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Water Environments Monitoring System Based on WSN

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ABSTRACT

This paper is devoted to the explanation and illustration for our new water environment monitoring system design. The system had successfully accomplished the online auto-monitoring of the water temperature and pH value environment of an artificial lake. The system's measurement capacity ranges from 0 to 80 °C for water temperature, with an accuracy of ±0.5 °C; from 0 to 14 on pH value, with an accuracy of ±0.05 pH units. Sensors applicable to different water quality scenarios should be installed at the nodes to meet the monitoring demands for a variety of water environments and to obtain different parameters. The monitoring system thus promises broad applicability prospects.

Keywords: Water environment ;monitoring system; Sensors

INTRODUCTION

The water environment, consisting of the surface water environment and underground water environment, can be differentiated to water bodies like rivers, lakes, reservoirs, oceans, swamps, glaciers, springs, and shallow or deep underground waters. The water environment, as well as other environmental elements like soil, organism and atmosphere, etc., constitutes an organic complex. Once a change or damage to the water environment is observed in this complex, changes to other environmental elements inevitably occurs [1]. Due to the speed of China's economic development, we can also see the resulting speeding-up of contamination and damage to the water environment. In this sense, water environment monitoring, as one of the major methods for water resource management and water contamination control, is found to be more and more indispensable.

At present there are mainly four methods for monitoring water environments, each of which has its advantages and disadvantages:

1) Artificial sampling with portable water quality detecting devices and subsequent lab analysis. This method applies only to samplings on cross-sections of river and lakes with a sampling frequency ranging from several times a day to monthly.

2) Automatic and continuous monitoring of water environment parameters by an automatic monitoring system consisting of monitors & control centers, as well as several monitoring sub-stations. Data can be remotely and automatically transferred. Each station provides its real-time water environment parameters. These systems can be costly and have a great influence on the surrounding ecological environment.

3) Water environment monitoring with remote sensing technology, namely detecting the spectrum specifics of an electromagnetic wave (radiation, reflection and scattering) in a non-contacting method with respect to the water body. After the processing of the information from the collection of illustrative spectra, its physics and

chemical characteristics are to be identified. However this method can only provide a low accuracy, and it is also hard to perform real-time monitoring.

4) Water quality monitoring technology realized using some sensitivity of aquatic organisms to the presence of poisonous substances in water bodies by measuring or analyzing the change of activities of different organisms in different water environments, then coming to a qualitative evaluation report of the water quality. Basic measuring methods of this type being practiced include Fish Measuring and Beach Louse Measuring. Still, these methods can by no means be expected to reach high accuracy for water environment monitoring.

It is obvious that in a country like China, which has such an enormous water area, so diverse water bodies, so scattered spots on a water monitoring network, it will be insufficient to rely on the present numbers of monitoring stations and traditional monitoring technologies to satisfy the current monitoring needs, which emphasizes the fact that water environment monitoring must be continuous, dynamic, macro-scale, and swift; the water quality forecast must be prompt and accurate. In this sense, research and development on dynamic water environment monitoring technology, meeting the above-mentioned needs, must be conducted urgently, in order to achieve accuracy and comprehensiveness in reports of the changing situation of the water environment and finally reduce water contamination. As shown in fig.1.

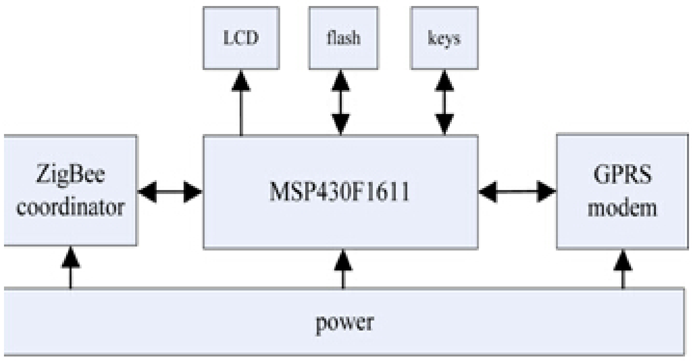

Fig.1:Power module.

Compared with the present water detecting methods, constructing a monitoring system based on the WSNs (wireless sensor networks) would present us with several advantages such as low cost, convenient monitoring arrangements, collection of a variety of parameters, high detection accuracy and high accountability of the monitoring network, etc.

A WSN (wireless sensor network) is an ad-hoc network system composed of a great number of tiny low cost and low power consumption sensing nodes which are capable of sensing, calculating and communicating data [2]. It is also an intelligent system, which automatically accomplishes all types of monitoring tasks in accordance with the changing environment. Typical real-time water environment monitoring systems of based on WSNs found abroad are systems such as EMNET (by Heliosware, USA), Fleck (by CSIRO, Australia), LakeNet (by Notre Dame University, USA) and SmartCoast, designed by researchers from Ireland. China has also been conducting research on the essential technology for real-time monitoring systems for water environments based on WSNs.

This paper studies and develops a water environment monitoring system based on a WSN, which was applied to water monitoring in an artificial lake, to realize remote and automatic on-line monitoring of both the pH and temperature of the lake water. The second part of the paper describes the comprehensive structural design of the monitoring system. The third part more specifically discusses the design of hardware and software of the data monitoring nodes. The fourth part explains the design of hardware and software of the data base station. The fifth part describes the software design for the remote monitoring center. The sixth part analyzes how this system is applied in pH monitoring in an artificial lake. The seventh part presents a summary of paper.

DESIGN OF MONITORING SYSTEM

The proposed water environment monitoring system based on a WSN is illustrated in Figure 1. It can be divided into three parts: data monitoring nodes, data base station and remote monitoring center for the water area being detected [3]. A great number of data monitoring nodes, distributed in water area to be detected, dynamically constitute a monitoring network, in which each node can only collect parameters such as pH, amount of dissolved oxygen, electrical conductivity rate and temperature, but also is capable of operating linearization and temperature compensation, data packaging, collected parameter memorizing and routing to a data base station; the data from the monitoring nodes is transferred to a remote monitoring center by the base station via a GPRS network; the monitoring center analyzes and processes the water quality parameters, gives an alarm for emergencies like water contamination, in addition any sudden changes in water quality, and provides support for decision-making in prevention and remediation of water contamination; the end-user can also realize an all-weather detection on the target water area via the Internet. The whole water environment monitoring system presents useful characteristics as large network capacity, flexible disposition, low power consumption, low cost, and minor influence on the natural environment.as shown in fig.2

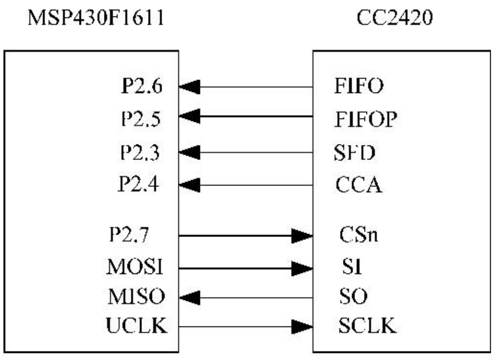

Fig.2:System hardware block

DESIGN OF HARDWARE FOR THE DATA MONITORING NODE

3.1 Design of the transmitter

The pH transmitter is a LE-438 integrated pH and temperature sensor manufactured by METTLER TOLEDO. A weak voltage signal, output by the sensor, was converted to a standard 4–20 mA signal via the pH and temperature transmitter circuit.

The transmitter circuit can be divided into two parts: the signal amplifying circuit and electrical level raising circuit. One magnifying circuit can amplify four-fold the original voltage from the pH transmitter. Since the original one is a two-way differential signal, it is still a two-way voltage signal after being amplified (–1.5 V to 1.5 V). The amplified signal should have its electrical level raised to 0–3.0 V to simplify the AD sampling of the microprocessor. Only the temperature signal should be amplified. The amplified voltage signal should convert the 0–3 V voltage signal to a standard 4–20 mA signal through V/I conversion circuit and output to an AD module in the MCU. level shall be raised can all be adjusted according to the practical needs.

3.2 Design of the Processing Module

The MCU in the processing module is the MSP430F1611, manufactured by Texas Instruments. The MSP430F1611 is a type of MCU with low power consumption, which makes it extremely suitable for the power consumption design requirement. The inside of the MSP430F1611 has integrated 2-channel and 12-digit A/D converter, which can realize the AD conversion of the 4–20 mA standard signal from the transmitter.

Figure 4 shows the node processing module, which includes the MCU module, real-time clock module, UART module, flash module, keyboards and LED module. The 4–20 mA signal, converted from the pH signal and temperature signal, will be input into the AD module integrated in the MUC to realize the AD conversion. After that, MCU will store the pH and temperature parameters according to the time sequence when they were collected. Finally, the MCU microprocessor will be communicating and organizing the network via the ZigBee module. In the meantime, the MCU microprocessor is connected separately with a real-time clock module, UART module, flash module, keyboard and LED module to realized functions such as time reading and writing, RS-232 SLIP communication, data storage and historic data reading, as well as man-machine communication.

3.3 Design of Software for the Data Monitoring Node

The development environment for the system software is IAR Embedded Workbench for MSP430, and the programming language is C [10]. The system software can be divided into two modules: the main processor program, which is responsible for processing the water environment parameters collected by the sensors, and the ZigBee wireless communication program, which is designed for receiving and sending the water environment parameters. The integration of the two modules enables the nodes to sense, collect, process and transfer the water parameters.

3.4 Design of the Master Routine
As the main controller of the whole system, the MSP430F1611's major responsibilities are initializing the system, receiving and executing the orders and memorizing the water parameters. The flow of the main programs is illustrated in Figure 7.

The operation of the main program of processor can be divided into five parts: (1) Setup the system, including initializing the clock, LED, KEY, RTC, Serial Port, ADC; setup the ZigBee module and switch off. (2) Processor goes into low-power-consumption mode and waits for the switch-off from the serial port. (3) The data input at the serial port will interrogate its breaking off and wake up the processor to resume normal working; it can also identify and operate the data at the serial port. (4) Decide whether the data received at the serial port is useful. If not, the processor shall return the low-power-consumption mode and keep on waiting for the serial port data; if useful, the processor shall decode and identify them and decide the content of the order. (5) As per the content of the order, by controlling the peripheral equipment, the processor sets up the time, measures the water parameters or uploads water quality parameters at a certain time. After the operation, the processor returns to the low power-consumption mode and waits for the data from the serial port.

3.5 Design of Hardware and Software for the Data Base Station
The hardware of the data base station uses a MSP430F1611 as the main processor to control the data base station; CC2430 is used as a co-processor to transmit monitoring data based on the ZigBee protocol between the data base station and data monitoring sub-network; a GPRS module is used to realize remote data communication between the data monitoring center and data base station; An AT45DB081D is used as the system's solid memory to store historical data, and the buttons and LCD are supplemented as a man-machine interface. The system hardware block diagram is shown in Figure 10. The software of the data base station uses μC/OS-II embedded operating system as the software platform of the MSP430F1611 to improve the real-time performance of the system; a ZigBee 2004 stack from Chengdu Wireless Dragon Information Technology Company is used as the software platform of the CC2430 module.

SYSTEM PERFORMANCE
4.1 Time Synchronization
Time synchronization is an important performance in WSNs, because it is a key factor in the process called data fusion [14]. In this system, we make the base station the master clock of a monitoring area. A monitoring area is a cluster, and the node which is nearest from the master clock in the cluster will be selected to be time synchronized with the master clock. Other nodes near with this node will choose it as their synchronization source in the monitoring area, and the remaining nodes which are far away from the master clock will choose the nearest node as their synchronization sources. This method of time synchronization is similar to NTP [15,16]. Using a 25 Kb/s radio, 16 bits can be transmitted in 1 ms, so, if there are 100 nodes in a monitoring area, the largest time-delay between two nodes will less than 0.1 s. In this monitoring system, the smallest sampling frequency is 1 minute, which is much larger than the largest time-delay, so this system will work well with this kind of time synchronization.

4.2 Data Analysis
Since the monitoring system is a low-power systems, having a long sampling period which is often more than half an hour, and the data is stored on the local node, the system doesn't have a lot of data traffic during the data sampling process. Only when the data monitoring center requests history data from the monitoring system, the nodes of the system will transmit their history data, which were stored locally to the base station, then the base station transmits all the date to the data monitoring center.

4.3 Reliability of Network Communication
In this monitoring system, we use ad-hoc multi-hop routing to support the ZigBee wireless communication [17,18]. It uses a shortest-path-first algorithm with a single destination node and active two-way link estimation. The multi-hop router is essentially transparent to us and easy to transplant into our system. With the frame check and re-send mechanisms, we could make sure that all the commands and the monitoring data will be sent to the target device successfully. To sum up, our monitoring system has good performance in the wireless communication reliability area.

CONCLUSION

A wireless sensor network was developed in the hope of tackling with the problem of the lack of a practical environment monitoring system. This monitoring system consists of three parts: data monitoring nodes, data base station and remote monitoring center. It presents us with useful features such as large monitoring ranges, flexible configuration, low power consumption, small damage to the natural environment and low cost.

This paper is devoted to the explanation and illustration for our new design of water environment monitoring system, based on a wireless sensor network. The system generally includes three parts: hardware and software of data monitoring nodes, hardware and software of the data base station, as well as software for the remote monitoring center. The system successfully performed an on line auto-monitoring of the water temperature and pH environment of an artificial lake. The system's measurement capacity ranges from 0 to 80 °C on water temperature, with an accuracy of ±0.5 °C and from 0 to 14 on pH value, with an accuracy of ±0.05. Sensors applicable to different water quality could be installed at the node to meet the monitoring demands in different water environments and to obtain different parameters. The monitoring system thus promises broad applicability.

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