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Design of Green Energy Intelligent Security Warning System Based on ZigBee

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Abstract: In this article, the author explores the design and system simulation of an intelligent security warning system based on ZigBee technology and green energy applications. The system architecture, functional modules, working principles, and advantages in energy saving and intelligence were elaborated in detail, and its effectiveness and reliability were verified through system simulation.

Keywords: ZigBee; Green Energy; Security Warning System; System Simulation

1. Introduction

Intelligent security warning system generally refers to a warning system used for home security, which, together with various sensors, function keys, detectors, and actuators in the home, constitutes the security system of the home. It can automatically alarm for accidents such as robbery, theft, fire, gas, emergency assistance, etc., and is an active behavior. For the safety protection of public areas, video surveillance is still the main method, lacking real-time proactive behavior. the security protection of residential communities usually involves installing cameras, access control, probes, RFID, alarms, and IP broadcasts at specific locations within the community, and using a dedicated network to transmit data to a management platform for monitoring.

The existing public area security warning schemes can be roughly divided into two types according to the warning scope: (1) applied to monitoring scenarios in smaller geographical areas of parks or communities for warning. Generally, the data collected by the camera collection terminal is transmitted back to the locally deployed video surveillance analysis platform through wired networks or wireless WiFi. (2) Applied in the scenario of unified monitoring of multiple public venues, communities, or parks, it is generally achieved by connecting terminal collection devices to local IP router devices through wired networks, further connecting them to the operator's data carrier network, and then connecting them to a centrally deployed cloud data center for video storage and processing.

However, the above security solutions bring three problems: (1) from the perspective of installation and deployment: traditional monitoring deployment uses wired methods, which have high wiring costs, low efficiency, and consume a large amount of wired network resources, while also causing inflexibility in networking methods. If Wi Fi backhaul is used, the stability is poor and the coverage area is small. A large number of routing nodes need to be added to ensure coverage and stability. (2) From the perspective of basic network, it is necessary to transmit monitoring information to cloud servers for storage and processing through the carrier network and core network of the operator, which not only increases the network load and cost expenditure, but also makes it difficult to effectively guarantee end-to-end low latency business key indicators. (3) From the perspective of security terminal equipment performance: camera acquisition terminals must have strong data acquisition capabilities, and there is inevitably a problem of cost-effectiveness.

In today's era of rapid technological advancement, the rapidly developing power of technology has enabled the widespread use of Internet of Things (IoT) technology, leading to unprecedented significant progress in many fields such as smart homes and industrial automation. With the rapid development of IoT technology, intelligent security systems have become an important means of ensuring public safety and personal privacy. ZigBee, as a low-power and low-cost wireless communication protocol, has been widely used in fields such as smart homes and industrial automation due to its unique networking capabilities and low energy consumption characteristics. ZigBee networks support multiple topologies, including star, tree, and mesh topologies, and can adapt to different physical environments and requirements. In addition, with the advancement of machine learning technology, especially the application of deep learning algorithms, intelligent security systems can not only monitor environmental changes in real time, but also self optimize through situational awareness and learning capabilities, improving the system's intelligence and response speed.

In response to the above issues, in order to reduce the cost of security in public areas, enhance the flexibility of system applications, and highlight the characteristics of the green, environmentally friendly, and energy-saving era, a ZigBee based green electric intelligent security warning system is proposed. the system consists of ZigBee wireless modules, thin-film solar cell chips, radar infrared sensing modules, control modules, brackets, connecting structural components, etc.

2. System Functional Design

The system designed for public area security warning will have the following functions: (1) remote monitoring, control, strategy issuance, fault alarm, group control, etc; (2) Intelligent control of equipment; (3) Unique light distribution warning technology, achieving low-power and high-efficiency operation mode; (4) New energy generation and lithium-ion storage, safe to use, with a beautiful and elegant appearance.

2.1 Overall System Design

ZigBee is a new type of wireless communication technology with the characteristics of close range, low cost, and low power consumption, suitable for a series of electronic component devices with short transmission range and low data transmission rate. Compared to traditional network communication technology, ZigBee wireless communication technology exhibits more efficient and convenient features.

2.1.1 Composition of Warning System

According to the system proposed above, the ZigBee based security warning system designed for this project will consist of multiple security monitoring nodes and a coordinator. ZigBee will be used for data transmission between the coordinator and the nodes, as shown in ***Figure 1***. Each node is composed of a human sensing module, a disaster detection module, an alarm module, a lighting control module, a main control module, a communication module, and a power module to form a self-contained power supply system with control, communication, detection, and alarm functions.

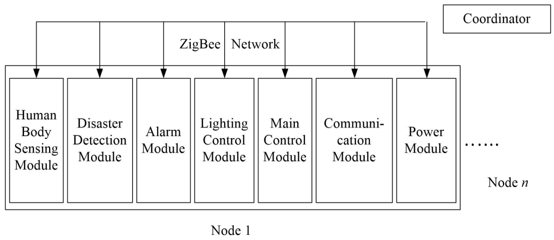

Figure 1. Overall Composition Diagram

2.1.2 System scheme design

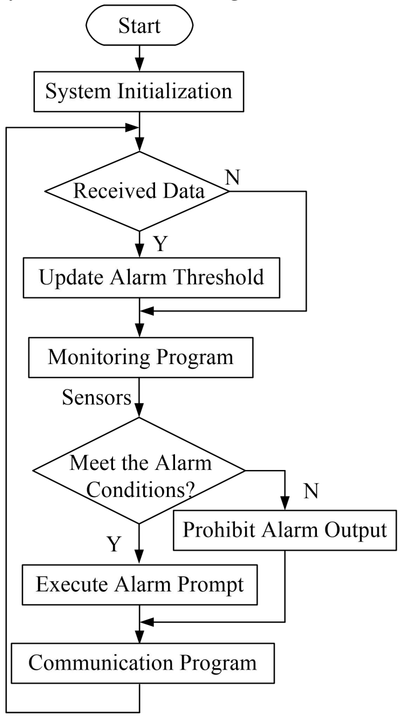

Figure 2. Main Flow Diagram of Monitoring Node Program

According to the system architecture, the system design consists of two parts: nodes and coordinator. Develop a program execution process based on system functionality. After the node main program is executed, configure the external pins of the microprocessor chip and provide a clear initial state for each unit circuit. After the main program of the monitoring node is executed, configure the external pins of the AT89C51 chip and provide a clear initial state for each unit circuit. the main program execution process of the monitoring node after configuration is shown in ***Figure 2***.

2.2 Wireless Network Node Design Scheme

2.2.1 Monitoring Node Scheme

The hardware module of the monitoring node should have the following functions: design a human body sensing module to detect whether there are personnel in the danger zone within the monitoring area; Design a disaster detection module to detect whether there is a spontaneous combustion disaster in the monitoring area; Design a lighting control module to control changes in lighting and alert personnel whether they are in a hazardous area through changes in lighting; Design an alarm module to send alarm signals and enable broadcasting function; the purpose of designing a power module is to provide electrical energy for the operation of various components in the node hardware; the purpose of designing the main control module and communication module is to establish communication with the coordinator, while also controlling various hardware modules. The overall structure diagram of the monitoring nodes is shown in ***Figure 3***.

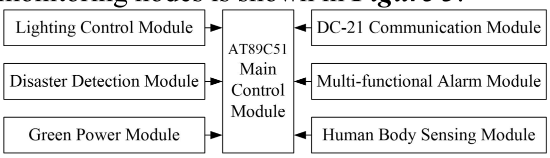

Figure 3. Overall Structure Diagram of Monitoring Nodes

The selection analysis of each module is as follows:

(1) the main control module is implemented using AT89C51 chip, and the communication module is implemented using ZigBee wireless module DL-21. the communication and control scheme using AT89C51 and DL-21 wireless modules has two advantages compared to the traditional CC2530 module scheme. Firstly, it avoids the cumbersome protocol stack at the bottom layer, greatly reducing the amount of software code design. the second is to delegate communication and control to different modules, which can ensure the real-time performance of the system.

(2) the human body sensing module is implemented using HC-SR501. Compared to HC-SR04 ultrasonic sensing module or other laser tube sensing modules, HC-SR501 module is less expensive, has a wider monitoring angle, and has very high real-time and accuracy.

(3) the early warning monitoring module is implemented using the MQ-2 sensor and AD0832 chip acquisition scheme. Compared to traditional warning monitoring sensors, this configuration can monitor the appearance, warning, and prompt of targets in the monitoring area environment in real time, which helps monitoring personnel to grasp the sudden information of dangerous situations in the area in real time. In addition, when the alarm threshold in certain usage environments is a variable, this solution can also meet the design requirements well.

(4) Implementation of alarm selection buzzer and indicator light. Compared with voice alarm schemes and Chinese short message alarm schemes, using sound and light alarm schemes is cost-effective, stable and reliable, and does not require too much software support for functional implementation, which will greatly reduce the overall implementation difficulty of the system.

(5) Install ZigBee coordinator software on the network coordinator and position it at the center; Use the ZigBee protocol stack in the ZigBee coordinator software to connect a sensor node for preliminary testing.

(6) Apply thin-film solar cells for power generation, providing green energy for the entire system equipment. Fully utilize the unique "light, thin, and flexible" characteristics of thin-film solar energy, and integrate it with public facilities according to local conditions. Using stacked 30Ah polymer lithium batteries for power storage, with high safety and long duration; Using high-efficiency and low-power LEDs to achieve low overall temperature, long lifespan, and minimal light decay of the lighting fixtures. Design a power generation and energy storage lighting control system for monitoring, control, feedback, fault alarm and other functions, to achieve high brightness and low brightness for people, and to improve battery usage time and lifespan.

2.2.2 Overall Circuit Design of Monitoring Nodes

When designing the overall circuit of the monitoring node, it should be ensured that the pins corresponding to the processor and each functional circuit are connected together to output the hardware control circuit; Develop the execution sequence for the overall circuit operation of monitoring nodes. When designing the overall circuit of the monitoring node, connect the AT89C51 core and the corresponding pins of each functional circuit together to output the hardware control circuit. Connect the positive and negative terminals of all device power supplies to both ends of a 5V power supply. Connect the AT89C51 chip, HC-SR501 module, DL-21 and other devices together according to the above wiring method to construct the overall circuit of the monitoring node hardware.

When monitoring the overall circuit operation of the monitoring node, the following operations should be performed in sequence:

(1) Read the output voltage of pin P1.7 to determine if any unauthorized personnel have entered the monitoring area.

(2) Using the serial port sending function of AT89C51 chip, the measurement data of this machine is sent to the coordinator through the DL-21 wireless module. By processing the interrupt received through the serial port, obtain the disaster alarm values issued by the coordinator.

(3) When the measured disaster value is greater than the alarm value set by the coordinator or when illegal personnel enter the monitoring area, operate pin P1.7 to issue an alarm command, control the buzzer and indicator light to work and output warning information.

(4) When the proximity value of the target within the domain is detected to be greater than the alarm value set by the coordinator, operate pin P1.7 to issue an alarm command and turn on the warning light to remind, control the buzzer and indicator light to work and output warning information.

2.3 Coordinator Node Design Scheme

The coordinator end is designed with 6 hardware modules, and a button module is designed to receive disaster alarm value commands input by users. the purpose of designing the main control module and communication module is to establish communication with nodes and complete the control of various hardware modules. the purpose of designing an alarm module is to output warning information when any node experiences an abnormal alarm event. the purpose of designing a display module is to display the information uploaded by nodes, the information used for input, and the alarm status information of nodes. the purpose of designing a power module is to provide electrical energy for the operation of various components in the node hardware. the overall structure diagram of the coordinator end is shown in ***Figure 4***.

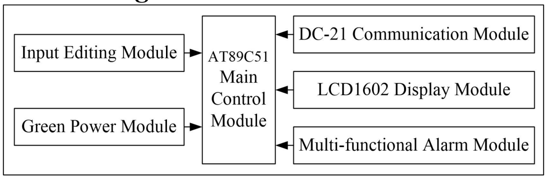

Figure 4. Overall Structure Diagram of the Coordinator End

The selection principles and monitoring nodes for the communication module, main control module, and alarm module on the coordinator side are the same, and the document will not repeat the discussion. Select the 1602 LCD screen scheme to implement the display module. Compared to digital tubes or 12864 display solutions, the 1602 LCD screen display solution has lower power consumption and lower design costs, as well as intuitive and clear display effects, effectively solving the problem of information interaction between users and devices.

2.4 Energy and Lighting Control System Design

The designed energy and lighting control system has monitoring functions, real-time monitoring of solar power generation, battery power, lighting fixture working status, etc. the system can automatically adjust the brightness of the lights based on the presence of personnel. When someone is present, the brightness of the lights increases; After people leave, the brightness of the lights decreases to save energy. the designed feedback alarm system provides users with feedback on the system's operating status, such as battery level, lighting failures, and other information, for timely maintenance and management. When the system malfunctions, such as damaged solar cells, low battery power, or lighting failures, it can promptly issue alarm signals to remind users to carry out repairs.

3. Application and Implementation of System Functions

When applying intelligent security warning systems, set corresponding thresholds for each type of sensor based on specific monitoring targets and application scenarios. Use the configuration function in the ZigBee coordinator software to send configuration commands to sensor nodes through the ZigBee protocol stack. Use the testing function in the ZigBee coordinator software to simulate different environmental temperatures and verify whether the behavior of sensor nodes meets the expected threshold triggering conditions. If the test results do not meet expectations, fine tune the threshold and trigger conditions, continuously iterate the testing and adjustment process until the performance reaches the expected level. In the process of aggregating sensor data into the coordinator, first start the Node RED data receiving application in the ZigBee coordinator software and add ZigBee input nodes; Next, configure the ZigBee input node connection port and set communication parameters; Then drag and drop the ZigBee input node onto the canvas of the Node RED editor, and add function nodes to process the received data; Finally, add a debugging node to view the received data, connect to the node and deploy Node RED. Use the conditional nodes in Node RED to determine if the data meets the alert conditions. When the conditions are met, use function nodes to construct alert messages and send them to users of the corresponding roles through MQTT nodes.

In the intelligent security warning system, sensors are used to collect network load and distance data between nodes, and a deep reinforcement learning algorithm is used to train a model to automatically adjust the transmission power. Deploy sensor nodes in ZigBee networks, with each node equipped with a dedicated network load sensor; Use ZigBee coordinator software to record network load data for each node; Measure the distance between nodes using RSSI method. Define a state space S in the system, where each state $s \in S$ is composed of network load L and inter node distance D, i. e. $s = (L, D)$. Define a reward function to evaluate the effectiveness of actions in a state. Choose DQN algorithm as the basic algorithm and improve it to adapt to specific network environments and requirements. Design a multi-layer neural network in the system, where the input layer receives the state s and the output layer predicts the Q value corresponding to each action a; Use experience replay mechanism to store and replay the correlation between experience reduced data, while regularly updating the target Q value through the target network.

When the value of R is too high, it is an ideal situation, indicating that the action taken is beneficial in reducing network load, shortening the distance between nodes, and adjusting the transmission power relatively small in the state. When the values of the two are equal, it is a normal situation, indicating that the current action maintains the network efficiency at a stable level, without significantly reducing network load and inter node distance, nor increasing too much transmission power adjustment. When the value of R is small, it is a non ideal situation, indicating that the action taken is not conducive to reducing network load and shortening the distance between nodes in the state, and the transmission power adjustment is relatively large.

4. System Simulation and Analysis

After the system design is completed, the performance of the ZigBee based security warning system is simulated and analyzed using the discrete event driven network simulator ns-3 to ensure that the system output meets the design requirements. From the test results, it can be seen that the system can work normally in initialization mode, normal working mode, and alarm mode. the simulation results show that the functions implemented by the nodes and coordinators meet the design requirements of the system. By analyzing the simulation results of ZigBee based security warning systems in various scenarios, the following conclusions are drawn: the first, the ZigBee based security warning system has strong self-healing ability, and even if some nodes fail, the network can still maintain stable connection. the second, the throughput of ZigBee based security warning systems is relatively high over short distances, making them suitable for transmitting small amounts of data, such as sensor data. the third, the ZigBee based security warning system has low latency and can meet the needs of real-time monitoring.

5. Conclusion

In summary, ZigBee technology has significant advantages in the design of smart green power security warning systems, not only improving system performance and reliability, but also reducing system costs and maintenance difficulties. Through system simulation analysis, the system can achieve intelligent inspection and monitoring of disasters and illegal personnel intrusion information in the monitoring environment, and can also achieve linkage alarm; the simulation outputs from nodes and coordinators indicate that the designed security warning system has achieved the expected results, verifying the feasibility and performance advantages of ZigBee technology in smart green electricity security warning systems. With the continuous development of ZigBee technology and further improvement of system design, ZigBee based smart green power security warning systems will play a more important role in the security field.

Acknowledgments

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