WATER QUALITY MONITORING OF DRINKING WATER

Srijan Routh Roy

WATER QUALITY MONITORING OF DRINKING WATER

Submitted in partial fulfilment of the requirement for the award of the degree of

Bachelor of Technology

in

Applied Electronics & Instrumentation Engineering

By:

Name	University Reg. No	University Roll No
Srijan Routh Roy	12620005054	2053009

Under The Supervision of

Dr. Pradip Saha

Project Guide

Department of Applied Electronics & Instrumentation Engineering

Heritage Institute of Technology

DEPARTMENT

OF

CERTIFICATE OF APPROVAL

This is to certify that the project work entitled

WATER QUALITY MONITORING OF DRINKING WATER

has been successfully completed by

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Maulana Abul Kalam Azad University of Technology, 2024

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Project Guide

Dept. of AEIE

External Examiner

Prof. (Dr.) Madhurima Chattopadhyay

Head of the Dept.

Dept. of AEIE

Department of Applied Electronics & Instrumentation Engg.

Heritage Institute of Technology

(An Autonomous Institute under MAKAUT, WB)

(An Initiative of Kalyan Bharti Trust)

994 Madhurdaha, Chowbaga Road, Anandapur, P.O. East Kolkata Township, Kolkata - 700 107

Phone : +91-33-6627-0600/0609/0614/0622 ● Fax : +91-33-2443 0455 ● E-mail : admin@heritageit.edu

www.heritageit.edu

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ABSTRACT

Water is important to our everyday life due to the fact they aid aquatic existence and offer a delivery of water for human beings and animals. This concept may be used within the drinking water reservoirs, by using this we are able to examine the levels of factors like the alternation of water parameters with the atmospheric weather. A further alarm device is carried out.

Monitoring the first-rate of the water is a vital system considering the fact that it's far necessary to deal with the issues surrounding the detection of water contamination. This idea suggests the usage of LoRa (lengthy range) technology to reveal the water environment. With reference to the statistics gathered by means of multi-sensor nodes (water temperature, pH, turbidity, and different water first-rate signs), the device operates on statistics series, actual-time statistics storage, and the pollution threshold described at Thingspeak. Moreover, the device uses Arduino Uno and ESP8266 microprocessors and multiple styles of water first-rate sensors to accumulate water first-rate parameters in actual time, and the statistics is packaged and sent to ESP8266 remotely by means of LoRa technology. Then, the single-channel makeshift gateway completes the bridging of the LoRa hyperlink to the IP hyperlink and forwards the water first-rate information to the Google Firebase, ThingSpeak. eventually, end customers can comprehend the water first-rate manage of monitored water regions by means of monitoring control systems, actual-time web sites.

CONTENTS

INTRODUCTION

Ponds in many towns are contaminated due to the increased human activity on natural water bodies. The reproduction of water-dependent organisms and the proper development of cells will be jeopardized by water pollution. Fish that carry heavy metal pollution will not only result in financial losses but also cause various harms and diseases to consumers through the food chain. Through this project we will be able to access the levels of variable factors remotely while remaining comfortable and easy to live in. We will receive this data twice a day so we will be updated about the parameters and able to make appropriate changes based on them.

Recently a paper suggested that the Chinese central government has implemented an innovative water quality management policy and actively advocates the development of informatized water pollution prevention and control [1]. It can be seen that obtaining water quality information of urban water bodies in a timely manner to make rapid and accurate pollution prevention and control strategies is the best detection technique. At present, people have obtained many research results in the water and air quality monitoring field [2].

Works like Polluino:An effective cloud based IoT device management platform for monitoring air quality. The development of intelligent devices that can perceive, compute, and communicate data streams in a ubiquitous information and communication network is the source of the Internet of Things paradigm. The massive volumes of data generated by these devices provide certain difficulties for the information's processing and storage capacities. This makes the new paradigm known as "Big Data" stronger. Cloud computing is a useful tool for organizing sensor data in such a complicated setting. This paper introduces Polluino [3], an Arduino-based air pollution monitoring system. Additionally, a cloud-based platform is built to manage data originating from air quality sensors.

Another paper named, "Development of a Low-Cost Internet-of-Things System for Monitoring Soil Water Potential Using Watermark 200SS Sensors [4]." The paper suggests Creation of a Low-Cost Internet-of-Things System with Watermark 200SS Sensors to Monitor Soil Water Potential. This study set out to create and evaluate a low-cost Internet of Things system for tracking soil moisture utilizing Watermark 200SS sensors. Arduino-based microcontrollers are used in the system, and LoRa radios are used to wirelessly transmit data from the field sensors (End Nodes) to a receiver (Coordinator). The coordinator then connects to the Internet via Wi-Fi and forwards the data to an open-source website called Thingspeak.com, where MATLAB can be used to further analyse and visualize the data.

The Watermark sensors were installed at four different depths in a wheat field to successfully test the system in real-world settings. The technique outlined here may help farmers implement inexpensive, user-friendly moisture detecting systems more widely [5].

Moreover, we also know about Zigbee [6]. Schools can install the solar-powered network sensor nodes to gather and report on air quality, temperature, relative humidity, dust particles, and carbon monoxide (CO) in real time. With the help of an application created with LabVIEW, the suggested system enables schools to keep an eye on the conditions of the air quality on a desktop or laptop computer Data Transferring and Analysis with Arduino and Lora Network. If the air quality characteristics surpass acceptable limits, an alert is sent out. They successfully tested the sensor network at the University of Newcastle, Australia's campus in Singapore. Their experimental results showed that the sensor network can measure air quality accurately over a broad range of concentrations of CO, NO2, and dust.

Here are some thresholds for drinking water quality parameters [7]:

- TDS: The ideal range is 150–250 mg/L, but it's acceptable up to 500 mg/L. The World Health Organization (WHO) recommends less than 300 mg/L, and the Bureau of Indian Standards (BIS) says the minimum should be 50 ppm.

- pH: The ideal range is 6.5–8.5, but too acidic or alkaline can be harmful.

- Turbidity: The WHO recommends 5–10 NTU, but other parameters include turbidity of the turbidity graph.

- Temperature: The WHO recommends 30 °C, but hot water systems should be above 60 °C when leaving heaters

THEORETICAL STUDY

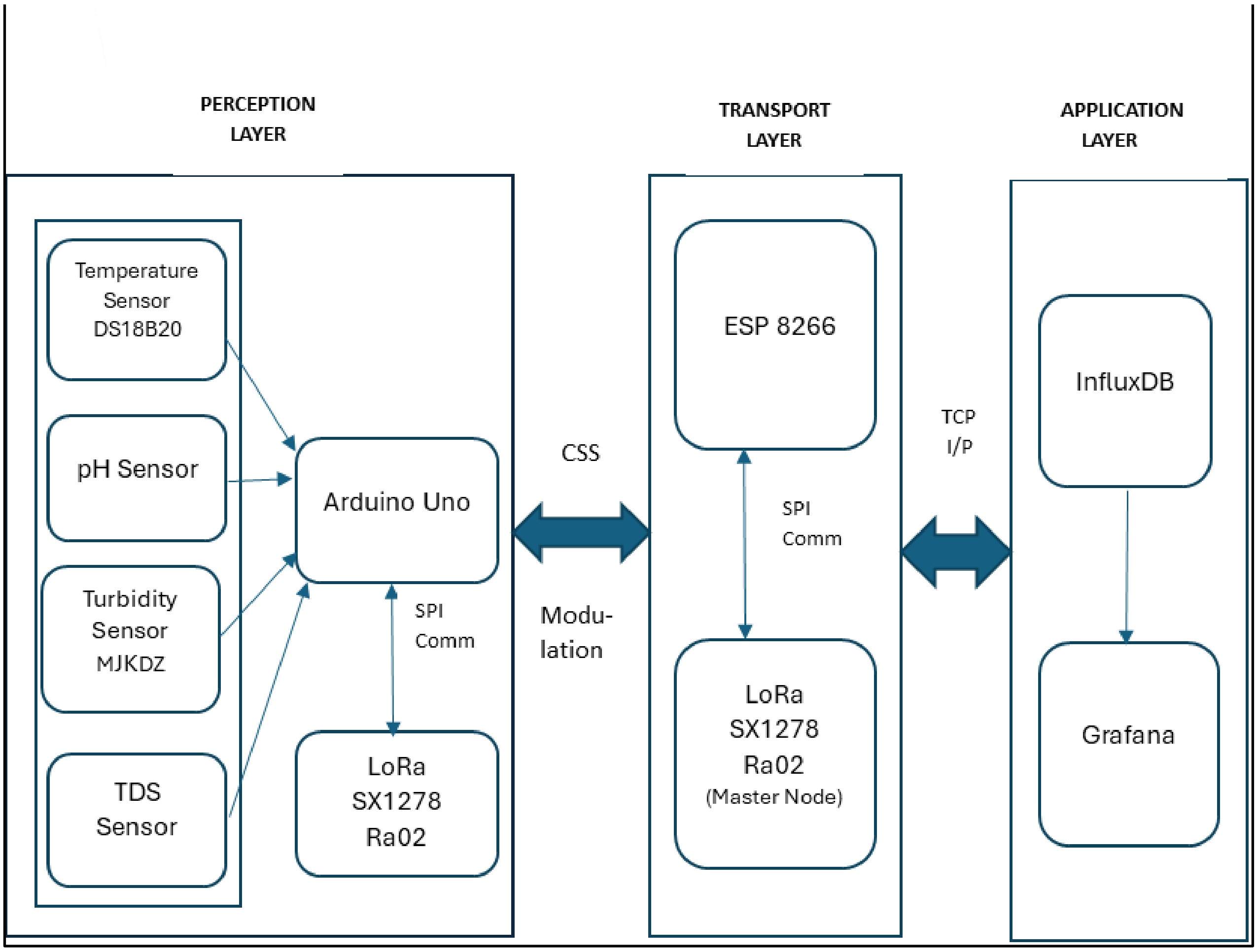

Figure 1: System Architecture Design

1. **PERCEPTION LAYER**

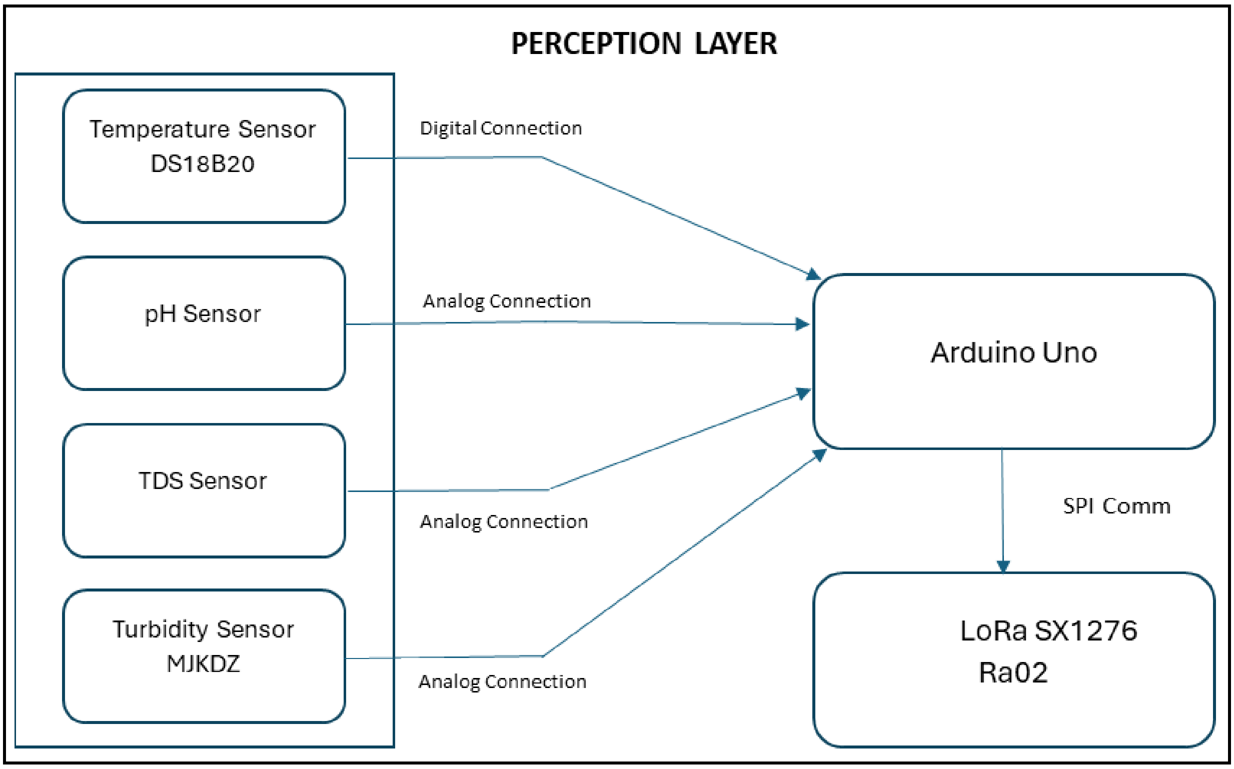

Figure 2: System architecture of perception layer

The perception layer (Fig.2) is made up of Arduino end node that have temperature, TDS, turbidity, pH sensors installed. This node continuously monitors these parameters and is positioned strategically in a specific area of the water reservoir. Analog communication is used to link the pH meter, turbidity sensor MJKDZ, temperature sensor DS18B20 and TDS sensor V1. 0. Water parameters that are predetermined are used to calibrate the sensors. Data is received by the Arduino which uses SPI communication to connect with the LoRa SX1278 module and then transmits the data using CSS modulation. To improve packet reachability and save power data transmission takes place twice daily. The end nodes go into sleep mode to maximize power consumption for long-term durability following a successful data transmission. The LoRa module is notable for maintaining its sleep current below 1μA which keeps it operational even when the sleep current falls below 3mA. The node uses the LoRa module to transmit sensor data that is encapsulated into a data packet with distinct headers for node identification. It then waits for the master node to acknowledge the transmission. Following acknowledgment, the Arduino module goes into sleep for a predetermined amount of time before waking up to send its second daily transmission. When a packet is scheduled for retransmission and there is no acknowledgment the node stays active and can retransmit up to five times before failing. In order to connect to the master LoRa node class, a communication and OTAA activation are used along with Spreading Factor 12 to transmit data at the 433MHz frequency which complies with Indian regulations. Less data is sent with smaller packet sizes in order to reduce packet loss. Due to a shorter air time, a higher

Spreading Factor ensures greater reachability of the packet and less packet loss on the receiver side.

- **COMPONENTS USED:**

1. Temp sensor (DS18B20)
    - Communication: The 1-Wire communication protocol is used.
    - Temperature Range: Usually -55°C to +125°C.
    - Accuracy: Within the given range typically ±0. 5°C.
    - Power supply: runs from 3 V to 5.5 V across a broad voltage range
.
2. pH sensor
    - Measurement Range: Generally pH values are measured between 0 and 14.
    - Accuracy: varies usually within ±0. 1 to ±0. 01 pH units.
    - Supply Voltage: Can operate between 3 and 5 volts.
    - electrode: internal resistance 250MΩ operating temperature range of 5 to 60°C
.
3. Total Dissolved Solids (TDS) sensor
    - Sensor of electrical conductivity type.
    - Measurement Range: This represents the total amount of ions dissolved.it is commonly expressed in mg/L or parts per million (ppm).
    - Precision varies but is typically better than ±2 percent.
    - Robust Compatibility: 0 to 2. 3V analog signal output suitable for 5V or 3. 3V controllers.

4. Turbidity sensor (MJKDZ): Unit- nephelometric turbidity units (NTU).
    - 5 VDC is the operating voltage.
    - Max. Current Draw: 30 mA.
    - Operating temperature: -30 to 80 degrees Celsius.

5. The LoRa SX1278:
    - Long-range (LoRa) spread spectrum modulation is used in communication technology.
    - Frequency Bands: Contains frequencies between 410 and 525 MHz.
    - Data Rate: Variable data rates typically in the 300 bps to 37 kbps range.
    - Transceiver IC based on the Semtech SX1278 transceiver.
    - Power Supply: 2. 5–3. 7 V is the range. (vi) Temperature Range: -30 to 85 degrees Celsius for operation.

The Temp sensor (DS18B20) sends data by digital connection whereas pH sensor, TDS and Turbidity Sensor (MJKDZ) sends data by analog connection to the Arduino which acts as an interface between LoRa and the sensors.

The tds and temperature sensor comes with their prebuilt libraries therefore does not require calibration as such, but the pH and turbidity sensors provide raw analog output from which pH and NTU values need to be calibrated and use a non linear equation to convert raw voltage value to the respective units.

The equations are as follows

1. *Turbidity = -1120.4*square(volt)+5742.3*volt-4353.8;*
2. *pH = -5.70 * volt + calibration_value;* *(calibration_value = 24.25)*

PROGRAM FLOWCHART:

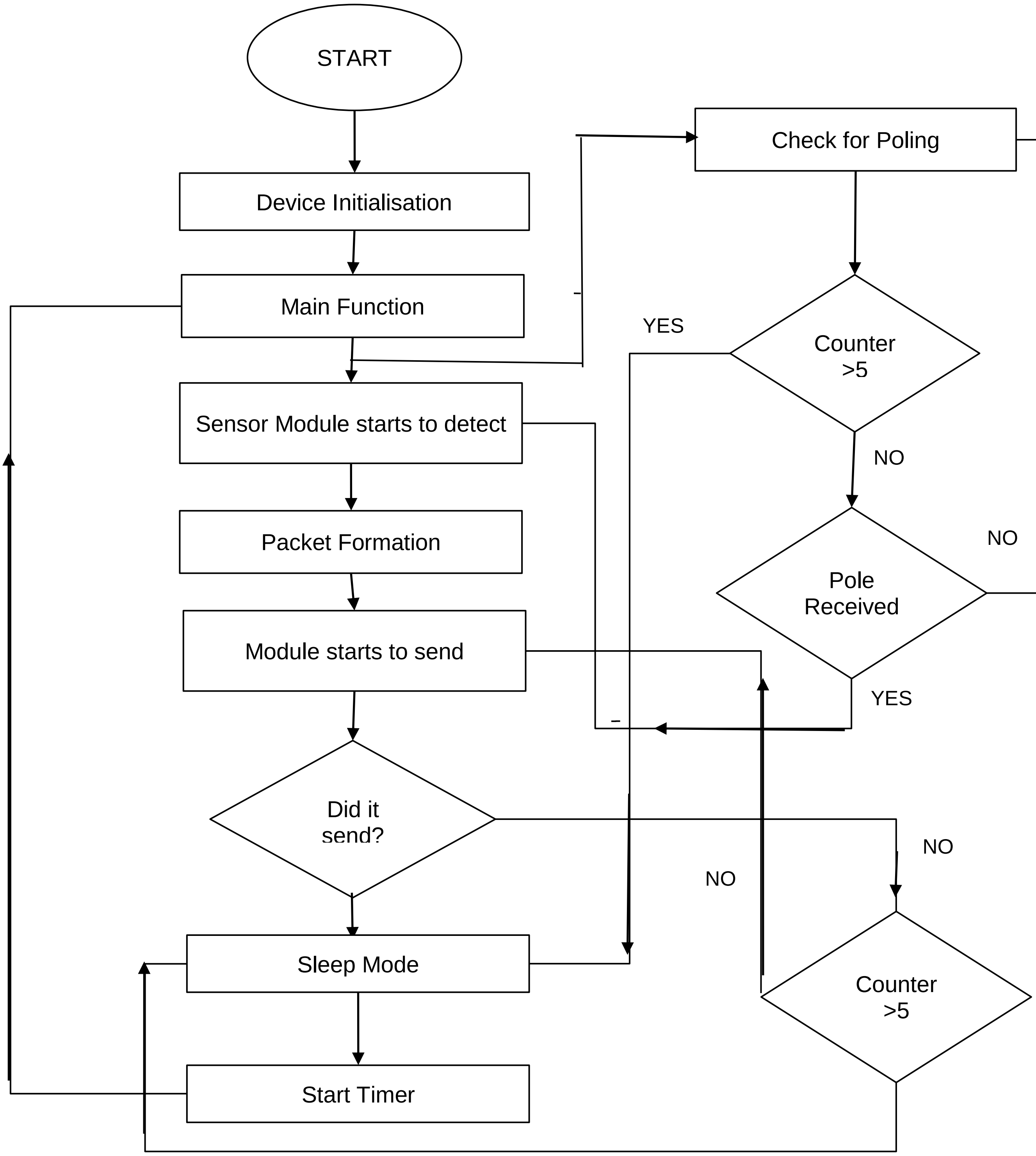

Figure 2.1: Flowchart of the sender node

The algorithm (Fig.2.1) works in the following stages-

1. Device is initialised and the main function is run in the Arduino IDE.
2. The module checks for the polling request, if it's received then the module proceeds to the sensor module.
3. If not received even after 5 times of checking it puts the module to sleep.
4. The sensor module starts to detect the values of the sample.
5. The data is packaged and these packets are sent by the module.
6. The program checks whether the values are sent or not.
7. It checks 5 times for the values.
8. If it is sent then the program enters sleep mode.
9. If it is not sent then it prints the message "Message lost".
10. It finally enters sleep mode before waking up again for the next packet.

2. **TRANSPORT LAYER**

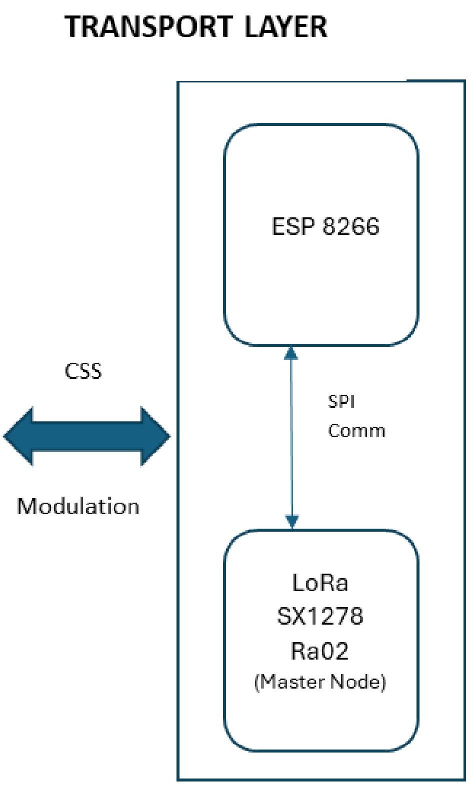

Figure 3: System architecture of the Transport layer

The transport layer (Fig.3) consists of an ESP8266 microcontroller and LoRa SX1278 transceiver module acting as a receiver. SPI communication is used to connect the LoRa SX1278 module and the microcontroller. As the Master node, this layer is in charge of using CSS modulation to receive data from the end nodes. After confirming that the data is received and accurate the master LoRa uploads it to the cloud along with the appropriate timestamp. Due to its single-channel receiver design the gateway had certain drawbacks most notably with regard to collision detection—a problem that occurs when two data packets are received at the same time. Using multiple channels (frequencies) in more sophisticated gateways can help to mitigate this problem. It's also important to remember that this version of the gateway only supports one spreading factor and data rate. The microcontrollers program module is intended to oversee the management of polling requests as well as to guide the end nodes and confirm the accuracy of received data. Since it is attached to the plug point on the server side we don't have to worry about the power consumption.

PROGRAM ALGORITHM

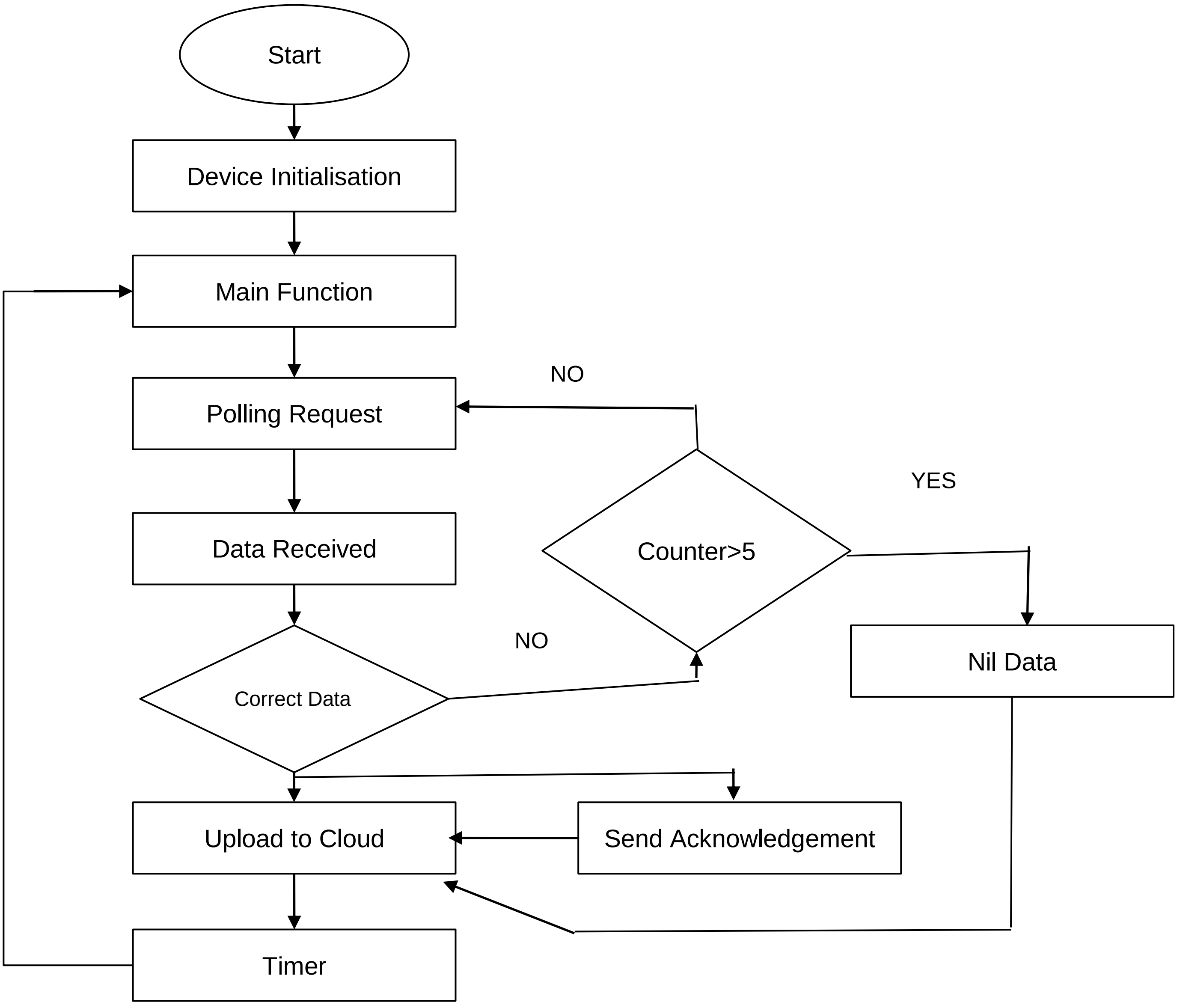

Figure 3.1: Flowchart of the receiver node

The algorithm (Fig.3.1) works in the following way-

1. The device is initialised and the main function is run in the Arduino IDE.
2. A polling request is sent.
3. If the data is received then it checks whether it's correct or not.
4. If the data is not received even after 5 times of counter then it inserts a nil value or message lost value to the database and waits for the next packet.
5. The corrected data received will make the module send an acknowledgement.
6. The corrected data is sent to the cloud and uploaded.

3. APPLICATION LAYER

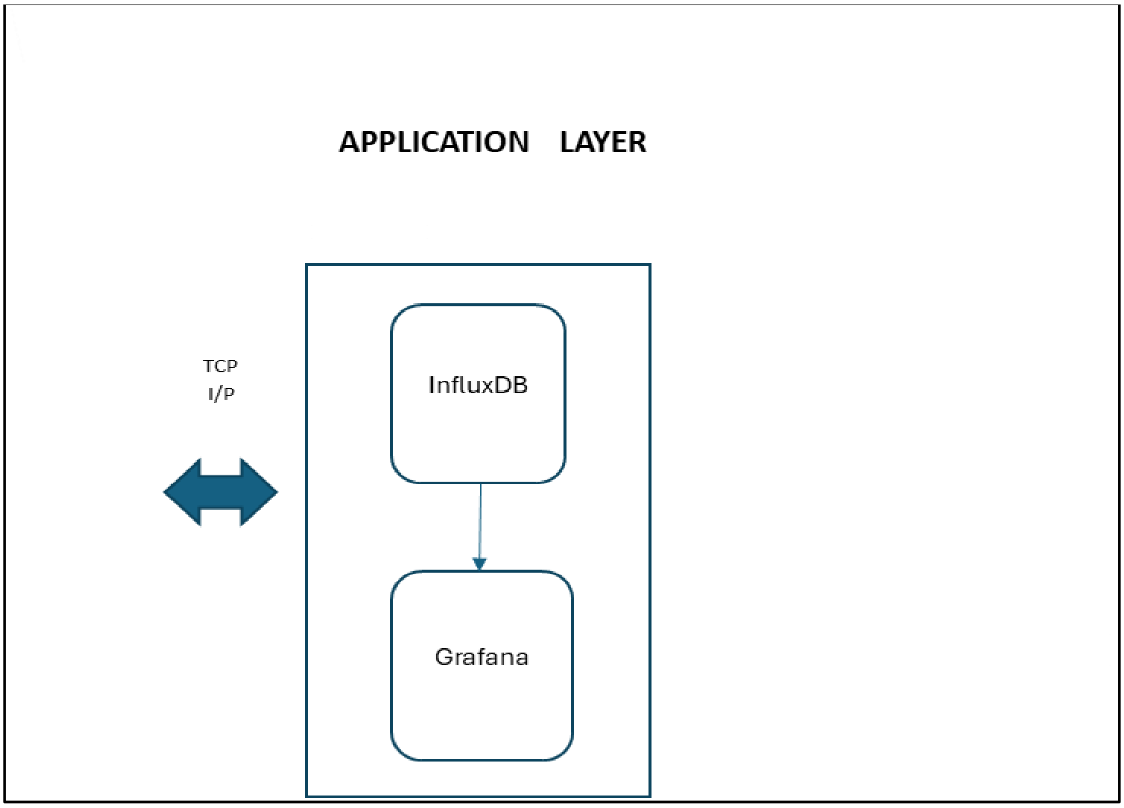

Figure 4: System architecture of application layer

1. **Influx DB-** Open-source InfluxDB is a time series database that is typically built to handle large query loads and high write volumes. The Go programming language is used to write it and InfluxData developed it. These time series databases are improved to store, retrieve and analyse timestamp-related data points including financial application and sensor metrics. When it comes to real-time analytics and monitoring InfluxDB is specifically utilized. It makes use of the SQL-like query language InfluxQL to retrieve and manipulate the data. InfluxDB is being used to integrate the

sensor data for additional data modulation. The structure of the table comprises the timestamp, the tags: node and device and fields: tds, temperature, conductivity, turbidity.

2. **Grafana-** Grafana is an open-source analytics and visualization platform that enables users to comprehend and keep track of data wherever it may be. It is compatible with numerous data sources such as cloud services, relational databases and real-time databases. The main functions of Grafana include data visualization, dashboard creation, data source integration and altering. In this project Grafana is being used to notify the user via email whenever any of the drinking water quality parameters (such as temperature, TDS, turbidity, pH and so on) exceed a threshold value set by the industry standards. For drinking water a pH between 6 and 8 is regarded as normal. The body may not respond well to water that is excessively alkaline or acidic. Water with a total dissolved solids (TDS) of 150–250 is optimal but 500 TDS is also acceptable. Water should normally be between 24 and 35 Celsius at room temperature. Turbidity of 5–10 NTU is regarded as typical. When a fluid has a lot of tiny particles in it that are usually invisible to the unaided eye it becomes turbid. For typical drinking water conductivity is typically 500 µS/cm although there can be large variations in this value. So for the Grafana’s threshold value, the pH we set for the alert is 8, the TDS is set at 500, and turbidity is set at 10 NTU. The conductivity is set at 500. The Grafana has been set for a time-series data of all the parameters individually and in the right side of these graphs are the gauge data of the real time values.

EXPERIMENTAL STUDY

The arduino end node was calibrated using the HI9829 Multiparameter to compare the results of our end node and determine the accuracy and precision of our device. To evaluate our devices performance we took three experimental samples. Our first sample was purified RO water from a Kent RO Purifier, the second sample was regular tap water and third was water mixed with sand and left out in the open, uncovered for a few hours. We took 10 sample readings for each sample both with our device and our calibrated instrument and the result were as follows:

	Arduino End Node					HI9289 Multiparameter meter				
	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH
1	32.58	6.02	31.37	65.16	6.04	29.38	4.71	31.50	58.76	6.04
2	32.55	6.15	31.44	65.09	6.05	29.39	4.71	31.50	58.78	6.02
3	32.55	6.35	31.44	65.09	6.02	29.54	4.71	31.51	59.08	6.10
4	32.55	6.36	31.44	65.09	6.21	29.54	4.72	31.50	59.08	6.10
5	30.78	7.08	31.37	61.56	6.33	29.54	4.73	31.52	59.08	6.10
6	30.81	7.29	31.39	61.63	6.24	29.54	4.72	31.52	59.08	6.10
7	32.62	7.35	31.25	65.23	6.33	29.54	4.78	31.53	59.08	6.10
8	32.65	7.54	31.19	65.31	6.05	29.54	4.65	31.53	59.08	6.10
9	32.69	7.77	31.19	65.38	6.19	29.50	4.65	31.53	59.00	6.12
10	32.69	7.65	31.12	65.38	6.22	29.50	4.70	31.54	59.00	6.11

Table 1: Purified RO Water

	Arduino End Node					HI9289 Multiparameter meter				
	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH
1	207.64	12.89	31.00	415.28	7.38	210.58	9.06	30.95	421.16	7.68
2	206.36	11.67	30.94	412.71	7.40	210.52	9.62	31.00	421.04	7.65
3	207.64	11.34	31.00	415.28	7.28	210.99	9.60	31.08	421.98	7.66
4	207.41	12.98	31.06	414.81	7.42	210.52	9.61	31.08	421.04	7.65
5	208.92	13.02	31.06	417.83	7.35	209.32	9.58	31.07	418.64	7.65
6	207.18	11.45	31.12	414.35	7.20	210.52	9.65	31.08	421.04	7.63
7	206.12	11.02	31.00	412.25	7.33	210.52	9.57	31.08	421.04	7.65
8	204.38	12.56	31.06	408.77	7.32	210.50	9.57	31.06	421.00	7.64
9	204.61	11.34	31.00	409.22	7.48	209.88	9.55	31.07	419.76	7.65
10	204.61	11.66	31.00	409.22	7.33	210.42	9.60	31.07	420.84	7.62

Table 2: Tap Water

	Arduino End Node					HI9289 Multiparameter meter				
	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH	TDS (ppm)	Turbidity (NTU)	Temp (C)	Conductivity (uS/cm)	pH
1	219.98	51.65	30.87	439.96	7.82	220.78	60.00	30.95	441.56	7.99
2	221.25	55.87	30.82	442.5	7.87	220.55	61.23	31.00	441.1	8.01
3	221.25	60.32	30.82	442.5	7.88	220.55	60.09	31.08	441.1	8.01
4	221.25	60.35	30.92	442.5	7.85	220.59	60.09	31.08	441.18	8.02
5	221.25	60.49	30.92	442.5	8.03	220.59	60.09	31.07	441.18	8.02
6	221.25	60.56	30.62	442.5	7.99	220.59	60.09	31.08	441.18	8.02
7	218.23	60.52	29.31	436.46	8.01	220.59	60.09	31.08	441.18	8.02
8	218.23	59.88	30.65	436.46	7.87	220.59	60.10	31.06	441.18	8.02
9	218.23	60.65	30.92	436.46	7.99	220.60	60.11	31.07	441.2	8.01
10	218.37	60.87	30.66	436.74	7.80	220.60	60.11	31.07	441.2	8.02

Table 3: Polluted sand water

The data packet upon being received by the transport layer is transmitted to the application layer of the device, specifically to Influx DB (Fig.5). Data is stored in the database and is retained and an account of the data is kept. This is how the influx DB database looks:

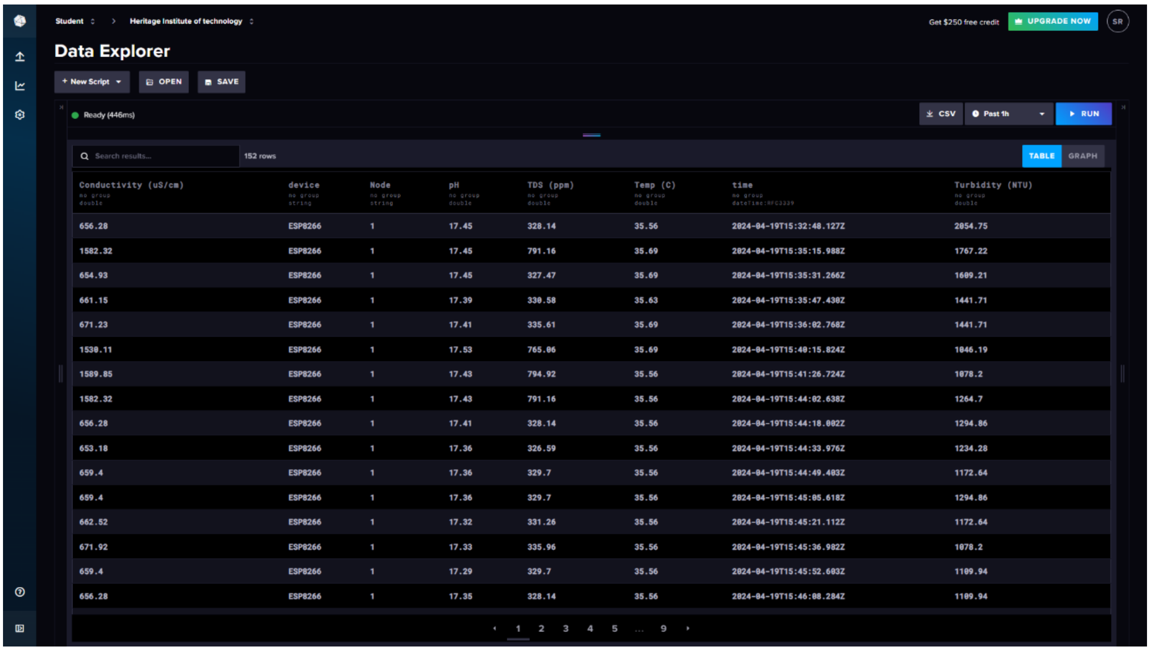

Figure 5: InfluxDB database

Grafana (Fig.6) is used to create the professional looking dashboard and also for the alerting system upon crossing of a particular threshold. Emails of the admin could be set up for receiving the alert notification along with other mediums like sms and telegram messages. The Grafana dashboard looks like this:

Figure 6: Grafana dashboard

And if a threshold is breached an alarm is triggered and an email is received by the admin which reads out:

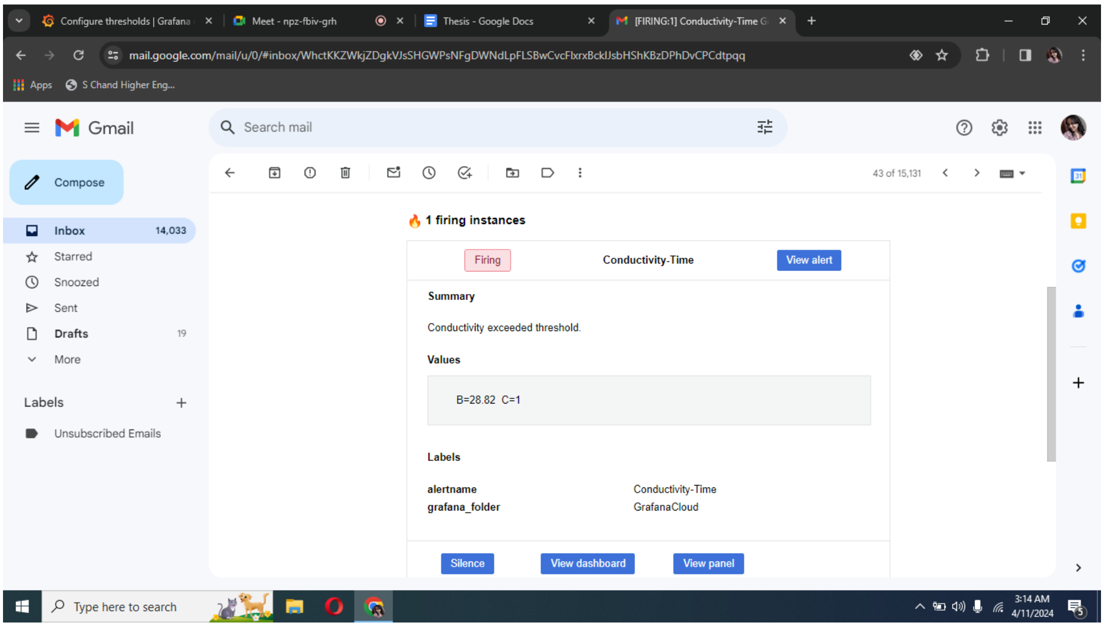

Figure 7: Sample alert notification in mail

RESULTS AND DISCUSSION

The HI9828 Multiparameter meter indicates that the Arduino end node is well-calibrated and approximately accurate as shown by tables 1, 2 and 3. However it should be noted that the variance is somewhat high and there is a lack of precision. All things considered the sensor performs admirably missing very little and producing almost abnormally high readings.

The end node uses sleep mode to conserve power and an end device's power supply is a problem. The user can measure the battery voltage and receive a data packet that tracks it. Currently the Arduino is powered by a 9v battery that is inserted into a DC barrel. Adding solar panels to the structure is another way to extend its lifespan.

The RSSI strength of the signal at the receiver end is something else to observe. Urban areas only allow a maximum range of 800 meters even with both the end node and the receiver node set to maximum spreading factor and transmit power. This maximum range can be increased by placing the receiver on a high end pole over the server side terrace and by using better antennas with higher dBm.

The single channel gateway functions well at a particular frequency and spreading factor but in the event that the no. a multichannel gateway which addresses issues like packet clashing and offers downlink capabilities to end node devices can be used if the number of nodes is intended to be increased.

Time series forecasting can be used to predict parameters after a certain quantity of data has been gathered aiding in predictive maintenance of the system. As a time series database InfluxDB has a significant querying advantage over SQL and NoSQL databases thanks to the use of tags which allows for much faster data queries. Another benefit of integrating Grafana is that it adds a professional-looking dashboard and precise alert management. Alerts can be distributed by Telegram, SMS and email. The alarm can be set to trigger based on complex queries and a log of all alarms is maintained. This feature makes the alarm very helpful in identifying and analyzing system malfunctions. Every parameter has a unique set of custom alarm queries that are always set off.

CONCLUSION AND FUTURE SCOPE

This device provides a robust solution to deploy at unsuitable conditions where it is difficult to deploy large devices and machinery which also requires active power throughout the day continuously and also to maintain them at a regular day to day basis due to various factors, subjected to the local environment. Hence, this can take up less space, yet can cater all the necessary technologies needed for efficient water quality monitoring at regular intervals while consuming much less energy. This portability also helps in saving up a lot of cost in transportation and gives us easy access for its manoeuvre which makes it flexible as well as suitable for a lot of use cases.

Irrespective of its size, we can scale this product for a more accurate measurement as well as for monitoring a cluster of water bodies at once, as it is very crucial for a lot of different industrial use cases and hence we can accommodate a large number of nodes which can send data in real time at regular intervals to our master node. Although we have calibrated this device with the HI9829 meter which is a waterproof portable logging meter, that monitors up to 14 water quality parameters, such as pH, conductivity, turbidity etc. for an almost precise measurement but it can also be further calibrated according to the industrial need. Thus, there are further more opportunities for its implementation on an industrial level.

Keeping this flexibility in mind we have been particularly wise in choosing LoRa, a LPWAN (Low Power Wide Area Network) technology, due to its multitude of advantages that have contributed immensely in making this device smaller in size, efficient and also low maintenance. LoRa, uses a proprietary spread spectrum modulation derived from chirp spread spectrum (CSS) technology which helps it to communicate over long distances (>10km) and have a very low demand of power and can also enter a low power sleep mode to conserve energy.

Further implementations include the use of Influx DB and Grafana to make the management and visualization of data more user friendly as well as, keeping a future scope for further development. While on one hand, Influx DB which is a powerful time series database that excels in handling time series data, it leaves us with the scope of further implementations of various Machine Learning Models in future. On the other hand, Grafana is an open source platform for visualizing and analyzing data which also helped us in implementation of an alert system that alerts the user if certain parameters of water quality falls below or rises above a certain threshold.

Though our device was well calibrated for general purpose use, for its usage in a particular industry it needs to be calibrated according to the industry standards. Moreover, the source of power can be provided from solar panels which will contribute towards a more eco-friendly solution and reduce our carbon footprint. This device currently works on a single channel gateway, but with further implementation of the Dragino, a hardware module we can make this device operate on multi channel gateway which will make this device more efficient and finally, we can further implement Machine Learning algorithms to analyze the data, find patterns, predict values and also can suggest various solutions regarding the particular problem or abnormality.

Though there is a wide scope of further development this device definitely paves the foundation stone for a robust water quality monitoring solution.

Future scope:

1. Through the use of adaptive models that can forecast future values the scope is improved by the trained determination of water quality parameters through machine learning. This helps with water quality management by streamlining real-time monitoring and enabling proactive actions based on predictive analytics.

2. Strong data transmission is ensured throughout the day in a water quality monitoring system that uses LoRa nodes by utilizing multi-channel gateways. In order to maximize the effectiveness and dependability of the entire system this dynamic data handling is essential for maintaining continuous monitoring particularly in the face of changing environmental conditions.

3. The project's scope is expanded through the integration of dissolved oxygen (DO) sensors whether they are store-bought or inexpensive indigenous solutions that allow for a thorough assessment of the water quality. The decision between premium and affordable sensors comes down to striking a balance between financial constraints and the requirement for accurate and trustworthy data.

4. The project takes on a futuristic aspect when LoRaWAN technology is utilized in place of conventional node polling. By integrating The Things Network (TTN) for downlink data nodes can be remotely controlled from a centralized server improving scalability and facilitating more effective data management. This opens doors for automation and advanced analytics in addition to enhancing real-time monitoring capabilities.

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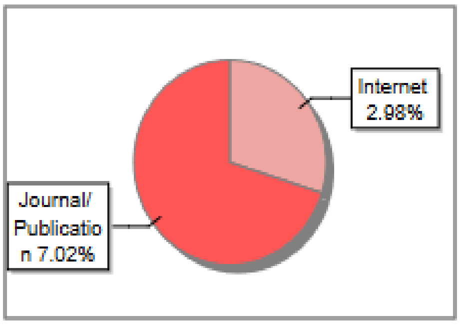

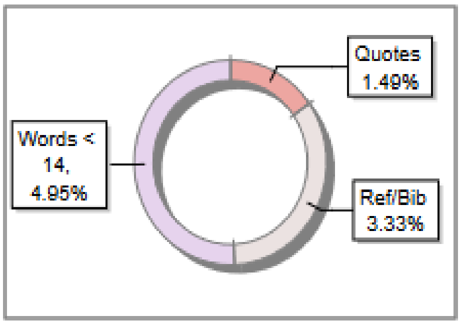

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