Design and Implementation of Fire Monitoring System Based on Wireless Sensor Network

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Abstract: With the maturity of communication technology, embedded computing technology and sensor technology, people have developed wireless sensor nodes with sensing, computing and communication capabilities. Wireless Sensor Networks (WSNs) are multi-hop ad hoc networks composed of multiple sensor nodes. The feasibility of wireless sensor network applied to fire monitoring is discussed, and the solution of fire wireless detection node is given. It combines sensor technology, embedded technology, distributed information processing technology and communication technology to monitor and sense the environment in real time. And it also can process the collected information and transmit it to users who need it.

1. Introduction

Fire is one of the most frequent and widespread threats to public safety in the world today. It has caused many serious losses to life and property to human society. With the continuous development of society, while the social wealth is increasing, the risk factors for fires are also increasing, and the danger of fires is increasing[1]. Fires endanger human life and health, hinder economic prosperity and development, and thus generate ever-expanding fire safety requirements[2]. It is the direct guide and original driving force for the development of fire science and fire technology. Fire detectors are effective guarantees for early warning of fires, prevention of fires, and timely fire suppression.

The energy supply and information transmission of the traditional fire detectors are usually connected by cable wires. The laying of the cables during the installation process is not only expensive, but also it takes a lot of work, and is sometimes destructive to the building structure[3]. In some special occasions, such as fire safety in ancient buildings, emergency detection of hazardous chemical spills, and other places where manpower is difficult to reach, wired detectors are difficult to apply. Therefore, combining fire detection technology with wireless communication technology to realize wireless, network and intelligent fire detection is a new important direction of fire detection research. In recent years, the rapid development of a low-cost, low-power, small-volume, short-range wireless communication technology and Wireless Sensor Network (WSN) technology, has brought a new revolution in the field of fire safety[4]. The wireless sensor network adopts wireless communication technology and a small-volume, low-power micro-sensor, which is composed of a large number of micro-sensor nodes deployed in the monitoring area. And it forms a multi-hop

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self-organizing network system through wireless communication[5]. It is a device that can collaboratively sense, collect, and process perceptual objects within a network coverage area.

In this paper, multi-sensors are designed to monitor the characteristic signals of different stages of fire occurrence. The data fusion method is used to comprehensively judge various fire monitoring data, reduce the non-correlation between multi-sensor data, and improve the accuracy of fire monitoring. The designed fire monitoring system uses the mature In-ternet and ZigBee technology, combined with Dempster-Shafer (D-S) evidence theory to fuse multi-sensor data, the fire detection fusion results show that the system has high credibility and strongscalability.

2. Wireless Sensor Network Architecture

2.1 System configuration of wireless sensor network

A typical wireless sensor network system, including distributed sensor nodes, gateways, the Internet, users, and so on. The sensor node is used to collect sensor data and is a miniature embedded system, which constitutes the base layer support platform of the wireless sensor network. In addition to local information collection and data processing, it deployes multiple sensor nodes in the monitoring area store. It also manages and fuses data forwarded by other nodes, and cooperates with other nodes to accomplish certain tasks[6]. In these nodes, there is usually a sink node, which is responsible for transmitting data of other nodes to the gateway. The function of the gateway is to connect the external network such as the sensor network and the Internet to realize the communication protocol conversion between the two networks. It can access the Internet and transfer data to a web server so that users can easily access and retrieve the required data over the Internet.

2.2 Wireless sensor network node

A wireless sensor network node is an object deployed in a wireless sensor network to a research area for collecting and forwarding information and collaborating to perform specified tasks. The programs running on each node can be identical, but the ID is unique. The wireless sensor network node is generally composed of a processor module (including a CPU, a memory, an embedded operating system, etc.), a wireless communication module, a sensor, an AD conversion module, and an energy supply module, as shown in figure 1.

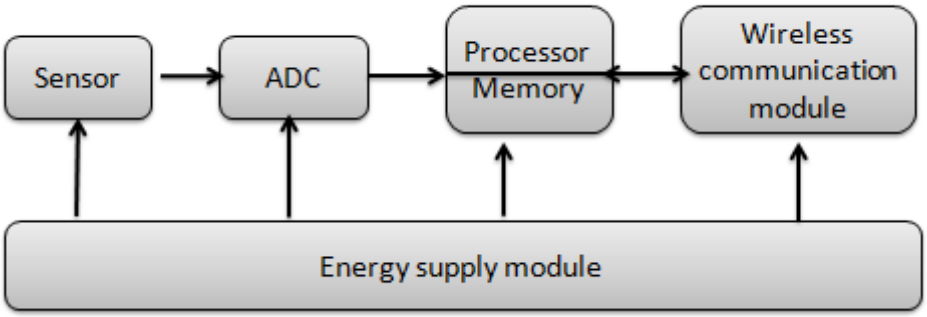

Figure 1. Node hardware block diagram

In essence, a wireless sensor node is a networked distributed embedded system that communicates between networks over a wireless channel. In order to reduce the amount of communication, the necessary calculations are performed locally for data fusion, thereby collaborating to complete the collection of deployment spatial data. The sensor is a module that

senses external physical information, and generally includes a sensor probe and a transmission system. The probe can sense physical information such as external temperature, luminosity or magnetic field, and send the perceived physical quantity to the transmission system. The transmission system converts it into the original electrical signal that the system can recognize. Usually, the electrical signal is very weak and needs to be performed. The amplification process is then output to the A/D conversion module, and finally the information of the sensing object becomes a digital signal that can be processed and stored by the processor module.

3. The Analysis and Design of Wireless Sensor Network Fire Monitoring System

3.1 System function requirements analysis

The main purpose of fire monitoring is to grasp the real-time status of the environmental parameters and historical data in the monitoring range, and provide an effective basis for the monitoring personnel to predict and control the fire. Therefore, the fire monitoring system must have real-time data collection and historical data. Basic functions are such as query, view of node information, and setting of alarm values. From the application point of view, the main functions of the fire monitoring system designed in this paper are divided into:

3.1.1 Data collection

1) Collect conventional fire parameters, and the collected parameters must be consistent with the measured environment. Accurate phenomena occur to ensure the accuracy of the data.

2) All the collected data information is transmitted wirelessly to the remote server, and the collected data is verified at the same time. The packet data is secondarily transmitted in time to ensure the validity of the transmission.

3.1.2 Data monitoring

1) The received data is processed in turn, and the processed data is displayed in real time. At the same time, the data and the reference value are compared and analyzed, and the node with the disaster is alarmed to notify the manager to view.

2) Store the node information, data information and analysis results of each monitoring point to provide data basis for the prediction of fire and escape path planning by the later algorithm.

3.2 Overall design of wireless sensor network fire monitoring node

According to the requirements of fire monitoring, this paper designs the hardware of the fire monitoring node. The hardware of the fire monitoring node consists of a fire sensor module, a ZigBee module, and a power module. The fire sensor module includes module circuits such as temperature, humidity, smoke concentration, and flame. The ZigBee module uses a single-chip integration scheme consisting of an on-chip MCU unit, storage unit, I/O interface, and RF transceiver, taking into account the relatively closed environment within the building and the relatively weak penetration of the 2.4 GHz signal. In the module design, it is divided into two types. The first one is the traditional ZigBee module without PA, which is used for the space with relatively empty space, the area with low transmission distance requirement. And the second is the new ZigBee with PA. Module for areas that need to penetrate walls or floors, as well as areas that are far away from the transmission. The power module provides energy for the normal operation of the whole node. The power module adopts different design schemes according to the energy consumption of different nodes, and is mainly divided into two modes: battery power supply and AC power supply.

3.3 Toverall design of wireless sensor network fire monitoring data monitoring center

The data monitoring center is an important part of the entire upper monitoring system. All the data of the monitoring system will eventually be collected here. According to the overall design requirements of the system, the data monitoring center should have the following functions:

(1) Support multiple communication methods: While considering the functions of the system, it can be applied to today's mainstream communication technologies. It should try to support more upper communication methods, and reduce other hardware support.

(2) Timely and effective data storage: Adding database functions can store real-time data efficiently.

(3) Intuitive and simple HMI: The man-machine picture with simple design and easy operation, while ensuring the functions of each part, reduces the difficulty of monitoring personnel and facilitates the later upgrade of the system.

(4) Alarm parameter setting: It is possible to set the alarm value of each parameter and timely and accurately transmit the alarm information to the staff.

4. Multi-Sensor Information Fusion

A single sensor often acquires a certain attribute information of a measurement object and is easily interfered by other factors of the environment. The occurrence of fire will produce characteristic signals such as changes in light, smoke, temperature, radiation and gas concentration. The CO concentration, temperature and smoke collected by the terminal nodes will be comprehensively used to determine whether a fire has occurred, which is beneficial to improve the fire detection performance.

The terminal node wirelessly transmits the obtained CO, temperature, and smoke values to the intelligent gateway, and the intelligent gateway obtains the fire occurrence probability of various components according to the specific numerical calculation and the trust degree function, and determines whether the fire occurs according to the set threshold, such as shown in table 1.

Table 1. Fire Probability Distribution of Multi-Sebsor

Sensor	Fire probability	No fire probability	Uncertain probability	Fire situation
Temperature	0.7	0.1	0.2	Yes
CO	0.4	0.1	0.5	Uncertain
Smoke	0.5	0.2	0.3	Not

The temperature value judges the occurrence of the fire. The smoke concentration value judges the occurrence of the fire. The CO cannot determine the fire. It can be seen that it is difficult for a single-sensor to accurately determine whether a fire has occurred and has a large uncertainty. The CO, temperature, and smoke values obtained by the three sensors were fused according to the D-S evidence theory. The results are shown in Table 2.

Table 2. Fire distribution and fusion of multi-sensor

Sensor	Fire probability	No fire probability	Uncertain probability	Fire situation
Temperature	0.700	0.100	0.200	Yes
CO	0.400	0.100	0.500	Uncertain
Smoke	0.500	0.200	0.100	Not
Fusion	0.873	0.085	0.042	Not

The data shows that the probability of a fire is increased from a single sensor maximum of 0.7 to 0.873, and the uncertainty probability is reduced to 0.042. Without the temperature and smoke sensor, the carbon monoxide gas sensor cannot confirm the fire. The occurrence of defects eliminates the contradiction between multi-sensor data and greatly improves the accuracy of judgment.

When a large amount of data is transmitted, the serial port method cannot guarantee the fastness and validity of data transmission. In order to prevent this from happening, this paper designs the TCP/IP transmission mode. The ZigBee network is different from the TCP/IP protocol, so this paper designed the ZigBee-WIFI gateway. The gateway is mainly composed of a ZigBee module, a WiFi module, a gateway controller module, and a display module. ZigBee module adopts ZigBee coordinator, which is responsible for ZigBee network establishment and node data collection. WiFi module adopts integrated chip solution, which is mainly responsible for sending data to the Internet. Gateway controller module is the bridge between ZigBee module and WiFi module, and the data sent by the ZigBee module is sent to the WiFi module through the transfer processing. The display module is convenient for the user to operate through the entire process state of the liquid crystal display gateway configuration.

5. Conclusion

The wireless multi-sensor information fusion fire detection system proposed in this paper uses D-S evidence theory to fuse multi-sensor information, which can more fully perceive the fire state than a single sensor. And it more accurately detects whether there is fire and reduces the false alarm rate. It improves the credibility of the system. At the same time, the flexibility of the ZigBee wireless network allows the system to arbitrarily expand the number and location of monitoring nodes. The system is flexible and scalable, and expands the fire system monitoring capability.

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