ISSN: 1813-4890

Design and Implementation of a Wireless Student Dormitory Earthquake Monitoring System

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Abstract

With the rapid development of science and economy, the investment in school construction by the state continues to increase, and the number of student dormitories is also growing rapidly. However, there are some safety hazards, such as the durability of building materials for student dormitories and the unobstructed escape routes. Due to these special characteristics, the risk of safety accidents has greatly increased, posing a significant threat to the safety of students' lives and the property of schools. The issue of student dormitory safety is increasingly drawing public attention. Researching a system capable of effectively monitoring and warning of earthquakes in student dormitories has become a very important topic. Many student dormitories today have established earthquake monitoring systems, but these systems still have some issues, such as aging monitoring equipment, insufficient monitoring stations, poor data sharing, technical difficulties, and insufficient equipment maintenance and management experience. Based on this, this article analyzes the limitations and application needs of the existing student dormitory earthquake monitoring system and designs a wireless-based student dormitory earthquake monitoring system. This system can provide unified information management for the earthquake monitoring system of student dormitories across the province and has certain application value for improving the earthquake monitoring capabilities of student dormitories across the province. The main work completed in this article is as follows. (1) Designed and implemented a wireless sensor network for earthquake monitoring system. Firstly, design the hardware part of the wireless sensor network, including the circuit connections between the ZigBee main control chip and various types of sensor modules and gateway modules. Secondly, the software part of the wireless sensor network was designed and implemented, including ZigBee programs for coordinator nodes and terminal nodes. Finally, a data conversion method was designed between the ZigBee data frame format and the data packets uploaded to the cloud platform. (2) In order to solve the problem of low accuracy of single sensor in earthquake alarm, the earthquake monitoring system adopts fuzzy reasoning technology to predict the probability of earthquake occurrence, thereby improving the accuracy of earthquake alarm. And according to the system requirements, a cloud platform system and a web-based management platform have been designed and implemented. Through the data push function of the cloud platform, the cloud platform is integrated with the web-based management platform, providing real-time environmental data charts, visualized earthquake probabilities, historical data queries, and user management functions. (3) We have tested various functional modules of the system, including the networking and transmission distance testing of wireless sensor networks, data communication and alarm testing of OneNET platform, testing of various functional modules of the web-based management platform, and earthquake warning function testing. The test results meet the expected expectations.

Keywords

Earthquake Monitoring; ZigBee; Cloud Platform; Web; Blurred Processing.

ISSN: 1813-4890

1. Introduction

With the frequent occurrence of global earthquakes, how to effectively prevent and mitigate the damage caused by earthquakes has become an urgent issue to be addressed. Especially in densely populated areas such as school dormitory zones, establishing an efficient earthquake early warning mechanism is particularly important. Traditional wired earthquake monitoring solutions have issues with complex wiring and high maintenance costs, therefore, developing a low-cost and easy-to-deploy wireless earthquake detection system has become very necessary.

2. System Design

2.1. System Requirements Analysis

The purpose of the unified provincial student dormitory earthquake monitoring system is to centrally monitor dormitory environmental data across the province, to sense real-time changes in the environment around the dormitories, to accurately assess earthquake risks, and to ensure the safety of students. The system helps managers better understand the conditions of the dormitories, promptly grasp any abnormalities that occur, quickly address potential risks, and enhance the safety level of the dormitories.

The system is managed at two levels: provincial and school-level management. Provincial administrators can remotely and in real-time grasp the dynamic information of dormitories in various schools across the province to take appropriate measures promptly. School-level administrators can remotely manage the dynamic information of all student dormitories on campus. In addition, the student dormitory earthquake monitoring system should be user-friendly, have low hardware costs, and require minimal maintenance expenses.

After analyzing the actual needs of administrators, the student dormitory earthquake monitoring system was designed and developed, and the various modules and functions that the system should possess were analyzed and summarized. It was determined that the required functions of the system are as follows.

User management is a crucial aspect of the laboratory fire monitoring system. Since the actual users of the system are collective users, to facilitate remote monitoring by managers, the system requires management of administrators and sets up two types of users within the system, namely school-level administrators and provincial-level administrators. School-level administrators can only view information about their school's student dormitories, while provincial-level administrators can view and manage information about student dormitories across the entire province.

Real-time environmental data acquisition. The system needs to achieve real-time acquisition of environmental data, and aggregate the collected data to the central node of the wireless sensor network, which then uniformly reports the data.

The environmental data monitoring interface is a key component of the student dormitory earthquake monitoring system. The system requires environmental data visualization monitoring across multiple platforms, including cloud platforms, mobile devices, and Web interfaces. The monitoring view is divided into two forms: line charts and numerical tables, which can intuitively display real-time data and changes in data flows, assisting administrators in timely understanding of student dormitory information.

The earthquake early warning function. It is crucial to analyze and warn about environmental parameters in advance, as it allows for a rapid response at the onset of an earthquake and timely measures to be taken to address potential risks.

ISSN: 1813-4890

2.2. Selection of wireless communication technology

ZigBee is a wireless communication protocol based on the IEEE 802.15.4 standard, widely used for low-speed, low-power, low-cost short-range transmission. The main features of ZigBee include:

(1) Support for a large number of network nodes: ZigBee can support up to 65,535 nodes, making it suitable for building large-scale wireless sensor networks.

(2) Fast, reliable, and secure: ZigBee uses CSMA/CA technology to avoid channel conflicts, AES encryption algorithm to ensure data security, and ACK mechanism to ensure data integrity.

(3) Long battery life: The low power consumption of ZigBee is due to its use of low-power wireless technology, including low-power transceivers, low-power anti-interference technology, and low-power network protocols.

2.3. Cloud Platform Design and Implementation

According to the overall design requirements of the earthquake monitoring system based on wireless student dormitories, it is necessary to upload the real-time data collected by the terminal wireless data acquisition module to the cloud platform. On the cloud platform, it is required to process each data stream to achieve functions such as visual monitoring of data streams, alarm notifications, and data push to third-party application platforms.

2.3.1. Cloud Platform Selection

A cloud platform is a type of remote server used for storing and computing vast amounts of data. Compared to traditional servers, it has various advantages. It can break the limitations of space imposed by traditional servers, allowing users to use basic services such as cloud storage and computing more conveniently. This system chooses the OneNET cloud platform developed by China Mobile IoT Company to achieve functions such as adding cloud devices, storing data in the cloud, and pushing data to third parties. The OneNET cloud platform has the following advantages. First, it supports the connection of sensing devices through various protocols, including HTTP, NB-IoT, MQTT, EDP, TCP, etc., and enables data sharing and communication between devices. Users can achieve remote monitoring, remote control, data storage, and analysis of devices through the OneNET cloud platform. Second, the OneNET cloud platform adopts a hierarchical architectural design, separating different functional modules at different levels, which enhances the platform's scalability and maintainability. At the same time, the platform uses an open interface design, allowing users to custom-develop applications to achieve compatibility with different hardware devices and operating systems. Finally, the OneNET cloud platform also has a high level of reliability and security. The platform supports various network connection methods, including GSM, WCDMA, LTE, WiFi, Ethernet, etc., and also employs various data encryption and authentication technologies to ensure the security and confidentiality of user data.

2.4. Design and Implementation of Web Segments

The primary users of the student dormitory earthquake monitoring system are schools. For a single school, they can directly use the monitoring application of the OneNET cloud platform. However, if provincial administrators need to oversee student dormitories across the province, they must manage all users of the system. Since the OneNET application platform does not have user management capabilities, it is necessary to develop a Web-based management platform to facilitate the management of all system users. Such system design can meet the user management needs and enhance the operability and management efficiency of the system.

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3. System implementation

The hardware and software design implementation of the system has been completed, thus requiring comprehensive testing to ensure the stability and reliability of the system. During the testing process, analysis will be conducted according to the system design, and the test results will be summarized and analyzed in detail. The ultimate goal is to determine whether the system meets the design requirements and can operate normally as expected.

3.1. Hardware implementation

Hardware implementation mainly includes the installation of seismic sensors, the configuration of wireless communication modules, and the setup of a central processing unit. Seismic sensors need to be installed at key locations in the dormitory building, wireless communication modules need to ensure signal coverage throughout the dormitory area, and the central processing unit needs to have powerful data processing capabilities.

3.2. Software implementation

The software implementation mainly includes writing data collection programs, data transmission programs, and decision support programs. The data collection program needs to monitor seismic information in real-time, the data transmission program needs to ensure the timely transmission of information, and the decision support program needs to make emergency response decisions quickly based on the received information.

4. System Testing and Analysis

System testing mainly includes functional testing, performance testing, and stability testing. Functional testing verifies whether all the functions of the system are operating normally, performance testing verifies the system's response speed and processing capacity, and stability testing verifies the system's stability and reliability. The test results indicate that the system has good functionality, performance, and stability, and can meet the needs of earthquake emergency response in student dormitories.

5. Summary

The earthquake monitoring system for student dormitories designed based on wireless technology can effectively improve the emergency response capability during earthquakes, ensuring the safety of students' lives. The system can monitor seismic information in real-time and take appropriate measures quickly, which has significant practical application value. In the future, the system performance will be further optimized, and the level of intelligence will be improved to better serve the safety management of student dormitories.

Acknowledgements

This work was supported by the research fund of the Quzhou University Student Innovation Project Q24X033 and Q24X031.

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