System Design for Landslide Warning use WIA Networks

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Abstract— In this paper, the technology of WIA (Wireless network for Industrial Automation) was utilized to detect the more frequent landslides, which are difficult to be predicted currently. WIA achieved real-time remote access to the mountains by collecting the real-time information of the mountain's water table, pressure and displacement, and transferring the data to a remote server by GPRS mobile communication. Thus, the obtained Mountain conditions can be used to predict landslides, and do scientific research. As a result, the low power and scalable monitoring of WIA plays an important role in detecting the natural disasters.

Keywords- Internet of Things; Landslides; Industrial Wireless; Mobile Communication

I. INTRODUCTION

Landslide is a geological phenomenon which refers that a part of geotechnical slope of the mountain moves down along some weak structural plane because of the gravity (including both the role of geotechnical gravity and groundwater dynamic and static pressure)[1]. It is one of the common geological disasters known as the "Walking Mountain", "collapse Mountain", "slippery", "soil slip" and so on.

There is a large area of the mountainous topography in China. A great number of buildings and roads are located in the mountains nearby. During the annual flood season, the instable landscape can easily take place landslides after the water erosion, which poses a huge threat to people's lives and property safety.

The wired monitoring networks are tried many times to monitor and warn the landslides, but the field cabling and power supplement are restricted due to the limited regional circumstance, making it difficult to deploy the cable system. In addition, the wired networks tend to collect the nearest deployed data, which is needed someone to go to the monitoring points to transcribe the data from time to time. As a result, real-time data cannot be collected from the wired system because of the less flexibility.

Thus, the system for field wiring and power supplement should be well established to detect landslides. In addition, it is also of much significance to focus on how to get the real-time data and improve the flexibility and accuracy of the data acquisition to access to the reliable decision-making system to forecast the disaster [5].

The landslide detection is also being investigated using wireless sensor networks by other foreign institutions [3][4]. According to the actual effect, the wireless networks show the high flexibility by exhibiting the efficient layout and periodic monitoring. However, the heavy rainfall in the early stage will influence the transmission of the wireless signal negatively. At the same time, the wireless transmitters and receivers are always be covered by the soil in the process of landslide, which will exert very serious impact on the quality of the communication.

Wireless Networks for Industrial Automation-Process Automation (WIA-PA) [2] is an intelligent multi-hop wireless sensor network technology with the high reliability and ultra-low power, which is introduced by Shenyang Institute of Automation Chinese Academy of Sciences with independent intellectual property rights. It can provide a self-organizing and self-healing intelligent mesh network routing and maintain the network reliable and stable to the dynamic changes of the environment.

WIA is a multi-hop self-organizing network without the support of the network infrastructure. The network equipment can rely on the power of the battery without manual configuration for a long time. It is a self-forming network.

The features of WIA can just match with the actual needs of the landslide measurement. Thus, this paper proposes a landslide monitoring design based on the wireless sensor networks.

II. THE PRINCIPLE FOR LANDSLIDE MEASUREMENT

The causes for landslides are very complex, mainly including the inside and outside stress and human factors. At present, landslides usually happen in the areas of crustal movement and human frequent activities. The main predisposing factors for landslides are earthquakes, rainfall and snowmelt, as well as surface water washing and soaking. For human factors, the irrational activities include excavation of the foot of the slope, upper slope heap load, blasting, water storage of reservoirs, mining. Other natural factors such as tsunami, storm surge, and thawing can also induce landslides.

When landslides happen, the position of the mountain will change and the groundwater level will be unusual. Therefore, landslides can be measured by pressure sensors, liquid level sensors and displacement sensors. As a result, a number of holes should be made along the mountains in the hazardous areas where landslides happen easily. And a liquid level sensor and a pressure sensor are needed in each deep hole. At the same time, multiple displacement sensors should also be deployed along the mountain.

Landslides are mostly generated by raining, thus groundwater table depth can illustrate the possibility of...
landslides to some extent. The level can be clearly acquired by liquid level sensor. When the water level has changed dramatically a period of time, the possibility of landslides could be analyzed according to the local temperature and rainfall situation. However, the accuracy of this kind of warning is not high and the warning can only be generated before dozens of hours of the landslides.

The accurate early warning can be obtained through the displacement and pressure sensors. When the landslide comes, the bottom will start moving, accompanied by the dramatic changes of the underground pressure and surface displacement. It is generally believed that the early warning can be achieved when the surface displacement is close to the centimeter level. This kind of warning is relatively accurate, but the warning can only start in one or two hours prior to the occurrence of landslides.

III. INTRODUCTION OF WIA

WIA-PA network protocol follows the ISO-OSI hierarchy definition, but only defines the physical layer, data link layer, network layer and application layer. Figure 1 shows the structure of industrial wireless network protocol stack based on the IEEE802.15.4.

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Figure 1 The comparison between WIA-PA protocol stack and the ISO-OSI reference model

Physical Layer is directly compatible with the physical layer of IEEE 802.15.4.

Data Link Layer contains both MAC layer and data link sub-layer. MAC layer is also based on IEEE802.15.4 MAC protocol. The data link sub-layer is composed by the time synchronization, time slot of communication, link and channel performance metrics, functional modules of the link layer security, management services and so on.

Application layer is comprised by the application sub-layer, the user application process, and the device management application process. The function of the application sub-layer is to provide communication mode, data aggregation and disaggregation, application layer security and management services. The user application process serves for multiple users of the application object. The device management application process is mainly responsible for the device status, security and information management.

The network structure of WIA is shown in Figure 2. The WIA host computer is used to display the network topology, data, equipment status, and network stability, which holds the function of human-computer interaction. The WIA gateway includes at least one wireless access point to connect with WIA wireless network and other wired networks. It is responsible for network resource management, network performance monitoring, data processing, as well as bridging all network equipment. The WIA routing is applied for the management of each local star network, data aggregation and routing the information which is from other routing equipment. WIA field devices are used to connect sensors, actuators, and the network terminal equipment. The WIA handheld devices are taken into consideration to detect and diagnose the network.

Due to the WIA network, the users can perceive the entire industrial process at a lower cost, obtain the accurate industrial process data which cannot be monitored by the traditional methods because of the cost reasons, and achieve the optimal control to improve product quality and energy saving. The industrial wireless network WIA technology is widely used in petroleum, petrochemical, metallurgy, environmental protection, sewage treatment and the chemical industry.

IV. SYSTEM DESIGN AND IMPLEMENTATION

A. System functions

The wireless sensor network for landslide monitoring, mainly mountain geomorphology monitoring, can collect the information by using a series of displacement sensors, level sensors, the auxiliary temperature, and the pressure sensors. The data can be collected into the gateway and transmitted to the remote server by GPRS. Thus, based on the obtained data, the landslides can be predicted to achieve the timely tracking of landslide disasters and strategic decision-making by sending the real-time data to the provinces and national departments of disaster prevention.

As is shown in Figure 3, the detecting system contains a new sensor node with WIA-enabled wireless communication protocols, which include WIA wireless gateway with GPRS module, an Internet server, system monitoring software,
landslide data analysis software, and the visual management platform.

The hierarchical network topology is taken into consideration during the actual deployment. As a result, the wireless sensor nodes of each target can form a subnet, which has a gateway and around 10-50 wireless nodes depending on the scope of monitoring. In general, the distance between nodes is 20-300m depending on geological conditions. The GPRS is located in the gateway which powered by both battery and solar energy. It is recommended to use the 220v power supply in the case of convenient access of electricity. But the wireless nodes can directly supplied by battery, which can provide power up to ten years if sampling every half hours. The communication in each subnet present meshes self-organizing structure. The data is transmitted to the wireless gateway by multi-hops and multi-paths, and then sent to the remote server.

WIA networks periodically collect the data from the sensor and transmit the data to the Internet server by the GPRS module of the gateway. Server-side operating system monitoring software can clearly obtain the data sources and the smooth degree of the networks. At the same time, the landslide data analysis software on the server can quickly and timely calculate the real-time accurate measurements, and send the relevant authorized departments can also connect the server to obtain the important information.

The detection cycles can be dynamically adjusted in the network. During the dry season, the detection cycle can be set to 1 hour or longer. During the landslide-prone season, the detection cycle can be set to 2 minutes or shorter, and the shortest can be set to 1s detected times.

B. Hardware design of the system

The WIA sensor nodes and the hardware structure of the gateway are designed to achieve the above functions. As is shown in Figure 5, the WIA sensor node is composed by four components: the sensor module, data acquisition module, the WIA protocol stack module, and power module.

The sensor module includes water level sensor, displacement sensor, temperature sensor and pressure sensor. Each sensor shows the characteristics of high precision, low power consumption and rapid response, which can access to the corresponding analog and transmit it to the data acquisition module according to the calibration range.

The data acquisition module holds an A / D converter, which can transmit the sensor output analog signals into digital signals. In addition, it also can process the collected data, calculate the real-time accurate measurements, and send the data to the gateway periodically through the WIA protocol stack module.

The WIA protocol stack module is responsible for running the WIA agreements, including node synchronization and network operations. The ultimate goal is to send the sensor data to the gateway in wireless way. On one hand, the WIA protocol stack module and the data acquisition module occupy two independent processor modules. They connect each other and transmit the digital signals through the serial. On the other
hand, the WIA protocol stack module can transmit RF signal through the wireless connection.

The power supply module is installed high-capacity lithium batteries to power the other three modules. Because of the low power consumption, the batteries can last for ten years if the average current reaches to 300mA, and the sending cycle for acquisition is 30 minutes.

Figure 6 demonstrates the combination of the WIA gateway. The four parts shown below are the WIA protocol stack module, the GPRS module, the Ethernet module, and the power module, respectively.

![Figure 6: Hardware of WIA gateway](image)

The WIA protocol stack module is the core of the WIA network. It is responsible for managing the running for the entire network, allocating resources for nodes and maintaining the network, as well as receiving and saving the data from sensor nodes.

GPRS module connects with the WIA protocol stack module through the serial. It can send the data collected by the WIA protocol stack module sensor nodes to the base station, and finally transmit to the remote specified server. This real-time monitoring can be achieved even in the remote mountainous areas.

The Ethernet module is another accessing server, parallel with the GPRS module. It can provide the Ethernet interface. When the wired network exists in the monitoring area, the WIA gateway can direct access to the present wired network via the Ethernet module, and transmit the data from the sensor to the specified server or host through the Ethernet interface.

The power module includes battery, solar, and 220V power, which can be chosen depending on the way for using. The WIA gateway is the most energy consuming equipment in the network. As a result, if the wired power cannot be supplied, the combination of battery and solar power is taken into consideration during power supply.

C. Software implementation of the system

Based on the above hardware design, and implementation of software features include: the sampling period setting, the WIA data transmission and the protocol conversion.

The WIA sensor nodes run the uc/os ii operating system, while the WIA Gateway runs the Nucleus operating system. Both two are embedded real-time operating system.

The order is set by the sensor nodes in a sampling period, and the visual management platform of the server sends the information to the WIA Gateway, and then the gateway transmits the data to the specified sensor node. Thus, the sensor node deletes the original timer after receiving the instruction, and creates a new timer according to the new specified sampling time. The specific methods include: Set_Data_Rate( ); Delete_Timer(); Create_Timer().

The WIA protocol to the Ethernet protocol or GPRS protocol. The specific method includes: Send_Data_By_Ethernet( ); Send_Data_By_GPRS().

V. CONCLUSION

The WIA network plays an important role in monitoring the landslides. Firstly, the WIA can effectively avoid the difficulties of wiring and power supply. In addition, it can also well meet the requirements of the landslide data monitoring because of the real-time and the high reliability. At last, the WIA is self-organization. As a result, it can easily increase or decrease the number of sensors to facilitate the expansion of the network.

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