RAJALAKSHMI
ENGINEERING COLLEGE
An AUTONOMOUS Institution
Affiliated to ANNA UNIVERSITY, Chennai

Department of ECE
GE19612 -Professional Readiness for Innovation, Employability and Entrepreneurship (Mini Project)
2024-25- Even
III Year ECE AD section

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Hydrosense:
Intelligent Water management ecosystem

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OUTLINE

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Abstract

The project introduces an intelligent water management ecosystem designed to tackle the challenges of water conservation and efficient resource utilization. By integrating state-of-the-art IoT sensors with robust, low-power communication protocols such as LoRa and ESP-NOW, the system continuously monitors water usage, detects leaks, and provides actionable insights through real-time analytics. Coupled with AI/ML-driven predictive algorithms, It not only identifies anomalies and forecasts water demand but also supports proactive maintenance of water networks. This innovative approach ensures optimal water distribution, reduces wastage, and enhances overall system reliability, making it a sustainable solution for both small-scale installations and larger community water management applications.

Objective

The primary objective of this project is to develop a **scalable** and cost-effective **water management system** that enhances water conservation by:

- **Real-Time Leak Detection:** Identifying leaks and irregular water usage immediately.
- **Usage Pattern Monitoring:** Leveraging IoT sensors to continuously track water consumption.
- **Predictive Maintenance:** Utilizing AI/ML models to provide proactive maintenance alerts.
- **Bridging Traditional and Smart Solutions:** Combining traditional water management practices with automated, smart technologies.
- **Hybrid Communication:** Integrating **low-latency ESP-NOW with long-range LoRa** communication for robust data transmission.
- **Interactive Dashboard:** Delivering real-time analytics and automated alerts via a modern web-based dashboard.

Proposed System

The proposed system integrates a network of **ESP32-based sensor nodes** equipped with ultrasonic water level sensors and flow meters

- **Sensor Network:** ESP32-based sensor nodes equipped with **ultrasonic water level sensors** and flow meters are deployed at critical points.
- **Communication:** ESP-NOW is used for **short-range, low-latency mesh** networking between nodes, while LoRa modules ensure **long-range data transmission** from sensor clusters to the gateway.
- **Data Aggregation & Processing:** A **centralized gateway** collects data from the nodes, which is then forwarded to a backend system for real-time analytics and predictive maintenance using AI/ML algorithms.
- **User Interface:** A responsive dashboard built with modern web frameworks **(Next.js, D3.js)** displays real-time visualizations and automated alerts.

Novelty in Proposed System

- **Hybrid Communication:** The innovative use of both **ESP-NOW and LoRa** allows for a balance between quick local response and long-distance data reliability.
- **Predictive Analytics:** Advanced ML models provide proactive maintenance alerts, reducing water wastage and improving overall system efficiency.
- **Scalability and Integration:** The seamless integration of IoT, edge-cloud computing, and AI/ML makes this system adaptable for both small installations and larger municipal applications.

Problems with Existing products

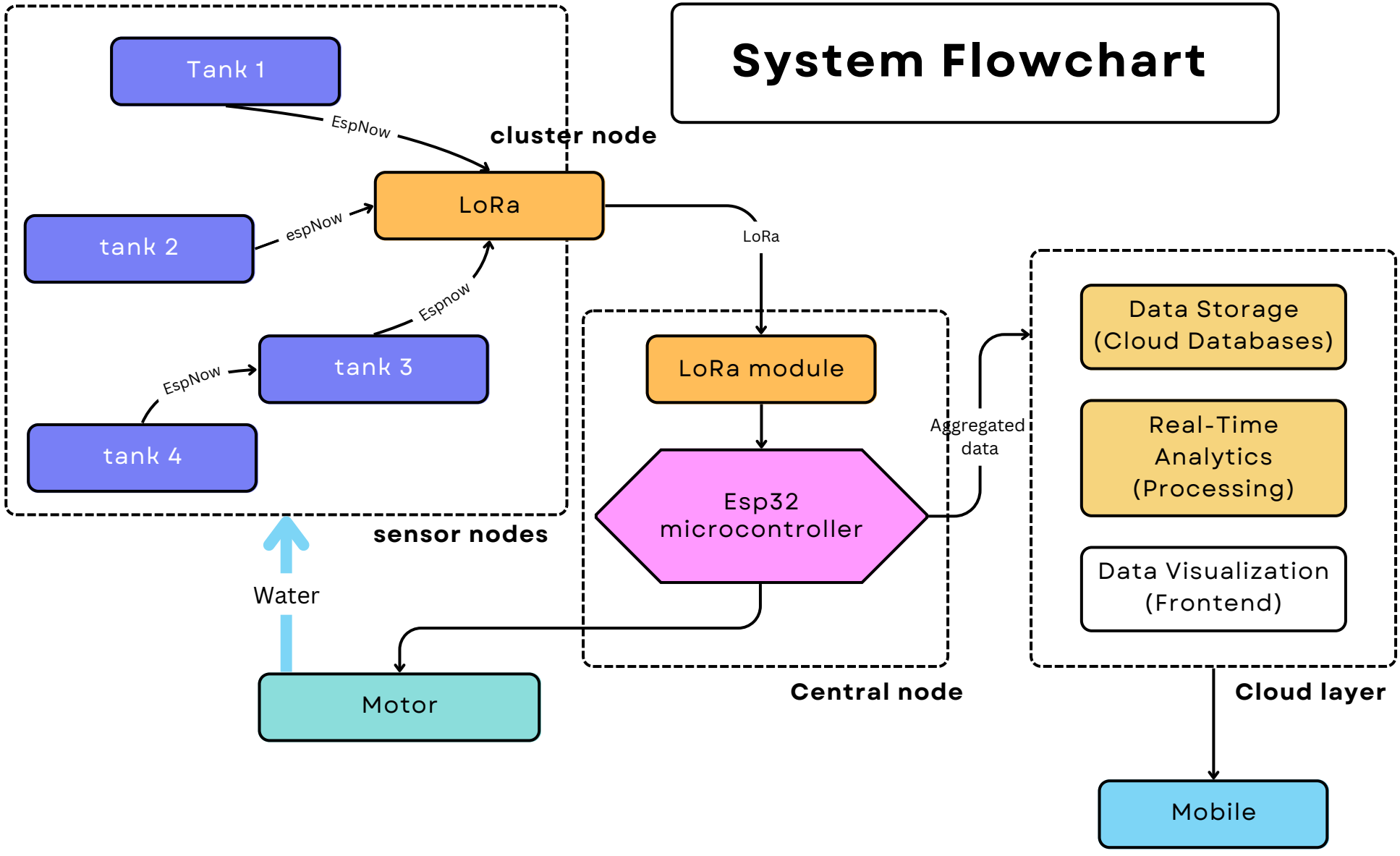
MECHANICAL FAILURE AND WEAR:
PRONE TO JAMMING AND STICKING DUE TO DEBRIS.
MOVING PARTS CAN WEAR OUT OVER TIME.
LIMITED ACCURACY:
ONLY PROVIDES POINT-LEVEL DETECTION, NOT CONTINUOUS MEASUREMENT.
INSENSITIVE TO SMALL CHANGES IN WATER LEVEL.
ENVIRONMENTAL LIMITATIONS:
SUSCEPTIBLE TO CORROSION IN HARSH CONDITIONS.
INEFFECTIVE IN VISCOUS OR CONTAMINATED LIQUIDS.
INSTALLATION AND MAINTENANCE CHALLENGES:
PRONE TO IMPROPER POSITIONING AND CALIBRATION ISSUES.
REQUIRES REGULAR MAINTENANCE TO AVOID FAILURE.
INCONSISTENT PERFORMANCE:
AFFECTED BY TURBULENCE, FOAM, AND TEMPERATURE CHANGES.
LACK OF REMOTE MONITORING CAPABILITY:
NO REAL-TIME DATA OR IOT INTEGRATION WITHOUT ADDITIONAL HARDWARE.LACKS DATA LOGGING AND HISTORICAL ANALYSIS.

Design and Analysis Performance of IoT-Based Water Quality Monitoring System using LoRa Technology	February 2023	https://doi.org/10.18421/TEM121-04	Sommart Promput Somkiat Maithomklang Chawalit Panya-isara	The system uses ESP32-based nodes with LoRa modules (operating typically at 868/915 MHz in the Thai context) and integrates with Node-RED for real-time data display. The paper reports a practical communication range of approximately 2 km under conditions with obstacles—a value that aligns with published literature on LoRa in urban or semi-urban environments.
Development of LoRaWAN-based IoT system for water quality monitoring in rural areas	May 2024	https://doi.org/10.1016/j.eswa.2023.122862	Waheb A. Jabbar a, Tan Mei Ting b, M. Fikri I. Hamidun b, Ajwad H. Che Kamarudin b, Wenyan Wu a, Jamil Sultan c d, AbdulRahman A. Alsewari e, Mohammed A.H. Ali f	The paper introduces a solar-powered, portable IoT solution for monitoring water quality using multiple sensors (pH, temperature, TDS, turbidity) integrated with a LoRaWAN microcontroller. Data is transmitted to a central gateway and visualized on a cloud platform (e.g., ThingSpeak). Field and lab tests confirm its accuracy and reliability.
Monitoring Industrial Systems Using ESP-NOW Protocol with Mesh and Ad Hoc Network	2023	https://doi.org/10.1109/INDUSCON58041.2023.10374804	Lucas Henrique Brito Santos, Eduardo José Monteiro Da Silva, Aleqssandro Alexandre De Oliveira Farias, Jhennifer Freitas dos Santos	This paper presents an embedded sensor network that leverages the ESP-NOW protocol combined with Mesh and Ad Hoc configurations to monitor various industrial systems. Among the applications demonstrated is a water level control system. The system uses ESP32-based sensor nodes to acquire water level data and other environmental parameters, then transmits the information via ESP-NOW to a central hub. .

Summary of Literature

Together, these studies demonstrate the versatility and adaptability of IoT communication protocols in water management:

- **LoRa** is shown to be highly effective for rural applications where **extended range and low energy consumption** are critical, ensuring accurate water quality monitoring over vast areas.
- **ESP-NOW—when integrated with Mesh and Ad Hoc networking**—offers a compelling solution for industrial settings, providing **low-latency, reliable communication for real-time control and monitoring**, such as in water level management.
- Both approaches highlight the importance of **balancing power efficiency, network reliability, and real-time data processing** to enhance water management strategies in diverse environments.


System Flowchart
Tank 1
EspNow
cluster node
LoRa
tank 2
espNow
Espnow
tank 3
EspNow
tank 4
sensor nodes
LoRa
LoRa module
Esp32 microcontroller
Aggregated data
Water
Motor
Central node
Data Storage (Cloud Databases)
Real-Time Analytics (Processing)
Data Visualization (Frontend)
Cloud layer
Mobile

Specifications

Hardware Components

- ESP32 Development Board (for sensor nodes and gateway)
- Ultrasonic Water Level Sensors (for real-time level monitoring)
- LoRa Modules (for long-range communication)
- Connection wires
- Breadboard

Software Stack

- Embedded Programming: Arduino IDE, ESP-IDF
- Communication Protocols: ESP-NOW, LoRa
- AI/ML Development: TensorFlow Lite, Scikit-Learn
- Cloud: SupaBase
- Backend: FastAPI (Python).
- Frontend: React.js / Next.js, D3.js for data visualization
- Database: Supabase(structured IoT data)

What have complete

- Evaluated the reliability of the LoRa signal by assessing its **penetration capability** within an eight-story building.
- Validated the **ESP-NOW ad hoc connectivity** by integrating a new sensor node using a fresh ESP32 module
  - these tests show the reliability of the connection protocols used in the project.
- Configured the entire system to operate offline, **successfully demonstrating its functionality**.
- Conducted a sample test run to successfully upload water level data to **Supabase directly via sensor node.**

What needs to be done

- To send the aggregated water level data and send it to supabase via the designated central node.
- To create UI for the data to display so the user can view it convieniently.
- To create 3D enclosures for each nodes to recreate it real life product.
- To add actuators to control motor via the app.

Possible future enhancements

- To design a Custom PCB to showcase it as a market ready product.