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Design of Lora-Based River and Reservoir Water Level Monitoring System Using Firebase at PDAM Bangodua Indramayu Branch

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ABSTRACT:
Fluctuations in river and reservoir water levels due to climate extremes disrupt water supply and pose flood risks. Manual monitoring is often delayed and error-prone, especially in remote areas with limited internet. PDAM Bangodua Indramayu lacks a real-time, internet-independent water level monitoring system, hindering rapid response to droughts or floods. This study designed an automated LoRa-based monitoring system using ultrasonic sensors to provide real-time data and early warnings without relying on internet infrastructure. The system integrates a JSN-SR04T ultrasonic sensor, ESP32/ESP8266 microcontrollers, and LoRa SX1278 for long-range communication. Data is transmitted to Firebase and displayed via an Android app built with MIT App Inventor. Testing evaluated sensor accuracy, data transmission success, and alert functionality. The system achieved 100% data transmission success up to 148 meters (line-of-sight) and 80% at 177 meters (with obstacles). It accurately detected water levels (1.03–2.46 m) and triggered alerts via buzzer and app notifications when thresholds were exceeded. This cost-effective, reliable solution enhances disaster preparedness and supports sustainable water management in regions with limited connectivity, offering a model for similar rural applications.

Keywords: Water Level Monitoring, JSN-SR04T Ultrasonic Sensor, LoRa SX1278, ESP32, Firebase, MIT App Inventor, Early Warning System

INTRODUCTION

The availability and management of water resources have become strategic issues worldwide due to increasing human demand for clean water, population growth, and the impact of climate change (Cosgrove & Loucks, 2015; Dixit et al., 2022). Projections show that global water stress will worsen, with nearly half of the global population living in water-stressed areas for at least one month a year by 2050. Additionally, global water demand is expected to increase by 20-30% compared to current levels (Preisser et al., 2025). To address this, technological innovation in water monitoring systems, including real-time sensing, IoT (Internet of Things), AI (artificial intelligence), and remote sensing, plays a vital role in detecting fluctuations in water levels in rivers and reservoirs, warning of potential floods or droughts, and ensuring continuous water supply for domestic, industrial, and agricultural use (Alonso-Sarria et al., 2025). For example, a real-time water level monitoring system on the Sakarya River uses ultrasonic sensors and GSM data transmission to measure water levels and flow continuously with high accuracy, sending alerts when levels reach critical thresholds (Demir & Sonmez, 2025). Moreover, satellite data integration, such as Sentinel-1 SAR, is now used for flood mapping and monitoring flood-prone areas, enabling spatial-temporal monitoring that is independent of weather conditions (Alito et al., 2025). The use of AI and machine learning has also grown to predict droughts through remote sensing indices, detect anomalies in water quality or quantity, and enhance early warning systems (Tao et al., 2025). With these advances, water monitoring systems are no longer passive or manual measurements but are increasingly becoming adaptive, predictive, and automated systems that assist decision-makers in maintaining water supply stability amid both natural and anthropogenic pressures (Islam et al., 2025).

In Indonesia, similar challenges are faced, especially in areas with highly fluctuating water discharge such as Indramayu, which is directly affected by prolonged dry seasons and extreme rainfall (Hadian et al., 2024; Umami et al., 2022). These fluctuations impact water distribution from sources such as the Cimanuk River to the reservoirs managed by local Water Supply Companies (PDAM), disrupting water processing efficiency and delivery to communities. A major issue is the continued use of manual water level monitoring methods, which are prone to delays, recording errors, and reliance on on-site personnel (Andrean, 2021). Inaccurate readings of water level conditions can cause delays in response during potential hazards such as excessive flooding or low reservoir levels.

This problem is further exacerbated by the lack of communications infrastructure in areas distant from commercial internet networks. Monitoring systems that rely solely on Wi-Fi or mobile networks often suffer from signal limitations, especially in outdoor environments or rural regions (Firmansyah et al., 2024). These limitations have encouraged the adoption of technologies that can transmit data over long distances in a stable and energy-efficient manner.

Several previous studies have explored IoT-based water level monitoring systems. For instance, Wibowo & Prasetyo (2021) developed a monitoring system using ultrasonic sensors and LoRa communication, demonstrating its effectiveness in long-distance data transmission with low power consumption. Similarly, research by JCRINN (2022) implemented a rapid flood warning system using LoRa in recreational areas, highlighting its reliability in real-time data delivery. In the context of reservoir monitoring, Jayadi & Saputra (2023) designed an IoT-based tool to monitor water levels, emphasizing the integration of sensors and cloud platforms for data visualization. However, these studies often focused on singular aspects, such as communication or sensor accuracy, without comprehensive integration with real-time cloud-based alert systems and user-friendly mobile applications.

One emerging approach in environmental monitoring is the use of the Internet of Things (IoT), which integrates sensors, microcontrollers, and wireless communication networks. Long Range (LoRa) communication technology has emerged as an efficient solution for long-distance data transmission without relying on internet access. LoRa is known for its long-range capability, low power consumption, and resilience to environmental interference (Wibowo & Prasetyo, 2021). In water level monitoring systems, LoRa technology enables data transmission from sensors in remote locations directly to control centers or cloud platforms in real time.

In addition to communication networks, selecting accurate sensors is equally crucial. The JSN-SR04T ultrasonic sensor has proven effective in measuring distances to water surfaces due to its waterproof design and suitability for outdoor environments. This sensor provides high precision and is resistant to splashes, making it superior to alternatives such as the HC-SR04 (Nari et al., 2023). When integrated with microcontrollers like ESP32 or ESP8266, the system can provide stable and accurate readings. These microcontrollers come equipped with built-in Wi-Fi modules and are compatible with various communication protocols, offering powerful processing capabilities for automation systems (Poetra et al., 2023).

To display the monitoring data in a user-friendly format and allow public accessibility, Firebase is used as a cloud-based data storage and distribution platform. It allows real-time data visualization and can be integrated with mobile applications on Android. MIT App Inventor, a visual programming platform, is used to build mobile apps capable of displaying water status, issuing early warnings, and delivering recommendations to users (Setiawan et al., 2023). The use of mobile applications is especially crucial in emergency situations where users require fast, accurate information for decision-making.

This study offers a unique approach (novelty) through its comprehensive integration of the JSN-SR04T sensor, LoRa SX1278 communication module, Firebase, and a custom Android application developed using MIT App Inventor. The system is designed to operate automatically and issue early warnings through visual indicators and a buzzer when water levels exceed a predefined threshold. Such integration has not been widely implemented in Indramayu, particularly within the *PDAM Bangodua Indramayu Branch*, despite the area's pressing need for an efficient, affordable monitoring system that functions without fixed internet infrastructure.

The urgency of this study stems from the local community and PDAM's critical need for a water level monitoring system that not only operates in real time but also provides early warnings to prevent greater losses. Floods and droughts often go undetected due to limitations in conventional monitoring methods. With this IoT-based system, anticipatory actions can be taken more quickly and accurately. Moreover, the system contributes to PDAM's operational efficiency by providing instant data without requiring time-consuming and labor-intensive manual inspections.

The primary objective of this research is to design and implement an automated river and reservoir water level monitoring system that transmits data in real time and issues alerts when water levels reach hazardous conditions. The system utilizes the JSN-SR04T ultrasonic sensor for measurement, ESP8266 and ESP32 microcontrollers as controllers, LoRa SX1278 for data transmission, Firebase as cloud storage, and an Android-based application developed with MIT App Inventor for data visualization.

The expected benefits of this research include: (1) providing an accurate, real-time water level monitoring system accessible to both the public and technical institutions; (2) enhancing disaster mitigation capacity through technology, particularly in the clean water supply sector; (3) serving as a reference and model system that can be adapted by other PDAM branches across Indonesia; and (4) contributing scientifically to the development of practical, low-cost IoT-based monitoring technologies suitable for rural areas or regions with limited infrastructure. Thus, this study not only improves the effectiveness of local water resource management but also contributes to nationally and globally relevant technological solutions for managing clean water and mitigating disaster risks through data-driven approaches.

RESEARCH METHOD

This research was a qualitative study with a descriptive approach aimed at providing an overview of the design and implementation strategy of a water level monitoring system based on Internet of Things (IoT) technology. The focus was on understanding how the monitoring system was designed to address delays in detecting water level fluctuations in rivers and reservoirs within the operational area of PDAM Bangodua Branch, Indramayu. The study explored the design process from technical, contextual, and operational perspectives and evaluated the integration of technological components to develop an efficient solution.

The research was conducted in the operational area of PDAM Bangodua Branch, Tukdana District, Indramayu Regency, West Java Province. This location was chosen due to its dependence on water distribution from the Cimanuk River and its active reservoir system for clean water treatment, alongside challenges related to limited automatic and responsive water level monitoring infrastructure. The study spanned three months, from May to July 2025, covering the initial study, system design, field implementation, and evaluation of monitoring results.

The research focused on two monitoring units: one installed on the Cimanuk River and the other above the reservoir managed by the Bangodua Branch of PDAM. These points represented critical stages in the water distribution process. Both units were designed, tested, and evaluated under real-world conditions and installed at locations critical for monitoring water level fluctuations.

The main instruments included hardware and software components forming the automatic monitoring system. Hardware consisted of the JSN-SR04T ultrasonic sensor, ESP8266 and ESP32 microcontrollers, LoRa SX1278 communication module, and supporting components like relays, buzzers, and indicator lights. The software comprised Firebase for cloud-based data storage and distribution, and an Android application developed with MIT App Inventor as the user interface.

These components were designed modularly to enable gradual system integration. For documentation and evaluation, tools such as a multimeter, serial monitor software (for debugging), and spreadsheets for recording measurement data were employed. Instrument validity was confirmed through repeated testing in both laboratory and field settings, comparing sensor readings with manual measurements to assess accuracy.

RESULTS AND DISCUSSION

System Design

The system design aims to build a water level monitoring and early warning device based on ultrasonic sensors that transmits data using LoRa communication. The system consists of two main components: a transmitter module for sending sensor data and a receiver module for receiving data and controlling the alarm.

This system is designed to monitor water levels at river locations and PDAM Bangodua IPA *Reservoirs in real time and* provide warnings via buzzer sounds and relay activation when the water exceeds the threshold.

System Block Diagram

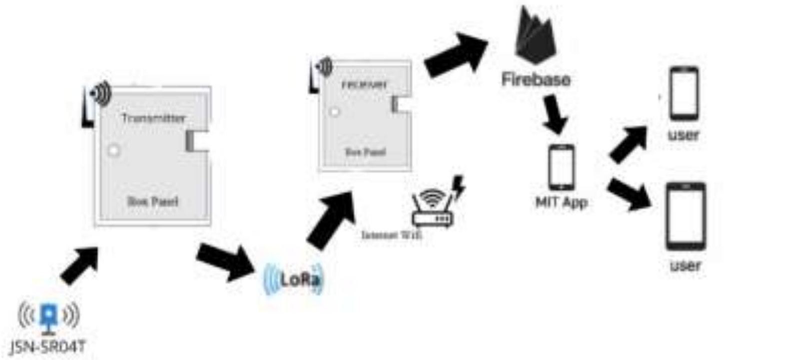

Figure 1. Block Diagram.

The block diagram in Figure 1 explains the overall system workflow. The JSN-SR04T sensor detects the water level and sends the data to the microcontroller in the transmitter module. This data is sent to the receiver module using LoRa communication. The receiver connects to the internet via WiFi and sends the data to Firebase. A mobile app created using MIT App Inventor will retrieve the data from Firebase and display it to the user in *real-time.*

Transmitter System Circuit

The transmitter module functions as a transmitter of measurement data from the ultrasonic sensor. The main components of this module are:

1. JSN-SR04T sensor (waterproof ultrasonic sensor)
2. ESP32 (as a microcontroller)
3. LoRa SX1278 Module
4. Power supply (SMPS 5V)
5. Relay modules and terminal blocks as safety and electrical connections

The JSN-SR04T sensor measures the distance of the water surface to the sensor, then the ESP32 processes the data and sends it via the LoRa module to the receiver.

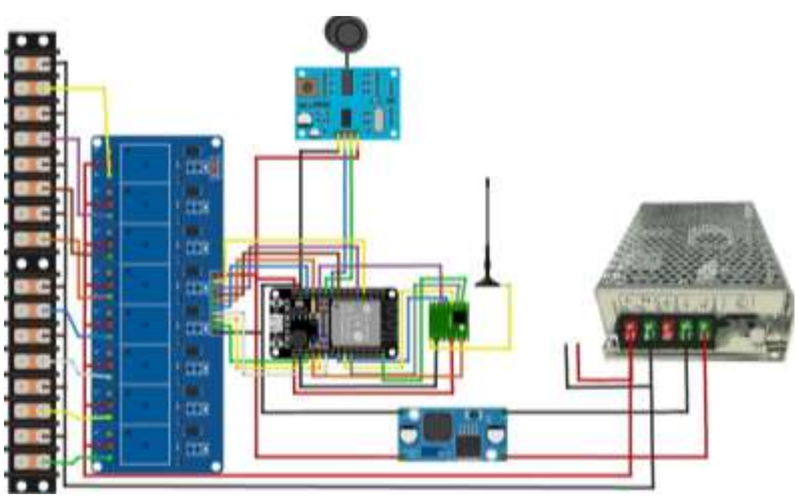

Figure 2. Transmitter System Circuit

Receiver System Circuit

The receiver module receives data from the transmitter over the LoRa network. The received data is processed by the ESP32 and sent to Firebase via a WiFi connection. The receiver components include:

1. ESP32
2. LoRa SX1278 Module
3. ESP32 internal WiFi module
4. Internet connection via router
5. Communication with Firebase

The ESP32 on the receiver will continuously monitor incoming data and upload it to the

Firebase to display on user apps.

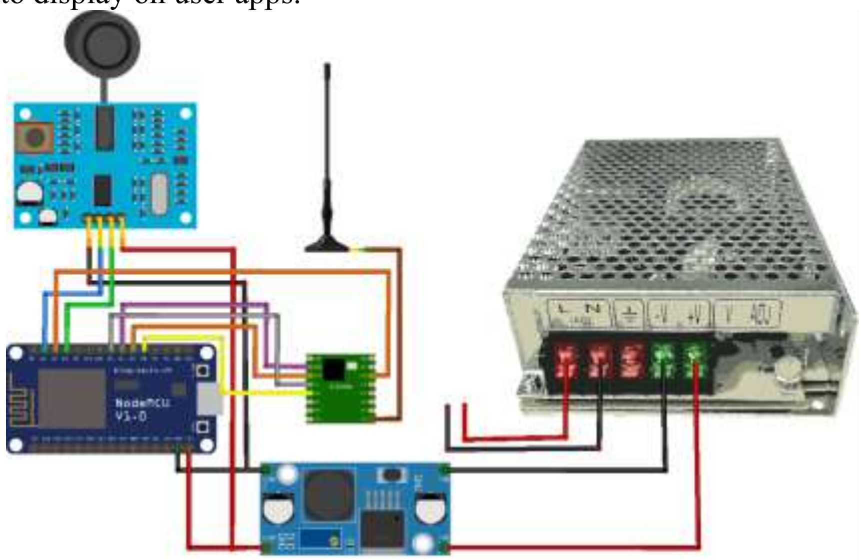

Figure 3 . Receiver System Circuit

Monitoring Application View

To facilitate real-time monitoring, the system is equipped with an Android-based mobile application. This application displays data on river water levels, reservoir water levels, alert status, and LoRa and Firebase connectivity status.

Figure 4. Monitoring Application Display

The app displays a river water level of 1.05 meters, which is considered ALERT, and a reservoir water level of 216 cm. Furthermore, the LoRa and Firebase connection statuses are displayed, indicating CONNECTED, indicating smooth communication between the device and the server.

Data Testing and Analysis

The system was tested over three consecutive days, from July 20, 2025, to July 23, 2025, to determine the device's performance in measuring water levels, sending data over the LoRa network, storing it in Firebase, and displaying the results in a mobile app. Recorded data included time, water level, reservoir water level, alert status, and LoRa and Firebase connections.

Table 1. Results of Water Level Monitoring System Testing for 3 Days

Timestamp	Time	Water Height (m)	Reservoir (cm)	Status	Connection LoRa	Firebase Connection
7/20/2025 15:50	15:50:53	1.31	218	ALERT	CONNECTED	CONNECTED
7/20/2025 18:50	18:50:53	1.05	163	ALERT	CONNECTED	CONNECTED
7/20/2025 21:50	21:50:53	1.06	178	ALERT	CONNECTED	CONNECTED
7/21/2025 3:50	3:50:53	1.02	176	ALERT	CONNECTED	CONNECTED
7/21/2025 6:50	6:50:53	1.06	172	ALERT	CONNECTED	CONNECTED
7/21/2025 9:50	9:50:53	1.27	169	ALERT	CONNECTED	CONNECTED

Timestamp	Time	Water Height (m)	Reservoir (cm)	Status	Connection LoRa	Firebase Connection
7/21/2025 12:50	12:50:53	1.29	165	ALERT	CONNECTED	CONNECTED
7/21/2025 15:50	15:50:53	1.80	220	ALERT	CONNECTED	CONNECTED
7/21/2025 18:50	18:50:53	1.85	202	ALERT	CONNECTED	CONNECTED
7/21/2025 21:50	21:50:53	1.67	181	ALERT	CONNECTED	CONNECTED
7/22/2025 0:50	0:50:54	2.03	197	READY	CONNECTED	CONNECTED
7/22/2025 3:50	3:50:54	2.46	174	READY	CONNECTED	CONNECTED
7/22/2025 6:50	6:50:54	2.12	160	ALERT	CONNECTED	CONNECTED
7/22/2025 9:50	9:50:54	1.67	187	ALERT	CONNECTED	CONNECTED
7/22/2025 12:50	12:50:54	1.75	210	ALERT	CONNECTED	CONNECTED
7/22/2025 15:50	15:50:54	1.68	192	ALERT	CONNECTED	CONNECTED
7/22/2025 18:50	18:50:54	1.53	183	ALERT	CONNECTED	CONNECTED
7/22/2025 21:50	21:50:55	1.22	172	ALERT	CONNECTED	CONNECTED
7/23/2025 0:50	0:50:55	1.78	178	ALERT	CONNECTED	CONNECTED
7/23/2025 3:50	3:50:55	1.72	162	ALERT	CONNECTED	CONNECTED
7/23/2025 6:50	6:50:55	1.65	168	ALERT	CONNECTED	CONNECTED
7/23/2025 9:50	9:50:55	1.62	162	ALERT	CONNECTED	CONNECTED
7/23/2025 12:50	12:50:55	1.23	155	ALERT	CONNECTED	CONNECTED
7/23/2025 15:50	15:50:55	1.05	152	ALERT	CONNECTED	CONNECTED

Based on the data in Table 1, the water level monitoring system was tested for three days, from July 20 to July 23, 2025, with a total of 24 data recordings. During the test, the water level detected by the sensor ranged from 1.03 meters to 2.46 meters. The water level in the reservoir varied between 152 cm and 220 cm. The system automatically classifies the alert status into *ALERT* and *STANDBY* based on a predetermined water level threshold. The *STANDBY status* appears when the water level exceeds 2 meters, as seen in the data from July 22, 2025, from 00:50 to 06:50. All data shows that the LoRa and Firebase connections are CONNECTED, indicating that communication between devices and data transmission to the cloud is running stably and without interruption. This proves that the system is capable of functioning properly in detecting, transmitting, and displaying water level data in *real-time.*

Water Level Test Results Graph

To analyze water level fluctuations during the testing period, data was mapped into a graph based on three consecutive days' recordings. This graph aims to provide a visual representation of the dynamics of water level changes detected by the ultrasonic sensor and to assist in the overall evaluation of system performance.

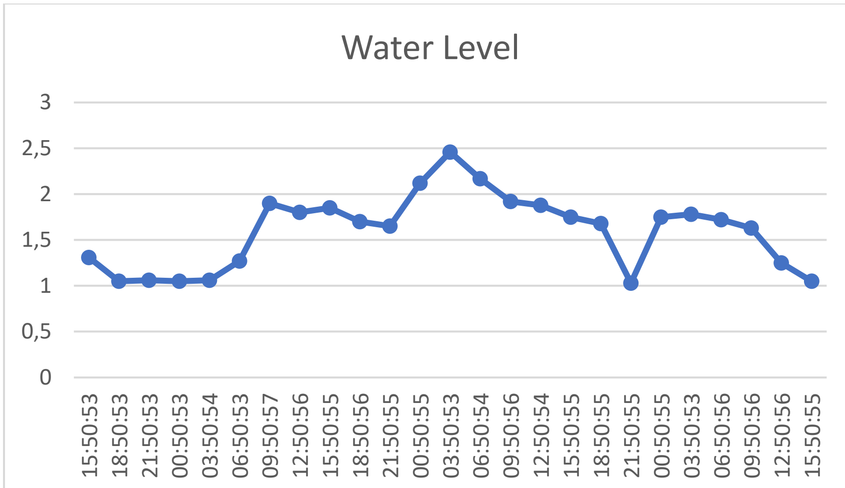

Figure 5. Water Level Graph

Based on the graph, the water level during the testing period ranged from 1.03 meters to 2.46 meters. The highest peak occurred on July 22, 2025, at 03:50:53, with a value of 2.46 meters, which is included in the SIAGA category. After reaching this peak, the water level trend showed a gradual decrease until it stabilized near the initial value. Most of the data is at the WARNING status, which indicates an increase in water levels but has not yet reached a dangerous level.

Reservoir Testing Results Graph

To analyze water level fluctuations during the test period, data recorded over three consecutive days was graphed. This visual presentation of the data aims to provide a clearer picture of the dynamics of water level changes detected by the ultrasonic sensor and serves as a basis for evaluating the system's overall performance and reliability.

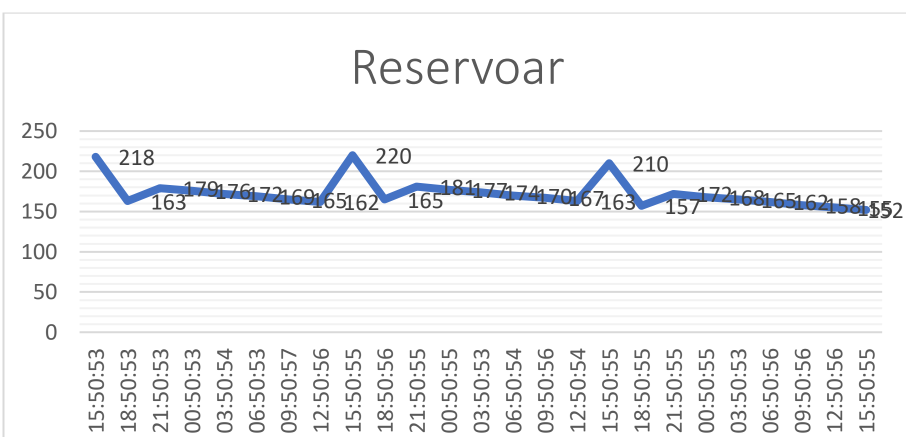

Figure 6. Water Level Graph

The graph shows that the reservoir water level fluctuated during the three days of testing. The lowest value was recorded at 152 cm on July 23, 2025, at 3:50:55 PM. Despite significant changes in river water levels, the system managed to adjust the reservoir's filling and discharge quite well, following a pattern like the river water level graph.

CONCLUSION

The research successfully designed and implemented a river and reservoir water level monitoring system using JSN-SR04T ultrasonic sensors, ESP8266 and ESP32 microcontrollers, and LoRa SX1278 communication integrated with Firebase for real-time data storage and Android app visualization. Testing over three days demonstrated accurate and stable water level measurements, with reliable data transmission achieving a 100% success rate at 148 meters without obstacles and 80% at 177 meters with obstacles. The system automatically issued early warnings via buzzer and light indicators when water levels exceeded thresholds, classifying warning statuses effectively. Communication between devices remained stable throughout, confirming system dependability. Future research could explore expanding the communication range, enhancing system scalability, and integrating additional environmental sensors to provide a more comprehensive water resource monitoring solution.

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