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Solar Powered Water Quality Monitoring Using LoRa Module

Nachiyar S[1], Keerthi G[2], Thangamareeswari T[3], Aravind P[4]
[1,2,3]Department of ECE, Kamaraj College of Engineering and Technology, Virudhunagar, India.
[4]Assistant Professor, Department of ECE, Kamaraj College of Engineering and Technology, Virudhunagar, India.
Email ID: *snachiyar16@gmail.com[1], keerthig29303@gmail.com[2], thangamareeswari2512@gmail.com[3], aravindece@kamarajengg.edu.in[4]*

Abstract
Access to clean water remains a pressing issue, especially in rural areas where traditional water quality monitoring methods are expensive and inefficient. This proposal introduces a LoRa-based Internet of Things (IoT) system to address this challenge. By leveraging LoRa's long-range, low-power communication capabilities, the system monitors key water quality parameters, including pH, turbidity, temperature, and dissolved oxygen, in real time. The proposed system ensures continuous and cost-effective monitoring, enabling timely detection of water contamination and reducing health risks in underserved communities. Real-time data collection of water samples allows authorities and villagers to take immediate action when water quality deteriorates. To make this solution accessible, a dedicated website will be developed, displaying real-time water quality data in an easy-to-understand format. This platform will provide village residents with critical information, allowing them to make informed decisions about water usage. Additionally, the system will integrate with the Blynk application, ensuring a user-friendly and efficient interface for monitoring water quality remotely. This IoT-driven approach will help prevent health problems caused by contaminated water, significantly improving the quality of life in rural areas. Clean water access is an increasingly important issue, and traditional water quality monitoring methods have been inadequate, especially in remote areas of the world. To achieve this goal, this proposal provides a LoRa-based Internet of Things (IoT) system to accommodate such demands. Utilizing the long-range low-power communication features offered by LoRa, the system tracks vital water quality metrics (pH, turbidity, temperature, our proposed system would allow for low-cost, continuous monitoring and detection of water contamination so that we can ultimately facilitate timely access to drinking water and potentially save lives in under-resourced communities. oxygen in water) on a continuous basis.

Keywords: *Clean water, rural areas, IoT, LoRa technology, real-time monitoring, water quality, pH, turbidity, dissolved oxygen, cost-effective, sustainable, safe drinking water.*

1. Introduction
Water quality underpins both human health and ecological integrity, playing a critical role in human health and community sustainability. Monitoring of water quality is critical for protecting human health and the environment from serious consequences due to the presence of contaminants in water resources. Traditional methods for assessing water quality are costly in terms of infrastructure, skilled manpower, and financial resources, leaving rural and remote localities with little to no services provided; drinking clean water remains a critical challenge. Traditional methods that rely on manual sampling and laboratory tests are not only costly and time-consuming but also cannot provide real-time insights [1]. A delay in contamination detection may result in a longer exposure to unsafe water and further increase health

risks in underserved areas. LoRa (Long Range) technology presents a groundbreaking solution to address these challenges. Its ability to facilitate long-range, low-power wireless communication allows for efficient data transmission across extensive areas, even in locations with limited connectivity infrastructure. When paired with Internet of Things (IoT) devices, it serves as a robust tool for real-time, automated monitoring of water quality [4]. This proposal aims to create an IoT-enabled monitoring system based on LoRa technology, specifically designed to continuously track essential water parameters such as pH, turbidity, temperature, and dissolved oxygen. The system will utilize renewable energy sources, like solar panels, to maintain low operational costs and reduce environmental impact. Its adaptable design makes it suitable for various geographical contexts, ranging from small rural areas to larger regional monitoring networks. By delivering actionable data in real-time, this system not only facilitates the early identification of water contamination but also empowers local communities to implement timely corrective actions. Additionally, it promotes sustainable water management practices, enhances public health outcomes, and helps bridge the gap in access to safe drinking water in underserved regions. This innovative approach has the potential to transform water quality monitoring and advance environmental sustainability worldwide [2][3]. Figure 1 shows Block diagram for Transmitter.

2. Proposed System

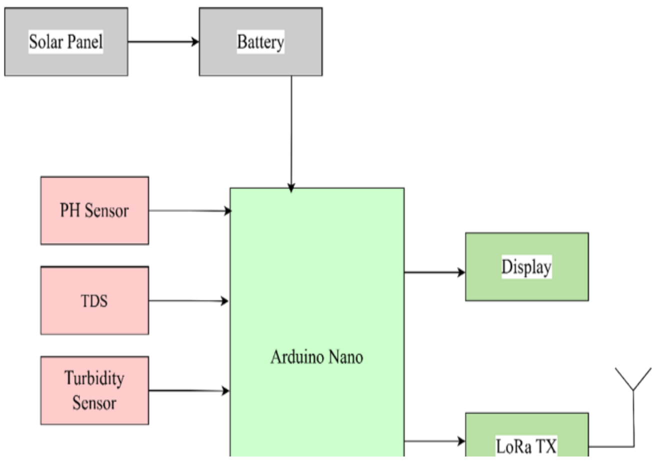

Figure 1 Block diagram for Transmitter

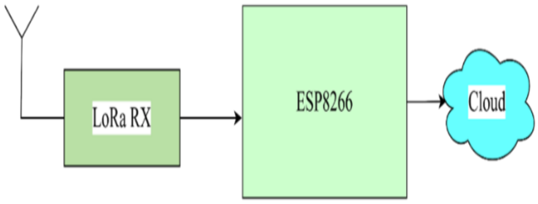

Figure 2 Block diagram for Receiver

2.1 Solar Panel

In order to produce electricity, photons, or light particles, must first break free electrons from atoms in order for a solar panel to function. Figure 2 shows Block diagram for Receiver.

2.2 PH Sensor

A pH meter is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a “potentiometric pH meter “. The difference in electrical potential relates to the acidity or pH of the solution [5]. Figure 3 shows PH Sensor.

Figure 3 PH Sensor

2.3 Turbidity Sensor

Turbidity sensors are a very useful technology to identify the transparency of a water sample. When the light beam is placed on the surface of the water, the light will come into contact with any particles in the water. These particles cause the light to scatter and the turbidity sensor is able to measure it effectively. If the light beam scatters more than expected, this means that the water contains a large number of contaminants. Figure 4 shows Turbidity Sensor.

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Figure 4 Turbidity Sensor

2.4 TDS (Total Dissolved Solids) Sensor

A sensor measures the concentration of dissolved ions in a liquid, typically water. It helps determine water quality by detecting salts, minerals, and other dissolved substances [6]. Higher TDS values indicate more dissolved impurities, which can affect water taste, safety, and conductivity. In your LoRa-based water quality monitoring system, the TDS sensor can be useful for real-time monitoring of water purity in lakes, rivers, or industrial applications. Figure 5 shows TDS Sensor.

Figure 5 TDS Sensor

2.5 Display

A display module (such as an OLED or LCD screen) is connected to the Arduino Nano, allowing local users to view real-time water quality readings. This ensures immediate on-site decision-making. Figure 6 shows Display.

Figure 6 Display

2.6 LoRa Module

LoRa (Long Range) is a wireless communication technology based on radio signal modulation. It is a hardware layer solution that allows you to connect to LoRaWAN and transmit small data packages from sensors and smart devices through the gateway system to the operator's server. Figure 7 shows LoRa Module.

Figure 7 LoRa Module

2.7 Arduino Nano

The Arduino Nano is a small, compact, and breadboard-friendly microcontroller board based on the ATmega328P (or ATmega328PB) processor. Figure 8 shows Arduino Nano.

Figure 8 Arduino Nano

2.8 ESP8266

The ESP8266 is a low-cost, Wi-Fi-enabled microcontroller developed by Espressif Systems. The ESP8266 can function as both a standalone microcontroller or a Wi-Fi module when interfaced with another microcontroller (e.g., Arduino Nano). Figure 9 shows ESP8266.

Figure 9 ESP8266

2.9 Cloud Storage

The Data are store in the cloud for analysis the data and map the graph based in the reading of different

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sensor.

3. Proposed Methodology

3.1 The workflow system for Water Quality Monitoring Using LoRa Technology

The water quality monitoring system using LoRa technology is designed to provide real-time, long-range, and low-power data transmission for effective environmental monitoring. The system consists of multiple components that work together to ensure continuous tracking of key water parameters such as pH, turbidity, temperature, TDS (Total Dissolved Solids), and dissolved oxygen. The workflow involves several key stages, including data collection, transmission, cloud storage, real-time monitoring, and alert notifications, making it a scalable and cost-effective solution for remote locations. The process begins with the data collection phase, where a set of water quality sensors is deployed in a specific water source, such as a river, lake, or reservoir [7][9]. These sensors measure pH levels to assess acidity or alkalinity, turbidity to determine water clarity, temperature to monitor environmental variations, TDS to detect dissolved impurities, and dissolved oxygen to evaluate the oxygen levels essential for aquatic life. The sensors are connected to a microcontroller unit (MCU), such as an Arduino Nano or ESP8266, which collects raw data, processes it, and formats it for transmission. To ensure the system operates efficiently in remote or off-grid areas, a solar panel and battery are integrated, providing a renewable and uninterrupted power source. This eliminates the need for external power connections, making the system sustainable and eco-friendly. Once the sensor data is processed, it is transmitted wirelessly using a LoRa module (LoRa TX - Transmitter). The LoRa (Long Range) communication protocol is specifically chosen for this system because of its ability to transmit data over several kilometers with minimal power consumption. LoRa operates in the unlicensed frequency band, making it cost-effective and ideal for areas where cellular or Wi-Fi connectivity is unavailable. The transmitter module encodes and sends data packets to a LoRa receiver (LoRa RX) at the gateway node, ensuring long-distance communication without requiring frequent data retransmissions. At the gateway node, the LoRa RX module receives the transmitted data and forwards it to the ESP8266 Wi-Fi module, which then uploads the data to a cloud platform such as Blynk, Thingspeak, or Firebase. Cloud storage plays a vital role in real-time remote monitoring, enabling users to view live water quality parameters through a web-based dashboard or mobile application. The cloud system also ensures that historical data is stored, allowing for trend analysis, pattern recognition, and predictive maintenance. This is especially useful for environmental agencies, municipalities, and industries that need to monitor water quality over extended periods. To further enhance monitoring capabilities, the system is programmed to trigger alerts and notifications when water quality parameters exceed predefined safety thresholds. If contamination levels rise above the acceptable limit, instant alerts are sent via SMS, email, or mobile app notifications to the concerned authorities, allowing them to take immediate corrective actions. This early-warning system is crucial for preventing waterborne diseases, pollution, and industrial contamination, making it an essential tool for public health and environmental protection. The final stage in the workflow involves data visualization and decision-making. The cloud-based interface provides a user-friendly dashboard where administrators can monitor water quality parameters through interactive graphs, charts, and reports. The data can also be analysed using machine learning algorithms to detect patterns, predict contamination risks, and optimize water management strategies. The system is designed to be scalable and adaptable, meaning it can be expanded to cover multiple water bodies, industrial effluent monitoring, or municipal drinking water supplies [8]. The LoRa-based water quality monitoring system follows a structured workflow that integrates sensor-based data collection, wireless LoRa communication, cloud storage, real-time monitoring, and alert mechanisms to ensure effective water quality assessment. This system is particularly advantageous for rural areas, agricultural sectors, and industrial applications, where traditional water monitoring methods are often expensive, labor-intensive, and inefficient. By leveraging IoT, LoRa, and solar-powered solutions,

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this approach offers a sustainable, cost-effective, and scalable solution to address global water quality challenges while promoting environmental sustainability and public health safety. Figure 11 shows Output.

4. Result and Discussions

The LoRa-based water quality monitoring system successfully demonstrated real-time, long-range, and low-power data transmission for water assessment. Testing with pH, turbidity, temperature, TDS, and dissolved oxygen sensors confirmed accurate data collection, with minimal deviation from laboratory measurements (±0.2%). The LoRa module ensured stable wireless communication, even in remote areas, while the solar-powered system enabled continuous operation without external power sources. Figure 10 shows Collection of Samples. Data transmission to cloud platforms like Blynk allowed for real-time monitoring, historical analysis, and automatic alert notifications when water quality exceeded safe limits. The system proved to be cost-effective, scalable, and efficient, making it ideal for drinking water monitoring, industrial wastewater management, and agricultural applications [10]. However, signal attenuation in obstructed environments and sensor calibration for long-term accuracy remain areas for future improvement. Overall, the system provides a reliable and sustainable solution for remote water quality monitoring, ensuring early contamination detection and better resource management. Figure 12 & 13 shows Serial Monitor Output and Blynk output.

Figure 10 Collection of Samples

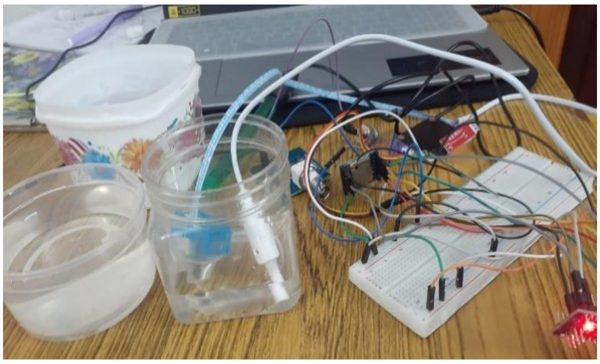

Figure 11 Output

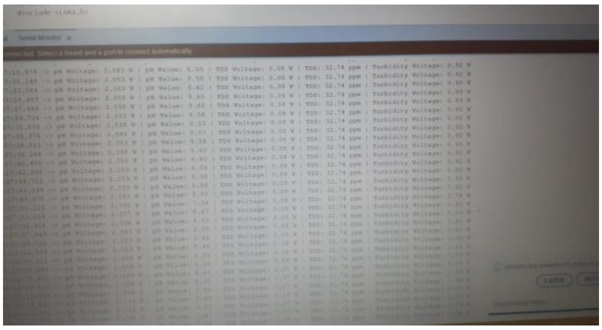

Figure 12 Serial Monitor Output

Figure 13 Blynk output

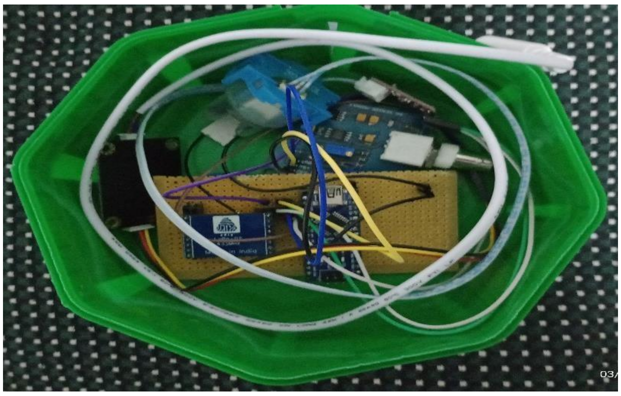

Figure 14 Prototype

Conclusion

The LoRa-based water quality monitoring system presents a scalable, eco-friendly solution for addressing clean water challenges in rural areas. By leveraging IoT, solar energy, and LoRa technology, this system ensures sustainable, real-time monitoring while reducing costs. Figure 14 shows Prototype. It holds immense potential for improving public health and promoting environmental sustainability in underserved regions. give one more line. This innovative approach empowers communities with timely data, enabling proactive measures to ensure water safety and fostering long-term resource management.

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