Research on Road Slope Compound Monitoring System Based on Internet of Things Technology

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Abstract. Because the stability of the slope is affected by many factors, in order to be able to collect as much information as possible about the stability of the slope, a multi-parameter, multi-device composite system integration based on the Internet of Things technology is proposed. Monitoring systems and slope monitoring projects require low real-time data because most monitoring cycles are long. However, due to the particularity of the monitoring process environment, there are higher requirements for energy saving, scalability, and robustness of wireless transmission networks. RF433MHz technology can meet the problem of wireless transmission in slope monitoring in many aspects such as power consumption, network scalability, network networking capabilities, and operating costs, so it is very suitable for slope monitoring and early warning systems with multiple parameters and multiple measurement points. Through engineering tests, the system works stably and the validity and accuracy of the monitoring data. The researched road slope composite monitoring system based on the Internet of Things technology has certain engineering application value.

1. Introduction
Landslides have been associated with volcanoes and earthquakes and are the three major sources of geological hazards today. China is a country with frequent landslide disasters, especially the large-scale artificial slopes such as highway slopes, whose instability and damage will inevitably bring huge threats to the lives and property safety of traffic and operators. With the rapid economic development and the continuous advancement of science and technology, the scale of transportation is constantly expanding, especially in the southern mountainous areas. Due to the irrational slope design or other natural and human factors, deformation and even instability will occur, causing huge loss. Monitoring the slope of traffic roads and grasping the deformation law of the slope can reduce the loss caused by the slope instability caused by the deformation of the slope.[¹]

Studying the road slope composite monitoring system based on the Internet of Things technology can solve the problems that cannot be solved in the current slope monitoring process [²]. First, the data acquisition network uses a wireless sensor network, combined with Beidou positioning, deep displacement and other measurement technologies. It has strong adaptability, is not limited by terrain and time, and does not need to manually collect data. Second, due to the self-organization of the wireless sensor network, one sensor node is destroyed during the construction of the field environment, which does not affect the normal operation of other nodes [³]. Once again, the collected data can be transmitted to the management and control Centre through the IOT base station, without the need for
staff to do it themselves. Finally, integrating the theory of slope stability analysis into the system can immediately discover potential dangers and play a real early warning role.

2. Slope monitoring system architecture design

According to the combination of slope monitoring technology required by the project, a complete slope monitoring system is shown in the figure 1.

![Figure 1. Structure chart of slope monitoring system](image)

The bottom left of the figure is the front-end data acquisition system, which is mainly composed of monitoring nodes and is responsible for collecting the internal displacement, humidity, and rainfall of the slope rock and soil. The upper left is a data transmission system, which is composed of a base station and a monitoring node, and is responsible for uploading and collecting data. On the right is the back-end data processing system, responsible for the construction and early warning of landslide models.

The front-end data acquisition system consists of monitoring nodes and monitoring sensors. Its main function is to sense and detect parameters such as displacement, structural tilt, soil moisture, rainfall, and pore water pressure. Its main components are various sensors and monitoring nodes connected to the sensors.

The mid-end data transmission system mainly implements the data upload function of each monitoring node, and is composed of monitoring nodes and base stations. The problem faced by the mid-range data transmission system is mainly how to transmit the data collected by the monitoring nodes to the base station in a timely and error-free manner, because the actual site is subject to obstacles such as energy, wireless transmission power, and mutual interference between nodes. It is necessary to set a communication rule to restrict the wireless communication behavior of each monitoring node, so that the communication indicators of the entire sensor network can meet the requirements of the slope monitoring system.

The back-end data processing system consists of a background server. Its main function is to process and analyze the data information transmitted from the front end to the database through
mathematical methods and related programs, study the law of slope movement, predict the development trend, and realize the early warning of the slope monitoring system. Its main components are a slope monitoring database and a geotechnical data processing system.

3. Architecture Design of Slope Communication System Based on Wireless Sensor Network

A complete communication architecture based on wireless sensor network technology is shown in the figure 2.

![Figure 2. Slope communication system diagram based on wireless sensor network](image)

In Figure 2, the monitoring node is shown below. The data monitored by the monitoring node needs to be collected to the base station. The communication method between the monitoring node and the base station is 433MHZ RF ad hoc network communication. The center of the figure to the left is the base station. After the base station collects the data of the monitoring node, it needs to upload to the server. The communication method between the base station and the server is NB-IOT, 4G wireless communication technology.

The communication part of 433MHZ wireless ad hoc network is mainly composed of base stations and nodes, and adopts Ad hoc multi-hop ad hoc network for communication. The difficulties and problems to be solved in the 433MHZ wireless ad hoc network are mainly topology control, network coverage strategy, priority-based congestion control, and error recovery mechanisms.

NB-IOT, 4G remote wireless communication part is mainly composed of base station and server. The base station uses the technology of the communication provider for remote wireless communication, connects to the Internet network, and communicates with the server located on the Internet network through TCP / IP protocol.

4. Design of communication protocols for wireless sensor networks

Classic communication models at home and abroad all use network segmentation and layered solutions to handle network communication behavior [6], [7]. In the traditional communication model, such as the ISO / OSI model, the communication protocol is divided into seven layers, which are the physical layer, data link layer, network layer, transport layer, session layer, presentation layer, and application layer from bottom to top. Large and complicated, and simplified communication model TCP / IP protocol, the communication model is divided into physical layer, data link layer, network layer, transmission layer, application layer (there are also literatures divided it into network interface layer, network layer, transmission Layer, application layer, where the network interface layer is a combination of the physical layer and the network layer). Whether the communication protocol system is divided into seven layers or five layers or other layers depends on the specific problems faced in the
communication model. There is no one layered method that is suitable for all applications, especially for slope monitoring networks. That said, both the ISO / OSI model and the TCP / IP model appear more complicated.

In the traditional communication network model, the definition of each layer comes from the problems that it needs to solve. Although the problem to be solved at each layer is single, the implementation process is more complicated. The complicated implementation process of solving a single problem is summarized into a single one. In the layer, it can make the entire communication process clear, efficient, and stable.

Taking the TCP / IP protocol as an example, its five-layer communication model actually solves five different types of communication problems. The physical layer mainly solves the specific communication hardware problems such as the communication medium, communication channel, communication bandwidth, modulation method, and encoding method; the data link layer mainly solves the communication of two directly connected communication nodes such as the medium access method and logical verification. Problem; the network layer mainly solves the problem of two indirect communication nodes in a specific network topology forwarding information through other communication nodes to communicate indirectly; the transport layer mainly solves the problem of data packets arriving during the communication between two indirectly connected communication nodes The order is wrong and communication is not normal; the application layer mainly solves the problem of the communication interface connection between the communication protocol and the application program.

Analyzing the slope monitoring network [8], there are only two kinds of nodes with different functions in the slope monitoring network-base station and monitoring node. The requirements of the base station and the monitoring node are slightly different, but neither the base station nor the monitoring node need to consider the problem of incorrect communication caused by the incorrect arrival order of the data packets, so the transmission layer appears redundant and unnecessary. In a communication network, it is necessary to solve the communication problem between two directly connected nodes, as well as specific hardware requirements such as physical channels. Therefore, the physical layer and the data link layer are indispensable. Considering that some sensor nodes in the slope monitoring network cannot directly communicate with the base station, it is necessary to send data packets to the base station in a multi-hop manner, so it is necessary to solve the network layer indirect communication between nodes. Finally, in order to make the protocol more adaptable and easier to transplant, and considering that monitoring sites such as warehouse supervision and management may also use the protocol, the protocol must have the characteristics of simple to use and easy to use to simplify user operations. The application layer also needs to exist.

Therefore, the entire slope monitoring network protocol is divided into four layers [9], namely the physical layer, the data link layer, the routing layer, and the application layer. Among them, the physical layer uses the ready-made module UTC4432 of Hangzhou Weibu Technology Co., Ltd., the data link layer is constructed with reference to IEEE802.15.4 protocol technology, the routing layer is constructed with reference to DSR routing, DSDV protocol, and ADOV protocol. The application layer is an independent layer and is a slope The monitoring application provides a program migration interface. The slope monitoring architecture is shown in the figure 3.
Data transmission

Routing

Data applications

Routing layer

Data link layer

Application layer

433MHz physical layer

Figure 3. Slope monitoring network architecture

The problem solved at each layer is different throughout the architecture. The physical layer mainly solves the problem of channel selection. Considering the tight radio frequency band, the slope monitoring network protocol selects 433MHz as the dedicated physical channel. The 433MHz radio frequency band is one of the application-free bands. After the wireless layer is selected at the physical layer, corresponding hardware needs to be designed to support the use of the physical channel. The data link layer mainly solves the problem of link connection, that is, how to communicate between individual points. The routing layer mainly solves the problem of route selection, that is, when data is sent from the monitoring node to the base station, multiple monitoring nodes may need to forward information to finally reach the base station. The routing layer mainly selects which nodes and forwards this information. The application layer is mainly responsible for the interface design with the application.

5. Engineering test

The experimental point of the project is the DZK19 + 500 ~ DZK20 + 087 highway section from the Dapu to Chaozhou expressway in Guangzhou Province. The extension of the construction line of the project is mainly in the direction of northwest to southeast, northeast to southwest and east to west. Northwest-to-Fuling faults and other structural faults generally appear in the area; North-east-to-LianhuaShan faults and structural faults intersect and intersect with the proposed project at medium to large angles; Multiple sets of fault structures intersect and stagger with each other, forming a network-like structural pattern.

After analyzing the natural environment and geological conditions of the slope and making a preliminary judgment on the stability of the slope, a measuring device is arranged in the slip zone of the highway section to monitor the displacement and angular displacement of the landslide zone. Adopting the arrangement from the top of the slope from top to bottom, the DZK19 + 864 section slope slide belt is equipped with a total of 3 cable displacement meters, and the upper and lower nodes are connected by the cable of the cable sensor. The base station is laid out according to the terrain and relative position. The plan layout of the project is shown in Figure 4.
Figure 4. Schematic layout of slope monitoring equipment for DZK19 + 864 section

The installation of base station equipment is mainly divided into two steps: assembling solar power supply equipment, fixing and installing the base station. The installation site is shown in Figure 5. According to the principles of geotechnical engineering, the geological situation of the slope is analyzed, and the position of the monitoring point is determined according to the force of the slope zone. After the location of the monitoring point is determined, the site where the monitoring point is to be installed needs to be leveled, so that the drilling machine can drill holes smoothly and try to avoid drilling deviation.

Figure 5. Site installation site map
The monitoring points of the DaChao Expressway section require monitoring nodes to return monitoring data according to a specific length of time. The duration is 3 uploads per day. The function of this slope monitoring system is normal, and the real-time performance is good, the real-time performance is almost within 1S. Slope DZK19 + 864 section monitoring point 6 # equipment within 3 months of the slope deep displacement sensor measurement data shown in Figure 6.

Figure 6. Monitoring data of deep displacement sensor

The 3-month data transmitted by the deep displacement sensor is continuous, and no packet loss occurs. The system has been running continuously for more than 12 months, and no packet loss or other phenomena that seriously affect the stability of the system have been found.

6. Summary
This paper studies and analyzes the data acquisition, data transmission, and communication networking stages in the entire process of road slope monitoring. The stability of the slope is affected by various factors. Stability parameter information, a multi-parameter, multi-device composite system integrated monitoring system based on the Internet of Things technology is proposed, and the key technologies that need to be resolved are fully demonstrated. Slope monitoring projects require low real-time data because most monitoring cycles are long. However, due to the particularity of the monitoring process environment, there are higher requirements for energy saving, scalability, and robustness of wireless transmission networks. RF433MHz technology can meet the problem of wireless transmission in slope monitoring in many aspects such as power consumption, network scalability, network networking capabilities, and operating costs, so it is very suitable for slope monitoring and early warning systems with multiple parameters and multiple measurement points. Among. The validity and accuracy of the monitoring data play a major role in accurately predicting slope stability. Therefore, the road slope composite monitoring system based on the Internet of Things technology has some engineering application value.

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