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Water Quality Monitoring and Assessment System Along Tigris River in Mosul City

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Keywords:
LoRa technology; Parameters; Sensor nodes; Tigris River in Mosul city; Water quality.

Highlights:

- *An environmental contribution is being made by continuously providing data on water pollution levels in Mosul city using a wireless sensor network to measure and monitor water quality.*
- *A technological contribution is being made by utilizing the LoRa network to transmit water data to the cloud in real-time.*

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Abstract: This paper aims to address the issue of water pollution in the Tigris River in Mosul city through continuous water quality monitoring. The proposed solution involves the use of LoRa-WAN wireless technology. Wireless sensor nodes would be placed at various stations along the river in Mosul, transmitting data to a LoRa gateway at the Nineveh Water Directorate. This gateway would then communicate with a server via a Cloud platform on the internet. The study utilized the OMNET++ program to simulate data transfer from sensor nodes to the LoRa gateway. Two main contributions are highlighted: an environmental contribution in providing data on water pollution levels and a technological contribution in utilizing the LoRa network for water quality monitoring. Thirteen parameters were measured at nine river stations. The sensor nodes will send notifications to the LoRa-WAN network if any parameter exceeds a predetermined value. The simulations analyzed the received signal strength indicator and packet delivery ratio with 117 sensor nodes managed by one LoRa gateway, covering a 20km area. The LoRa-WAN technology demonstrated satisfactory results in the simulated scenarios, improving network performance by studying the impact of increasing distance between sensor nodes and the gateway on RSSI values for different transmitting power levels (2-14 dBm).

نظام مراقبة وتقييم جودة مياه نهر دجلة في مدينة الموصل

فواز ياسين عبدالله، آمنة عبد المنعم فاضل، محمد طارق ياسين
قسم الهندسة الكهربائية / كلية الهندسة / جامعة الموصل / الموصل – العراق.

الخلاصة
تهدف هذه الورقة إلى معالجة قضية تلوث المياه في نهر دجلة في مدينة الموصل من خلال المراقبة المستمرة لنوعية المياه. يتضمن الحل المقترح استخدام تقنية LoRa-WAN اللاسلكية. سيتم وضع عقد استشعار لاسلكية في محطات مختلفة على طول النهر في الموصل، لنقل البيانات إلى بوابة LoRa في مديرية مياه نينوى. ستتواصل هذه البوابة بعد ذلك مع الخادم عبر منصة سحابية على الإنترنت. استخدمت الدراسة برنامج OMNET++ لمحاكاة نقل البيانات من عقد الاستشعار إلى بوابة LoRa. تم تسليط الضوء على مساهمتين رئيسيتين: مساهمة بيئية في توفير البيانات حول مستويات تلوث المياه، ومساهمة تكنولوجية في استخدام شبكة LoRa لمراقبة جودة المياه. تم قياس ثلاثة عشر معلمة في تسع محطات نهرية. إذا تجاوزت أي معلمة قيمة محددة مسبقًا، فسترسل عقد الاستشعار إشعارات إلى شبكة LoRa-WAN. قامت عمليات المحاكاة بتحليل مؤشر قوة الإشارة المستقبلة ونسبة تسليم الحزمة مع ١١٧ عقدة استشعار تدار بواسطة بوابة LoRa واحدة، تغطي مساحة ٢٠ كيلومترًا. أظهرت تقنية LoRa-WAN نتائج مرضية في السيناريوهات المحاكاة، مما أدى إلى تحسين أداء الشبكة من خلال دراسة تأثير زيادة المسافة بين عقد الاستشعار والبوابة على قيم RSSI لمستويات مختلفة من طاقة الإرسال (٢-١٤ ديسيبل ميلي واط). وهذا يوفر فهماً شاملاً لمستويات تلوث النهر ويسهل تحديد الحلول المناسبة.

الكلمات الدالة: تقنية LoRa، المعلمات، العقد الاستشعارية، نهر دجلة في مدينة الموصل، نوعية المياه.

1.INTRODUCTION

The Tigris River is the longest-flowing river in Southwest Asia, second only to the Euphrates [1]. Water pollution is a term used to describe the deterioration of natural water sources due to toxic elements and pollutants. This leads to a concentration of harmful substances in water bodies, either dissolving or becoming sediment at the bottom of rivers [2]. Water quality is a significant issue today, especially with the expected decrease in freshwater availability in the future. Water quality is typically assessed based on its physical, biological, and chemical characteristics [3]. One crucial strategy to preserve the quality of Iraq's surface water is to monitor sources of contaminants and take action to reduce or prevent their impacts [4]. The Water Quality Index (WQI) is an important method for assessing water quality within water treatment plants. Water contains dissolved materials and impurities that must be removed or reduced to certain limits in order to make it drinkable [5]. Many statistical methods exist to compute WQI, such as arithmetic weighted average, weighted average, and square-rooted average. These methods are used to calculate the deviation of included parameters from their standard limits [6]. The government of Baghdad conducted chemical and physical testing based on standard methods of WQI for eight years. This included testing for total hardness (as $CaCO_3$), turbidity NTU, magnesium, pH, calcium, sulphate, fluoride, iron, nitrate, chloride, conductivity, and TDS in water [7]. The data on water quality was collected from sensor nodes equipped with transceivers fixed in water stations and then sent to the network [8]. Some applications require wireless technologies to transmit data over long distances at a low cost, low data rate, and low power consumption, such as LoRa technology [9]. LoRa technology, which stands for Long Range, is a modern wireless sensor network that is part of LoRaWAN technology [10]. This technology is crucial for creating a new intelligent system for managing and monitoring data from sensor nodes [11]. A LoRa-WAN network consists of multiple sensor nodes connected wirelessly to a gateway communicating with the network server [12]. LoRa-WAN sensor nodes can access the internet without relying on WiFi or cellular networks [13] and do not require any additional infrastructure [14]. LoRa-WAN operates on unlicensed frequencies below 1 GHz, allowing for long-range communication over several kilometers [15]. The network uses a star typology design, eliminating the need for repeaters and reducing the cost of deploying network equipment [16]. Several hydraulic events can be modeled using the HEC-RAS software, including water quality analysis, stable riverbanks, and constant flow [17].

2.RELATED WORK

Hadi and Al-Juhaishi [18] examined the Water Quality Index (WQI), which involved selecting four measurement stations on the Tigris River to test eleven parameters of water quality: Mg, Ca, K, Na, SO_4, Cl, NO_3, HCO_3, TDS, EC, and BOD_5. The findings indicate that Mosul City has better water quality than Al-Amarah City. The two stations in Mosul City had water quality ranging from 83 to 94, while the two sites in Al-Amarah City had water quality ranging from 52 to 59. Najam and Wais [19] measured the natural radiation levels of Tigris River sediments in Mosul by employing gamma spectroscopy to calculate the activity concentrations of natural radionuclides: radium-226, thorium-232, and potassium-40. The average values calculated were 9.86, 23.05, and 232.91 Bq/kg, respectively. The results indicated values below the recommended safe limits set by UNSCEAR. Al-Soyffe et al. [20] employed mathematical models to estimate the water quality of the Tigris River in Mosul by collecting 120 water samples from six different locations in the river. According to the study, the water parameters (pH, Ca, Mg, Na, K, and

Cl) were determined. The study concluded that the water quality of the Tigris River in Mosul is good and suitable for irrigation based on the Kelly Index, which is accepted by international standard techniques. Abed et al. [21] assessed water quality through analysis and monitoring of the quality data of the Tigris River in Iraq. The twelve river parameters measured included Ca, Mg, Na, K, Cl, SO4, HCO3, NO3, TH, TDS, BOD5, and EC at 14 different stations. The results, based on the Iraq WQI application, showed that the best water quality indicator in Fishkhabour was 81.48, which was considered good, while the worst quality water indicator in Qurnah was 46.23, indicating bad quality. Promput et al. [22] utilized environmental sensor nodes to measure water quality indicators with a cordless electric boat designed to measure conductivity, turbidity, pH, and air quality. This data was transmitted using LoRa technology and displayed on the Node-RED dashboard. Experimental findings showed that data was successfully transmitted from sensor nodes to a gateway within a range of 2.0 kilometers. However, as the distance increased, the strength of the LoRa technology transmission signal began to weaken. The results indicated a decrease in signal transmission efficiency from 99% to 85.5 % when the distance between sensor nodes and the LoRa gateway increased to 3km. Ly et al. [23] use sensor nodes based on LoRa-Cloud to monitor water quality and detect pH (SEN0161-V2), humidity (DHT11), and temperature. This data is displayed in real-time via the Ubidots IoT platform using a smartphone at Taman Metropolitan Lake in Malaysia. The sensor nodes were placed beside the lake where there was steady surface water movement, while the gateway node was placed more than thirty meters away. The sensor data was uploaded every five minutes to Ubidots. The results showed that the pH of the water ranged between (7.32 and 9.08, with updated data every five minutes. Taha et al. [24] developed a water quality monitoring program to reduce epidemics and pollution during COVID-19 in Malaysia. This program used sensor nodes based on IoT to measure turbidity, pH, temperature, and dissolved oxygen in the water. These sensor nodes communicated wirelessly with a LoRa gateway. Three LoRa nodes were deployed at the fish pond, with a LoRa gateway located approximately 10 meters away from the sensor nodes. They found that results such as SNR, RSSI, received power, and path loss were affected by LoRa parameters, such as SF. Increasing the SF can increase network coverage but decrease the bit rate and RSSI value. The recorded values were RSSI -77 dB, Received Power -34.91 dBm, SNR 9.5 dB at SF=7, and Transmission Power 14dBm. The values were RSSI -87 dB, Received Power -33.76 dBm, SNR 12.25 dB at SF=9, and Transmission Power 14 dBm. Ahmed et al. [25] evaluated the groundwater quality in the northern Salah al-Din Governorate and highlighted the dangers that nitrate ionspose to the health of locals. Thirty wells in the Baiji industrial district were sampled to determine whether groundwater is suitable for irrigation and drinking. According to the Drinking Water Quality Index (DWQI), 96.67% were poor, while 3.33% of the water samples were subpar. Al-Saedi et al. [26] mentioned the increased concentration of pollutants in the Tigris River due to a lack of precipitation, as well as an increase in medical and industrial waste in the river. The review studies presented information about biological, chemical, and physical pollutants such as pH, Na+, TH, BOD5, TDS, SO4, and turbidity in the river. The station used in this review study is the Sarai Baghdad gauging station. They concluded that the decrease in water quality of the Tigris River is due to climate change, a decrease in water supply, and the illicit disposal of wastewater and effluent into rivers. Shareef [27] conducted a study on statistical techniques using Factor Analysis to explain the water quality data of the Tigris River in Baghdad. Eleven locations were chosen to evaluate water quality, considering 20 criteria along the river. The findings showed that twenty quality variables could be categorized into five factors: surface runoff and erosion, pollution, pH, nutrients, and silica. These factors accounted for 72.291% of the overall variance in the Tigris River's water quality, aiding in water quality assessment and pollution prevention. Alghamdi et al. [28] developed an automated system to monitor and detect water leakage based on IoT using the LoRaWAN Network in the OMNeT++ platform. They utilized a pressure sensor, water meter, and smart valve fixed in a LoRa node. The area of operation is 1-25 km², with the LoRaWAN gateway positioned in the center of the design, surrounded by 72 sensor nodes. During the simulation, the time frame was 7 minutes, with a spreading factor of 7-12, frequency of 868 MHz, bandwidth of 125 KHz, coding rate of 4/8, and transmission power of 14 dBm. The success rate of packet delivery ratio (PDR) from sensor nodes to the gateway was up to 100% in a 1 km² area, decreasing to 88% over a 25 km² area. The average energy consumption of sensor nodes increased from 40 mJ at 1 km² to 70 mJ at 20 km². The average throughput of received data also increased from 300 bits/s at 1 km² to 600 bits/s at 25 km², leading to an increase in data collisions from zero at 1 km² to 1200 at 25 km². This paper aims to address the problem of water pollution by monitoring and evaluating the water quality of the Tigris River in Mosul. Researchers faced challenges in transmitting data over long distances. The study employed the OMNET++ program to simulate the transfer of data from sensor nodes to the LoRa gateway. This LoRa-WAN wireless technology was utilized to collect information on water quality and upload data to an IoT Cloud platform. To accomplish this purpose, the LoRa-WAN architecture has been prototyped in Fig. 1 to illustrate how sensor nodes can communicate to measure parameters such as turbidity, temperature, alkalinity of water, and total water hardness using LoRa technology [29-32].

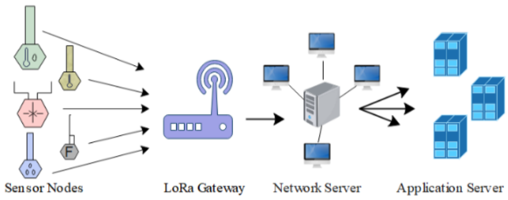

Fig. 1 LoRa-WAN Architecture was Utilized for Water Quality Monitoring.

3.SIMULATION SCHEMES

The primary objective of the system's design and implementation is to monitor the quality of the water, may measure data, and send it to the cloud in real-time. Fig. 2 shows the system's overall layout.

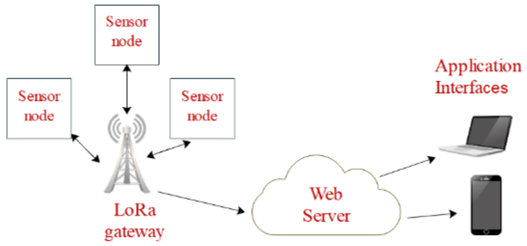

Fig. 2 System Overall Layout.

3.1.Sensor Nodes Methodology

Thirteen sensor nodes were strategically placed in nine stations along the Tigris River in Mosul city to collect water samples. Thirteen parameters were selected, including turbidity, temperature, pH, SO4, EC, Mg, Ca, Na, Cl, SO4, K, TDS, water alkalinity, and total water hardness, in order to assess the water quality at these stations. The samples were analyzed to evaluate the quality of the river water, with the results being rated on a scale that averaged readings between the minimum and maximum levels recorded by the sensor nodes.

3.2.LoRa Simulation Methodology

This scenario demonstrates the implementation of an OMNET++ program simulation. It is a modular and scalable system that relies on a C++ simulation library, and LoRa technology and is executed using the FLoRa framework. FLoRa is an open-source project that includes LoRa emulation modules for the physical layer, LoRa-WAN's MAC protocol, and network components such as network servers and gateways connected to the cloud internet. The European regional LoRa physical layers were utilized in the deployment area to configure parameters such as spreading factor, frequency, bandwidth, transmission power, and code rate, as outlined in Table 1. The window of the LoRa simulation screenshot displayed in Fig. 3 simulates the distribution of 117 sensor nodes across nine stations along the Tigris River. Each station has 13 sensor nodes that communicate with the LoRa gateway positioned at the center of the deployment region.

Table 1 Simulation Parameters.

Parameter	Value
Time of Simulation	1day
Number of Gateways	1
Number of Sensor nodes	117
Transmitted Power	(2-14) dBm
Carrier Frequency	868 MHz
Spreading Factor	7-12
Bandwidth (BW)	125 kHz
Code Rate	4/5

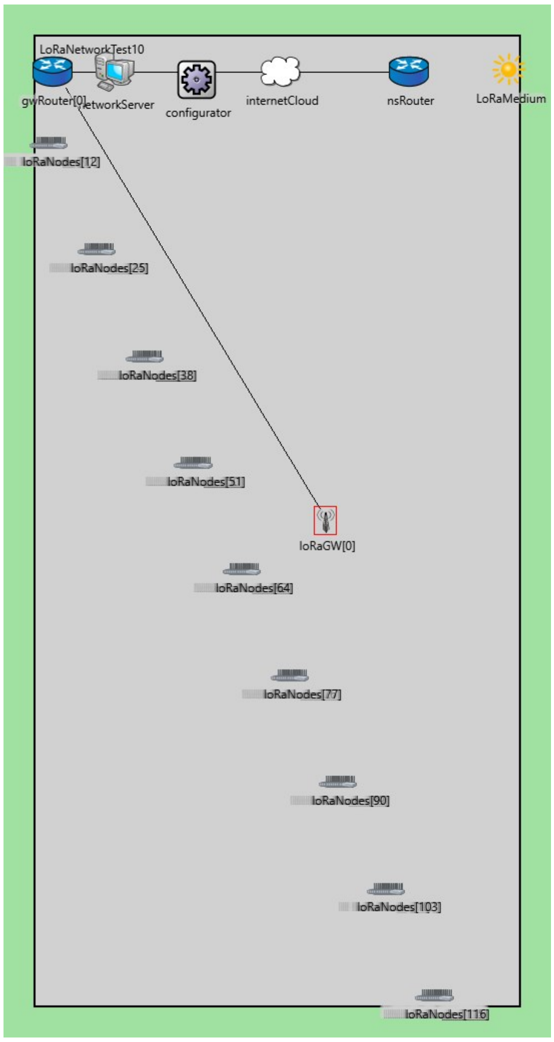

Fig. 3 The Simulation Window for LoRa in the Screenshot Shows (117) Sensor Nodes Dispersed Across the Deployment Region with Just One LoRa Gateway Communicating Across the Wireless Network to the Network Server.

Fig. 4 The Map Displays the Stations of Water in the Tigris River.

The parameters of the sensor nodes were evaluated from nine stations located near water treatment plants along the Tigris River in Mosul city, as shown in Fig. 4. The paper explores the impact of LoRa parameters (spreading factor, transmission time interval, and the distance of the sensor nodes from the gateway) on various aspects such as packets received in the network server, energy consumption of the network, packet delivery ratio, and received signal strength indicator.

4.HARDWARE PART

The primary objective of this study is to utilize sensors to measure water quality parameters and transmit the data wirelessly using LoRa technology. The transmitter component included a serial port connected to a LoRa device (type ZLAN9700) and sensors that collect data on water quality parameters like temperature, conductivity, pH, and turbidity. The receiver device gathered data through the LoRa gateway's communication link to the serial port (type ZLAN 9743), which then transmitted the data to a USB adapter via RS485 to the water quality application program on the laptop. The water quality monitoring diagram is presented in Fig.5.

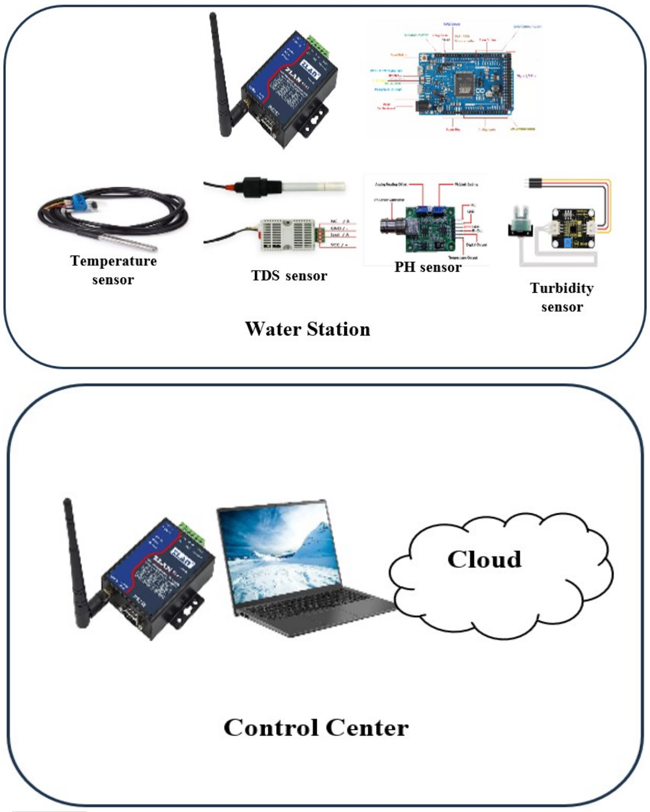

Fig. 5 Diagram of Water Quality Monitoring System.

The system consists of the following sensors:

1) **Temperature Sensor (TEMP. S)**: The DS18B20 digital thermometer is a precise sensor that communicates with the Arduino through a single-wire bus, requiring data, power, and ground connections as illustrated in Fig. 6. This sensor was utilized to track water temperature, measured in degrees Celsius (°C) with an accuracy of ±0.5°C. Monitoring water temperature is essential in evaluating the suitability of a water source for human consumption and other purposes.

Fig. 6 Temperature Sensor.

2) **Water TDS Sensor:** The total dissolved solids (TDS) sensor, as shown in Fig. 7, is a device used to measure the electrical conductivity of liquids in units of "micro Siemens per centimeter" of water (µS/cm). The TDS sensor utilized in this study is the BGT-D718-TDS, which has the following specifications. Power consumption <1W, Working Temperature (0-100) °C, Working Humidity 0-100%RH, Detection Range 0-2000ppm, Output Signal (RS485), Response Time <2S, Accuracy ≤±2% (full scale).

Fig. 7 Pin Out of TDS Sensor.

3) **pH Sensor:** The pH sensor is employed to measure the acidity and alkalinity of water. The acceptable pH range for human life is approximately 6.0-8.5. The pH sensor utilized in this study is an Analog pH Sensor Electrode, depicted in Fig. 8, with the following specifications.

4) **Turbidity Sensor**: The key studio turbidity sensor detects water quality by measuring the turbidity level. The principle involves converting the current signal into voltage output through the circuit. Turbidity was measured in Turbidity Units (NTU). The turbidity sensor utilized in this study was the KS0414 Keyestudio Turbidity Sensor V1.0, as shown in Fig. 9. Its detection range is 0%-3.5% (0-4550 NTU) with an error range of ±0.5% F*S.

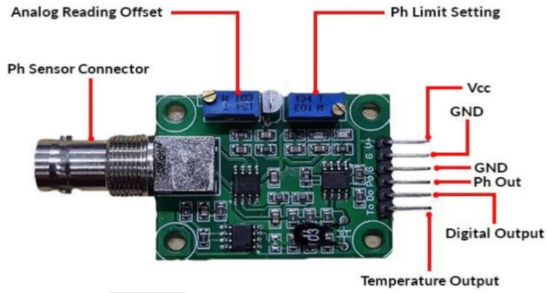

Fig. 8 Pinout of PH Sensor.

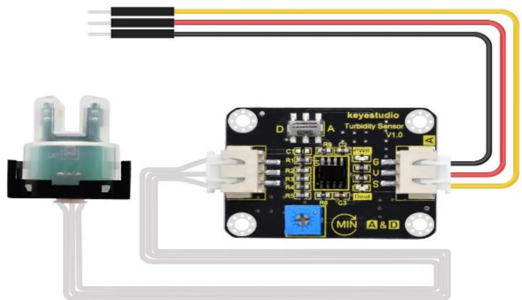

Fig. 9 Pin Out of Turbidity Sensor.

5) **Arduino Due:** The Arduino Due, depicted in Fig. 10, is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU. The Arduino Due was selected for its capability to support multiple ports, including the serial port and analog-to-digital conversion ports to connect all the sensors mentioned above. It is the first Arduino board based on a 32-bit ARM core microcontroller.

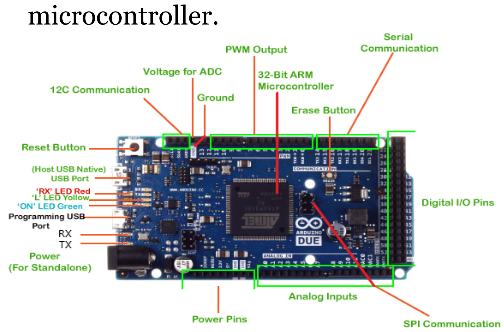

Fig. 10 Pin Out of Arduino Due.

5.SCENARIOS AND RESULTS

In this paper, three scenarios for analyzing the performance of LoRa networks were evaluated. The mechanism of Adaptive Data Rate (ADR) was enabled to control the transmission power within (2–14) dBm and the appropriate spread factor within (7–12) for each sensor node based on the distance between the LoRa gateway and each sensor node. This allows for estimating each packet's link budget, which improves the network's capacity and extends the life of each terminal device's battery.

- **First Scenario**: In this scenario, 117 sensor nodes were installed at nine water stations along the Tigris River in Mosul city, as depicted in Fig. 4. Thirteen sensor nodes were installed to measure turbidity, temperature, EC, pH, SO4, Ca, Mg, K, Cl, Na, TDS, water alkalinity, and total water hardness at each station. The stations included the new left station, the new right station, the old right station, the old left station, the left expansion station, the water liquefaction al-Zuhur station, the Danadan station, the Ghazlani station, and the Sahirun station. These measurements were used to assess the water quality of the Tigris River, with parameter values shown in Table 2.

Table 2 Parameter Values of the Sensor Nodes.

Parameters	Average	Less value	Highest value
Turbidity (unit)	22.1	2.9	312
Temperature	20.36°	18°	23°
pH	7.78	7	11.2
Electrical conductivity -EC- (μS)	451	378	586
Water alkalinity (mg/ L)	142.32	126	161
Total water hardness (mg/ L)	206.5	176	240
Ca (mg/L)	54.3	46	78
Mg (mg/L)	17.25	10.2	23.4
Cl (mg/L)	17.83	12	23
SO4 (mg/L)	62.32	39	88
Na (mg/L)	9.41	5.1	13
K (mg/L)	1.96	1.1	2.8
TDS (mg/L)	284	238	360

- **Second scenario**: In this scenario, the LoRa network was used to simulate data transmission from sensor nodes to the LoRa gateway in Nineveh Water Directorate. This allows for communication with the server across the Internet's cloud platform. The performance of the LoRa network was evaluated by analyzing the effect of SF on the packet delivery ratio (PDR). It was observed that the PDR increased from 13% to 48% when SF increased from 7 to 12 to cover all sensor nodes at the remote stations, as shown in Fig.11. Then, the distance of the sensor nodes in relation to the gateway was studied to determine its effect on the received signal strength indicator for all values of transmitting power (2-14) dBm. The RSSI decreased with increasing distance, as shown in Fig. 12.

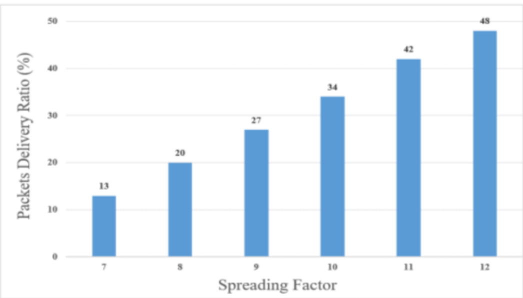

Fig. 11 PDR Values vs Spreading Factor Between (7 to 12).

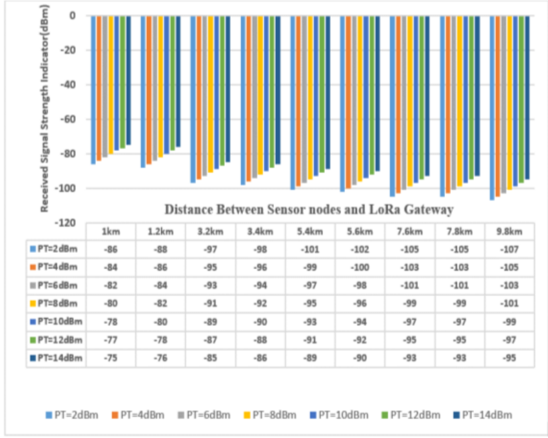

Fig. 12 The Graph Displays RSSI Values vs the Distance of the Sensor Nodes in Relation to the Gateway for Each Transmitting Power (2-14) dBm.

- **Third scenario**: In this scenario, Figures 13-16 displayed the effect of the time interval of transmitted packets on various factors (energy consumed for the network, throughput, number of received packets at the network server, number of packet collisions at the gateway) to assess the performance of the LoRa network. The performance of the LoRa network improved as the power consumption decreased from 1164 mJ to 278 mJ when the time interval of transmitted packets increased from 10 minutes to an hour in ten-minute increments, as shown in Fig. 13. However, reducing the number of sent packets due to the longer transmission time interval decreased throughput, as shown in Fig. 14, and consequently led to a decrease in the number of received packets at the network server, as seen in Fig. 15. Nevertheless, increasing the time interval of transmitted packets improved network performance by reducing the number of collisions at the LoRa gateway, as depicted in Fig. 16.

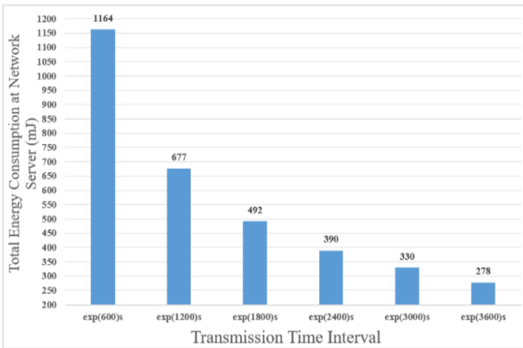

Fig. 13 NEC Values vs Transmission Time Interval.

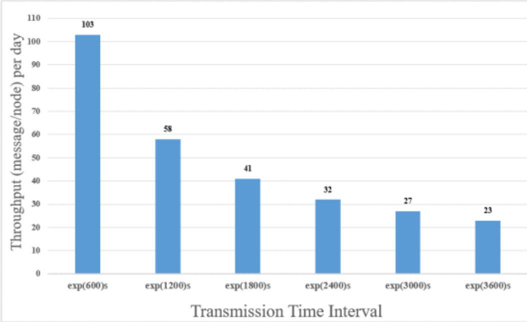

Fig. 14 Throughput Values vs Transmission Time.

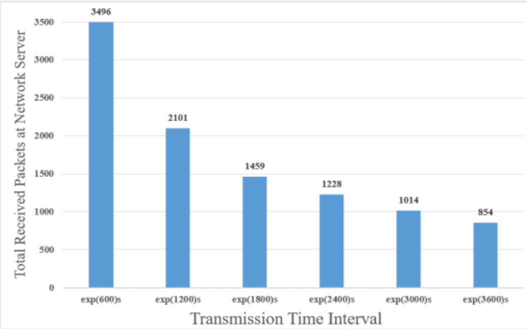

Fig. 15 Total Received Packets Values vs Transmission Time Interval.

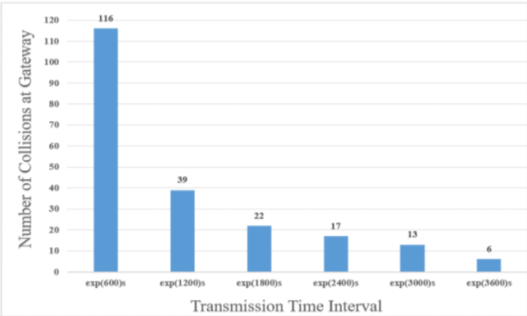

Fig. 16 Number of Collisions at the Gateway Values vs Transmission Time Interval.

6.EXPERIMENTAL WORK

This section explains the practical implementation of the adopted network that contains two water stations. Each station sends the data of the sensors to the gateway at the control center, as shown in Fig. 17. The transmitter portion in the water station was made up of a serial port to a LoRa (type ZLAN9700), and the sensors gathered data on water quality (such as turbidity, temperature, pH, electrical conductivity and dissolved solids). The recipient device in the control center gathered data using the LORA gateway to the serial port (type ZLAN 9743), which transferred the data to a USB adaptor via RS485 to the application water quality program on the laptop, see Fig. 18.

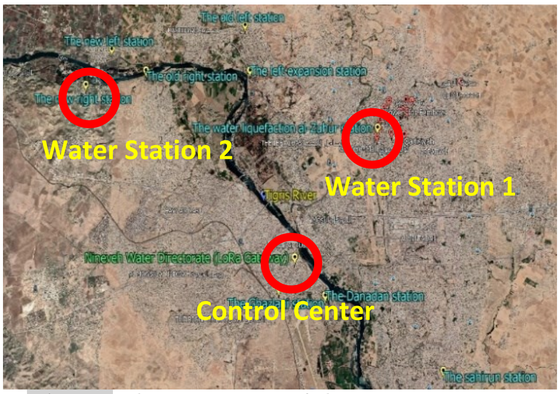

Fig. 17 The Positions of the Water Stations and the Control Center.

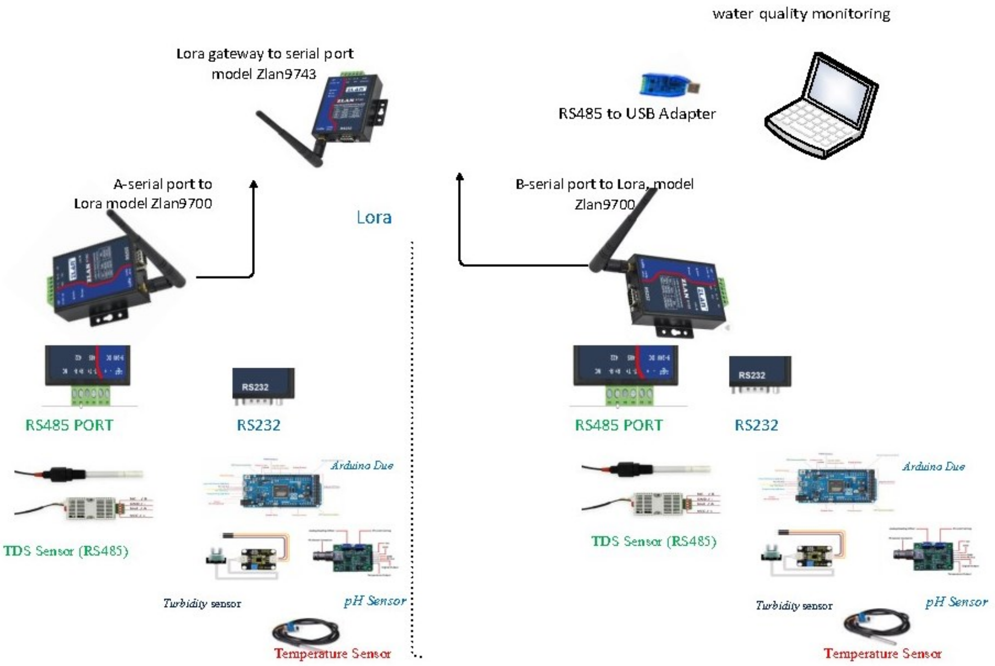

Fig. 18 Diagram of Water Quality Monitoring System.

The temperature sensor employed in this work is the DS18B20 digital thermometer. It is a high-precision sensor dealing with a single-wire bus to communicate with the Arduino, which requires data, power, and ground. The temperature sensor was used to monitor how cold or hot the water is and its measurement in degrees Celsius (°C) with a temperature accuracy of ±0.5°C. Water temperature is important in determining whether a particular source is suitable for human consumption and use. While the water total dissolved solids (TDS) sensor is a device for measuring the electrical conductivity of liquids; hence, it deals with the unit of "micro Seimens per centimeter" of water (μS/cm). The type of exploited TDS sensor was BGT-D718-TDS. A pH sensor was exploited to measure the pH, acidity, and alkalinity of water. The acceptable range of normal pH for human life was about 6.0-8.5. The type of pH sensor used in this study was an analog pH sensor electrode. Moreover, the keyestudio turbidity sensor detected water quality by measuring level of turbidity. The principle was to convert the current signal itself into the voltage output through the circuit. The Turbidity sensor used in this study type was KS0414 Keyestudio Turbidity Sensor V1.0. Its detection range was 0%-3.5% (0-4550NTU) with an error range of ±05%F*S. In this work, the sensor nodes were installed in two water stations on the Tigris River in Mosul city, as shown in Figure 10. These sensors at each station sent their information to the control center, as shown in Fig. 19. Table 3 illustrates the results of parameter values at the control center.

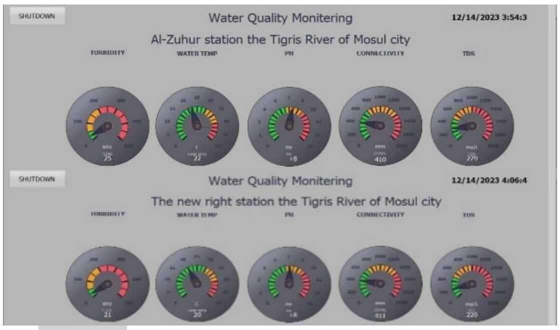

Fig. 19 The Data Received at the Control Center from Water Stations.

Table 3 The Received Data at the Control Center.

Parameters	Average	Less value	Highest value
Turbidity (unit)	22.1	2.9	312
Temperature	20.36°	18°	23°
pH	7.78	7	11.2
Electrical conductivity -EC- (μS)	451	378	586
TDS (mg/L)	284	238	360

7.CONCLUSIONS

This paper introduces an analysis and monitoring system to assess water quality in the Tigris River in Mosul city, following the World Health Organization's Water Quality Index (WQI) standards. The purpose is to evaluate the water for irrigation and agriculture at nine stations using 117 sensor nodes. The results show that turbidity and pH levels are low, while temperature, Na, Ca, Mg, EC, K, SO4, Cl, TDS, water alkalinity, and total water hardness readings are within acceptable limits set by the World Health Organization and Iraqi criteria for water quality. All sensor node readings at stations (1–9) are within permissible limits, resulting in a good rating for water quality at these stations. This paper demonstrates the successful use of LoRa technology for monitoring the water quality of the Tigris River, utilizing the OMNET++ simulation program to transmit sensor node data to the cloud via a LoRa gateway. This allows real-time monitoring and intervention to reduce the risk of river pollution. In conclusion, optimizing LoRa parameters (CR, BW, SF, PT, and FC) improves network efficiency, and the network energy consumption is reduced from 1164 mJ to 278mJ by increasing transmission time intervals for packet transmission. Additionally, optimal RSSI is achieved by positioning sensor nodes and the gateway at suitable distances, and the packet delivery ratio (PDR) increases from 13% to 48% when SF is increased from 7 to 12. The results of the experimental test prove that the sensors' transmitted data are received correctly at the control center. Moving forward, future work will focus on adding other types of sensor nodes such as oxidation-reduction sensors, ammonia nitrogen (NH3-N), water depth, chlorophyll, water color, blue-green algae, and oil-in-water ratio to further enhance the water quality of the Tigris River.

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NOMENCLATURE

ADR	Adaptive data rate
Ca	Calcium, mg/L
CL	Chloride, mg/L
CR	Code rate
FC	Carrier frequency
Flora	Framework LoRa
K	Potassium, mg/L
LoRa	Long Range.
LoRa-WAN	Long Range- Wide Area Network
MAC	Media Access Control
Mg	Magnesium, mg/L
Na	Sodium, mg/L
PDR	packet delivery ratio
pH	potential hydrogen
RSSI	Received Signal Strength Indicator
SF	Spreading factor
SO4	Sulfate, mg/L
TDS	Total Dissolved Solids, mg/L

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