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Design of Sensor-based Water Pollution Monitoring System

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Abstract: As a product of the development of the information age, the intelligent automatic water quality monitoring method is the main feature of wireless sensor network, which uses database and other technologies. Based on this, this paper first analyzed the overall design of the water quality monitoring system, focused on the overall structure design of the water quality monitoring system, and put forward the requirements of the water quality monitoring system. Then this paper designed the monitoring system, discussed the monitoring node design and remote monitoring, and proposed the data processing task. This paper also discussed the software design of the water quality monitoring system, starting from the analysis of the network coordinator node program, router node program, and sensor node program, and used the residual repair algorithm to strengthen the design of the water quality pollution monitoring system. After comparison, it can be seen that the data accuracy of the new water pollution monitoring system was 20.2% higher than that before prevention and control, and the monitoring perfection was 16.9% higher than that before prevention and control. After using the new water pollution monitoring system, the real-time data integrity was 0.25 higher than that of the traditional monitoring system, and the monitoring system integrity was 0.24 higher than that of the traditional system.

1. Introduction

There are still many problems with water quality testing, such as insufficient sampling capacity of water quality testing centers at all levels, low testing frequency, aging water quality laboratory testing instruments and equipment, large imbalance of analytical instruments, inability to achieve automatic testing and reporting, difficulty in real-time testing of water quality in key functional areas, etc. Wireless sensor network consists of multiple sensor nodes, which has high node density, frequent changes in network topology, limited node performance, computing power and storage capacity.

Water pollution monitoring system is widely used in water pollution. Kumar Vinod found that water quality is a major issue of human concern through investigation, because water is the most important natural resource. However, in rapidly developed countries such as India, uncontrolled growth in rural and urban areas has affected water quality [1]. Singh Nirala believed that with the reduction of the cost of renewable power and the increasing demand for converting water pollutants into benign or useful chemicals, the electro-catalytic treatment of polluted water is becoming a feasible remediation technology [2]. Obinna Isiuku Beniah investigated the water pollution of heavy metals and organic pollutants, and also reviewed the source, impact and progress of aquatic phytoremediation [3]. He Xiaodong found through research that the water quality of the Loess Plateau in China is deteriorating due to the comprehensive impact of the unique natural environment and increased human activities, and hexavalent chromium pollution is a serious water environmental problem in the loess area [4]. Li He, based on the quasi-natural experiment of the construction of the Yangtze River Economic Belt, adopted a differentiation model to test the impact of regional integration on cross-border pollution [5]. Lyu Yizheng's research found that the environmental impact of the whole system's life cycle mainly comes from the sewage treatment plant in the factory of the chemical manufacturer because the multi-stage advanced oxidation technology consumes chemicals and electricity, while the increase of human toxicity potential and marine aquatic ecotoxicity potential is mainly due to sludge incineration [6]. The above studies have described the application of water pollution, but there are still some deficiencies in the research of water pollution monitoring system.

Many scholars have analyzed and studied water pollution. Dhingra Swati believed that the Internet of Things is a global "smart device" system that can sense and connect with the surrounding environment and interact with users and other systems. Global air pollution is one of the major problems of our time. The existing monitoring system has low accuracy and sensitivity and needs laboratory analysis [7]. Kaivonen Sami introduced the experimental study of real-time air pollution monitoring using wireless sensors on public transport vehicles. He used the Internet of Things to measure the level of air pollution. By deploying low-cost wireless sensors, more fine-grained and real-time air pollution levels can be obtained at different locations [8]. Bales Elizabeth believed that people have learned a lot about the impact of air pollution on health, but it is still a challenge to provide people with information to make appropriate choices [9]. Kumar Sanjay P proposed regular monitoring of air, water, sound, soil around industries and recording the readings to cloud storage and IoT (Internet of Things) to prevent industrial pollution [10]. Nour Hamdy El Sayed used environmental pollution indicators and multifactorial statistical analysis to evaluate the potential ecological risk and pollution of surface sediments [11]. All the above studies have described water pollution, but there are still some deficiencies in the water pollution monitoring system.

This paper analyzes the risks in the design of water quality pollution monitoring system in order to understand the specific development of water quality pollution monitoring system design, and studies the construction of countermeasures for water quality pollution monitoring system design, so as to better deepen the reform of water quality pollution monitoring further. Compared with the current water quality pollution monitoring system, the use of residual repair algorithm to strengthen the water quality pollution monitoring system is more accurate and can build up a more complete pollution monitoring system.

2. Overall Design of Water Quality Monitoring System

2.1. Overall Structure Design of Water Quality Monitoring System

Since metals are non-degradable and can accumulate in the human system, they require

continuous monitoring. If the concentration of heavy metals in drinking water is increasing, it may increase the threat to human health and the environment [12]. Water quality monitoring is characterized by a large number of monitoring points, long monitoring time, and complex monitoring conditions. The design of the quality monitoring system consists of three main parts: the data acquisition part, the remote data transmission part and the monitoring center. The bottom layer of the water quality monitoring system is a network setup, node paths, and data acquisition components consisting of wireless sensor networks (including sensor nodes). The sensor nodes are distributed in the monitoring area and dynamically form a wireless network to detect water temperature and other parameters. The network coordinates the reception of data sent by the sensor nodes and the processing of the collected data. It is the center of data collection and dissemination, being in the existing design and operation of good also easy to use common set of services network installed in the remote data relay system. It can also analyze and process water quality parameters for upstream transmission, display the raw data and processing results on top of the machine interface, and notify the area where water pollution is found.

2.2. Requirements for Water Quality Monitoring System

In water quality testing, it is very difficult to collect raw data by conventional methods. Considering factors such as transmission speed and network connectivity, the water quality monitoring network must be commensurate with energy consumption and coverage for transmission to a remote central server. Sensor endpoints control the active area within range and access the network through network routing nodes. Wireless sensor networks have dynamic routing and fewer network nodes. It can reduce the processor workload by considering the node energy savings, but also can always access the water quality information of the target area through the network. The requirements of the water quality monitoring system are shown in Figure 1.

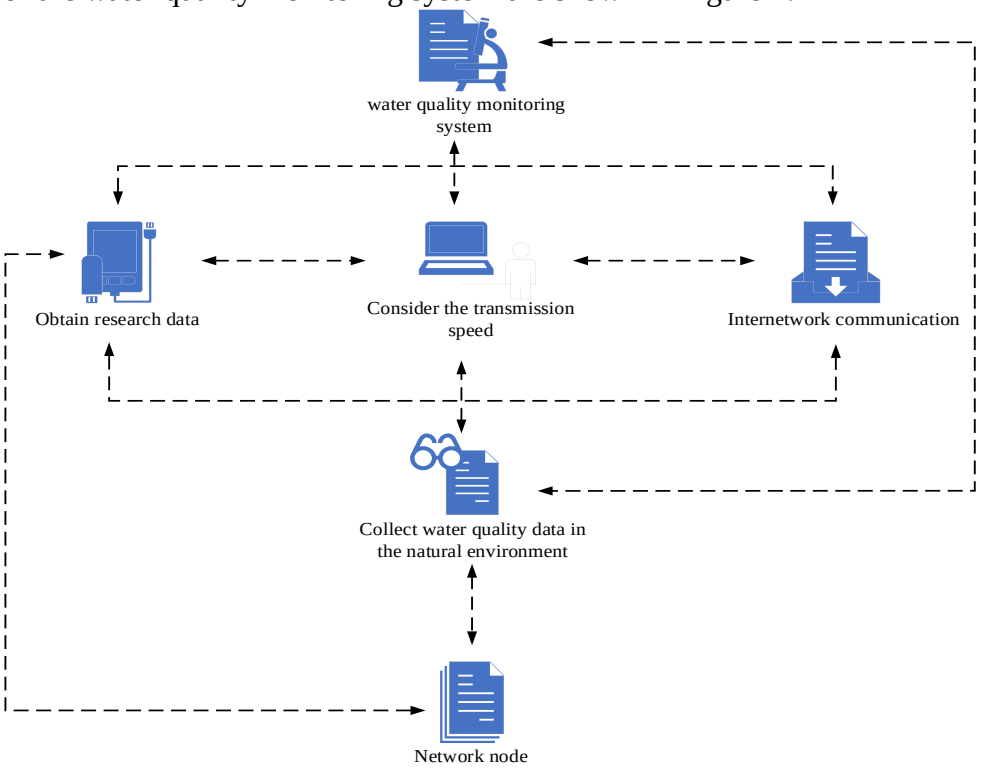


Figure 1. Requirements of the water quality monitoring system

3. Monitoring System Design

The waste discharged by humans causes a series of physical and chemical changes in the environment, as well as biological factors of water quality degradation can also affect aquatic ecosystems [13]. The water environment monitoring system includes data monitoring nodes, workstation databases, and remote monitoring centers for water resources monitoring. The monitoring network consists of a large number of data monitoring nodes. Data from the monitoring nodes are transmitted from the base station to the remote monitoring center through a common wireless cluster network to ensure water pollution and water quality monitoring other emergency alerts. It also monitors sudden changes in water quality and supports water pollution prevention and monitoring decisions [14]. Each node contains parameters such as hydrogen ion concentration index, dissolved oxygen, capturing temperature and conductivity, allowing linear and temperature compensation, packing operational data, storing the collected parameters and sending them to a database workstation.

3.1. Monitoring Node Design and Remote Monitoring

In wireless sensor networks, sensor nodes can be used as routing nodes and end nodes to store data from other nodes on the same network while collecting, receiving, processing and transmitting data. This can be used not only for monitoring and transmission, but also for interoperability with other nodes. Therefore the design of the system sensor nodes and the monitoring of the system data collection execution are central to the research and construction. The components are mainly responsible for detecting facilities in the observation area and collecting data and information. The signal processing module converts the information received by the sensors into data. The main function of the wireless communication module is to provide wireless communication, information exchange, and wireless data transmission and reception between the nodes and other sensor nodes.

3.2. Data Processing Tasks

The data processing task analyzes and processes data monitoring center commands on the data monitoring nodes that can be activated in the interrupt subroutine that is resumed in the cluster share. Wireless technology receives interrupt messages via e-mail. Data center commands can be divided into two types. One type is the database disk configuration command and the other is the data monitoring command and the host monitoring command. The main function of the monitor node control command is to create a sample channel for the monitor node, read the current null sample value and invoke the corresponding module. The data processing task must periodically send requests to support shared packet service connections, that is, if it does not need to connect to the source packet service to obtain the source packet service, it needs to disable the request from the data and stop sending requests. After one minute, the Common Package Service module can automatically switch to sleep mode. If the data processing task re-monitors the node to receive messages, the node status table needs to be updated, as shown in Figure 2.

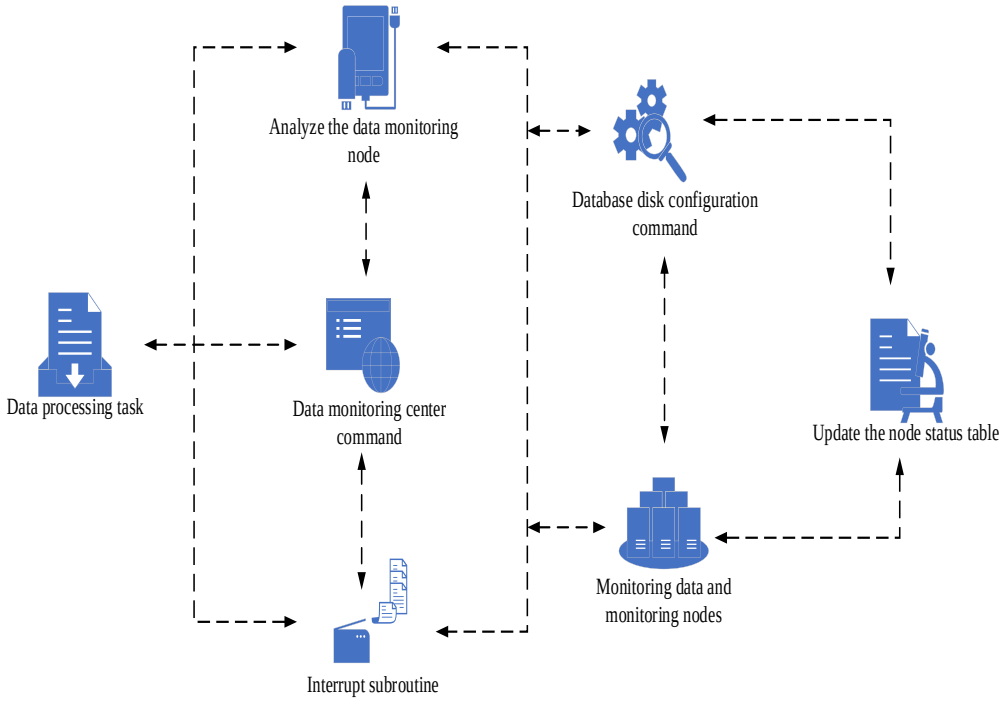


Figure 2. Data processing task

4. Water Quality Monitoring System Software Design

The software design flow of the water quality monitoring system is network coordinator node program, router node program, and sensor node program, respectively, as shown in Figure 3.

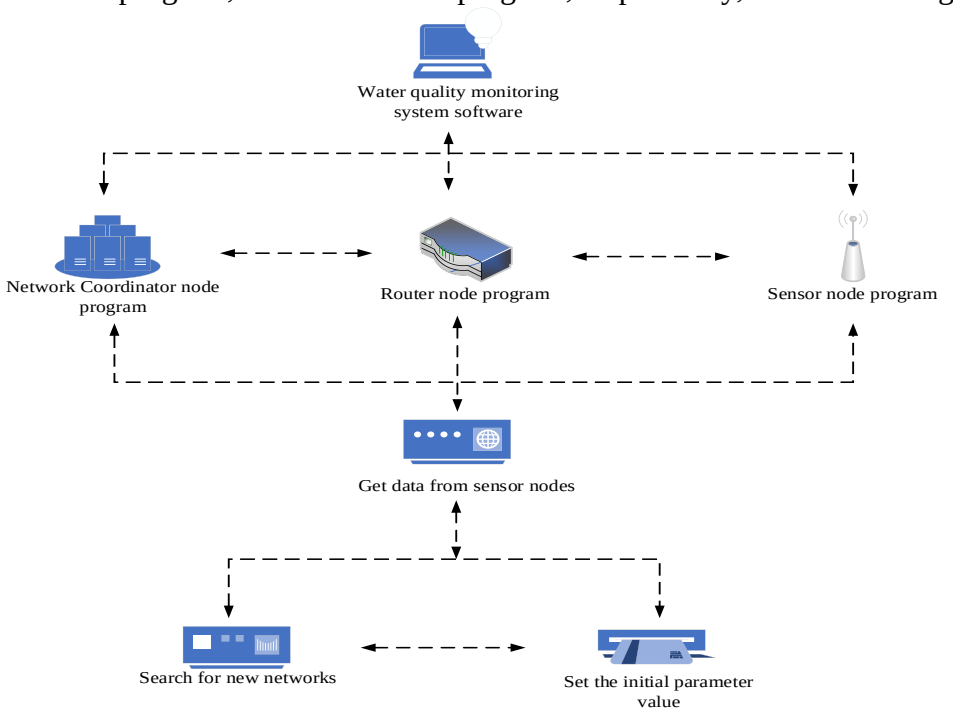


Figure 3. Software design of water quality monitoring system

4.1. Network Coordinator Node Program

The network coordinator is the first device on the network to run the entire network. Wireless sensor networks have only one network coordinator, but may have multiple routers and endpoints. The network coordinator first selects the channel and domain name, and then runs the entire network. The software of the network coordinator mainly consists of creating a new network, getting data from the sensor nodes, and sending the data to the host.

4.2. Router Node Program

Routers must have functions such as endpoint connectivity or network disconnection, assigning logical addresses at the end of the network, and creating and maintaining adjacency tables. Unlike a network coordinator, a router node cannot create a network. In this process, the router node program consists of several main parts. After initializing the router node, a network scan searches for new networks and then sends a request to the coordinator to add a network for use. It also verifies that the network connection is successful to verify that the host is connected to the network or that data is sent to the routing host, and responds in different cases.

4.3. Sensor Node Program

Wireless sensor nodes typically provide only the function of receiving and processing the data collected by the sensors and sending it to the network coordinator or routing node. Sensor nodes are not responsible for protecting the network structure, so they must wait or wake up when data collection is not needed. They can be powered using a battery containing the inductor and network communication components. The software includes sensor detection and network communication components, including data reception and transmission, sensor node initialization and setting initial parameter values, and selecting network scans and corresponding network connections.

5. Application of Residual Restoration Algorithm to Enhance Water Quality Pollution Monitoring System Design

In general, water pollution is evaluated based on relevant indicators that affect water quality and its relevance. An appropriate system of performance indicators is established according to the evaluation objectives and evaluation data are collected. The specific process of the method is:

$$(\alpha_0,\alpha_1,...,\alpha_n)=\begin{pmatrix}\alpha_0(1),\alpha_1(1),...\alpha_n(1)\\ \alpha_0(2),\alpha_1(2),...\alpha_n(2)\\ ...,...,...\\ \alpha_0(x),\alpha_1(x),...\alpha_n(x)\end{pmatrix} \tag{1}$$

The reference data column is a rationalized comparison specification, which usually consists of the optimal value of each indicator, noted as:

$$\alpha_0=(\alpha_0(1),\alpha_1(2),...\alpha_n(n)) \tag{2}$$

The number of operational links is:

$$e(\alpha'_0(\beta),x'_1(\beta))=\frac{p+\delta\cdot P}{\Delta_1(\beta)+\delta\cdot p} \tag{3}$$

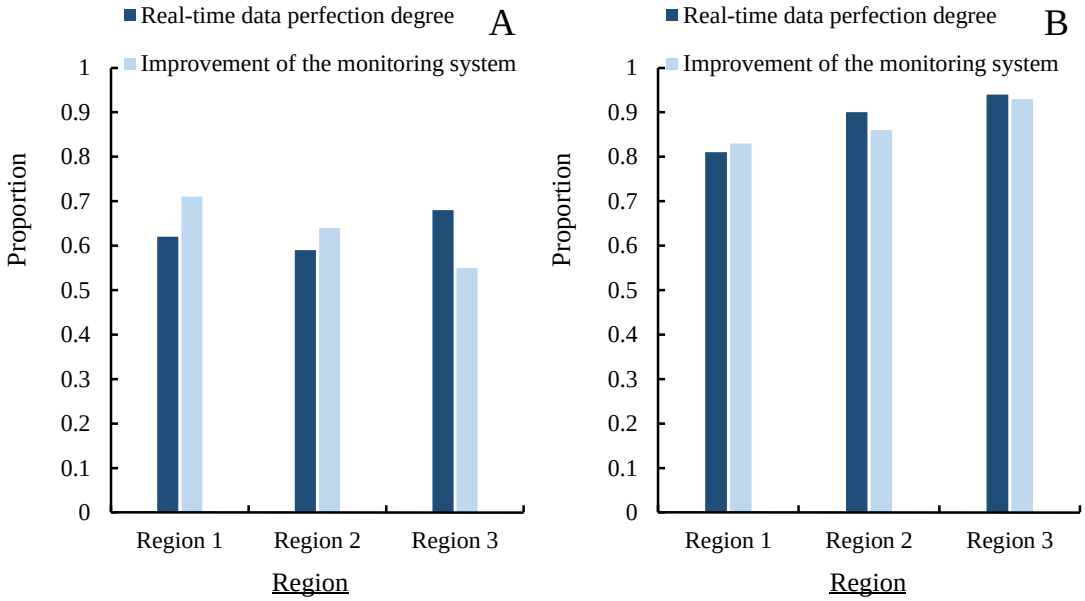
6. Residual-based Repair Algorithms and Experimental Investigations

In order to study the specific monitoring effect of water quality pollution monitoring system design, this paper analyzes the data accuracy and monitoring perfection in water quality pollution monitoring system design, constructs a new water quality pollution monitoring system using wireless sensors, and then analyzes the data accuracy and monitoring perfection of the new water quality pollution monitoring system using residual repair algorithm. First, this paper investigates the data accuracy and monitoring perfection in water pollution prevention and control in three regions, and compares with the indicators of traditional water quality pollution monitoring system, as shown in Table 1.

Table 1. Data accuracy and monitoring perfection of the traditional new water pollution monitoring system

	Data accuracy		Monitoring perfection	
	Traditional monitoring system	New monitoring system	Traditional monitoring system	New monitoring system
Region 1	68.4%	85.1%	72.6%	90.6%
Region 2	62.3%	83.6%	75.7%	91.5%
Region 3	64.5%	87.1%	71.3%	89.8%

According to the data in Table 1, it can be seen that under the traditional water quality pollution monitoring system, the data accuracy of area 1 is 68.4% and the monitoring perfection is 72.6%. The data accuracy of area 2 is 62.3%, and the monitoring degree of perfection is 75.7%. The data accuracy of area 3 is 64.5%, and the perfect monitoring degree is 71.3%. After using the new water quality pollution monitoring system, the data accuracy of area 1 is 85.1%, and the perfect monitoring degree is 90.6%. Area 2's data accuracy is 83.6%, monitoring perfect 91.5%. The data accuracy of area 3 is 87.1%, and the monitoring perfection is 89.8%. Under the traditional water quality pollution monitoring system, the average value of data accuracy is 65.1%, and the average value of monitoring perfection is 73.2%. After using the new water quality pollution monitoring system, the mean value of data accuracy is 85.3% and the mean value of monitoring perfection is 90.1%. Through comparison, it can be seen that the data accuracy after the new water quality pollution monitoring system is 20.2% higher than before the prevention and control, and the monitoring perfection is 16.9% higher than before the prevention and control. Finally, the use of residual repair algorithm to analyze the three regions in the use of traditional and new water quality pollution monitoring system after the real-time data perfection and monitoring system perfection, the specific findings are shown in Figure 4.



A. Traditional water pollution monitoring system

B. New water pollution monitoring system

Figure 4. Real-time data perfection and the monitoring system perfection of the traditional and new water pollution monitoring system

Figure 4a shows the results of the survey on the traditional water quality pollution monitoring system, and Figure 4b shows the results of the survey on the new water quality pollution monitoring system. It can be seen in Figure 4a that in the use of traditional water quality pollution monitoring system, the real-time data perfection of area 1 is 0.62, and monitoring system perfection is 0.71; area 2's real-time data perfection is 0.59, and monitoring system perfection is 0.64; area 3's real-time data perfection is 0.68, and monitoring system perfection is 0.55. It can be seen in Figure 4b after using the new water quality pollution monitoring system, the real-time data perfection degree of area 1 is 0.81, and the monitoring system perfection degree is 0.83; area 2's real-time data perfection is 0.90, and monitoring system perfection is 0.86; area 3's real-time data perfection is 0.94, monitoring system perfection is 0.93. Through the comparison can be seen, in the use of new water quality pollution monitoring system after the real-time data perfection than the traditional monitoring system before 0.25 higher, monitoring system perfection than the traditional system 0.24 higher.

7. Conclusion

The system architecture consists of a central controller and a basic monitoring system. It also consists of a local network, a bearer application and a computer. The front-end computer receives data from the base station system and sends basic commands. The base station system maintains contact with the control center. Data signals from high-quality water quality sensors, can control multiple base stations . Therefore, you can build a large wireless network, through the computer automatically monitor water quality. According to the developed wireless water quality monitoring network platform, the water quality parameters in different remote environments are connected to the central monitoring server, which can record and display in real time.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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