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LoRa-Based Communication System for Monitoring Water Quality of Lakes and Reservoirs

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***Abstract*—This paper describes a conceptual framework for the establishment of a Long-Range Wide Area Network (LoRaWAN)-based communication system for monitoring water quality of lakes and reservoirs. The proposed system allows connection of multiple sensors to the LoRa transceivers and enables data transmission to a cloud server. In a proof-of-concept test, the LoRa gateway was set up, a temperature sensor node was connected and used to monitor lake water temperature, and data was transferred to LoRa gateway which serves as the central monitoring system and is visualized on a centralized dashboard. In this work, a coverage test of the proposed system is also carried out to test the LoRAWAN communication range in the urban environment. We find that the range of the system varies from 150-2,500 m and it is affected by the antenna positioning placement and obstacles in between the gateway and the sensor node. The maximum range was found to be 2.5 km when there was clear line of sight between the gateway and sensor node.**

***Index Terms*—Lake Monitoring, Water Quality, LoRaWAN**

I. Introduction

Due to degrading freshwater ecosystems, water quality management has emerged as a crucial issue in India. Threats of eutrophication or extinction have emerged due to heavy loads of pollution and contamination from multiple sources like rapid industrialization, exponentially growing population pressure, urbanization, modern agricultural practices and other anthropogenic activities, saltation, discharge of domestic sewage, immersion of idols and other religious activities [1].

Lakes are the worst affected because of low surface velocity, long water retention time, and isolation from other terrestrial and aquatic ecosystems. In order to prevent these assets from vanishing, urgent mitigation measures need to be adopted. The availability of real-time information of water quality is a crucial tool necessary for successful and effective implement of water quality improvement programs [2]–[4].

Conventionally, water quality testing is performed by field collection of samples of water, transporting these samples to a testing laboratory, and lab analysis for detecting chemicals and microbial contaminants [5]. This process has several limitations as mentioned below:

- Chances of human error
- Single point measurement with no spatio-temporal variability
- No idea on contaminant point source
- No information on seasonal or short-term variations
- High operating costs
- Change in properties during transport

Therefore, it is necessary to have other, more reliable approaches for continuous in-situ monitoring of water quality. Environment monitoring sensors can fill this gap by providing real-time data, which makes it easier to make decisions and react to changes in water quality in a timely manner. Also, compared to lab tests, in-situ sensors are cheaper and require less work. Although the in-situ sensors are not perfect, they are subject to calibration errors, errors due to changes in the environment, and regular wear and tear. A regular check on the accuracy and workings of in-situ sensors can help prevent these errors and provide long term monitoring of water quality parameters. An important aspect of developing a sensor network is the transmission of sensor data to the user. The integration of in-situ water quality sensors with the Internet of Things (IOT) is an effective way to keep track of the quality of large water bodies. In this approach, the water quality sensors are placed at multiple points and data is transmitted over the wireless communication network to the cloud server and visualized on a web-based platform. There are various methods that can be used for wireless transmission of data but each technology has its advantages and disadvantages. In this study we present an overview of the most popular wireless communication protocols and a proof of concept of a temperature sensor node to measure water temperature in real-time.

II. Technology Review

There are various technologies available in the market for wireless communication but communication over cellular, Wi-Fi, and LoRaWAN are the most used. Here we present an overview of the current state of the art technologies available.

A. Cellular

Cellular IoT protocols are extremely popular and don't require need pre-established gateways for creating a coverage

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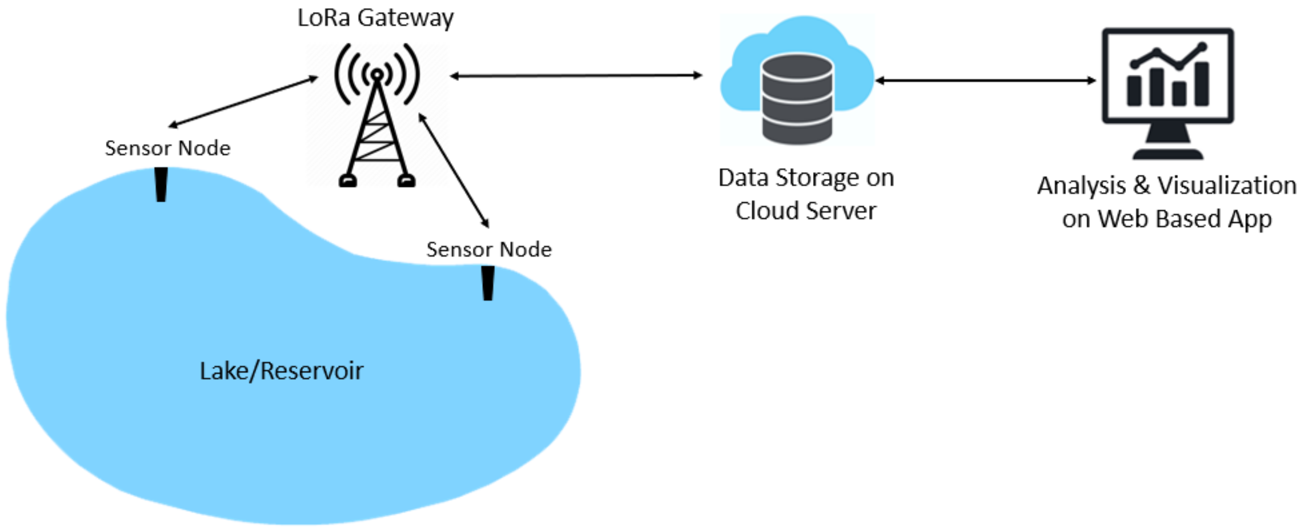

Fig. 1: Measurement station architecture

TABLE I: Comparison of different wireless communication Protocols

	Cellular	Wi-Fi	LoRaWAN
Standard	GSM/GPRS/EDGE(2G), UMTS/HSPA(3G), LTE(4G)	Based on IEEE 802.11ac	LoRaWAN
Frequencies	900/1800/1900/2100MHz	2.4GHz and 5GHz	865 MHz – 867 MHz (licence free band in India)
Range (Approx.)	90.9% (4G coverage in India)	50meter that can go up to 100 meters	2.5 km(Urban environment), 15 km (Suburban environment)
Data Rates	Up to 20 Mbps or more (4G)	150mbps- 1gbps	0.3 to 50 Kbps

area. For applications over large domains such as a region, country, or transcontinental, they are preferred over other protocols. Though cellular networks can transfer vast amounts of data, it comes at a large power cost incurred by cellular-enabled IoT devices. For smart city applications involving streetlights, parking meters, hospitals, industrial applications in manufacturing and agriculture, cellular protocols are well-established. With growing 5G connectivity and the infrastructural simplicity of the protocol, cellular communication protocols are the go-to choice. But the major limitation of using cellular networks is their high cost subscription plans, especially when multiple networks of sensor nodes are involved.

B. WiFi

WiFi is one of the most popular IoT communication protocols, powering fast data transfers in a Local Area Network (LAN) environment [8], [9]. Since this protocal enables large transfers of data, it is widely adopted by developers for data-intensive applications. The protocol is based on the latest IEEE 802.11ac standard and allows a range of hundreds of megabit/secs, which is useful for large file transfers but is not suitable for IoT applications like persistent long term sensing which requires low power consumption and intermittent transfers of data in small packet sizes.

C. LoraWAN

LoRa is a long-range radio wide area network that is perfectly suited for large number of IoT applications in smart cities and industrial applications. Since the protocol is optimized for connecting to millions of nodes and low power consumption, it enables a different class of applications than Cellular or WiFi. It also comes with value-added features such as signal detection below the noise level along with built-in security and GPS-free positioning. Presently, LoRa operates in two service models: network provider or private network.

III. Proof-of-Concept

The use of transmission technology depends upon the end use application and for lake monitoring purpose the technology selection is decided based on cost, security, coverage and longevity. For the purpose of lake monitoring, wireless communication using LoRaWAN is promising as it covers a wide range and allows us to connect multiple sensor nodes at the same time. As LoRaWAN operates at license-free sub-gigahertz radio frequency bands, it requires less power and the battery can last upto 10 years [6], [7]. This makes LoRa a viable option for installation in remote locations where accessibility is an issue and cellular network coverage is not present. LoRaWAN is also less dependent on the network service provider thereby reducing the operational expenditures significantly when multi point monitoring is required. Based on these considerations, LoRAWAN was selected as the data transfer method. As there was no LoRA network service provider at Gwalior, India (Latitude:26.25312, Longitude: 78.21295), a private LoRa-based communication network was setup using Dragino outdoor gateway DLOS8 and a temperature sensor node was used for real-time monitoring of water temperature. The temperature and battery voltage data from the sensor node is visualized on the ThingSpeak platform (https://thingspeak.com/) and the data frequency was set to 5 minutes.

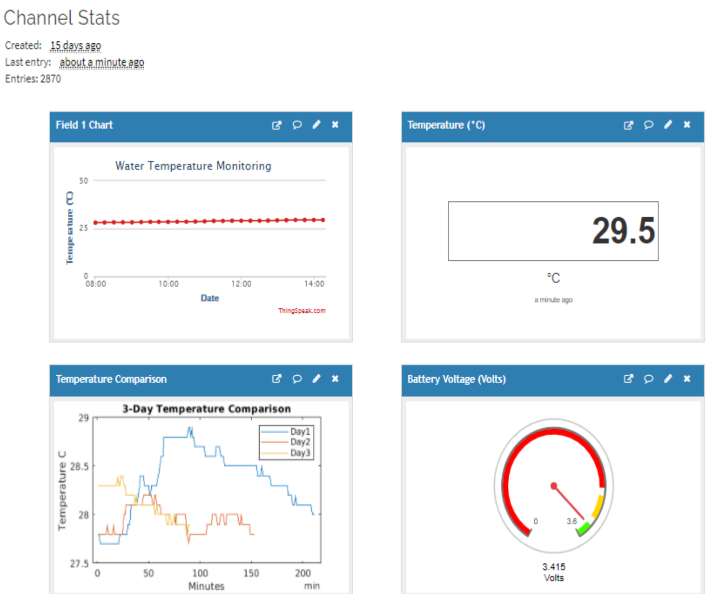

Fig. 2: Data Visualization on Thingspeak Platform

A. 3.1 Coverage Test

Initially, the gateway was placed indoors and the radial range varied from 100-150 metes. When it was placed outdoors at around 10m height from the ground level in the urban environment, the range was found between 500-600 meters. The maximum range was observed to be 2.5 km when there is a clear line of sight (LOS) between the gateway and the sensor node and no/little obstacles in between.

IV. Discussions

On testing the proof of concept, LoRaWAN was found promising in providing point-to-point connection, gateway connection, and high scalability as a single gateway can cover a large area. The other most relevant characteristics are its high sensitivity in receiving data (End nodes: Up to 137 dBm, Gateways: Up to 142 dBm) and low consumption of energy allowing approximately 10 years of battery lifetime.

Lakes are big water bodies with areas exceeding 10 hectares. The only limitation of LoRa is that the range decreases significantly when there are obstacles in between. These tests were conducted in the urban environment surrounded by buildings and trees around the gateway. Therefore, range limitations can

Fig. 3: LoRa Gateway and Sensor Node

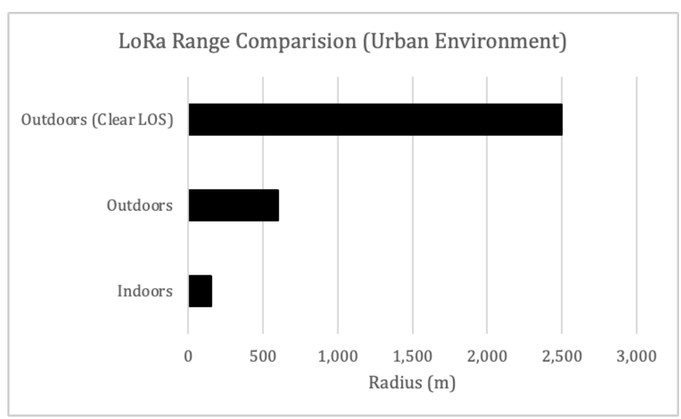

Fig. 4: LoRA Range Comparison

be overcome by installing the gateway antenna and sensor node antenna as high as possible so that it can get a clear line of sight.

V. Conclusions and Future Scope

In this study we have shown a conceptual framework for environmental monitoring using LoRaWAN. LoRaWAN communication was successfully setup for water temperature monitoring. Only one sensor node was used to deploy a proof of concept, and the data was directly transferred to a dashboard. LoRaWAN is revolutionary in environmental monitoring due to its low cost setup, low power consumption, high temporal resolution of data transfer, long range, scalability and security. In the future, we aim to include other water quality parameters such as Ph, TDS, BOD to develop a comprehensive lake monitoring system. The collected data will help discover the temporal change in water quality, identify contaminants and understand the processes behind phenomenas such as algal bloom. We also aim to develop water quality forecasting models based on data collected by the network.

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