch the 12 V water pump ON or OFF.

Working

The working of the system begins with the farm-side sensors continuously monitoring the surrounding conditions. The soil moisture sensor checks whether the soil has sufficient moisture, the DHT11 measures temperature and humidity, and the MQ-135 monitors air-quality changes. These sensor readings are collected by the Arduino Nano and processed into useful data.

The processed data is then sent from the Arduino Nano to the LoRa transmitter. LoRa converts the information into a wireless signal and sends it over a long distance to the receiver located at the main station. This makes it possible to monitor the farm without installing long communication cables.

At the receiving end, the LoRa receiver captures the transmitted information and sends it to the ESP32. The ESP32 interprets the received data and displays the sensor readings on the LCD. If a parameter exceeds its set limit, the system activates the buzzer to notify the user about the abnormal condition.

For irrigation, the soil moisture reading is compared with a predefined moisture level. When the soil becomes too dry, the controller can activate the relay, which switches ON the water pump. Once sufficient moisture is reached, the pump can be switched OFF. In this way, the system combines long-range wireless monitoring, environmental sensing, alert generation, and basic automatic irrigation control in a single system.

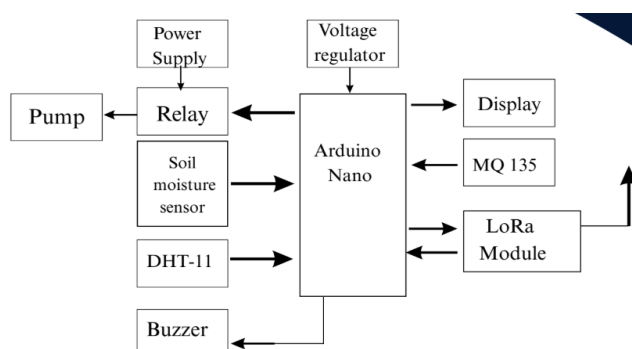


Figure 1: Block Diagram of the Transmitter

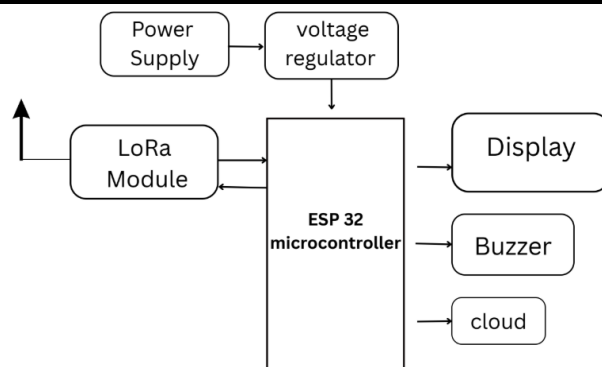


Figure 2: Block Diagram of the Receiver

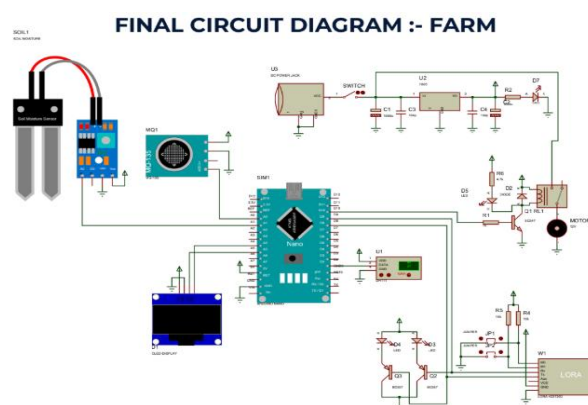


Figure 3: Circuit Diagram of the Transmitter

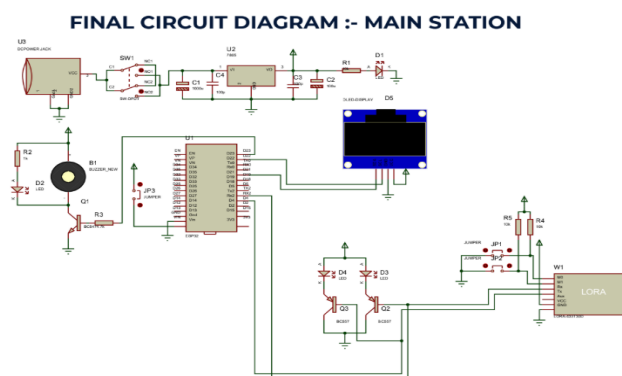


Figure 4: Circuit Diagram of the Receiver

V. RESULTS AND CONCLUSION

Results:

The developed LoRa-based wireless sensor network successfully provides long-distance monitoring of important farm and environmental parameters. The soil moisture sensor, DHT11, and MQ-135 collect information about soil moisture, temperature, humidity, and air quality, while the Arduino Nano processes the readings and transmits them through the LoRa module. At the main station, the ESP32 receives the data and displays the information on the LCD. The buzzer provides an alert when the monitored values cross the predefined limits, and the relay can operate the water pump according to soil moisture conditions. Overall, the system provides a practical method for remote monitoring with reduced wiring and low-power wireless communication.



Figure 5: Hardware Model of the system

Conclusion:

The proposed LoRa Based Wireless Sensor Network for Long Range Data Communication offers a simple and effective solution for monitoring agricultural conditions over a large area. By combining multiple sensors with Arduino Nano, ESP32, and LoRa communication, the system can collect, transmit, and display important farm information without the need for long wired connections. The addition of alert and water-pump control features makes the system more useful for basic agricultural automation. The project can be further improved by adding cloud-based data storage, mobile notifications, more advanced sensors, and automatic analysis of collected data for smarter farm management.

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