Water Quality Monitoring System Based on LoRa

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Abstract. In recent years, global water pollution problems have become increasingly serious, and work to control and protect the water environment has become increasingly important. In order to achieve real-time monitoring of water quality throughout the day and in a wide range, it provides an important basis for water environment management. This paper designs and implements a water quality monitoring system based on LoRa technology. This paper includes the hardware selection and software design of end-devices and gateways, the deployment and application of open source LoRa Sever, and the design and implementation of websites based on Java Web. It realizes the user's remote access to water quality information and has certain practical value.

Introduction

With the rapid development of science and technology, and the continuous improvement of the level of social productivity, the quality of people's material life has been greatly improved, and the problem of water pollution has become increasingly serious. In order to govern and improve the ecological environment, China has also stepped up its protection of the ecosystem and raised water environmental protection to a strategic height. Water quality monitoring is the basic means of assessing water quality and provides a basic source of information for water environmental protection[1,2]. Therefore, monitoring water quality is the key to managing and improving the water environment.

As a new generation of information technology, the Internet of Things has been widely used in smart homes, smart cities, green agriculture, warehousing and logistics[3]. The application of Internet of Things technology in the field of water quality monitoring, the use of electronic sensors[4] to monitor the content of various elements in real time, can increase the scientific and accuracy of monitoring, greatly improve the monitoring efficiency and monitoring range. However, due to the limitations of equipment conditions, power consumption, and wireless communication coverage, it is difficult to monitor all aspects of water quality in real time and at all times. It can only cover part of the water environment and discharge of fixed source sewage[5], and it cannot respond to some sudden water pollution incidents in a timely manner.

The low-power wide area network technology is the best choice to make up for the short layer of the Internet of Things network layer[6]. In low-power wide area networks, LoRa technology is a fast-growing, relatively mature technology. LoRa has the characteristics of long distance, low power consumption, low cost, and standardization[7,8], and is a flexible ad hoc network. Even in many harsh conditions, where the operator's infrastructure is not fully covered[9], LoRa's market is. Therefore, the realization of the water quality monitoring system based on LoRa technology can avoid the problems caused by large power consumption and incomplete coverage of the communication network, so as to achieve real-time monitoring of water throughout the day and in a wide range.

LoRa Technology

LoRa's full name is "Long Range." It is a low-power long-distance wireless communication
technology based on spread spectrum technology\cite{10,11} and was released by Semtech in the United States in August 2013. LoRaWAN \cite{12} is a low-power wide area network specification introduced by the LoRa Alliance\cite{13}, which defines the LoRa communication specification and the structure of the network when LoRa is used as a physical layer for long-distance communication links.

Based on the excellent characteristics of LoRa itself and the active promotion of the LoRa Alliance, more and more websites or software that support LoRa technology communications have emerged. The implementation of LoRa server is roughly divided into two types. One is a third-party service platform website represented by TTN (The Things Network)\cite{14} and LORIOT\cite{15}. After the user implements the functions of the end-device and the gateway by himself, as long as he is registered on the website, his gateway can be operated through the functions provided by the website, and all modules and sensor data that access the gateway can be managed. Users of this method do not understand the logic of data processing and their participation is not high. The other is the open source method represented by LoRa Server\cite{16}. LoRa Server is an open source LoRa server sponsored by CableLabs. It provides multiple deployment methods on LoRa Server. Users can freely choose the implementation method and participate in the server setup and configuration process. And can perform custom processing and application development on the collected data. This paper is based on the method provided by LoRa Server.

**LoRa Server Network Architecture**

The network architecture of LoRa Server is shown in Figure 1. This framework is mainly composed of three components: gateway-bridge, LoRa Server, and LoRa App Server. LoRa Server is an open source LoRaWAN network server, LoRa App Server is an open source LoRaWAN application server. They are relatively independent from the gateway-bridge and rely on the MQTT broker to implement interconnection and intercommunication between components.

![Figure 1. LoRa Server architecture.](image)

MQTT (Message Queuing Telemetry Transport) is an instant messaging protocol developed by IBM. It can provide real-time and reliable message services for connecting remote devices with minimal code and limited bandwidth\cite{17}. The MQTT broker is software that implements the MQTT protocol and this system uses Mosquito as the MQTT broker.

The bridge converts the data packet sent by the gateway into a JSON (JavaScript Object Notation) data packet through the MQTT protocol, and then uploads it to the LoRa Server in the form of MQTT protocol. The LoRa Server is responsible for network communication and node access. Also packages the verification data into new JSON data packets and uploads it to LoRa App Server. The LoRa App Server is responsible for processing the network access request of the device and encrypting and decrypting the data, and provides the user with a web page for managing the end-device and the gateway, as shown in Figure 2. The application ID can be used to classify the end-devices. In the water quality monitoring field, the monitoring area and the application ID can be associated. Finally, the application can receive the water quality monitoring data collected by the sensor by subscribing to the MQTT topic.
LoRa-based Water Quality Monitoring System Structure

The overall architecture of the LoRa-based water quality monitoring system is shown in Figure 3. The whole system is mainly composed of three parts: data layer, service layer, and application layer.

In the application layer, the water quality monitoring end-device is connected to the sensor to collect data, and is sent to the gateway through the LoRaWAN protocol. The gateway is a key device in the system structure, which can alleviate conflicts caused by a large number of device data reports.

After receiving the water quality monitoring data sent by the end-device, the gateway sends the data to the gateway-bridge in the form of UDP protocol, where the data is converted from the LoRa mode to the network mode. Before each end-device joins the LoRaWAN network, node activation is required to transmit data. LoRa has two network access modes, namely ABP (Activation by Personalization) and OTAA[18] (Over-the-Air Activation). Regardless of the network access mode, both the end-device and the LoRa Server will store three parameters, namely DevAddr (device address), NwkSKey (network session key) and AppSKey (application session key). The system adopts the ABP network access mode, and writes the above three parameters into the end-device, and completes the device registration in the management webpage provided by the LoRa App Server, and the parameters can be set to be consistent.

In the service layer, water quality monitoring data is obtained from the MQTT broker through a topic subscription service for the management area. The acquired data is stored in a relational database (this system uses a MySQL database) and finally displayed on the water quality monitoring system webpage.

System Function Requirements and Database Design

System Function Requirements. The main design goals of the system are: automation and intelligence of water quality monitoring, intuitive and safe operation. To achieve the goal, the system intends to use the administrative district of Nanjing as the classification standard for water quality monitoring end-device, and the end-device of the same district is registered under the same application ID.

The main functions of the system are as follows:
1. User's role assignment and login. According to different roles, the system divides the user into
two types: ordinary users and administrators. Ordinary users can view real-time data, historical data, and alarm logs of the device; the administrator can also register, edit, and delete device information.

2. View the water quality monitoring data. The real-time water quality data information of all devices in a certain district or watershed can be classified and viewed.

3. Set the monitoring parameter threshold. Set the threshold for the parameters monitored by the device. When the monitoring data is abnormal, write this record to the alarm log for query.

**Design of Water Quality Monitoring End-device and Gateway.** Design of water quality monitoring end-device: This system selects Arduino Mega2560 and Dragino LoRa Shield to form the main body of the end-device. The sensor group mainly includes the turbidity sensor, PH sensor and temperature sensor DS18B20. These three parameters are the most common indicators in water quality monitoring. The device is battery powered and the deployment location is more flexible.

Design of gateway: The gateway consists of Raspberry Pi and Dragino LoRa Shield. Here LoRa Shield and end-device use the same LoRa module to ensure the stability of communication. The gateway does not process the data packet, but simply sends the data to the server through the socket technology.

**Database Design.** According to the results of the function requirements, the database of the system is designed. The database logical structure design relationship diagram is shown in Figure 4.

**System Implementation**

The system uses Java as the programming language, eclipse as the Java encoding tool, Apache Tomcat as the Web server, and MySQL as the user and sensor information storage database. Adopt JavaWeb, based on the mainstream framework integration of Spring+Struts+Hibernate, combined with JSP and CSS for development and design.

The user's login page is shown in Figure 5. Enter the account password and select the identity. If the verification is successful, the user can log in and enter the corresponding management page.

![User login page.](image-url)

After the verification is successful, enter the main page of the system. The left side of the main page is the menu bar. As shown in Figure 6, it is a menu bar when a ordinary user logs in, and the
sensor data can be viewed by district or watershed. The administrator’s menu bar is shown in Figure 7. In addition to querying the data, the end-device can be managed and thresholds set.

Taking the Gulou District as an example, the district data inquiry table is shown in Figure 8. Clicking on “Historical Data” will jump to the historical data table of the device, and click “Alarm Log” to view the alarm record when the monitoring data of the device is abnormal.

The device management page of Gulou District is shown in Figure 9. Click “Edit” to modify the basic information of the device.

### Conclusion

This paper mainly studies LoRa wireless communication technology, and studies the method of LoRa combined with specific fields. Finally, water quality monitoring is taken as an example. There is room for enhancement in the webpage display part of the system, but the method studied in this paper is still useful for the application of LoRa in other fields. It is believed that LoRa technology will have a broader application prospect.

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References

[1] Bartram J. Water Quality Monitoring: A Practical Guide to the Design and Implementation of Fresh Water Quality Studies and Monitoring Programs, J. Trans Faraday Soc, 66.2(1996)537-545.

[2] Dong Y X, Zhang X X, Tan Z W, et al. Key Points and Difficulties of Water Environmental Protection and Treatment of Chenghai Lake, J. Environmental Science Survey, 2017.

[3] Arasteh H, Hosseinnezhad V, Loia V, et al. Iot-based smart cities: A survey, C. IEEE, International Conference on Environment and Electrical Engineering. IEEE, 2016.

[4] Adu-Manu K S, Tapparello C, Heinzelman W, et al. Water Quality Monitoring Using Wireless Sensor Networks: Current Trends and Future Research Directions, J. Acm Transactions on Sensor Networks, 13.1(2017)4.

[5] Behmel S, Damour M, Ludwig R, et al. Water quality monitoring strategies - A review and future perspectives, J. Science of the Total Environment, 571(2016)1312-1329.

[6] Han F, Safar Z, Lin W S, et al. Energy-efficient cellular network operation via base station cooperation, C. IEEE International Conference on Communications. IEEE, (2012)4374-4378.

[7] Petajajarvi J, Mikhaylov K, Roivainen A, et al. On the coverage of LPWANs: range evaluation and channel attenuation model for LoRa technology, C. International Conference on ITS Telecommunications. IEEE, (2016)55-59.

[8] Trasviña-Moreno C A, Blasco R, Casas R, et al. A Network Performance Analysis of LoRa Modulation for LPWAN Sensor Devices, M. Ubiquitous Computing and Ambient Intelligence. Springer International Publishing, (2016)174-181.

[9] Liu S, Xia C, Zhao Z. A low-power real-time air quality monitoring system using LPWAN based on LoRa, C. IEEE International Conference on Solid-State and Integrated Circuit Technology. IEEE, (2017)379-381.

[10] Augustin A, Yi J, Clausen T, et al. A Study of LoRa: Long Range & Low Power Networks for the Internet of Things, J. Sensors, 16.9(2016)1466.

[11] Bor M, Vidler J, Roedig U. LoRa for the Internet of Things, C. International Conference on Embedded Wireless Systems and Networks. Junction Publishing, (2016)361-366.

[12] Information on Semtech, “LoRaWAN Specification v1.1”, Oct. 2017

[13] Information on https://www.lora-alliance.org/

[14] Information on https://www.thethingsnetwork.org/

[15] Information on https://www.loriot.io/

[16] Information on https://www.loraserver.io/

[17] Niruntasukrat A, Issariyapat C, Pongpaibool P, et al. Authorization mechanism for MQTT-based Internet of Things, C. IEEE International Conference on Communications Workshops. IEEE, (2016)290-295.

[18] Toussaint J, Rachkidy N E, Guitton A. Performance analysis of the on-the-air activation in LoRaWAN, C. Information Technology, Electronics and Mobile Communication Conference. IEEE, (2016)1-7.