IoT-Based River Water Level Monitoring System Using LoRa Technology

Y.M.R.N.T. Yapa
Department of Computer Science & Engineering
University of Moratuwa
Moratuwa, Sri Lanka
rashmikay.22@cse.mrt.ac.lk

S.J. Sooriyaarachchi
Department of Computer Science & Engineering
University of Moratuwa
Moratuwa, Sri Lanka
sulochanas@cse.mrt.ac.lk

C.R. De Silva
Department of Computer Science & Engineering
University of Moratuwa
Moratuwa, Sri Lanka
chathura@cse.mrt.ac.lk

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I. INTRODUCTION

Floods are one of the most destructive natural disasters, particularly affecting rural riverbank communities with limited access to early warning systems. Existing methods, such as manual monitoring and GSM(Global System for Mobile Communications)-based solutions, are often costly, power-intensive, and unsuitable for remote deployment.

The aim of this research is to design and implement a low-cost, reliable, and energy-efficient IoT-based river water level monitoring system that provides real-time monitoring and alerts. The objectives include (i) accurate measurement of river water levels, (ii) reliable long-range data communication, (iii) real-time data processing and visualization, and (iv) threshold-based alert generation for disaster preparedness.

II. LITERATURE REVIEW

Several studies have investigated river and water monitoring systems using GSM-based communication [1],[2], NB-IoT, or satellite links. While effective in urban areas with reliable networks, these approaches face challenges in rural regions due to weak connectivity, high deployment costs, and limited battery life.

LoRa technology offers long-range, low-power communication, making it highly suitable for remote river monitoring [3]. Recent LoRa-based systems have demonstrated reliable data transmission and scalability, but many still use JSON payloads that increase packet size and airtime and often lack robust cloud-based analytics.

Most existing systems do not optimize payload efficiency, implement robust error detection, or provide seamless cloud integration. This project addresses these gaps using a compact binary payload (TABLE 1) with CRC (Cyclic redundancy check) validation, MQTT (Message Queuing Telemetry Transport) communication, a FastAPI backend, and a real-time dashboard to ensure reliability.

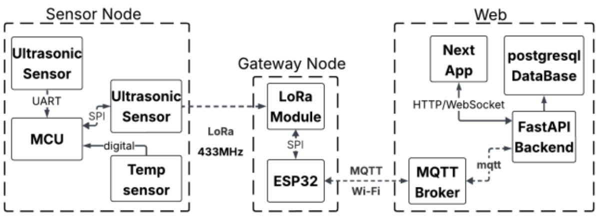

Fig.1. System Architecture

TABLE 1. BINARY DATA PACKET STRUCTURE

Binary Data Packet (9 bytes)									
Byte	0	1	2	3	4	5	6	7	8
Data	Device ID (16-bit)		Distance*100 (unsigned 16-bit)		Temperature*100 (signed 16-bit)		Battery (8-bit)	CRC-16 (16-bit)	
Range	0-65535		0 to 655.35cm		-327.68°C to +327.67°C		0-100	Error Check	

III. MATERIALS AND METHODS

A. *System Overview*

The system consists of three layers: (*Fig.1*)

- Sensor Node: (*Fig.2*)

  An ESP32 microcontroller reads water level data from a JSN-SR04T ultrasonic sensor and temperature from a DS18B20 sensor. Values are averaged and corrected for temperature effects. Data is packed into a 9-byte binary payload with CRC-16 and transmitted using a LoRa RA-02 module .(*Fig.5*)

- Gateway Node: (*Fig.2*)

  Another ESP32 receives the LoRa packets, validates CRC converts data to JSON, and publishes it to an MQTT broker via Wi-Fi.

- Backend,DataBase & Dashboard:

  A FastAPI server subscribes to the MQTT topic, processes incoming readings, and stores them in a PostgreSQL database. The server compares readings with predefined safe thresholds and generates alerts when necessary. A Next.js web application provides real-time visualization using WebSockets, configuration options, and alert notifications.

B. *Hardware Setup*

- Ultrasonic sensor (JSN-SR04T).
- DS18B20 temperature sensor.
- ESP32 boards for sensor and gateway nodes.
- LoRa RA-02 modules (433 MHz).
- 2*18650 rechargeable Li-ion batteries with DC-DC regulator.

C. *Deployment*

The sensor unit is mounted above the river surface inside a weatherproof enclosure(*Fig.4*,*Fig.4*). Power is supplied by rechargeable batteries, with future integration of solar charging.

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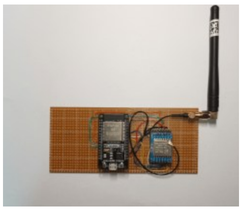

Fig.2. Gateway Node

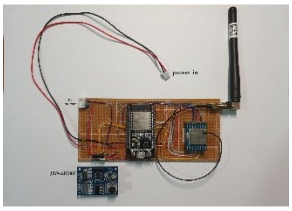

Fig.3. Sensor Node

Fig.4. Test

Fig.5. Enclosure

IV. Results and Discussion

A prototype system was deployed for field testing. Key outcomes include:

- Communication Efficiency: Binary LoRa payloads reduced airtime by 74% compared to JSON. CRC-16 validation ensured reliable packet delivery.
- Measurement Accuracy and Sensor Validation: Ultrasonic sensor readings, corrected for temperature, were stable and consistent, with variations typically around 1 cm (*Fig.7*) adequate for this river monitoring application. Temperature readings (*Fig.8*) fluctuated according to environmental conditions, and incorporating these values improved distance measurement reliability.

  Once fixed near the river, the sensor unit records an initial average to establish the normal water level. Subsequent measurements are expressed relative to this baseline, which is dynamically refined using historical water-level data to maintain long-term accuracy.

  The temperature sensor outputs –127°C and the ultrasonic sensor outputs 0 cm for failed measurements. Such invalid readings are flagged and excluded from processing.
- Alerts: Thresholds were correctly detected, triggering warnings at predefined LOW, MEDIUM, and HIGH levels.

Compared with GSM-based systems, the proposed solution achieved lower power consumption, reduced costs, and robust connectivity in rural environments.

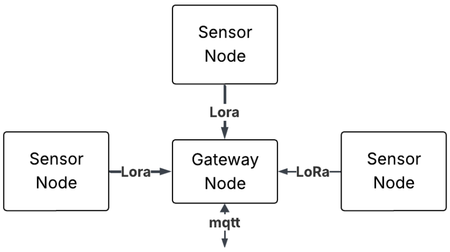

Fig.6. Multiple sensor nodes connecting to a single Gateway Node

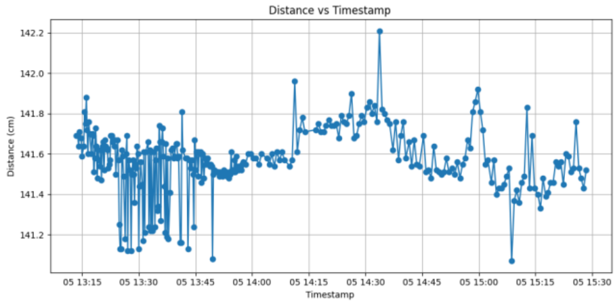

Fig.7. water level variation with time

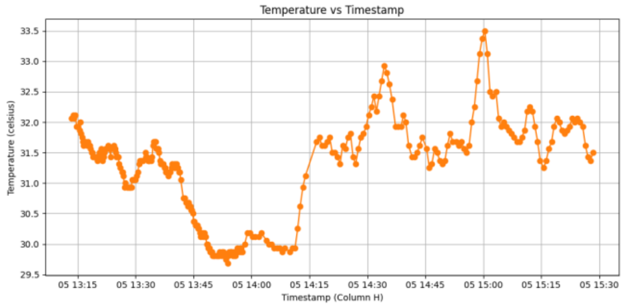

Fig.8.Temperature variation with time

V. Conclusion

This research developed a smart, low-cost IoT river monitoring system providing real-time alerts. A key advantage is connecting multiple sensor nodes to a single gateway (*Fig.6*) for efficient regional monitoring. However, signal obstruction in dense urban areas may cause message delays. Future work will focus on radar upgrades for rain resilience, solar integration, and predictive analytics.

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