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Water Quality Monitoring System Using Lora Network

Sistem Pemantauan Kualiti Air Menggunakan Rangkaian Lora

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ABSTRACT

Environmental pollution has occurred over the past few decades. Air, water and soil pollution are the three main pollutions on Earth due to human negligence. Despite the rapid development of many technologies, new forms of pollution have emerged, including light and noise pollution. There are few attempts to make environmentally friendly products or raise awareness of the issue, but it has not always been successful. The difficulty of detecting water pollution makes it one of the pollutants that is challenging to manage. Some pollution, such as illegal oil dumping into the sea and oil spills, cannot be identified early and has harmful environmental effects that cannot be reversed. This can cause adverse effects not only on aquatic life but also on humans. Thus, this system was created to specifically deal with water pollution by obtaining data from pH, turbidity, and temperature sensors. The data will then be sent to the user's smartphone in real time over the LoRa network due to the network's ability to transmit data over long distances. Any abnormal data readings will be reported to the user, who may notify the authorities to immediately reduce any bad effects on the water.

Keywords: LoRa, IoT, Sensor Network, Water Pollution, Water Quality

ABSTRAK

Pencemaran alam sekitar telah berlaku sejak beberapa dekad yang lalu. Pencemaran udara, air, dan tanah adalah tiga jenis pencemaran utama yang berlaku di Bumi kita disebabkan oleh kealpaan manusia. Perkembangan teknologi, bentuk pencemaran baru telah muncul, termasuk pencemaran cahaya dan bunyi. Walaupun terdapat usaha untuk menghasilkan produk mesra alam dan meningkatkan kesedaran mengenai isu ini, ia tidak begitu berkesan. Kesukaran mengesan pencemaran air menjadikannya salah satu pencemar yang sukar dikendalikan. Sesetengah pencemaran, seperti pembuangan minyak haram ke laut dan tumpahan minyak, tidak dapat dikenal pasti lebih awal dan mempunyai kesan berbahaya terhadap alam sekitar

yang tidak dapat dipulihkan. Ini boleh menyebabkan kesan buruk bukan sahaja kepada hidupan akuatik, tetapi juga kepada manusia apabila kita makan makanan laut. Oleh itu, sistem ini dicipta untuk menangani pencemaran air secara khusus dengan mendapatkan data menggunakan sensor untuk pH, kekeruhan, dan suhu. Data tersebut kemudiannya akan dihantar ke telefon pintar pengguna secara masa nyata melalui rangkaian LoRa disebabkan oleh keupayaan rangkaian tersebut untuk menghantar data dalam jarak jauh. Sebarang bacaan data yang tidak normal akan dilaporkan kepada pengguna, yang kemudiannya boleh memberitahu pihak berkuasa untuk mengurangkan sebarang kesan buruk terhadap air dengan segera.
Kata kunci: LoRa, IoT, Rangkaian Sensor, Pencemaran Air, Kualiti Air

INTRODUCTION

Environmental pollution has increased in recent decades. Air pollution, water pollution, and soil contamination are the three primary types of pollution on Earth. Human activities have become the main source of environmental harm due to selfish motivations, despite humans relying on the world for survival. For instance, the usage of plastic contributes to the annual death toll of up to a million wild animals due to plastic contamination (Laura, 2019). With technological advancements, an increasing number of techniques are being developed to address various difficulties.

Nevertheless, it is difficult to address environmental degradation. Water contamination is tough to eliminate due to the complexity of the detecting process. Once the pollution is detected, it will have already caused significant damage to the water's ecosystem, maybe reaching a point where it is irreparable or irreversible. One is when thermal fluid leaks into rivers and lakes (Laura, 2019). Numerous individuals have experienced adverse consequences due to water pollution. Marine species have been significantly impacted by 83% decline in numbers over the last 50 years (Manish, 2022). Water pollution can lead to several ailments in humans, including diarrhea, gastrointestinal disorders, and other illnesses (Li et al., 2022).

The Internet of Things (IoT) refers to the Internet-enabled communication among electrical equipment or sensors (Mohd Aman et al., 2020). The Internet of Things has significantly impacted human lives by improving efficiency, creativity, and convenience (Mohd et al., 2021). IoT uses sensors to monitor surroundings and transfer the data to other devices and individuals for appropriate action. This allows for automated task completion. The sensors usually operate on batteries and provide remote communication features (Mohd Aman, Shaari, Ibrahim, 2021).

LoRa is a type of radio modulation that uses unique physical properties. Semtech obtained control of the firm after it was originally developed by Cycleo (Mistry R. et al, 2022, Bhargava et al., 2022). Kim et al. (2019) stated that LoRa technology utilizes CSS (Chirp Spread Spectrum) modulation techniques to transmit data over radio waves using chirp pulses. LoRa can be used by any individual or organization because it operates in an unlicensed band. Figure 1 illustrates that LoRa has a significant connectivity range enabling remote data transmission. It can only transmit small amounts of data because of its limited bandwidth. Nevertheless, LoRa remains popular because of its minimal energy usage (Jáquez et al., 2023) . A study by Michael in 2017 discovered that a nine-volt battery can power LoRa for up to 10 years. Moreover, the expense associated with utilizing LoRa technology is minimal and within reach for most people.

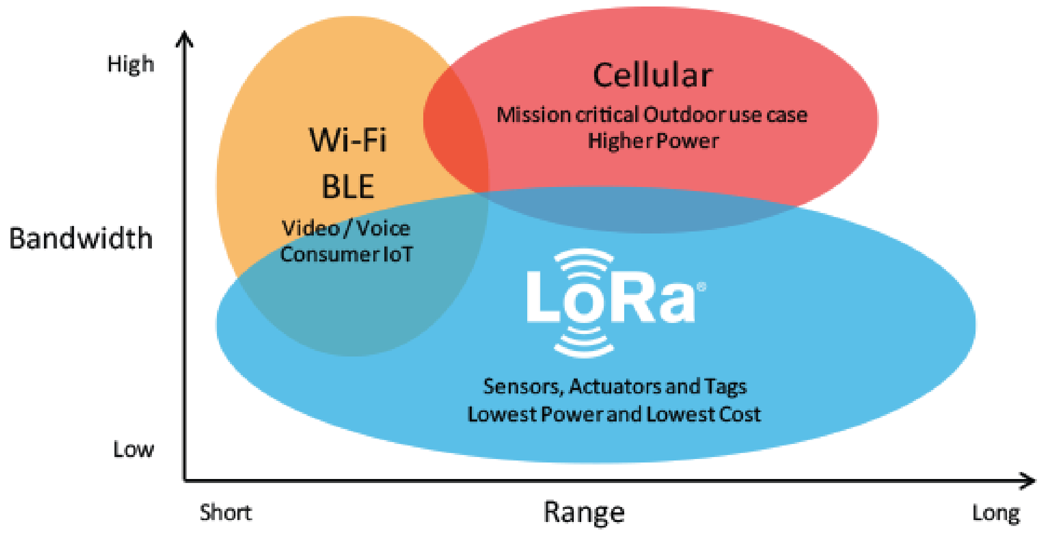

FIGURE 1. Differences between LoRa and Wireless Networks

Water contamination occurs when water quality is altered by changes in content, color, and chemical composition because of contaminants (Abdelghaffar, 2023). Water pollution can be categorized as either a point source or a non-point source. Pollution originating from a singular source is known as a point source, while pollution from various sources is termed as a non-point source. Identifying sources of pollution from non-point sources is more challenging than from-point sources due to numerous origins. This study aims to create a system capable of remotely detecting water contamination and to evaluate its performance through suitable technical analysis methods to determine if it meets the anticipated standards.

The study's scope involves developing a system capable of detecting changes in water quality using three sensors: pH, turbidity, and temperature (Sendra et al., 2023; Ponni et al., 2023). The system will signal the application in real-time using the LoRa network. The system is compatible with both iOS and Android. The device can be installed in locations like riversides and ponds with a minimum distance of 100 meters. If water pollution is suspected, users can notify the authorities, who will then take quick action to address the problem. Constraints may arise during the project's development. One problem is the insufficient knowledge among technological professionals regarding the establishment of the LoRa network.

A number of studies have been conducted to produce a variety of different types of water quality monitoring systems. Using a Wi-Fi network, Chengcheng et al. (2020) built a system that can obtain information regarding the quality of water using sensors. At the beginning of the process, information is gathered from system sensors regarding pH values, turbidity, and temperature. This information is then transmitted to the microcontroller, an STM32 module, to convert analog data into digital signals. The information was sent to the Internet through a Wi-Fi network by utilizing an ESP8266 module, which is a component that enables the microcontroller to establish a link with cyberspace. At the same time, the information was saved in a cloud database, which means that it is accessible through a smartphone or computer equipped with the system's software and has an Internet connection. In addition to that, the system can trigger an alarm if the data becomes aberrant.

Qiuchan et al. (2020) propose using sensors to determine water quality status and transmit data via the ZigBee standard. The STM8 module processes the data, which includes information on water quality, such as pH and temperature readings, to overcome the issue of weak data signals. The data contains information on water quality. The information was then transmitted to the computer utilizing the ZigBee coordinator, with the assistance of the CC2530 module, over a relatively short distance. In that system, the computer can receive and analyze the data in real-time and display the analysis results on the screen. While this is happening, the system also uses the GSM module to communicate the data collection results to the mobile phone in the form of an SMS.

The methodology for the study has used the Waterfall Model. The purpose of using the model is because it is simple and easy to understand. As for the rest of this paper, it has been compiled into three sections: the methodology of the study, the results and the discussion, and the conclusion. All three sections will provide a more detailed explanation of the developed project.

MODEL METHODOLOGY

This project employs the Waterfall Model as its methodological foundation. The waterfall model is considered one of the most traditional methodological models. This strategy is often favored because of its straightforwardness and accessibility. The primary characteristic of these models is that each phase is carried out in a sequential manner. Therefore, it is essential to thoroughly plan each stage before moving on to the subsequent one. The first stage of the Waterfall Model is the planning phase. The objectives, problem statements, limits, scope, and other project components have been established during this planning and development phase. Comprehensive planning is crucial for the successful implementation of the project.

The next phase is the analysis phase, which is crucial for gathering project information. A deeper comprehension of project requirements to fulfill users' expectations can be obtained by employing meticulous analysis techniques. The analysis focuses on global water contamination issues and the occurrence rate. Simultaneously, the existing systems are evaluated to pinpoint the shortcomings and strategize ways to improve them. Furthermore, analyzing the project's cost is crucial for estimating expenses throughout the project's duration. It encompasses two distinct expenses: direct and indirect costs. Direct costs are the specific expenses incurred in the production of a project, including raw materials and machinery. Indirect costs refer to expenses like car gasoline, tolls, and Internet payments incurred during the project term.

Another important phase is the design phase. The design phase determines the operational framework of the system. This involves the system in terms of hardware, networking, software, and other relevant aspects. This is crucial because the use of the system is intricately linked to all mentioned variables. Errors in this step can impact the overall system functionality. Next, not to be missed, is the implementation phase. During the implementation phase, the system is tested individually to ensure that each unit functions smoothly and meets the project criteria outlined in the analysis phase. This phase is conducted simultaneously to detect any issues encountered by the system to make enhancements to guarantee the system operates as intended. The test phase is conducted to verify the integration between units inside the system. This phase aims to verify that the project fulfills the specified objectives and satisfies consumer needs.

RESULTS AND DISCUSSIONS

The proposed water quality monitoring system utilizing the LoRa network consists of two distinct systems: a transmitter system and a receiver system, as illustrated in Figure 2 and 3. The system comprises an Arduino Uno Rev3 microcontroller and a pH sensor, turbidity sensor, and temperature sensor. The recipient system utilizes the MCU1.0 Node ESP8266 as a microcontroller. Both systems utilize the LoRa SX1278 Module for network connectivity. The system utilizes the C/C++ programming language for system coding within the Arduino IDE software.

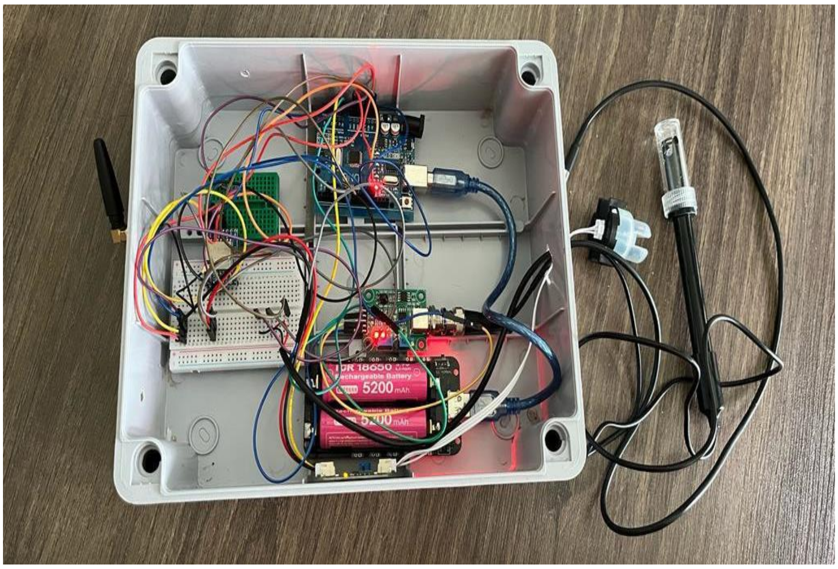

FIGURE 2. System Sender

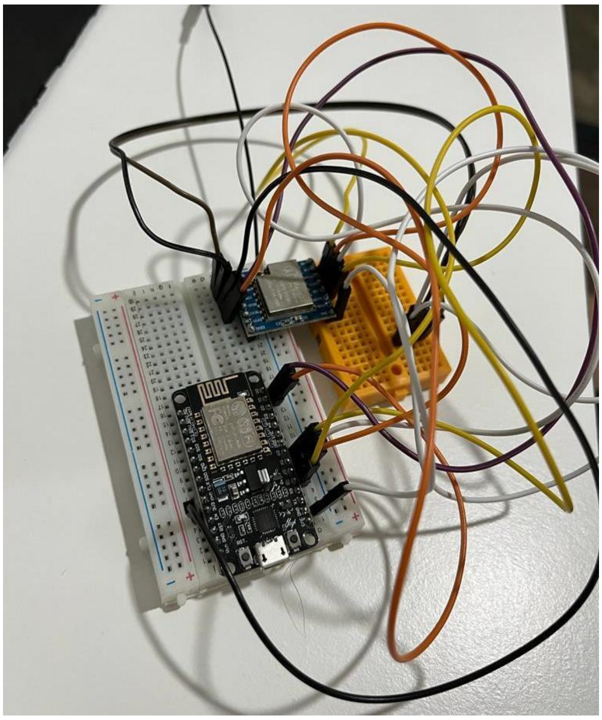

FIGURE 3. System Receiver

To use the system, the user must first open the system switch on the system sender. The switch is in the battery section, as shown in Figure 4. At the same time, the system receiver should also be connected to any source of electricity, as shown in Figure 5. In the Blynk software interface, users can see the displayed water quality values as in Figure 6 when one of the water quality values looks less common. The system notifications and alarms will be triggered so that users are aware of the issue, as shown in Figure 7.

FIGURE 4. Battery Switch

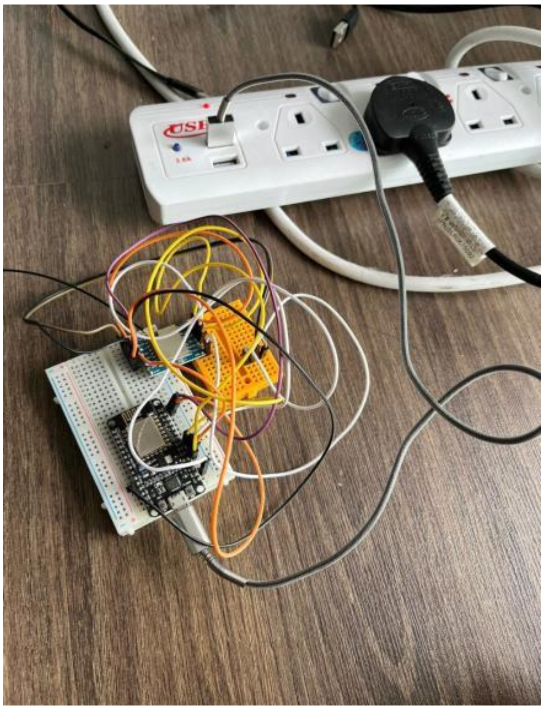

FIGURE 5. Connection of System Receiver to Power Source

FIGURE 6. User Interface Figure

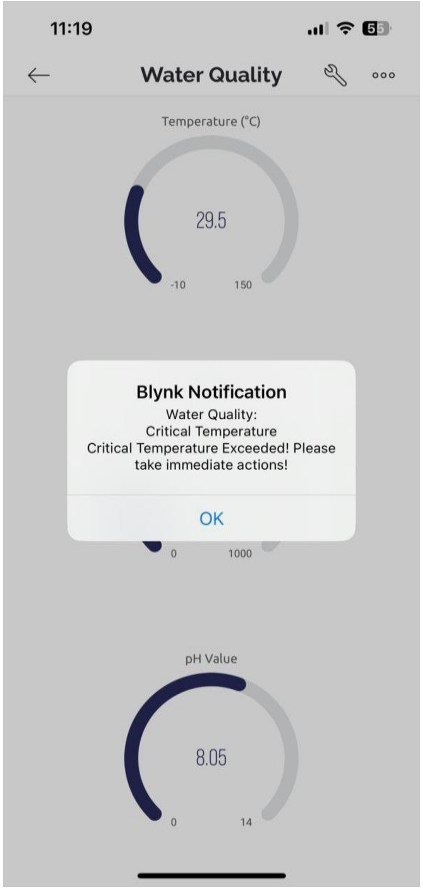

FIGURE 7. User Interface Diagram and Notification when the alarm is triggered

When the system is not online or it is offline, the status will be displayed on the user interface, and a notification will be issued to the user, as shown in Figure 8 and Figure 9. System testing is also done using black box testing and system component testing. The findings of each test, which were completed under approved testing protocols, are shown in Table 1 and Table 2.

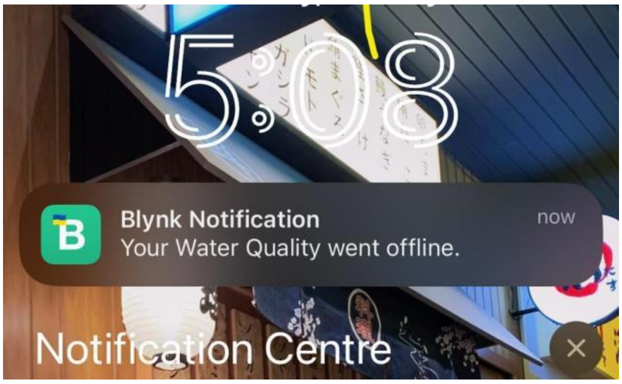

FIGURE 8. Notification when the System is in *Offline Status*

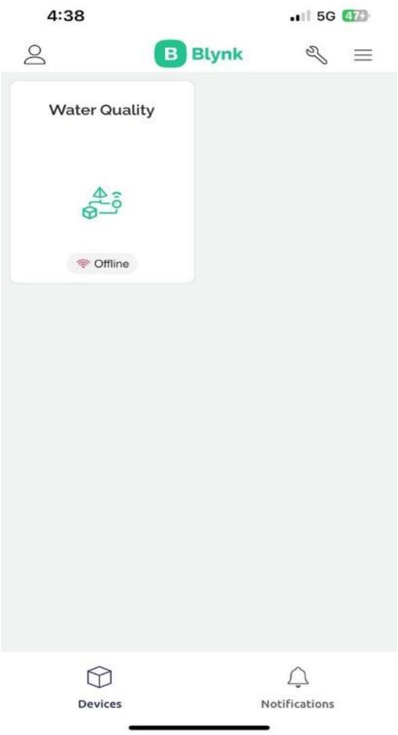

FIGURE 9. System User Interfaces in *Offline Status*

TABLE 1. Component Testing

Test Case	Components tested	System Sender/Receiver	Decision Expectations	Decision
K01	Arduino Uno Rev3	Conductor	▪ Able to withstand the installation of various types of sensors ▪ Receive uploaded codes and perform all functions	Pass
K02	Node MCU 1.0 ESP8266	Recipient	▪ Able to withstand the installation of various types of sensors ▪ Receive uploaded codes and perform all functions	Pass
K03	LoRa SX1278	Deliverer, Receiver	▪ Communication between both the sender and receiver of the system can be connected ▪ Sensor values can be transmitted from the system conductor and received by the system receiver	Pass
K04	Temperature Sensor Sonoff DS18b20	Conductor	Temperature values are displayed Top Serial *Monitor*	Pass
K05	Liquid Turbidity Sensor	Conductor	Turbidity value is displayed in Serial *Monitor*	Pass
K06	pH sensor Liquids	Conductor	The pH value is displayed above *Serial Monitor*	Pass

TABLE 2. Black Box Testing

Test Case	Function Illumination	Function Source	Decision Expectations	Decision
TC01	Getting and displaying water quality data	SRS	System aforementioned will display water quality values over the Blynk software interface on smartphones user.	Pass
TC02	Issue alarms and notifications	SRS	System aforementioned will issue alarms and notifications related to values that seem less unusual for all three liquids were tested.	Pass
TC03	System response	SRS	Follow reply system should not exceed the term 5 moments.	Pass
TC04	The lifespan of the system uses energy Battery	SRS	The lifespan of the system should exceed at least 2 Sunday	Pass
TC05	Connecting distance	SRS	The connection distance must be exceed at least 100m in urban areas.	Pass

CONCLUSION

The development of the Water Quality Monitoring System Using the LoRa Network was successful. The system effectively performed its functions during testing and met the study's objectives. The technology was created to identify water pollution in real-time, allowing users to promptly address the problem before it escalates into an irreparable condition. Moreover, incorporating the LoRa network into the system can enable long-distance coverage. Simultaneously, these systems also have low energy consumption. Due to the waterproof enclosures, these systems can operate effectively in rainy weather. However, the quality compromises the sensors' precision, leading to inadequacies. This method can assist users in identifying water pollution in real-time to promptly address the issue with relevant stakeholders. The hope is that the system can be enhanced in all areas for future investigations.

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