Design of Train Carriage Abnormal Noise Alarm System Based on Zigbee

Yongsheng Zhang\(^{1,2,*}\) and Miaomiao Liu\(^{1,2}\)

\(^{1}\) School of Computer and Information Technology, Northeast Petroleum University, Daqing, Heilongjiang, 163318, China
\(^{2}\) Key Laboratory for Oil Big Data and Intelligent Analysis of Heilongjiang Province, Daqing, Heilongjiang, 163318, China

zhyshqhd@163.com

**Abstract.** In order to realize the timely and accurate alarm for abnormal conditions in train carriages, a scheme of abnormal noise alarm system based on zigbee is proposed. The overall system architecture as well as the hardware and software structure of each node is designed. Meanwhile, the workflow and implementation process of each module are elaborated in detail. The system includes five parts: sensor node, zigbee router, coordinator, video module and intelligent terminal. Firstly, the decibels collected by the sound sensor are processed through threshold judgment and sent to the coordinator through the zigbee router module. Secondly, the video module recognizes and analyzes the video of the alarming carriage by means of artificial intelligence. Finally, the detailed alarm information is sent to the intelligent terminal. The development cost of this system is low while its installation and maintenance is convenient. It improves the monitoring facilities of train carriages, which can not only guarantee the accuracy and real time of the warning, but also set the threshold value and delete alarm mark manually. It has strong expansibility and portability, which is of practical significance for improving the safety of train operation.

1. Introduction

Nowadays, with the rapid development of high-speed railway, how to find abnormal conditions in the carriage in time under the condition of high-speed train operation is a problem that needs to be carefully considered. Generally, smoke alarm system is installed in the carriage to judge whether there is a fire or not. However, smoke sensors and some other sensors are unable to detect abnormal situations such as passenger shouting for help or quarrelling in unexpected circumstances, which need to be detected and handled by staff in time in train operation. But so far there is no relevant alarm technology. At present, most of the security monitoring alarm systems still use bus connection mode, which brings a lot of inconvenience to the installation and maintenance of the system. Considering the potential safety hazards of the existing train monitoring measures, a train carriage abnormal noise alarm system based on zigbee is designed, which mainly includes five modules: sensor node, router, coordinator, video module and intelligent terminal.

At present, there are five kinds of communication technologies that can be used in short-distance wireless sensor networks[1]: Wi-Fi, Ultra Wideband, Near Field Communication, Bluetooth and Zigbee. Zigbee is a low-speed and short-distance wireless network technology[2]. Compared with Wi-Fi and Bluetooth technologies, the main characteristics of zigbee technology are low power consumption, low cost, supporting a large number of network nodes, supporting a variety of network
topologies, low complexity, fast, reliable, security and so on[3]. These characteristics determine that it is very suitable for the application of wireless sensor networks[4]. Now zigbee wireless communication technology has been successfully applied in many fields such as industrial monitoring[5], agricultural environment monitoring[6-7] and intelligent home system[8-10].

2. Overall system architecture design

The train carriage abnormal noise alarm system based on zigbee is mainly composed of five parts: sensor node, router, coordinator, video module and intelligent terminal, as shown in Figure 1.

![System Structure Diagram](image)

**Figure1. The system structure diagram**

1. Sensor node: It is mainly composed of BR-ZS4 sound sensor, STC89C52 smallest system and zigbee communication module. The sound in the carriage is measured by the sound sensor, and then the collected decibels are sent to the single chip computer. After processing, the data is transmitted to the router through the zigbee wireless communication module.

2. Zigbee router: It has the function of information forwarding and network maintenance. It is responsible for collecting the data of each sensor node and deciding whether the decibel exceeds the threshold. Then it transmits alarm information to the coordinator through USB interface or GPRS.

3. Coordinator: It is mainly composed of the smallest system based on STC89C52 and communication module. When the alarm information transmitted by the zigbee router is displayed on the screen, the coordinator sends the command to the video module to call the video captured by the camera and finally delivers the processed alarm information to the intelligent terminal.

4. Video module: After receiving the instructions related to retrieving alarm information from the coordinator, this module will read and operate the video captured by the camera in the abnormal carriage, process it by artificial intelligence, input the key frames into the trained model for identification, and send the final judgment results to the intelligent terminal.

5. Intelligent terminal: Mobile phone is used as intelligent terminal and the alarm information are displayed and deleted through the APP on it. It is carried by train staff in order to process exceptions in time when receiving the alarm information from coordinator and video module.

The overall workflow of the system is as follows. Firstly, multiple sound sensors are installed in each carriage. Secondly, zigbee module is set in each sound sensor. When abnormal conditions occur, the sound sensor will send the detected decibel to the single chip system for processing. Thirdly, a zigbee router is installed in each carriage, which is responsible for receiving the decibel of each sound sensor node and determining whether it exceeds the given threshold, and then transmitting the alarm information to the coordinator. Fourthly, a coordinator is set in each train which is connected with zigbee router to receive information from zigbee router and send final alarm information to the intelligent terminal. Fifthly, a video module is set in each train. When it receives the command of retrieving video, the video in abnormal alarming carriage is processed by means of intelligent analysis, and the result is sent to the intelligent terminal so as to facilitate the staff to handle the abnormal situation in the carriage timely. The above five modules work together to perform the function.
3. Hardware design of the system

3.1. Hardware design of sensor node
The sensor node mainly includes five parts: sound acquisition module, the smallest system of single chip computer, communication module, display module and power module, as shown in Figure 2.

![Figure 2. Hardware block diagram of sensor node](image)

1. Smallest System of Single Chip Microcomputer: In our design, a SCM system based on STC89C52RC is adopted. Through the control program of PC, the user’s program code can be downloaded to the single chip computer faster, which saves the purchase of general programmer. At the same time, it has a new simplified instruction set structure and integrated MAX810 special reset circuit. Its maximum working clock frequency is 80 MHz and the actual working frequency can reach 48MHZ. It has high performance and low power consumption.

2. Sound acquisition module: A BR-ZS4 noise monitor which supports reading and displaying decibels on site is used. It is compatible with the smallest system of single-chip computer. It can detect noise at fixed point in whole day. Its frequency range is from 20HZ to 8KHZ and its measuring range is from 30dB to 130dB. It can alarm environmental noise by setting alarm limit. It has the characteristics of high precision, strong versatility and high cost performance. The decibel collected by the sound sensor is transmitted to the display module and the zigbee communication module.

3. Display module: The 160*32 dot matrix LCD module is used to display the current collected sound decibel value, which is easy to troubleshoot and proofread.

4. Communication module: Zigbee module is used to send the decibel value received by the sound sensor to the zigbee router set up in the carriage.

5. Power supply module: It provides the working power supply for voice acquisition module, the smallest system of single chip computer, communication module and display module. It is powered by mains supply in the carriage.

3.2. Hardware design of the router
In the design of this system, the zigbee router is connected with all zigbee communication modules in the carriage to obtain the sound decibel value transmitted by all sensor nodes through the zigbee protocol. At the same time, it is also used to connect with the coordinator, which sends the alarm information beyond the decibel threshold to the coordinator to indicate that there is an abnormal sound in a carriage. The design of zigbee module in the router and the sensor node is basically the same, which is based on CC2530 and CC2591 chips. CC2530 is a wireless communication chip which supports zigbee protocol and can easily realize self-organization of network. It has the advantages of high stability, low power consumption and few peripheral devices. CC2591 is an effective expander of communication range with a power gain of 11 dB. The communication frequency of this system is 2.4 GHz and the longest communication distance can up to 1 km. Star topology structure is adopted between nodes, which can basically meet the needs of normal use.

3.3. Hardware design of the coordinator
This system includes a full-functional coordinator which is the control center of the whole system and responsible for the management of the entire network. The coordinator is for train staff so its function design is different from sensor nodes. It mainly includes the smallest system of single chip computer, communication module, power module, voice module, display module, key module and alarm module, as shown in Figure 3.
In the hardware design of the coordinator, the alarm module adopts the sound-light alarming circuit composed of buzzer and light emitting diode. The voice module is used to input some different levels of alarming voice prompt information in advance. When there is an alarm, voice information can be invoked to remind train staff through voice broadcast. The display module uses 240128 LCD screen to display alarm information. The key module uses matrix keyboard to handle the alarm information manually. Communication module uses Zigbee, USB, WIFI, GPRS or other modes to connect to routers and sends alarming information to the video to call those videos.

A coordinator is set up in each train which is connected with the zigbee router in each carriage to receive information from the router and make judgments. If the coordinator decides that the received information includes the alarming information, it will display the information on the screen of the train cab to remind the train staff. For example, the carriage number and alarming value are displayed on the LED. After judging the alarm information by video surveillance, train personnel send the alarm information manually to the intelligent terminal and use matrix keyboard to eliminate the alarming.

### 3.4 Hardware design of the video module

Video module uses a small industrial computer built-in WIFI with Intel i7-7700 CPU, 32G memory and 512G solid-state hard disk. It provides external wired and wireless network card, WIFI, USB and GPRS interfaces, through which the video module can be connected to the coordinator and intelligent terminal. The AI system is trained by several groups of data, and each group of data includes a photograph of the carriage and identification information used to identify whether the photograph is an alarm category. Firstly, the key frames of the video captured by the camera are extracted and input into the trained data model as images to determine whether there is any abnormality in the carriage. Then, combined with the sound alarm information and the judgment result of artificial intelligence model, the video module determines whether to send an alarm to the intelligent terminal or not.

### 4. Software flow design of the system

The software design of the system follows the modular design principles, which is divided into three levels from top to bottom: parameter setting, data transmission and data processing. The parameter setting module is responsible for the basic parameter setting of sensor node, router, coordinator and video module, such as the working mode, working frequency and alarming threshold. Data transmission module is responsible for the transmission and storage of the collected data. Data processing module is responsible for data processing, including numerical calculation, logical judgment, data query and analysis and so on. In addition, the software design also includes the sending of alarm information and system maintenance which is mainly responsible for the control and maintenance of log files, configuration information and so on.

#### 4.1 Workflow design of the sensor node

In this system, zigbee is used as the core to design sensor nodes. First of all, initialization is completed. After that, the node starts network module to establish the network and join it. In order to reduce power consumption of the system, two modes are designed for data acquisition and reporting mechanism of the sound sensor. One is to collect data automatically on time while the other is to wake up the sensor node to collect and report data only when the query command from the coordinator is received. This can make the terminal node enter the dormant state when no command is received.
4.2. Workflow design of the router node
After the router is initialized, the zigbee network is constructed, and then the sensor node can join the network successfully. If the router receives a command from the coordinator, it will broadcast the command to the connected sensor nodes, wait for the response data to be sent back to the coordinator through the wireless network interface, and then it enters the monitoring state again. If receiving the decibel from the sensor node, the zigbee router first judges whether the received decibel exceeds the first predetermined threshold. If so, it will further judge whether the proportion of the number of sound sensors that detected the decibel exceeding the first threshold exceeds the second threshold. When the proportion exceeds the second threshold, the alarm information is sent directly to the coordinator through the network, and then it enters the monitoring state again after completion.

4.3. Workflow design of the coordinator node
A coordinator is set up in each train. It is initialized after power-on and connected to the zigbee router in each carriage for receiving information from it. If the coordinator found that the received information included alarm information, the information will be displayed on the screen set in the train cab. When the staff issued the acquisition order, the router node processed it and distributed it to the sensor nodes, and the sensor nodes in the network then entered the information acquisition state. When sound and light alarm is issued, the router sends the specific alarm information to the coordinator through the wireless module so as to inform the train staff to judge the abnormal situation combined with the video monitoring information, and record the alarm information through the memory storage circuit. When the intelligent terminal receives the alarm information, the staff can process the alarm in time and delete the alarm mark through the intelligent terminal.

4.4. Workflow design of the video module
When the video module receives the command related to the alarm information sent by the coordinator, it will read and analyze the video captured by the camera in the abnormal carriage. In this paper, the framework of intelligent monitoring video analysis platform is built by C++ language, which combines wxWidgets architecture library and OpenCV vision library effectively. The application algorithm under MATLAB is also transplanted to the platform to realize real-time analysis and process of the video. The platform can detect the abnormal behavior in the carriage, and then determine whether to send the alarm to the intelligent terminal by combining the sound alarm information and the judgment result of the artificial intelligence video module.

4.5. APP design of the intelligent terminal
With the popularization and application of 3G/4G network, mobile terminal has become the terminal of communication network and the Internet. It has become a trend to monitor train abnormalities through mobile terminal. According to the actual needs, various APP can be developed for managing and controlling train information by scientific and convenient means which can effectively improve train safety. In the design of this system, the APP in mobile terminal can display alarm information, set alarming mode, view video and release alarm and so on. The development of APP in mobile terminal uses java programming language, myEclipse and mySql as tools with android system as running platform. It makes requests by browsing pages or clicking buttons. Then the coordinator makes logical judgment and processing. If the command is to display the data, the data will be encapsulated and transmitted to the mobile terminal for analyzing and displaying. If the control instruction is received, the instruction will be transmitted to the coordinator to eliminate the alarm.

5. System testing
After the completion of the system design, the connection simulation was implemented and evaluated in two adjacent large classrooms to verify the feasibility of the scheme. Each classroom was equipped with multiple rows of seats and every three rows of seats were equipped with two sound sensors at both ends of the row. Each sound sensor had a zigbee module and each classroom was equipped with a
camera and a zigbee router. In addition, a coordinator, a video processing module, a PC and an intelligent terminal were also equipped. The system test mainly includes the speed and stability of networking, the accuracy of data acquisition of the sensor, the response speed of data transmission and the simulation work of each node. Test results showed that the router build the zigbee network after all nodes powered on, all terminals can join the network normally and the data acquisition of each terminal node is accurate. When simulating the abnormal situation, the coordinator and the intelligent terminal can alarm and display the information in real time. The response speed is high and there is no false alarm phenomenon, which meets the requirements of the system design.

6. Conclusions
A train carriage alarm system based on Zigbee is designed which realizes the functions of multi-point measurement and display of the decibel, manual setting of decibel threshold, automatic alarming of abnormal situation and so on. It solves the potential safety problems caused by the imperfect monitoring measures in the related technology of train abnormal detection. The design of this system has the characteristics of convenient maintenance, high intelligence, low cost, low power consumption, timely alarm, accurate data and low false alarm rate. It not only guarantees the accuracy and real-time of safety warning in train operation, but also has strong expansibility and portability. It has practical significance in improving train safety.

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References
[1] Li Yuwei. Research and Design Implement of Wireless Sensor Network Protocol based on Zigbee [D]. Nanjing University of Posts and Telecommunications, 2014:14-22.
[2] LI Y, GE NM, CHEN J. Design of Wireless Monitoring System for Multi-Sensor Internet of Things Based on Zigbee [J]. Automation Technology and Application, 2015, 34(1): 47-51.
[3] Huang ZX, Shan HT, Zhou JY, et al. Environmental Safety Monitoring System for Campus Dormitory based on Zigbee[J]. Measurement and control technology, 2019, 38(3):42-46.
[4] Duan FR, Shi JF. A Real-time Acquisition System for Greenhouse Data Based on Zigbee Technology [J]. Automation and Instruments, 2015, 30(10):41-44.
[5] Das A, Ganesh A. A study paper on power management in electrical devices using Zigbee network[C]//International Conference on Advance Computing Conference, Banglore, 2015: 444-448.
[6] Guo CL ,Wang H. Design of the Greenhouses Wireless Monitoring System Based on Zigbee Technology [J]. Journal of Huanggang Polytechnic, 2017(03).
[7] REN Y, SHEN RY, HE Q, et al. Soil Temperature and Humidity Monitoring System Design for Farm Land Based on Zigbee Communication Technology [C]//International Conference on Energy, Power, Environment and Computer Application. Wuhan: China, 2019:191-195.
[8] Zhong DX, Ji W, Liu YL, et al. An improved routing algorithm of Zigbee wireless sensor network for smart home system [C]// Proceedings of the 5th International Conference on Automation, Robotics and Applications (ICARA), Dalian, 2016: 346 -350.
[9] Su GL, Zhu Y. Smart Home System Based on ZigBee Wireless Sensor Network [J]. Application of Computer System, 2015, 24(6):66-70.
[10] Song XD, Shen GZ, Li ZB, et al. Design and Realization of Intelligent Home System based on Zigbee Internet of Things Technology [J]. Scientific and Technological Innovation, 2018(17).