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IoT-Based Water Quality Sensor Node with Cloud Storage and Iterative Dashboard

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Abstract

This paper presents the development of an IoT-based river water quality monitoring system integrated with cloud storage and an interactive dashboard for real-time analysis. In this context, a Heltec WiFi LoRa32-V3 microcontroller was applied with various water quality sensors such as pH, turbidity, temperature, dissolved oxygen and total dissolved solids. Sensor data transmitted by LoRaWAN to The Things Network are processed using Node-RED, stored in a cloud-based MySQL database and then visualized on a Grafana dashboard. Field testing carried out at Sungai Panchor, Muar, Johor attested to the reliable transmission of data, effective cloud integration and clear visualization in real time. The proposed system offers a scalable, cost-effective and efficient solution for the continuous monitoring of the quality of river water.

1. Introduction

Based on the findings from environmental reports in Malaysia, river water pollution is a serious issue resulting from rapid urbanization, agricultural runoff, as well as the disposal of industrial and domestic waste [1]. Rivers constitute vital water sources for domestic, agricultural and natural usage; thus, it is important for water quality in rivers to be monitored regularly in order to avert environmental and health hazards. Traditionally, water quality analysis in rivers is performed using a tedious, expensive and non-real-time technique involving the collection of water samples for analysis by laboratories.

Conventionally, the assessment of water quality is conducted periodically by the concerned authority. In this method, the water quality is evaluated through the collection of water samples from the location. The captured water is then taken to the laboratory. However, the method is characterized by the lack of immediate data and the fact that the selected locations might not be easily accessible. Furthermore, the method is expensive and may not be feasible to implement along the entire river [2].

However, with the advent of Internet of Things (IoT) technology, smart environment monitoring systems that can overcome these issues have been developed recently. In this way, the combined use of sensor technology, microcontrollers and wireless communication solutions enables the continuous collection of data and real-time monitoring in an IoT system [3]. In particular, the long-distance transmission of data with less power consumption of the LoRaWAN communication solution is the most appropriate solution for monitoring the quality of the river's water.

This research work is centered on the design and development of an IoT river water quality monitoring system using the Heltec WiFi LoRa32 V3 microcontroller in collaboration with various water quality sensors such as pH sensors, turbidity sensors, temperature sensors, dissolved oxygen sensors and total dissolved solids sensors. These sensors' data is communicated through the LoRaWAN network into the Things Network for Node-RED analysis. This analysis is stored in a cloud MySQL database and displayed on a Grafana dashboard. Real-world testing was also performed at the Sungai Panchor in Muar, Johor Malaysia. This system is expected to offer a full and economical means of carrying out the continuous monitoring of the water quality in the river.

The scopes of this project include:

• Development of an IoT-based river water quality monitoring system using a Heltec WiFi LoRa32 V3 microcontroller.

• MariaDB (MySQL) used as the primary cloud-based database, while Node-RED processes the data before storage.

• Grafana used to develop an interactive dashboard for real-time data visualisation through graphs and charts.

2. Methodology

This section highlights the methodology adopted to develop the IoT-based river water quality monitoring system. This includes architecture, hardware development, sensor implementation, data transmission to the cloud platform and data visualization. This IoT-based river water quality monitor is designed to measure the river water quality factors continuously and send the data to the cloud platform.

2.1 Block Diagram

Figure 1 presents the block diagram of the proposed river water quality monitoring system. The system comprises several sensors for water quality interfaced with the microcontroller Heltec WiFi LoRa32 V3 as a primary processing and communication unit. The sensors measure in real-time pH, turbidity, temperature, DO and TDS. The collected data are transmitted using LoRaWAN to TTN. Further, Node-RED processes the received data and stores them in the cloud-based MariaDB (MySQL) database. Finally, the data visualisation is performed through a dashboard created using Grafana for real-time monitoring and analysis.

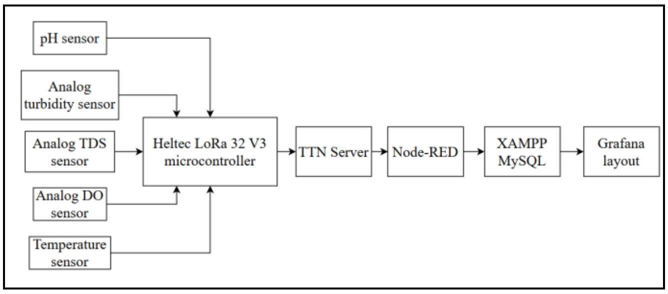

Fig. 1 *Block diagram of the system*

2.2 Hardware Development

The hardware development focuses on the integration of the Heltec WiFi LoRa32 V3 microcontroller with various water quality sensors to create a sensor node. The selection of the Heltec board for the project is informed by its features, including the LoRa communication component, low power consumption and the capacity to support long-distance communication.

The pH sensor is applied to measure the acidity or basic nature of the river water. The turbidity sensor is used to measure the clarity of the river water. A temperature sensor is applied to measure the variations in the water temperatures. The water temperature could be a factor affecting the aquatic life. Further, DO and TDS sensors are applied to measure the levels of dissolved oxygen and total dissolved substances in the water. The interfacing of all the sensors is done by a microcontroller. The assembled hardware components are packed in a case to safeguard them from environmental factors as shown in Figure 2. Figure 3 presents the wire connection between sensor node and the microcontroller.

Fig. 2 *Hardware diagram of the system*

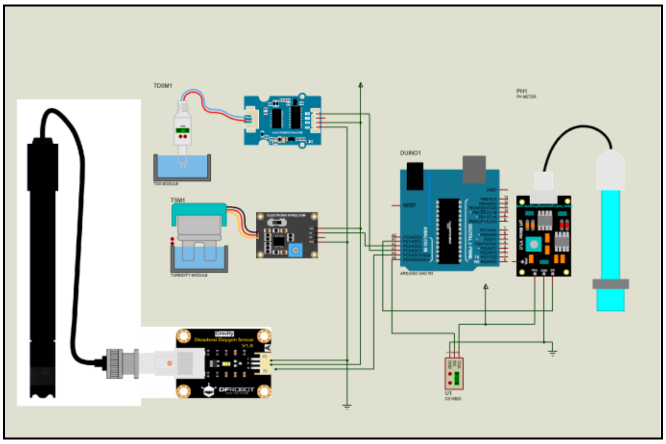

Fig. 3 *Circuit diagram of the system*

2.3 Software Development

Figure 4 shows the flow of the system in the software. The development of the software entails programming of the Heltec WiFi LoRa32 V3 microcontroller using the Arduino IDE. The software developed initializes all the sensors connected to the project, retrieves real-time data concerning water quality and prepares this data for transmission. LoRaWAN settings including credentials and transmission periods are appropriately set to support interaction with The Things Network.

Node-RED acts as the middleware platform in which the uplink data from TTN is received. The node processes, filters and formats the incoming data from the sensor before it is stored in the cloud database. This method ensures there is an efficient flow of data from the hardware to the cloud services.

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 374-379

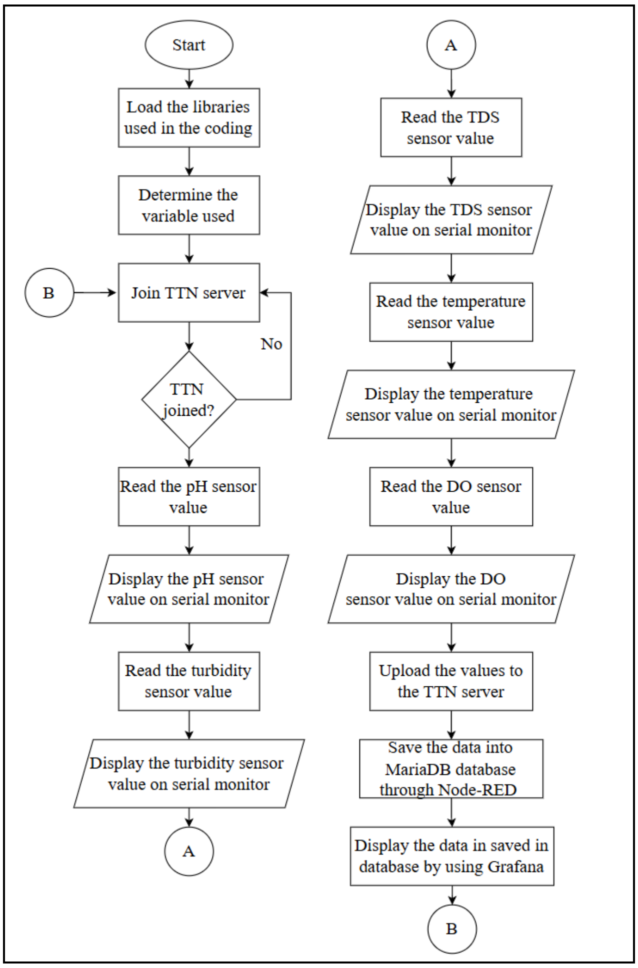

Fig. 4 *Flowchart of the system*

2.4 Cloud Database Integration

A cloud database service using MariaDB (MySQL) is employed for the long-term storage of data. Node-RED is setup to allow the storage of the processed sensor data into appropriate structured tables of the database for the easy retrieval of the data and analysis of the past trends of the variations in the data.

2.5 Data Visualisation

A graphical interface using Grafana is developed to create an interactive dashboard to visualize real-time data. The parameters of water quality are expressed through graphs and charts on the dashboard to display river conditions easily. The graphical interface helps to monitor data continuously and makes it possible to test the quality of river water using an internet-connected device.

2.6 Field Deployment and Testing

Field testing is done at Sungai Panchor in Muar, Johor, Malaysia. In the experiment, the sensor node is placed close to the riverbank. Data transmission performance, sensor node stability and accuracy of visualization are monitored. Data collected is then analyzed for the reliability and effectiveness of the system in the real-time river water quality monitoring process.

3. Results, Analysis and Discussion

In this section, the results that have been achieved through the practical application of the IoT-based river water quality monitoring system shall be discussed. These results shall include the performance of the hardware components, the network, cloud integration, as well as data visualization.

3.1 Data Transmission Performance

Figure 5 shows the Heltec WiFi LoRa32 V3 microcontroller was successfully able to communicate the sensor data to The Things Network (TTN) using LoRaWAN in field testing at Sungai Panchor, Muar, Johor. The communication link was able to maintain a stable long-range data transmission with a low packet loss rate. The low power capabilities of LoRaWAN supported continuous data transmission for an extended period of time, which was needed for river monitoring.

The uplink received data was correctly decoded in the TTN and transmitted to the Node-RED. This proves the robustness of the communication system design using LoRaWAN technology for the real-time monitoring of the environment.

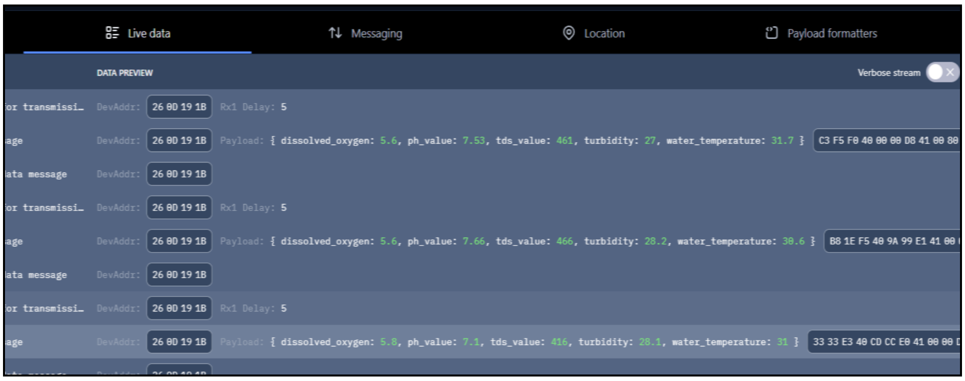

Fig. 5 *Data received by TTN server*

3.2 Cloud Data Processing and Storage

Figure 6 shows that Node-RED was successful in handling the incoming sensor data from TTN and storing the values in the cloud-based MariaDB (MySQL) database without any corruption or loss of data. The data in the form of records with timestamps allowed for proper recording and easy collection for analysis without facing corruption or loss of data in the process of data storage. The use of cloud database enables accumulation of data over time. Such data can then be analyzed to evaluate changes in the water quality parameters.

id	temperature	ph	tds	turbidity	dissolved_oxygen
25	31.7	7.2	456	24.7	5.6
26	31.8	7.47	408	25.9	5.8
27	30	7.41	410	27.2	5.4
28	32.2	7.64	491	24.6	5.7
29	31.9	7.1	445	26	5.7
30	31	7.1	416	28.1	5.8
31	30.6	7.66	466	28.2	5.6
32	31.7	7.53	461	27	5.6
33	30.5	7.53	428	26.5	5.7
34	32	7.15	480	26.6	5.4
35	30.9	7.4	441	27.6	5.2
36	32.3	7.67	468	25	5.4

Fig. 6 *Data stored in MySQL Database*

3.3 Data Visualisation Using Grafana

Figure 7 shows the dashboards in the Grafana system were very effective in showing graphs of the real-time values of the water quality parameters in the form of charts. It was possible for the user to observe the variations in the values of pH, turbidity, temperature, DO and TDS from anywhere using an internet-enabled device.

The feature of live update in Grafana ensured that the newly received sensor values were reflected on the dashboard without delays.

Fig. 7 *Grafana Dashboard's Visualization*

4. Conclusion

In this project, an IoT-based river water quality monitoring system which was designed with cloud storage support along with real-time data visualization has been successfully developed. The system used a Heltec WiFi LoRa32 V3 microcontroller along with sensors such as pH, turbidity, temperature, dissolved oxygen and total dissolved solids. All these sensors were used to continuously monitor the water quality of the river. Data transmission to the cloud storage was done through LoRaWAN connectivity to The Things Network. Node-RED helped in storing the data into a cloud MariaDB database.

Field deployment in Sungai Panchor, Muar, Johor showed stable sensor operation, proper data transmission and successful real-time visualization with a Grafana dashboard. The results obtained reveal that the proposed system provides a scalable, cost-effective and efficient approach toward continuous monitoring of river water quality. This present system is capable of performing only monitoring and visualization, yet it lays a solid foundation for further development that includes automated alert mechanisms, predictive analysis and the incorporation of more environmental sensors.

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