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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (15): 3357-3362, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.3357.3362

Mountain Landslide Monitoring Based on Wireless Sensor Network

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Abstract: The study provides a design scheme for the mountain landslide monitoring System based on wireless sensor networks. Different sensors are mainly used to collect data about the water depth in the soil and the sloping angel of the hillside in real-time. After data analysis and processing by monitoring center, the warning information is provided for related departments to take effective measures rapidly to protect people's lives and properties.

Key words: Mountain landslide monitoring, wireless sensor network, sensor, gateway node, GPRS

INTRODUCTION

China is one of the countries that topography is complex and geological disasters are easy happen. In recent years, landslides is in the second place largest geological disaster only next to earthquake, landslides not only caused a certain degree of casualties and property losses, but also caused serious threat for traffic. In railway, highway, water conservancy, shipping, mining, construction and national defense we have to face the slope stability problems. Damage caused by landslides exceeds $3 billion annually in China and more than $10 billion each year worldwide, making losses attributed to landslides greater than any other natural disaster except earthquake. Potentially, much of this property damage and many of the injuries and deaths can be avoided with an operational landslide warning system.

The existing landslide monitoring technology and methods with high equipment costs, poor performance, lowly real-time seriously and vulnerable to the effects of climate change affects a wide range of layout of monitoring equipment and the monitoring results. Therefore, it has been the general trend to develop real-time the Mountain Landslide monitoring system based on the wireless information transmission mode (Sun *et al*., 2010; Liang *et al*., 2010; Deng *et al*., 2012; Chen *et al*., 2010; Mehta *et al*., 2007).

In this study, a Mountain Landslide monitoring system based on wireless sensor network is studied and analyzed (Wang and Sassa, 2003; Ohbayashi *et al*., 2008; Yu *et al*., 2008; Takayama *et al*., 2008; Rehana *et al*., 2008). It is a wireless Mountain Landslide monitoring system with IEEE 802.15.4 protocol, which consists of wireless sensor, wireless router and wireless network management. The whole system is used by full wireless mode, with each powered by battery, which significantly reduces the complexity of system installation. After testing, the system complies with the design standards.

THE MOUNTAIN LANDSLIDE MONITORING SYSTEM

Monitoring of landslides mainly depends on the liquid level sensor and the tilt sensor. It need punch holes along mountain in the earth's surface and distribute the liquid level sensor at bottom of every hole for monitoring the water depth in the soil and more tilt sensor for monitoring the sloping angel of different depth. Acquainting the water depth and angle signals, Sensor network node convert them into digital signals and transfer them to GPRS gateway and then to the monitoring center. Intelligent analysis system of the monitoring center cans determine the strength, the trend kinds of data. of the landslide and the threat of size by the two The sensor placement of the wireless monitoring system is shown as Fig. 1.

The system is mainly composed of three parts, including remote monitoring center, wireless sensor monitoring network and GPRS transmission gateway.

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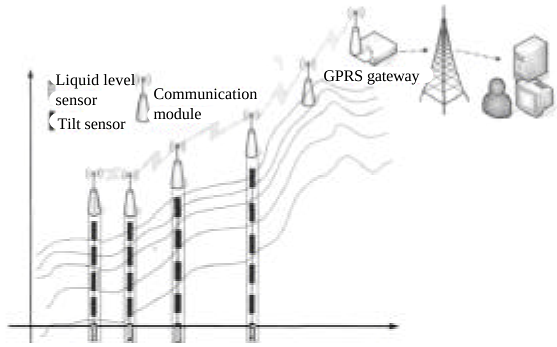

Fig. 1: Sensor placement of the wireless monitoring system

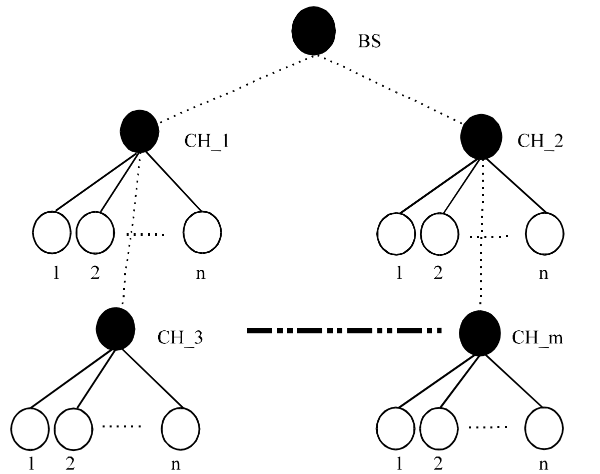

Fig. 2: Network topologic structure diagram of the system

OVERALL SCHEME OF THE SYSTEM

According to the mountain's conical shape and landslide area's Fan characteristics, the network topology of the system is shown in Fig. 3 by taking the scalability of the system into account (Zhang *et al*., 2009).

As shown in Fig. 2, the system is divided into two-level structures. According to geographic location or close degree of the network connection, the sensor node is divided into a number of regions with each known as a "cluster". Each cluster is provided with a route in the tree structure and is a sub-network as the star structure. The combined structure of this tree and star network can effectively extend the coverage of network, enhance the signal strength of network and reduce data loss, which can be used for monitoring larger region. When the region monitored is small, the communication radius of the node can be completely covered and the network structure can be simplified as the two-level star network.

There are three nodes in the whole network, i.e., the management node, cluster-head node and sensor node. The management node is responsible for the data exchange between the sensor network and the internet. The acquisition task released by the host is forwarded to the sensor network, or the data collected by the sensors is forwarded to the host, sometimes also referred to as gateway.

In the system, two gateways are designed, i.e., the conversion gateway for the sensor network to the USB and for the sensor network to the GPRS network, which are applicable to the data transmission of the short-distance and the ultra long-distance, respectively.

Cluster-head node has two functions: Managing the cluster sensor nodes and routing forwarding backbone network data. The management of cluster sensor nodes mainly includes the clock synchronization of nodes, releasing acquisition command, receiving collection data and data fusion, etc., Each sensor node is connected to a pressure measurement water level sensor to collect water level information.

The position of each node is relatively fixed, as the system will generally not be changed after installation; thus, the network structure is essentially unchanged. Corresponding network protocols can be designed based on the characteristics, which can significantly improve the transmission efficiency while have certain scalability.

Design of system nodes: According to the characteristics of the wireless sensor network and some special requirements of the bridge monitoring system, the design of node shall comply with the following: ultra-low power consumption, good moisture proof performance, low cost, safety and reliability, strong communication ability and calculation ability. Typically, various indices are related with each other and the performance of one index will be reduced, if the performance of the other is improved. Thus, considering various indicators, it is more important to choose the appropriate combination point.

Design of sink node: The circuit diagram of the sink node is shown in Fig. 3. UPG2214 is an antenna switch with its Pin 1 connected to the receiver circuit and Pin 3

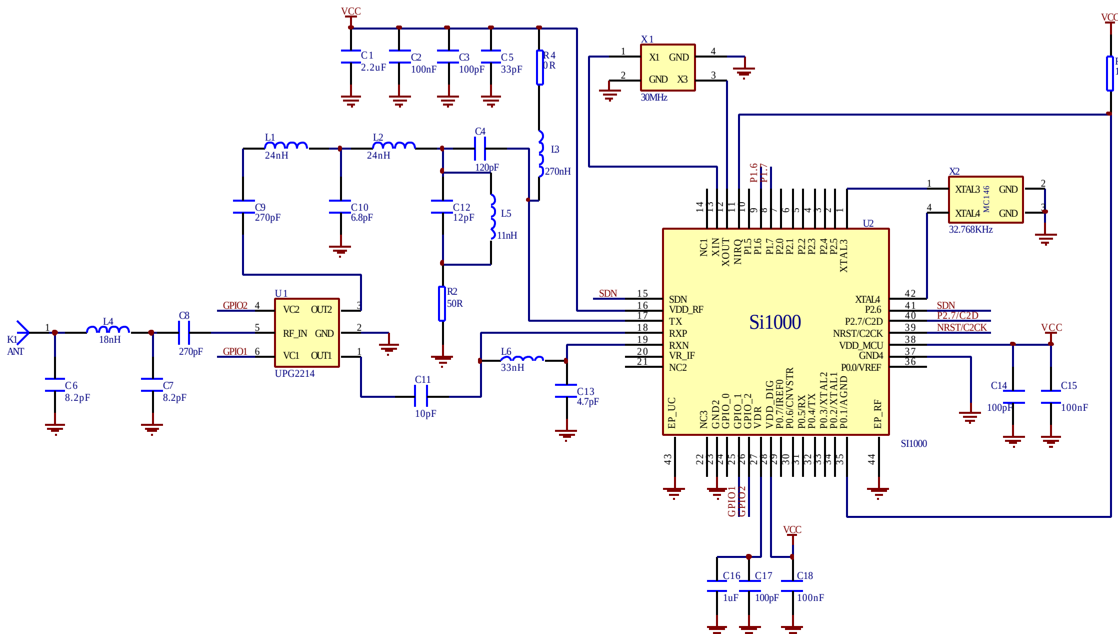

Fig. 3: The circuit diagram of the sink node

connected to the transmitter circuit. Pin 4 and Pin 6 are two input control logics of the antenna switch and connected to the corresponding output pins of Si1000. When Pin 4 is inputted high level and Pin 6 inputted low, Pin 5 is connected to Pin 1, conversely, connected to Pin 3. The benefit of using the antenna switch is that the antenna can be either used as a transmission or a receiving antenna. Thus, the volume of sensor nodes can be saved, as two antennas cannot be used at the same time. C11, C13 and L6 constitute a reception circuit and L6 is connected to two differential inputs RXP and RXN of the Si1000 by bridge connection. Because the Si1000 A low noise amplifier (LNA), the differential receiver, is adopted for Si 1000, it is better to input a differential signal between the RXP and RXN pins with the differential signal phase difference of π. C11-L6-C13 combination can provide a signal to the Si1000, the phase difference of the signal is approximately 180 degrees. In the part of RF power supply of the Si1000, C1, C2, C3 or C5 is used as a filter capacitor to reduce the ripple of the power supply. L1, C9 and L2, C10 etc. compose PA matching. The microstrip line between C6 and the antenna should achieve the impedance matching of 50 ohms. The impedance matching is one of the important indicators affecting the RF performance and can be calculated by microstrip line model calculation tool. In addition, 30MHz crystal oscillator in the circuit is used to provide a reference frequency to the RF part and 32.768 KHz crystal oscillator to the RTC (real-time clock) in the chip.

Circuit design of the sensor node: In order to avoid the analog signal from being interfered signal during long-range transmission, the sensor circuit is designed by using the front-end digitized mode, the specific circuit is shown in Fig. 4. In the graph, the 16F690 is a micro controller of Microchip's PIC16 series, which integrates 10 bit AD converter and I2C bus controller. The system selects SCA60C to measure the sloping angle of hillside that is converted by Eq. 1 and uses PTP601 to measure the water depth in the soil.

$$A = \arcsin\left(\frac{V_{out} - \text{offset}}{\text{Sensitivity}}\right) \quad (1)$$

Design of the gateway circuit: USB is used to realize the data transmission and power supply between the gateway node and the PC. But Si1000 only supports UART

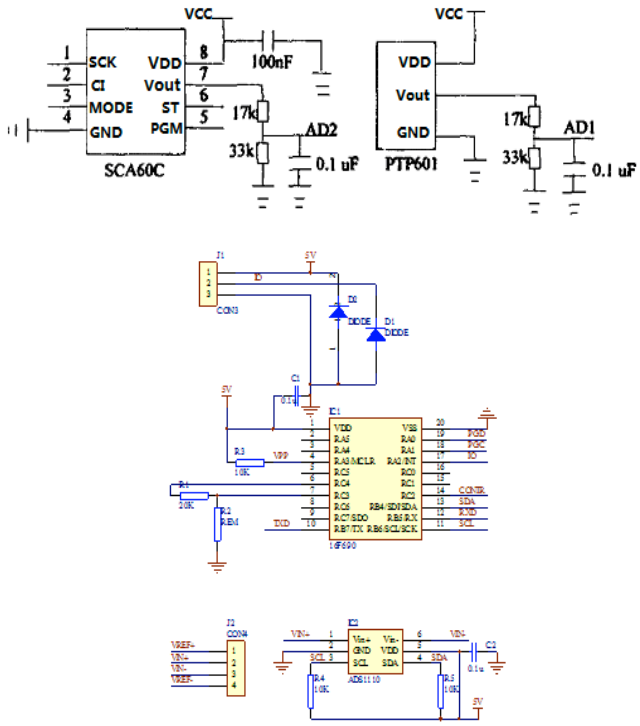

Fig. 4: The circuit of the sensor node

communication, so Microchip's PIC18F14K50 is used as data conversion intermediary. The data flows into 14K50 from the line D+ and D- of USB , After the protocol conversion of 14K50, then form the standard interface TX and RX of the UART to connect Si1000. 14K50 can be powered directly by USB.

The GPRS gateway circuit is increasing a GPRS module SIM900A on the basis of the cluster head circuit, the UART standard interface is used to communicate between Si1000 and the module, the circuit diagram of SIM900A is shown in Fig. 5.

SOFTWARE DESIGN

Two layers of nodes-the N th layer and the N +1 th layer node-are taken as the example to explain the process of software.

Detection scheme for wireless sensor nodes: The flowchart of the N th layer node is shown in Fig. 6. All nodes are in a low-power mode after being powered up and the nodes of each layer are not synchronized, so it is required to initialize the first synchronized action. The N th cluster head sends continuously the “local ID + time series” synchronous frame, using the momentary synchronization technology to synchronize the two layers of nodes to "zero".

The Sync is an unsigned char variable, which can track the growth of time. The initial value of the Sync is 0 and every RTC interrupt makes the value of the Sync to plus 1. RTC interrupt event occurs once every 5 seconds, so Sync with the value 60 means 5-minute compensation. When sending the local clock, to ensure that the N +1 th layer node can reliably receive the time correction signal, it is necessary to send the same content twice. The time information carried by the two transmission frame is identical and the time difference the physical layer needed to send two signals is 22 m sec^{-1}. Header 0×81 and 0×82 are used to help the lower nodes to distinguish the receive time correction signal which one is sent.

The flowchart of the N+1 th layer node is shown in Fig. 7. When receiving the ID header of the parent node, at momentary synchronization mechanism, the node is synchronized initially with the upper layer node at first. When receiving the 0×81 or 0×82 header node, between which the clock is proofread: the difference D-value between the local clock and the upper layer clock is saved and the reference clock received from the upper layer is write in the CAPTUREn register of the local RTC.

This layer node realizes one crystal offset compensation every 600 sec: The local clock minus D-value and is then written to the RTC register to complete proofreading.

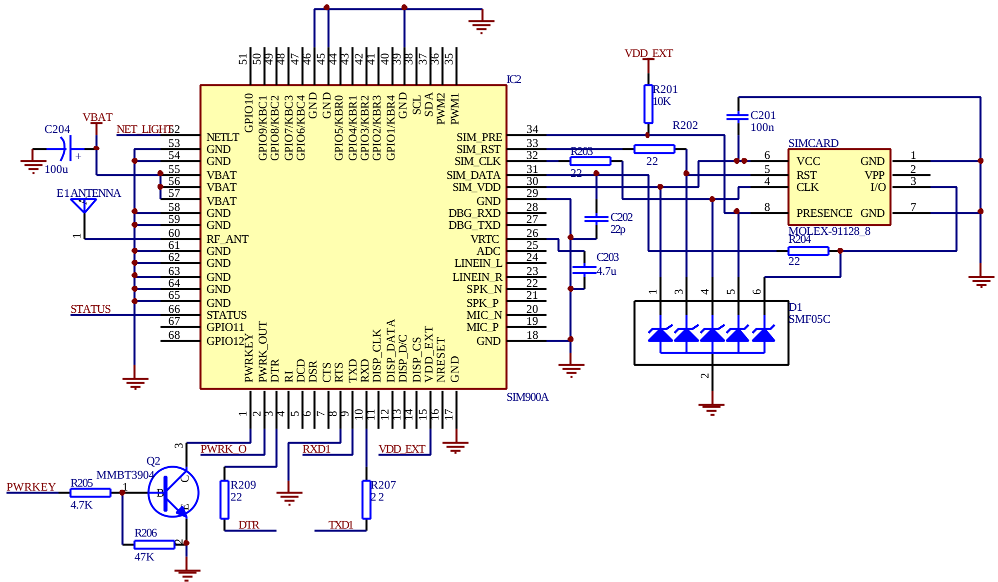

Fig. 5: The circuit diagram of SIM900A

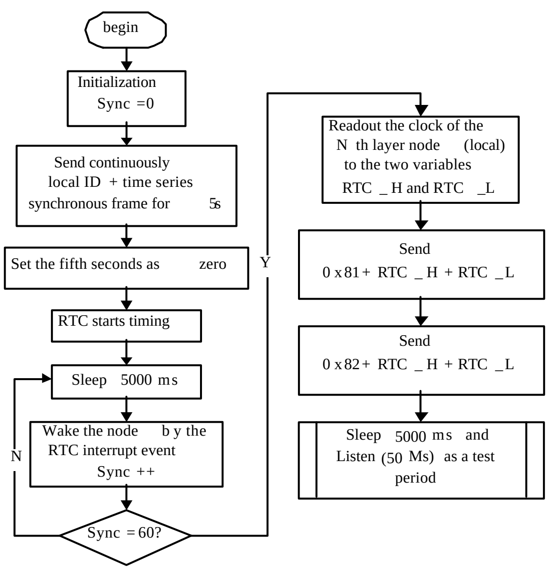

Fig. 6: Flowchart of the N th layer node

Since the listener window of the sensor node is 5 m sec^{-1}, if the same 20 ppm crystal is used, the clock check is needed in the first minute, otherwise beyond the listener window after calculating.

GPRS wireless network access program: The GPRS module can be controlled by terminal through the AT command so as to achieve the wireless network access

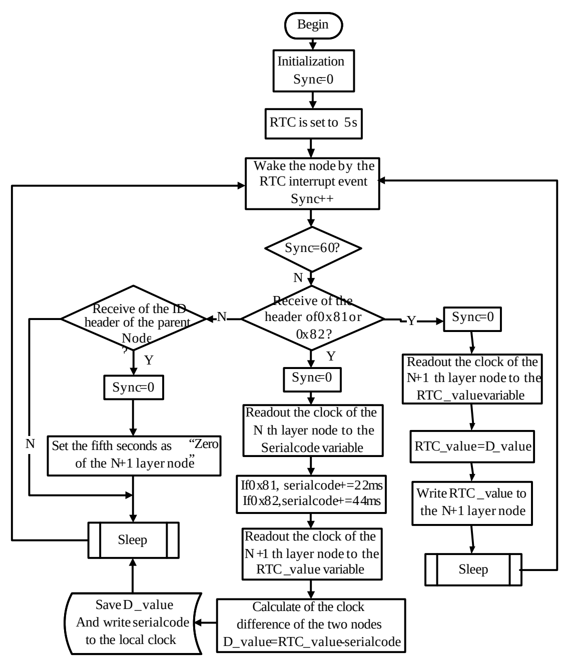

Fig. 7: Flowchart of the N+1th layer node

and the network data transmission .When the system is operated, the GPRS module should be initialized. Then it will be kept in the dial-up waiting state. The terminal will connect with the logon network through the PPP dialup. The user name and the password are of card type. After launching the Internet, it is necessary to send the information of the terminal to the monitoring center through the timing mode.

The AT command with the TCP (Transfer Control protocol) connection as well as the return values can be shown as follows:

```
AT+CCCLASS="B"
OK
AT+CCDCONT=1,"IP", "CMNET"
OK
AT+CGATT=1
OK
AT+CIPSTART="TCP", "***", "***"//The first "***"is the other side of the IP, the second "***"is the port number.
OK
AT+CIPSEND
```

GPRS wireless network communication program: General Packet Radio Service is the data packet communication network based on IP address, so this system realize connection from sensor to data acquisition center by using GPRS network, dynamic dns, Data Transfer Unit (DTU) of GPRS and ADSL network. The specific implementation process is as follows:

```
Set DTU of GPRS
Set data acquisition center
Key code to connect login data acquisition center are as follows:
Int32 i = prj-> m _ AxDataCenterX1->
StartService (PortNum)
if ( i = = 0)
{
prj-> m_ CenterPortNum = PortNum;
prj-> m _ AxDataCenterX1-> SetDataFormat (2)
LogDisplay ( " Service started successfully ! The service port number:" + PortNum)
prj-> IsDTUCenterRunning = true
} else {LogDisplay ("The service failed to start " )}
```

CONCLUSION

By using the technology of wireless sensor network and modern measurement, a network is built to detect and monitor mountain landslide. Analyzing the structure of the mountain based on the real-time data of monitoring signal can meet the demand for the real monitoring of the mountain landslide. It is important for the mountain to avoid potential safety hazards and so, it provides evidence for the management and maintenance. The practice shows that, based on the wireless sensor network technology, this monitoring system is featured by small volume, convenient installation and real-time monitoring.

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