Design of Early Warning System Based on Wireless Sensor Network

https://doi.org/10.3991/ijoe.v14i01.8060

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Abstract—In order to solve the shortcomings of the landslide monitoring technology method, a set of landslides monitoring and early warning system is designed. It can achieve real-time sensor data acquisition, remote transmission and query display. In addition, aiming at the harsh environment of landslide monitoring and the performance requirements of the monitoring system, an improved minimum hop routing protocol is proposed. It can reduce network energy consumption, enhance network robustness, and improve node layout and networking flexibility. In order to realize the remote transmission of data, GPRS wireless communication is used to transmit monitoring data. Combined with remote monitoring center, real-time data display, query, preservation and landslide warning and prediction are realized. The results show that the sensor data acquisition system is accurate, the system is stable, and the node network is flexible. Therefore, the monitoring system has a good use value.

Keywords—landslides, wireless sensor networks, minimum hop routing protocol, GPRS

1 Introduction

Geological disasters are frequently occurring in China. According to statistics, the annual economic losses caused by landslide in China is reached several billion yuan and the death toll is over thousands [1]. A total of 26580 kinds of geological disasters occurred in China. Landslide will cause debris flow and other disasters, which brings great harm to the construction of the project. Therefore, the monitoring and forecasting of landslide hazards is necessary. Through the use of scientific and reasonable monitoring and forecasting tools, we can take precautionary measures to reduce landslide disaster losses to a minimum [2]. There are many methods and means of landslide monitoring at home and abroad. However, in practical application, the monitoring result is not satisfactory. For example, close-range photogrammetry has low monitoring accuracy and is susceptible to factors such as the weather [3]. GPS monitoring method is not affected by weather, but it is expensive under the high precision monitoring requirements. Therefore, it is not suitable for large-scale promotion and use [4]. In addition, in the wild and other high-altitude environment, satellite signals are easily blocked. The TDR method is inexpensive, but it cannot determine the amount of displacement and the direction of displacement. Many of the existing monitoring methods are wired. The deployment of the system is not flexible, which is susceptible to the impact of the monitoring site geographical environment. Landslide monitoring systems for wireless sensor networks are used. However, it uses a single type of sensor, which cannot effectively collect the environmental data of the landslide monitoring area [5]. In addition, the remote data transmission is based on GSM short message mode, which seriously affects the efficiency and real-time performance of data transmission, thus affecting the overall performance of system monitoring [6].

In order to solve the problem of landslide monitoring method, real-time monitoring and warning system of landslide based on wireless sensor network is studied. Low-power acceleration sensors, temperature sensors and humidity sensors are used to measure the mountain's environmental information, which reduces the overall power consumption of the system. Cheap wireless sensor nodes are used to reduce the cost of monitoring the system. The flexibility of monitoring system deployment is enhanced. A wide range of layout and large-scale promotion of monitoring system is achieved. Remote monitoring center is connected by GPRS to realize remote real-time transmission of monitoring data. The transmission distance of monitoring data is expanded. Monitoring data analysis, processing, query and display, as well as early warning and prediction of landslides are realized.

2 State of the art

The application of wireless sensor network in landslide monitoring has become the focus of research and development in various countries [7]. Some research institutes and companies have done a lot of work in this area and have made great achievements in scientific research and products. For example, the Indian Institute of Technology designed wireless sensor distributed monitoring system for landslide monitoring [8]. The system design includes two parts. The first part is the system's fault tolerance, energy efficiency and routing protocols. The second part is the method of distributed decision-making when landslides occurred. In order to test the monitoring effect of the system, the designer simulates the pressure changes of rock samples and monitors them, so as to verify the monitoring ability of the system. The energy consumption, routing efficiency and decision effect are obtained. However, the monitoring information collected by the system is less and is not verified in practice. Its reliability in harsh monitoring environment needs to be further tested. The accuracy of monitoring and prediction of landslides is still to be proved.

Japan Ritsumeikan University developed a self-organizing network and self-healing wireless sensor network landslide monitoring system [9]. The system classifies the working modes of the nodes: initialization mode, measurement mode and emergency mode. According to the specific environmental monitoring information, the node automatically selects the working mode, realizes the timely and reliable transmission of data, and finally realizes the early warning and prediction of landslides. The acceleration sensor and soil humidity sensor are used to monitor the mountain information, and the acceleration integral is used to get the velocity, and then the integral is used to get the displacement. Due to the large error in the acceleration processing, it cannot meet the monitoring accuracy of the displacement monitoring in landslide monitoring, and affects the monitoring effect of the system.

Johns Hopkins University proposed a three-step forecast algorithm of landslide monitoring based on wireless sensor networks. First, the sensor nodes monitor the surface displacement of the mountain area to distinguish the sliding area from the rest area. Second, the sensor nodes in the sliding area locate the nodes and calculate the node displacements through the trilateration mechanism. Third, the location of the sliding surface is calculated according to the direction and position of the node displacement. Combined with the soil information (the pore pressure of the soil), the finite element model is used to predict whether the landslide and the landslide time. Simulation results show that the algorithm is very effective and achieves centimeter accuracy. However, in the actual landslide monitoring environment, the external interference is large, and the positioning accuracy is hard to be guaranteed. Therefore, the algorithm is difficult to accurately obtain landslide displacement. Its reliability and system stability need to be further proved.

The Coimbatore University in India, in cooperation with the European Commission and the Indian Space Research Organization, has developed a wireless sensor network monitoring system for landslide monitoring. The system is part of the WINSOC (wireless sensor network with self-organization capabilities for critical and emergency applications) research project [10]. Through the installation of sensor nodes to 15 meters below the surface, a variety of soil parameters were collected, such as soil moisture, vibration and displacement. Monitoring data is transmitted to Coimbatore University campus via a wireless base station. Through the background processing, warning and forecast of landslides are realized. The system places the sensor node 15 meters below the surface. It affects the reliability of wireless communication between nodes. In addition, in order to implement data communication between underground nodes and surface nodes, the node's RF transmission power is set to be larger, which reduces the life cycle of nodes and affects the overall system performance.

Foreign studies include the German SLEWS program, the United States and India's Senslide program. In China, only Wang Yan-ying and Yang Bin from Southwest Jiaotong University School of Computer Science developed a real-time monitoring system for landslides based on wireless sensor networks. The system focuses on μC / OS-II operating system migration and sensor network topology. Among them, the topology control routing algorithm for routing control is weak. It cannot be precise routing, which easily lead to node packets sent invalid and waste node energy. Routing does not take into account the remaining energy nodes, which easily lead to the death of nodes in advance, and affect the life cycle of the network. The long-distance transmission of data adopts the GSM short message mode instead of the GPRS data transmission mode, resulting in large data transmission delay, high cost and poor real-time performance, which does not meet the requirements of low cost and high real-time performance. It severely affects the overall system performance.

3 Remote monitoring center software design and system testing

3.1 The architecture of remote monitoring center

The environment information of landslide monitoring area is collected by wireless sensor network. Combined with GPRS network, remote transmission of monitoring area data is realized [11]. The sensor nodes in the monitoring area have a large number of nodes and the collected environment information is relatively complicated. The effective management of the data can effectively monitor the landslide area. The remote monitoring center first receives the sensor network data packet, and extracts the valid data and stores it in the database. At the same time, the extracted valid data is analyzed and processed. The node's sensor data curve is plotted. The topology of the network is displayed. The data query and the image display are realized. Sensor alarm threshold is set, and alarm function is implemented.

Based on the above functional analysis of the remote monitoring center and the characteristics of C #, Visual C # is used for remote monitoring center software design. Software design includes data communication module, data storage and query module, graphical display and alarm module and topology query module. Diagram of remote monitoring center is shown in Figure 1.

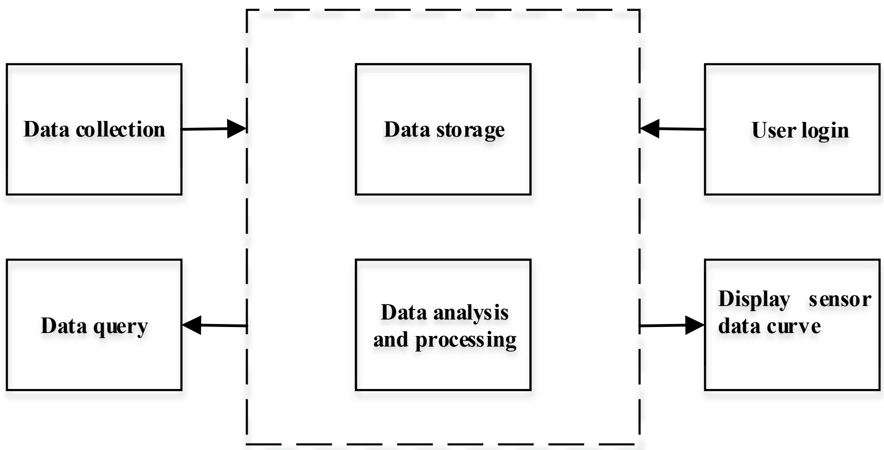

Fig. 1. Diagram of remote monitoring center

3.2 Data communication module

Visual C# 2008 provides the standard Socket (socket) control for network data communication. Socket is a API interface function of TCP/IP network. In fact, its data transfer is a kind of special I/O. Socket is divided into two types: Socket stream and datagram type Socket. Streaming Socket is a connection oriented Socket, which is mainly for connection oriented TCP service applications. Datagram Socket is a connectionless Socket, which is mainly for connectionless UDP service applications [12].

The main steps of Socket control to realize network data receiving are as follows: First, a Socket instances are established. Second, the IP and port of this instance to the machine is bound. Third, the local network port is monitored. Fourth, when the connection request is monitored, the data is received. The GPRS module uses the connection oriented TCP service to transmit data to the remote monitoring center. Therefore, when the Socket instance is bound to the IP and port of the machine, it is necessary to monitor whether data is transferred to the port. Data transmission is interrupted. In order to achieve the normal data reception, it is necessary to use the thread to judge whether there is data in the received data buffer. When there is data, the corresponding data is read immediately, so as to achieve data reception. Data receiving process is shown in Figure 2.

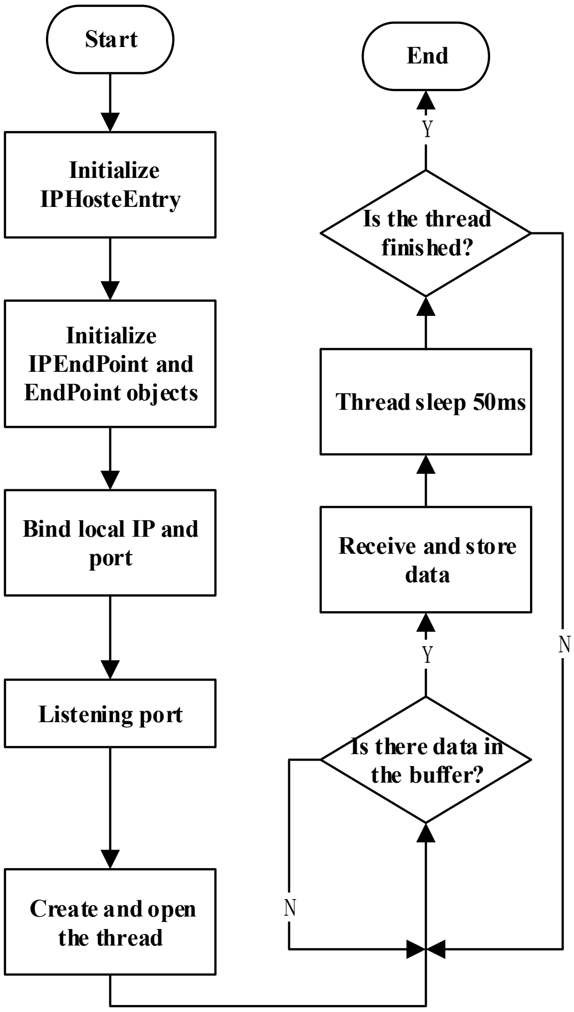

Fig. 2. Data receiving process

3.3 Topology query module

In order to check the network topology of the sensor network, the network topology must be graphically displayed. When drawing a node topology, drawing classes such as Graphics, Pen, Rectangle, and Point are mostly used. The Graphics class provides methods for drawing objects to a display device. Pen class draws the specified width and style of the line. Rectangle class draws a rectangle of the specified width and length. The Point class determines the drawing coordinate position in a blank area of the window. The process of establishing the network topology is as follows: First, the remote monitoring center receives the data frame, analyzes and extracts the routing information contained in the node, and saves and keeps with the topology table in the new database. Second, to determine whether the topology table is modified. When modified, the topology table is analyzed. Third, the network nodes of the topology structure in the display window coordinates are calculated. According to the topology table in the database, the parent-child relationship between nodes is determined. Combined with the coordinates of the node location and the drawing control in the .NET environment, a graphical display of the topology is implemented. In the meantime, in the left part of the display window, the ID numbers of the sink node, the routing node, and the terminal node are respectively displayed. Monitoring and alarm interface is shown in Figure 3.

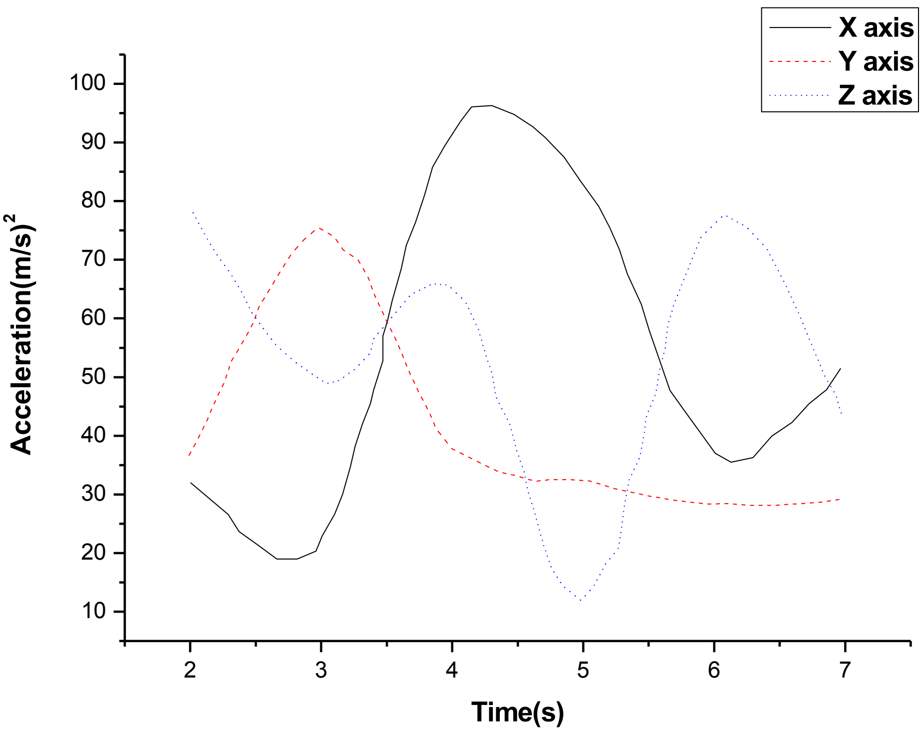

Fig. 3. Monitoring and alarm interface

4 System test

4.1 Test program

In the indoor environment, wireless sensor monitoring network is built. The following tests are mainly conducted: node wireless communication and networking test; sensor data acquisition and transmission test; node communication distance and power consumption test. The test program uses a sink node, two terminal nodes and two routing nodes. The sink node ID is 0x01. The ID numbers of the two terminal nodes are 0x11, 0x12 and 0x13, respectively. The ID numbers of the two routing nodes are 0x21 and 0x22, respectively.

Node wireless communication and networking test: Sensor network nodes are used in landslide monitoring. The effective communication distance between nodes is very important for the networking of nodes and the transmission of network data. Therefore, firstly, the effective communication distance of the node is tested, and then the node's networking function is tested. In order to reduce the impact of the external environment on the wireless communication performance of the node, when the weather is sunny, the effective communication distance of nodes is tested in the school playground which is relatively open. When testing, a rod antenna is used. Receiver sensitivity is -94d Bm. Transmit power is set to 0d Bm (1mw). Data packet loss rate should be less than 2%. In order to test the networking function of the sensor network node, the sensor network node is arranged on the playground. During the test, the terminal node and the routing node send query packet frames and data frames. When starting the test, the terminal node and the routing node are opened first, then the sink node is opened, and the network is established. The network building function of the node is tested. In order to test the network access and off-grid function of the node, after the networking is completed, an end node with a node ID of 0x11 is added to the network. Through the program settings, after the node 0x11 enters the network successfully for a period of time, it actively sends off-line requests to leave the network to test the network access and off-grid functions of the nodes.

Sensor data acquisition and transmission test: Terminal nodes are placed in the indoor environment. Indoor temperature and humidity are collected. Due to the limitations of the experimental conditions, in order to collect acceleration values, the sensor nodes with acceleration sensors were placed on the inclined plane of the building. Vibration signal of slope is continuously collected. During the test, the terminal node 1s collects and sends data once (it can be set by software). Through the established node routing and GPRS network, the sensor data is transmitted to the remote monitoring center. The remote monitoring center classifies the received data according to the type of data and separately stores different tables of acceleration, temperature and humidity values to the database. Through the data query window and graphical display and alarm window, the sensor data are queried separately.

Sensor network node power consumption test: Through the DC power supply for the sink node, routing nodes and terminal nodes, 3.3V DC voltage is provided. When the sink node, the routing node and the terminal node work normally, the power consumption of each node is calculated by measuring the output current of the DC stabilized power supply.

4.2 Test results

The test environment is the school playground. The experimental data of point effective transmission distance is shown in Table 1.

Table 1. The experimental data of point effective transmission distance

Test distance	Transmit power	Packet length	The number of packets	Packet loss rate
10m	0dBm	10Bytes	1000	0%
20m	0dBm	10Bytes	1000	0%
30m	0dBm	10Bytes	1000	0.1%
40m	0dBm	10Bytes	1000	0.15%
50m	0dBm	10Bytes	1000	0.32%
60m	0dBm	10Bytes	1000	0.56%
70m	0dBm	10Bytes	1000	0.97%
80m	0dBm	10Bytes	1000	1.42%
90m	0dBm	10Bytes	1000	10.87%
100m	0dBm	10Bytes	1000	18.72%
110m	0dBm	10Bytes	1000	30.19%

It can be seen from Table 1 that within 80m, the packet loss rate of data transmission is very small, which hardly affects the normal data transmission. When the distance is more than 80m, the data packet loss rate increases sharply. Data packet loss is very serious, which seriously affects the reliable transmission of data. The actual length of the network frame data is generally not more than 10 Bytes. Therefore, when testing, the packet length is set to 10 Bytes.

The test results of node networking are shown in Figure 4. The test results of node access network are shown in Figure 5.

As can be seen from Figure 4, the sink node of the monitoring network is 0x01. 0x22 and 0x21 are used as routing nodes and data forwarding is achieved. 0x13, 0x12 are used as terminal nodes to collect sensor values, and then sent to the next hop routing node. Finally, the data transmission and convergence are achieved. As can be seen from Figure 5, node 0x11 joins the established network as the terminal node.

During the test, the graphical display and alarm interface of the remote monitoring center is shown in Figure 6.

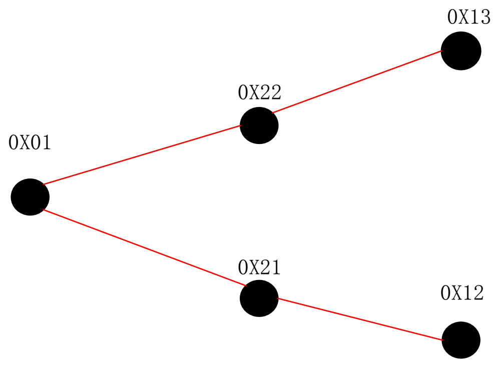

Fig. 4. The test results of node networking

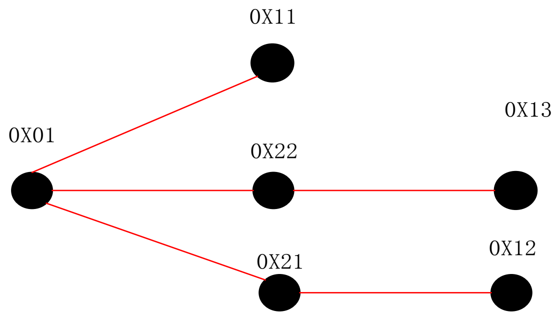

Fig. 5. The test results of node access network

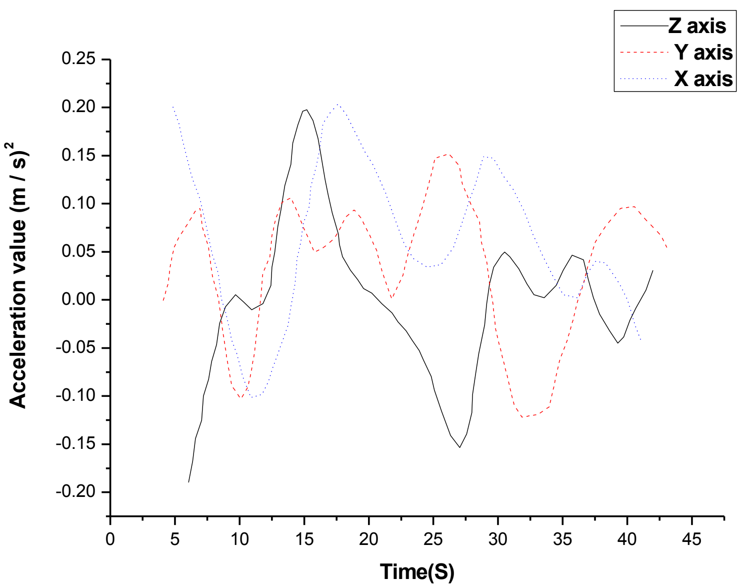

Fig. 6. The graphical display and alarm interface of the remote monitoring center

As can be seen in Figure 6, the curve is the acceleration value curve for node 0x12 (decimal 10). The alarm thresholds are set as follows. The humidity threshold is 60%, the temperature threshold is 15 °C, and the acceleration threshold is 0.5 m / s^2. Because the room temperature is above 15 °C, the alarm node list shows the node IDs that exceed the threshold and the type of sensor values. Two terminal nodes for testing are integrated with temperature and humidity sensors. Therefore, the alarm node list shows the ID of two terminal nodes. The sensor data query results are shown in Table 2.

Test results of node distance and power consumption: When the sink node runs normally, the current consumption is 47mA. When the routing node works normally, the current is 40mA. When the terminal node works normally, the current is 43mA.

Table 2. The sensor data query results

Time	ID	Temperature value	Humidity value	X-axis acceleration value
2016-10-21	0x13	17.5	73	0.1
2016-10-22	0x12	17.4	74	0.15
2016-10-23	0x13	17.6	74	-0.1
2016-10-24	0x12	17.5	75	0.1
2016-10-25	0x13	17.2	72	0.2
2016-10-26	0x12	17.6	75	-0.15
2016-10-27	0x13	17.5	74	-0.1

5 Conclusions

In view of the shortage of landslide monitoring technology and the research and development of wireless sensor networks, landslide monitoring and early warning method based on wireless sensor network is proposed. The software design and system test of remote monitoring center are introduced. The software design of remote monitoring center mainly includes the architecture of remote monitoring center, data communication module, data storage and query module, graphical display and alarm module and topological structure query module. Socket controls and their usage are studied. Database and data storage process, image display and alarm function design ideas as well as network topology query implementation were investigated. The test system mainly introduces the test scheme and test results. It includes node wireless communication and networking test, sensor data acquisition and transmission test, node communication distance and power consumption test. Finally, the test results are analyzed. The results show that under the experimental environment, the sensor data acquisition is accurate, and the transmission is reliable. The packet loss rate is very small, and it is less than 2%. The network has strong robustness and low power consumption. Remote monitoring center can accurately realize data storage, query, alarm, and network topology display and other functions.

6 References

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Article submitted 03 December 2017. Published as resubmitted by the authors 12 January 2018.