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A Monitoring System for Mountain Flood Geological Hazard Based on Internet of Things

HUANGFU Zhong-Min, CHEN Meng, LIU Ming-Tang, LIU Xue-Mei
School of Information Engineering, North China University of Water Resources and Electric Power, Zhengzhou 450011, China
Tel.: +8615838086608
E-mail: chenlinximeng@qq.com

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Abstract: In order to avoid the shortcomings of the poor real-time data collection and the insufficient information coverage in the traditional geological hazard disaster monitoring measures, this paper designs a monitoring system for mountain flood geological hazard based on the Internet of Things, in which the overall architecture of the system is built, and the design of hardware combined with its driver program for the remote terminal system is presented in detail. This system uses STC12C5A60S2 MCU as the core controller to handle such data as rainfall, groundwater level and displacement of the mountain which are collected by the sensors, and employs GPS module to get the location information. Then the data processed is encapsulated into TCP/IP data packs by GPRS module. Through GPRS accessing the Internet, these data packs are transmitted to the monitoring center. The experimental results show that the system has good reliability, stability and real-time in communication. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Geologic hazard, Internet of Things, Signal conditioning module, GPRS module, GPS module.

1. Introduction

China is one of the countries with the most serious geological disasters in the world. There are more than one million hazard points such as landslides, collapses and so on all over the country, and every year there will be about 100,000 new hazard points. Over the past decade, the annual geological disasters caused thousands of casualties and ten billion Yuan of economic losses, seriously affecting the sustainable development of our society and economy [1, 2]. In order to obtain disaster information timely to avoid casualties and property losses effectively, our country has taken various measures, such as establishing the monitoring and prevention system by groups of population, carrying out the inspection measure in flood season, searching for disaster points, monitoring the major disaster points and so on. However, many of these measures are still using the traditional manual methods so that the data collection and transmission are not timely and the information coverage is insufficient [3]. Therefore, we must adopt new technologies and methods for real-time monitoring of mountain flood geological hazard.

The Internet of Things is an important part of the new generation of information technology, which is defined as a network used for intelligent identification, positioning, tracking, monitoring and management to things. According to the agreed protocol, things can be connected to the Internet for information exchange and communication by information sensing devices [4]. Research on the Internet of Things technology application in geological disaster monitoring is of great significance for effective early warning of geological disasters as well as drastically minimizing people's life and property loss. To this end, this paper studies and designs a set of mountain flood geological hazard monitoring system based on the Internet of Things, which can do multi-parameter automatic online monitoring to mountain flood geological disasters.

This paper is organized as follows. Section 2 designs the overall architecture of the system. Section 3 presents the hardware design of the remote terminal system. Section 4 introduces the design of the driver. Section 5 shows the experimental results and analysis. Conclusions are given in section 6.

2. Architecture of the System

The architecture of the Internet of Things contains three main layers: sensing layer, network layer and application layer. Sensing layer includes data acquisition devices such as sensors and the sensor network established before the data is entered into the gateway; Network layer is mainly responsible for network access, network transmission and the corresponding control; Application layer solves the problem of information processing and human-machine interface [4]. According to the three layer architecture, this paper designs the overall architecture of the system as shown in Fig. 1, which consists of the monitoring center, the Internet network, GPRS/GSM network and the remote terminal system.

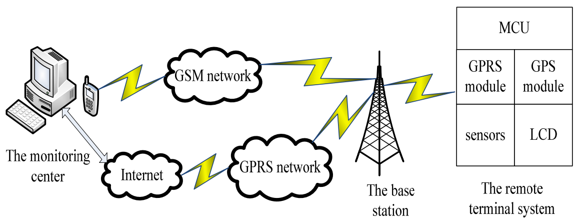

Fig. 1. The overall architecture of the system.

Because the communication mode of GPRS has many characteristics such as real-time online, billing by byte, quick login, high-speed transmission and not being restricted by terrain conditions [5], the way of data transmission is mainly through the interconnection of the Internet and GPRS network, supplemented by SMS. The remote terminal system collects the information of rainfall, groundwater level and displacement of the mountain by distributed sensors while controls GPS module to get the geographic information of monitoring points such as latitude, longitude and altitude and so on. Meanwhile, the information is displayed on the LCD screen, then packed up and sent to the monitoring center by GPRS module. The monitoring center receives and then processes the data from the remote monitoring points, as well as sends data commands to the remote terminal, for example changing the frequency of the packet transmission, the monitoring center's phone number, the early warning value of the sensors, opening the alarm and so on. When the system needs to create a new network connection, the IP address can be changed by the mobile phone with sending messages. Besides, if the network connection goes wrong, the remote terminal can send messages to the staff in the monitoring center.

3. Hardware Design of the Remote Terminal System

Throughout the system, the remote terminal system is the key of the design. The structure diagram of the remote terminal system is shown in Fig. 2. It includes the system of MCU, distributed sensors, signal conditioning module, GPRS module, GPS module and power module.

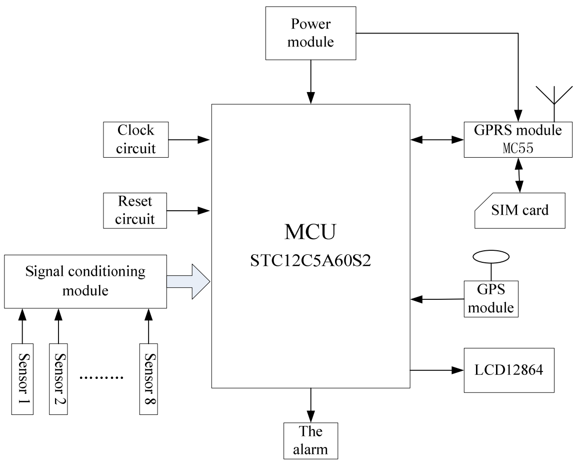

Fig. 2. The structure diagram of the remote terminal system.

3.1. Signal Conditioning Module

The output signal of the most sensors which are used in the system is 4~20 mA current signal. It must be converted to 0~5 V voltage signal which can be input the microcontroller, so this paper designs a signal conditioning module. We select a current loop receiver RCV420 as the main chip of the module. RCV420 is a precise chip produced by RURR-BROWN company in American, and can convert the 4~20 mA signal to the 0~5 V signal. It contains an advanced operational amplifier, an on-chip network with precise resistors and a precise voltage reference with 10 V. The total conversion accuracy is 0.1 %, CMR (common mode rejection) is 86 dB, ICMR (input common-mode range) is ±40 V. Within the scope of the full range the input impedance only has 1.5 V voltage drop so that the chip has a strong transformation ability for the loop current [6]. Compared with the circuit designed by discrete components, RCV420 has lower development cost, manufacturing cost and maintenance cost. So it is very suitable for implementing a weak loop current signal conversion in integrated circuits and portable devices. However, RCV420 chip requires dual power supply, and the power used in the system is only 12 V single power supply, so we choose the industrial-grade isolated power module A1212S. A1212S has small shape, stable performance and high reliability, which can convert +12 V to ±12 V power supply for RCV420 very well. Fig. 3 shows a circuit diagram of the signal conditioning module.

3.2. GPRS Module

The system selects MC55 module which is a GPRS module launched by Siemens company. MC55 module is one of the smallest tri-band modules on the market, which can complete tasks such as voice calls, data calls, network access, sending messages and faxes. MC55 has a built-in TCP/IP protocol stack, which makes the application access network easily through the control of AT commands. The stack can use TCP socket, UDP socket, FTP, HTTP, SMTP, POP3 and other services in the GPRS network [7]. According to the TCP socket service, the system connects to the circuit board by the connector with 50-pin, and then sends commands and data to the microcontroller through the serial port. The circuit diagram of the GPRS module is shown in Fig. 4, including the connection between the microcontroller and MC55, the connection between MC55 and SIM card and so on. After turning on the module, there must be a drop-down pulse and at least 100 ms delay on IGT pin of the module, or it cannot work normally.

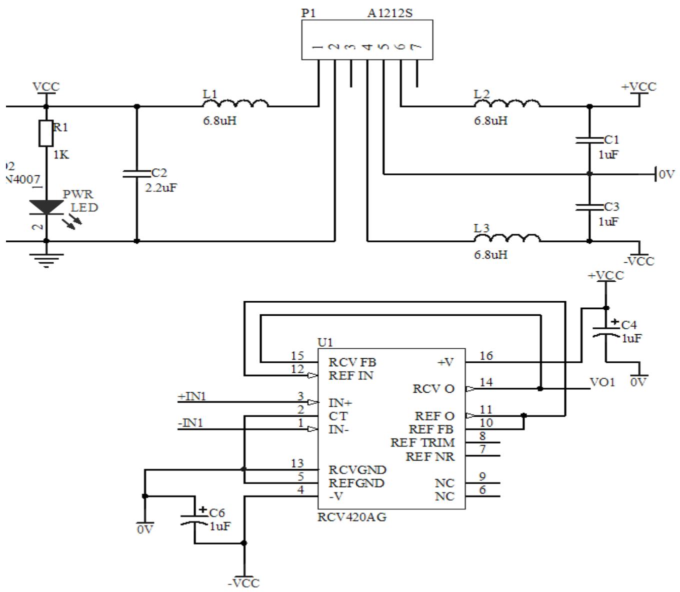

Fig. 3. The circuit diagram of the signal conditioning module.

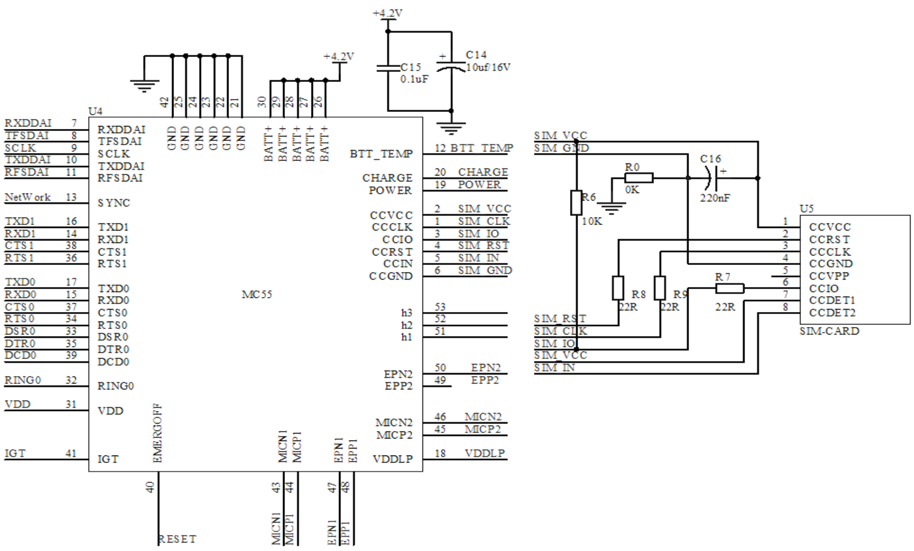

Fig. 4. The circuit diagram of the GPRS module.

3.3. GPS Module

The system uses a high-performance GPS module, of which the core uses U-BLOX's NEO-6M module. The positioning accuracy is 2.5 mCEP, the tracking sensitivity is -162 dBm, and the navigation update rate is up to 5 Hz. On the one hand, the module comes with a high-performance passive ceramic antenna so that there is no need to buy expensive active antenna. On the other hand, it comes with a rechargeable backup battery which can sustain about half an hour of receiving GPS data during the power outage. The module is connected with external systems via the serial port, and the baud rate of the serial port supports different rates such as 4800, 9600, 38400, 57600 and so on. It is compatible with the SCM system of 5 V / 3.3 V and can be connected to the outside through four pin (VCC, TXD, RXD, GND) [8].

3.4. Power Module

In order to make the whole system run stably, the design of the power is also very important. On the one hand, the microcontroller of STC12C5A60S2 is 5 V power supply and has a high-precision A/D converter which requires a reference voltage source, so the main power requires a power supply with high efficiency and low output ripple voltage. There the power supply of 5 V is designed by a switching voltage regulator LM2576 combined with a linear regulator L7805. On the other hand, because the working voltage of MC55 module is 3.3~4.8 V (The recommended value is 4.2 V), we select MIC29302 regulator chip to convert 5 V to 4.2 V. Fig. 5 is the circuit diagram of the power module.

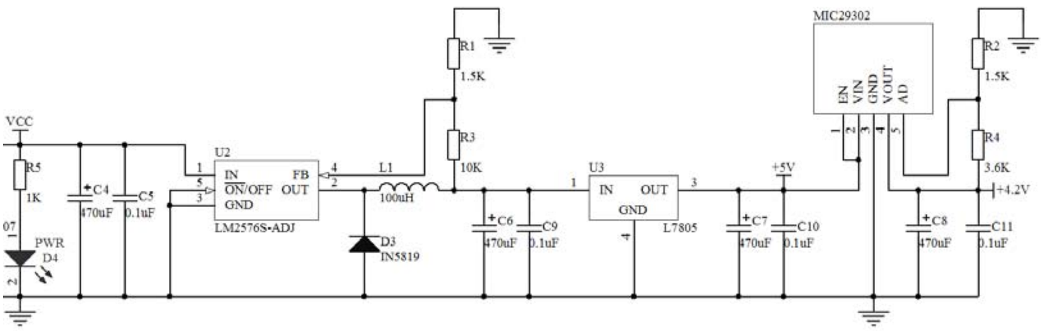

Fig. 5. The circuit diagram of the power module.

4. Design of the Driver

The hardware driver program is written by using C language based on STC microcontroller, the main program flow is shown in Fig. 6. The program of the system is designed with modular structure, the main program modules and their functions are as follows:

1) The main program module: After the system starts, the module initializes such hardware as the microcontroller, LCD module, GPS module and GPRS module. Then it tests the state of MC55 module, process and packages the data from the sensors and GPS module.

2) A/D converter module: The analog signal collected by the sensor is input into the microcontroller’s P1 port (up to 8 channels) after being processed by the signal conditioning module. Then it is converted to the corresponding digital quantity with the function of A/D conversion.

3) The setting module of the serial port: At first, the module initializes the baud rate of the serial port and the way of interruption. Then it defines the sub-function of the serial port to send and receive data.

4) LCD module: The module mainly includes the program of LCD’s driver and display, at the same time initializes the display interface of the system.

5) GPRS communication module: MC55 module is embedded with TCP/IP protocol which is used for communication by GPRS network. It shields the user from the transport layer, the network layer and the data link layer. So the user can directly make software development in the application layer, which reduces the programming complexity. The software part of MC55 module provides a set of AT commands to control the operation of a system, so the module can interpret and implement the appropriate action by receiving AT commands from the serial port, achieving the corresponding function of the wireless MODEM. According to AT commands, MC55 module will complete the task of its own initialization, network connection, short message service and so on [9]. The process of establishing a network connection is as follows [10]:

AT^SICS=0,conType,gprs0 //Select connection type GPRS0.
AT^SICS=0,user,cm //Set user name.
AT^SICS=0,passwd,gprs //Set password.
AT^SICS=0,apn,cmnet //APN to access the GPRS services provided by the CMNET.

AT^SISS=1,srvType,socket //Select service type Socket.
AT^SISS=1,conId,0 //Select connection profile 0.
AT^SISS=1,address,"socktcp:// 202.196.145.1:7010" //The service profile of the client contains the IP address and the TCP port of the remote host.
AT^SISO=1 // Open the service.

6) GPS module: The module connects with external devices by the UART mode while uses the NMEA-0183 protocol to output the positioning data, and its control protocol is the UBX protocol. NMEA - 0183 is a standard format which is formulated by the National Marine Electronics Association of American for the marine electronic equipment. And it has become a standard RTCM (Radio Technical Commission for Maritime services) protocol for GPS navigation device. The NMEA-0183 protocol uses the ASCII code (Frame format) to transmit the positioning information, whose common commands are shown in Table 1 [8]. Since the module outputs the data of $GPGGA, $GPGSA, $GPGSV, $GPRMC and so on once per second, the speed is so slow that we must apply the interrupt way to receive the data [11]. The system gets the longitude, latitude, altitude, geoid height and other information by receiving the frame statement of $GPGGA from the serial port 2. The frame format is as follows (Here is an example):
$GPGGA,023543.00,2308.28715,N,11322.09875,E, 1,06,1.49,41.6,M,-5.3,M,,*7D.

The underlined part is the data which we need to get. After being analyzed, the result is 23° 8.28715' north latitude, 113° 22.09875' east longitude, 41.6 m altitude and 5.3 m ground height.

Table 1. NMEA-0183 Common Command Table.

No.	Command	Direction	Frame length
1.	$GPGGA	GPS positioning information	72
2.	$GPGSA	Current satellite information	65
3.	$GPGSV	Visible satellite information	210
4.	$GPRMC	Recommended positioning information	70
5.	$GPVTG	Ground speed information	34
6.	$GPGLL	Geodetic coordinates information	
7.	$GPZDA	Current time information	

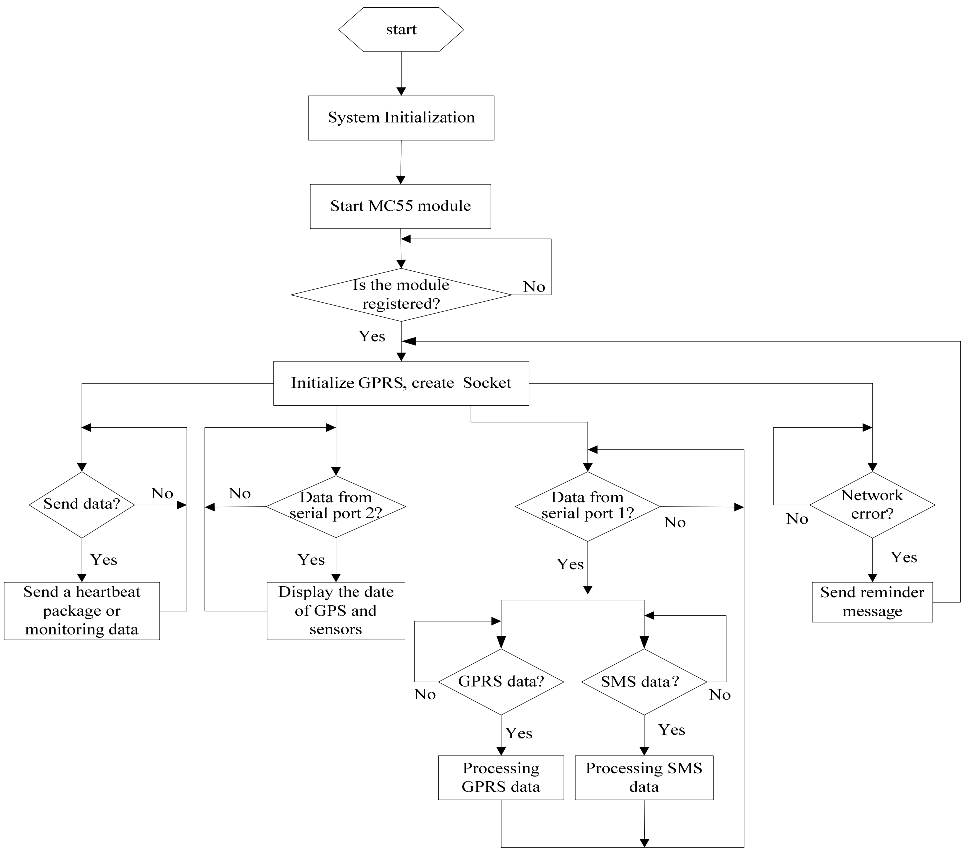

Fig. 6. The main program flow diagram.

5. Experimental Results and Analysis

During the experiment, we chose water level gauge and inclinometer to make the experiment. After connecting them with the sample machine, we could collect the corresponding voltage value to the water level, X-axis angle, Y-axis angle and the temperature through four channels. The experimental platform is shown in Fig. 7. After the terminal was connected with the monitoring center, the system started to send a heartbeat packet of "OK" at every minute to keep network online. Meanwhile, according to the set time (Default 3 minutes) the system regularly sent monitoring data to the monitoring center, including the voltage value from four channels and the GPS positioning information. The data was consistent with the data displayed on the LCD of the terminal. The data receiving interface of the monitoring center is shown in Fig. 8.

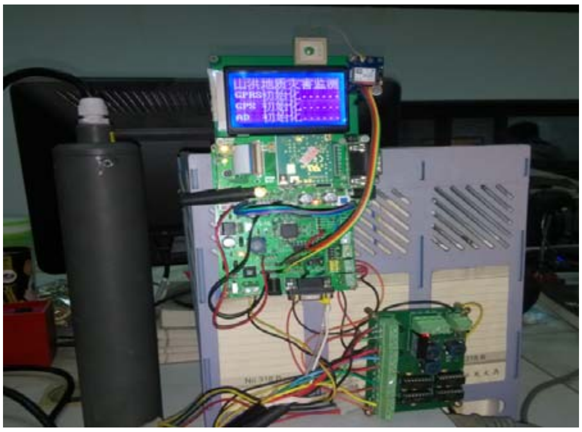

Fig. 7. The experimental platform connected with sample machine.

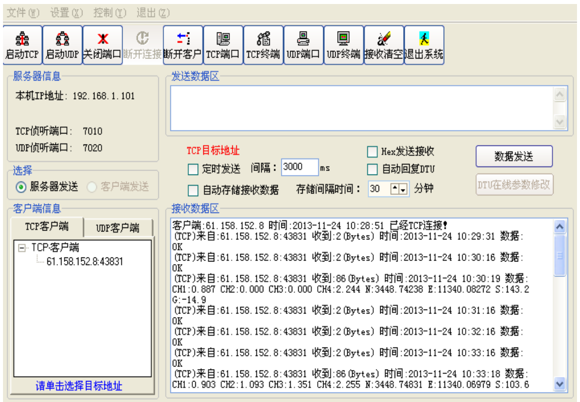

Fig. 8. The data receiving interface of the monitoring center.

In order to verify the accuracy of the data collected during the experiment, we used a high precision multimeter to measure a set of water level gauge's voltage value as the practical value, and compared them with the value displayed on the LCD screen. Data error analysis is shown in Fig. 9, it can be seen from the figure that the error is about 0.02 V, fully meeting the accuracy requirement of the system. In addition, we selected some subsets from the data received by the monitoring center, then converted the voltage value of each channel to the corresponding monitoring value for a comprehensive analysis, which is shown in Fig. 10. We can see that the value of the water level (about 0.35 m) and the temperature (about 22 °C) keep stable, which is consistent with the actual value. When the inclinometer was constantly tilted to one side, X axis angle and Y axis angle would change(max 15°) and kept the maximum figure after 15 minutes, indicating that there would be an obvious surface change. Combining with rain gauge, telescoping gauge and other sensors to make a comprehensive analysis, we can determine whether there are landslides, mudslides and other mountain flood geological disasters. After a long test, the system runs stably and transmits data normally, better achieving the intended function.

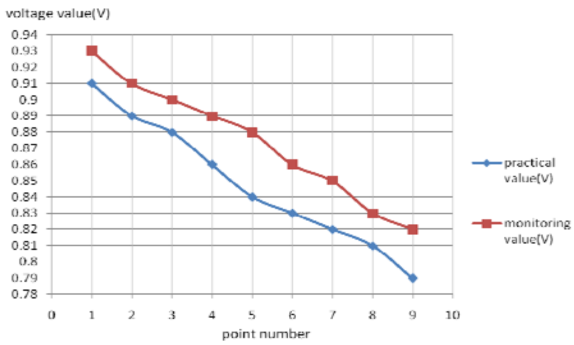

Fig. 9. Data error analysis diagram.

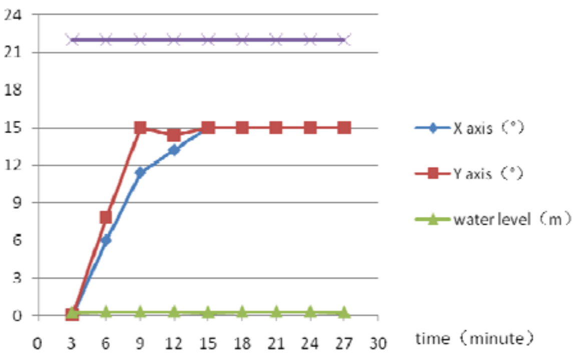

Fig. 10. Data comprehensive analysis diagram.

6. Conclusions

This system is designed for small watershed mountain flood geological disaster monitoring. The remote transmission of the data uses the way of GPRS access to the Internet, which is suitable for the areas where the monitoring sites are scattered, the environment is relatively harsh, and the manual inspection is inconvenient. Meanwhile, the communication cost is relatively low. Compared with the existing monitoring device, the system not only has a stable performance, but also can effectively guarantee the accuracy and real-time performance of the monitoring data. Besides, the system increases the sensor channels to raise some function interface, which is convenient to extend more applications. Therefore, the application of this system can also be extended to the other fields such as hydrological monitoring, environment pollution monitoring and so on. It is the next goal that we will make a research on the mountain flood geological disaster monitoring system with large-scale monitoring points. In order to achieve the purpose of disaster warning**,** we will build a wireless sensor network, combining with the multimedia technology.

Acknowledgements

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