Sensors & Transducers, Vol. 168, Issue 4, April 2014, pp. 150-154

www.sensorsportal.com

Sensors & Transducers

http://www.sensorsportal.com

Design of Heavy Metals Monitoring System in Water Based on WSN and GPRS

Ke Lin, Ting-Lei Huang
School of Computer Science and Engineering, Guilin University of Electronic Technology, Guilin, 541004, China
Tel.: 13768439305, fax: 0773-5602048
E-mail: linke@guet.edu.cn

Received: 8 January 2014 /Accepted: 7 March 2014 /Published: 30 April 2014

Abstract: In order to realize the real-time monitoring of heavy metals in water environment, a new type of heavy metal monitoring system was developed. The system was composed of monitoring terminal, gateway, GPRS network and upper computer monitoring center. The system detected the heavy metal ion concentrations by ion-selective electrode array and came into the system error automatic compensation method in the detection process. The collecting data was transported to the monitoring center through the cooperation between the wireless sensor network constituted by CC2530 and General Packet Radio Service network. The test result shows that the system can increased precision dramatically and strengthens the real-time transmission capacity effectively. The system is reliable in transmission, high real-time performance, flexible in networking and can be applied to continuous remote monitoring of heavy metals pollution. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Heavy metals, Water environment, System error automatic compensation, Wireless sensor network, GPRS.

1. Introduction

In recent years, the environmental pollution has become rather serious with the rapid development of economy. Emission of industrial wastewater and overexploitation of metallic minerals strengthens the heavy metal pollution in aqueous environment [1, 2]. The dissolved heavy metal ions in water enter into human body through drinking water, bio-concentration and food chain, etc. and harm to human health [3]. Ultimately the heavy metals can harm human health. Real-time monitoring of heavy metal in water environment is of great significance.

The traditional detection methods of heavy metals usually adopts manual sampling, laboratory analysis method. The detection devices on the market are usually expensive, huge volume, poor real-time and can't accurately reflect the dynamic changes of heavy metals in water environment. Thus the best period of pollution prevention is missing.

This paper presents a heavy metal monitoring system based on the wireless sensor network and General Packet Radio Service (GPRS). The system can collect the heavy metal ion concentrations accurately by the monitoring terminal, transmit the data reliably through the ZigBee ad hoc networks and GPRS network. At the same time, the monitoring center receives and processes the data, displays the real time content of heavy metals in water environment and puts forward the corresponding countermeasures. The user can issue commands to the monitoring terminals through management system.

Article number P_1972

2. The Overall Scheme of the System

The structural diagram of the system is showed in Fig. 1.

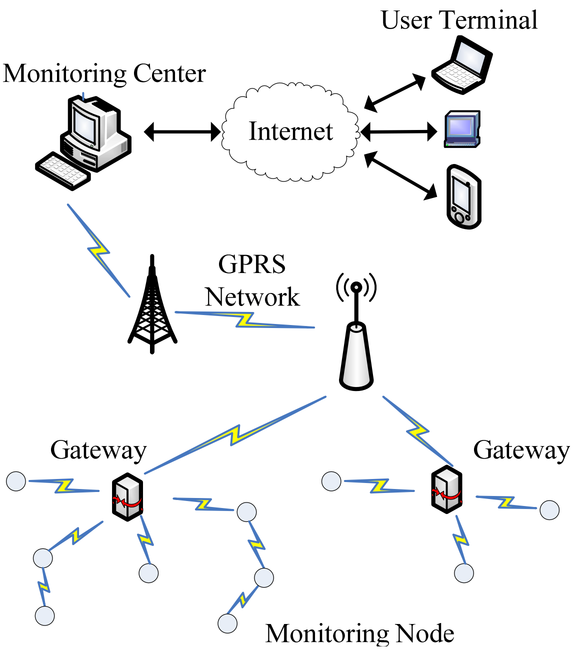

Fig. 1. Structural diagram of the system.

The system consisted of monitoring terminal, gateway, GPRS network, monitoring center, user terminal etc. Monitoring terminals were arbitrarily distributed in a monitored area and formed a self-organizing network. The monitoring terminals collected the heavy metal information in water environment and transported to gateway through ZigBee ad hoc networks. The gateway sent the information to the monitoring center through GPRS network. The monitoring center could save, analyzed and displayed the information. Users can observe the current or historical through computer and intelligent phone.

3. Hardware Design

The hardware of the system mainly includes the gateway and monitoring terminal.

3.1. Monitoring Terminal

The monitoring terminal was consisted of embedded processor, test chamber, PH electrode, heavy metal sensor array, liquid level detection module, signal processing module, pipeline control module, error compensation module, voltage management module and wireless communication module. The hardware block diagram of monitoring terminal is showed in Fig. 2.

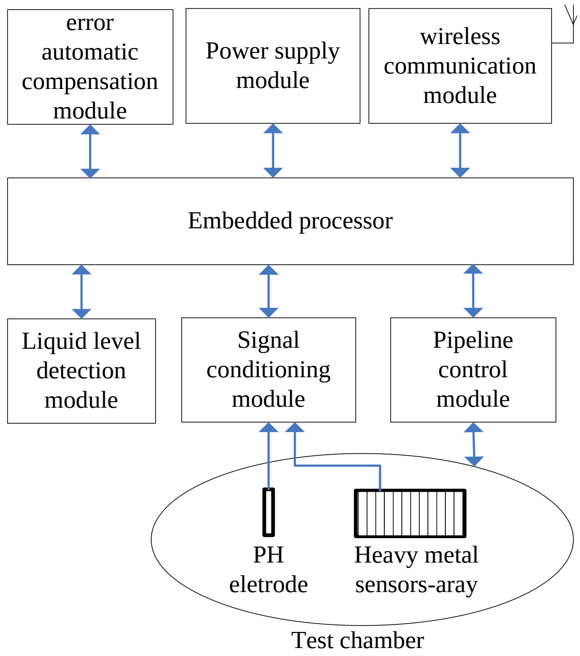

Fig. 2. Hardware block diagram of monitoring terminal.

Embedded processor is the core of monitoring terminal. It is responsible for the management of monitoring terminal, including the collection, storage, processing and transmitting the data. Meanwhile, it receives and monitoring data of other node. The embedded processor which called MCF52235 [4] is a member of the ColdFire® family of the Freescale Semiconductor. This 32-bit device is at a frequency up to 60 MHz, offering high performance and low power consumption.

Heavy Metal Sensors-array and PH electrode were in a test chamber. Pipeline control module which composed of the peristaltic pump and the electromagnetic valve was used to control the instrument pipeline. The Pipeline control module would input a different fluid to the test chamber in the detection process, empty and clean the test chamber and pipeline in the after test. Heavy metal sensors-array was composed of multiple ionic electrodes, which can simultaneous measurement of multiple heavy metals such as lead, cadmium, mercury information, copper etc. The data of heavy metal sensors-array was I/V converted, filtered, amplified through signal conditioning circuit, and then was A/D transformed by embedded processor conversion. According to the weak acid requirement of the testing water samples, the system uses PH electrode to detect water pH value, and adjust the pH value of testing samples by Pipeline control module, so as to realize the accurate measurement of heavy metal ions.

Liquid level of test samples need to be perceived in the working process. System designed of liquid level detection module with pressure sensor based on MPXV5004G. The MPXV5004G transducer is a integrated silicon pressure sensor on-chip signal conditioned, temperature compensated and calibrated. This sensor provided an accurate, high level analog output signal that is proportional to the applied pressure. The relationship was as showed in Equation 1:

$$V_{out} = V_s(0.2P + 0.2), \tag{1}$$

where V_{out} is the output voltage, V_s is the supply voltage and P is the value of pressure.

In this system, the power supply of MPXV5004 was 5 V DC. The detection accuracy can reach 1 mm and maximum error was 1.5 %.

Because of the Environmental disturbance and the zero drift of ion selective electrode drift, the error inevitably existed between testing data and the actual data. In order to eliminate the error, the error compensation module is used. The method could automatically measured system error of Monitoring terminals in each system initialization process and eliminated the error in the measuring process. Automatic error compensation module includes a programmable current source and an analog switch. In the detection process, Monitoring terminal obtained the heavy metals concentration values through the current change of working electrode in the electrode array. According to this characteristic, Monitoring terminal simulated the current change of working electrode by controlling the programmable current source and recorded the output results. The system error is obtained and saved through the comparison between the test value and the expected value.

Wireless communication module was based on a low power consumption chip which called CC2530 [5]. The CC2530 is a true system-on-chip (SoC) solution for IEEE 802.15.4, ZigBee and RF4CE applications. It enables robust network nodes to be built with very low total bill-of-material costs. The CC2530 combines the excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful features. The CC2530 has various operating modes, making it highly suited for systems where ultralow power consumption is required. Short transition times between operating modes further ensure low energy consumption.

3.2. Gateway

The gateway is responsible for communication between ZigBee network and GPRS. The gateway managed the wireless sensor network, collected, cached and transmitted the monitoring data, exchanged the information with the monitoring center data. Gateway was consisted of STM32F103 processor, CC2530 wireless transceiver module and GPRS module. The hardware block diagram of gateway is showed in Fig. 3.

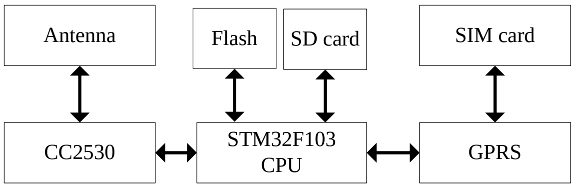

Fig. 3. Hardware block diagram of gateway.

The GPRS module which called GTM900C was produced by Huawei company. The GPRS module was a dual band 900, 1800 MHz highly integrated GSM/GPRS module and connected with the STM32F103 through the serial port.

4. Software Design

Software design of the system was divided into three parts: monitoring terminal, gateway software program and monitoring center software.

4.1. Program Design of Gateway

The gateway has coordinated networking function. The new node can flexibly join network through the gateway. The gateway could received and sent the control information from the monitoring center and the test data from monitoring terminal based on query mechanism. In the gateway, it mainly completes the following steps, which can be showed in Fig. 4:

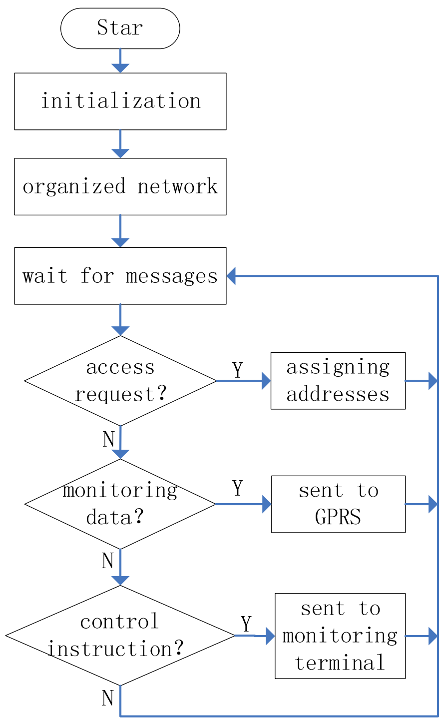

Fig. 4. Hardware block diagram of gateway.

On turn on this device, the gateway initialized hardware and protocol stack. If the initialization is finished, it constructed the network waited for messages. When data received, it was analyzed immediately and the corresponding operation is performed. If the data was access request, it would assign addresses and update the routing table. If the data was monitoring data which come from the monitoring terminals, the data would be sent to the monitoring center through GPRS module. If the data was control instruction which come from the monitoring center, the instruction would be sent to the monitoring terminal.

4.2. Design of Monitoring Terminal

The monitoring terminal software mainly included network management, data transmission, information collection and data processing.

The program flow chart of monitoring terminal was showed in Fig. 5.

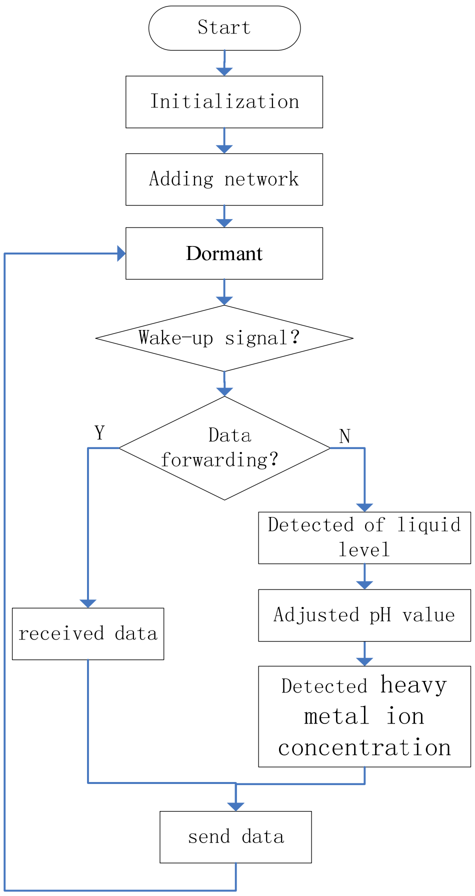

Fig. 5. Monitoring terminal program flow chart.

The monitoring terminal was initialized the processor and wireless communication module after power on. Then, monitoring terminal searched and joined the available network through scanning the available channel after the initialization. In order to reduce the energy consumption, the system generally lay dormant and was awakened by broadcast when it need to collect and transmit data. In the collection process, the pH value of the solution needs to be adjusted to the appropriate range in order to ensure the accuracy of the measurement results. After completion of testing, the sensor and the test chamber need to be washed in order to reduce the interference to the next test.

4.3. Design of the Monitoring Center

Management system of the monitoring center is completed in Visual Studio 2008 programming environment using C#. The Serial Port class is used to realize serial communication, the Thread class is used to multi thread programming and SQL Server is used to store data. The monitoring center software program is divided into user management module, data receiving module, data display module and database module. The monitoring center software can manage users, receive and process the data, display the real-time data and the historical data. At the same time, the monitoring center software with alarm function.

5. Experiment

5.1. Power Consumption Test

A multiturn cermet trimpot which called 3296 W-102 was in series in the circuit. The oscilloscope was used to view working states conversion and power change of monitoring terminal through 3296 W-102. The resistance was 10 Ohm during the working state of the terminal node and was adjusted to 500 Ohm in the dormant state. The monitoring results are as follows: Data collection continued 3 s and the current was 50 mA. The sending or receiving state continued to 20 ms and the current was about 35 mA. Wake up time was about 5 ms and the current was about 10 mA. Sleep timer running needed 0.05 mA.

The sampling period of system was 1 hour and wake-up interval of the monitoring terminal was 2 seconds. Sending and receiving data interval was 30 seconds. The power consumption in a working status was showed in Table 1.

Table 1. The power consumption of working status.

State	Current (mA)	Duration (ms)	Times	Power consum-ption (mA*ms)
Collection	50	3000	1	150000
Send or receive	35	20	120	84000
Wake-up	10	5	1800	90000
Sleep	0.05	1995	1800	179550
Total				503550

Table 1 lists the current, working time and power consumption of the different status. The total power consumption of 1 hours was 503550 mA*ms which about 0.14 mA*h. A Lithium battery with capacity of 1200 mA*h can make the nodes work 357 days. The system can meet the requirement of long time monitoring.

5.2. Performance Test

The detection accuracy of monitoring terminal was assessed by the mixed solution of lead ion, cadmium ion, mercury ion, copper ion from 10 ug/L to 50 ug/L concentration gradient under the using the system automatic error compensation method and without using it. The experimental results were shown in Fig. 6.

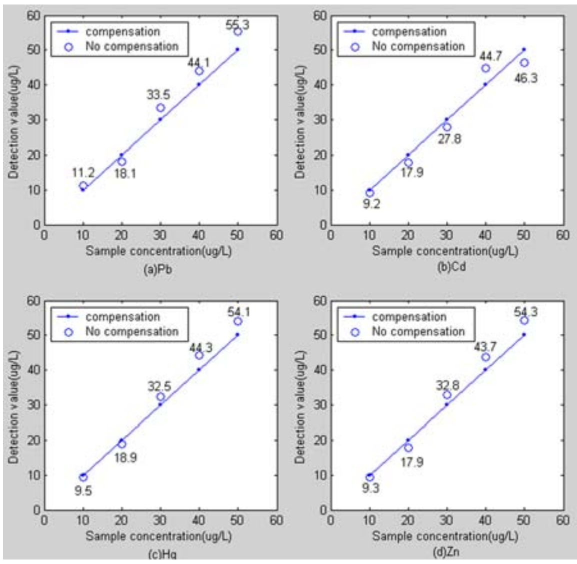

Fig. 6. Experimental results of detection accuracy.

The values of measured and sample concentration were basically equal under the using the system automatic error compensation method. While there is no automatic compensation case, there were about 10 % errors between measurement value and actual concentration of samples. The results showed that the method can eliminate the system error effectively and improve the accuracy.

6. Conclusions

The system combined the advantages of both the ZigBee and GPRS technology to solve the problems of real-time remote transmission of heavy metals detection in water environment. The system can effectively improve the detection accuracy by using the system error automatic compensation method. The experimental results show that the system realized accurately concentration collection of heavy metals in water environment and real-time data transmission. The system can be used for real-time monitoring of heavy metals in different occasions such as drinking water sources, rivers, sewage discharge.

Acknowledgements

The research work was supported by the National High Technology Research and Development Program of China (863 Program) No. 2013AA065502.

References

[1]. Geng Ya'ni, Research Progress of Heavy Metal Pollution in River, *Chinese Agricultural Science Bulletin*, 28, 11, 2012, pp. 262-265.

[2]. Sun Bo-Si, Zhao Li-Jiao, Ren Ting, Zhong Ru-Gang, Progress on Detection Methods of Heavy Metals in Water Environment, *Environmental Science & Technology*, 35, 7, 2012, pp. 157-174.

[3]. Sun Wei-Ping, Liu Xiao-Ya, Pan Jian-Ming, Weng Huan-Xin, Levels of heavy metals in commercial fish species from the near-shore of Zhejiang Province, *Journal of Zhejiang University (Science Edition)*, 39, 3, 2013, pp. 338-343.

[4]. Jiang Yinzhen, Wang Yihuai, Designing MCF52233-Based Embedded Web Server, *Computer Applications and Software*, 29, 3, 2012, pp. 52–148.

[5]. Li Jun-Bin, Hu Yong-Zhong, Design of ZigBee network based on CC2530, *Electronic Design Engineering*, 19, 16, 2011, pp. 108-111.