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Design of Wireless Automatic Fire Alarm System

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Abstract

To meet the application requirements of wireless automatic fire alarm system, based on the analysis of the applicable sites of wireless fire alarm system and the characteristics of communication service, this paper designs a dedicated wireless communication protocol for fire detection and alarm, and develops a complete set of wireless automatic fire alarm system, to achieve rapid fire detection and alarm and state supervision of fire-fighting facilities with low power consumption.

Peer-review under responsibility of the organizing committee of ICPFFPE 2015

Keywords: wireless communication; inspection protocol; fire alarm system

1. Introduction

In recent years, with the rise of the Internet of Things technology and wide spread of big data, cloud computing and other concepts, wireless communication-based automatic fire alarm system has attracted extensive attention at home and abroad. Although the construction and wiring of dual bus system has been relatively simple, but there are still problems of high installation and maintenance costs, as well as upgrading difficulty, especially for families and some special applications where actual needs have been unable to meet. For example, in ancient relics, in the installation process of wired fire alarm system, slotting and through-wall duct installation are required and can cause damage to buildings. So wired fire alarm system is not applicable. In addition, for buildings with multiple property rights, small street shops and temporary buildings, etc., wireless system is very suitable.

The convenient installation of wireless fire alarm system requires no through-wall ducting and wiring, with no damage to buildings, and is adaptable to changes of use and function of buildings, therefore attracting wide attention of researchers at home and abroad. 2.4G wireless networking technology, represented by zigbee, is a common technology used in automatic fire alarm system. But 2.4G transmission's advantage lies only in the range of visibility, and obstacles still present significant influence to its transmission. For some large scale and complicatedly separated buildings, to ensure better transmission quality of 2.4G network, large number of relays or radiation power increase will be needed, which will result in increased costs, conflicting with the low-cost, low-power target of wireless fire alarm system.

In view of the above problems, this paper analyzes the business characteristics of wireless fire alarm, proposes 433M wireless fire alarm system architecture and dedicated communication protocol scheme, and completes the design of a wireless fire alarm system, in order to solve the actual firefighting requirements of 3-in-1 places, multi-property street shops, brick or wooden historical buildings, temporary buildings and other places.

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2. System Architecture Design

Wired automatic fire alarm system takes high cost, and is difficult in construction, but wired signal transmission, and sheath and brass pipe protection ensure high signal quality, therefore realizing a high-capacity, high-stability system. Wireless fire alarm system uses open signal transmission, which is greatly influenced by distance and obstructions, so that the system transmission rate and capacity are slightly lower compared to wired system; and in order to ensure error-free real-time transmission of fire alarm signal and fire-fighting facility's monitoring signal, the system scale should not be set too large. Thus, for the application mode of wireless fire alarm system, different design of architectural pattern should be adopted depending on available fire-fighting facilities on site:

1) For large-scale buildings where wired system has been set, when the layout of internal unit changes, or local transformation or expansion of existing systems is needed as building units partially increase, the wireless system can be used as a supplementary sub-system connected to the existing wired system of cable systems. Under this combination mode, the wired system still serves as backbone network with high overall system stability, while wireless system is used depending on local environmental characteristics, to realize configuration flexibility, and low cost of transformation;

2) For small-scale buildings where wired system has not been set, or temporary buildings with period of service, wireless form shall be used for the entire automatic fire alarm system as the system capacity is not large and can ensure error-free real-time signal transmission.

According to the two different situations, this system adopts two separate architecture modes to be used in full wireless communication environment and combined wired-wireless environment, which can be connected to fire alarm controller respectively through wireless signals or CAN bus, as shown in Figure 1. The whole system consists of a fire alarm controller, relay modules, and field modules:

1) Router. Router provide externally data exchange interface of wireless fire alarm system, and are responsible for establishing a local wireless network to connect with the field modules by way of 433M RF as well as polling on field modules. Fire power is used as power supply. Compared with 2.4G band, 433M RF wavelength is longer, and can pass easily around obstacles with interference resistance, so it is suitable for use as foundation communication technology of wireless automatic fire alarm system.

Both wired and wireless connection between the fire alarm controller and Router can be chosen according to the field environment: CAN bus communication for wired system, and 433M RF or GPRS communication for wireless system. Router only report to the controller when fire signal or fault signal is polled.

2) Field modules. Field modules include 3 types: fire trigger module, facility monitoring module, and output module. The fire trigger module comprises fire detector and manual alarm button. The facility monitoring module includes fire door monitoring device, and fire hydrant pressure monitoring device. The output module includes sound and light alarm and linkage output module, etc.

Multiple Router can be set up to connect with the fire alarm controller. Each relay module manages part of the fire trigger modules, facility monitoring modules and output modules, establishing its own network of same frequency. Between networks built by different Router, frequency hopping is used to avoid same frequency interference. By extending the number of Router, complete coverage of business needs for field automatic fire alarm can be achieved.

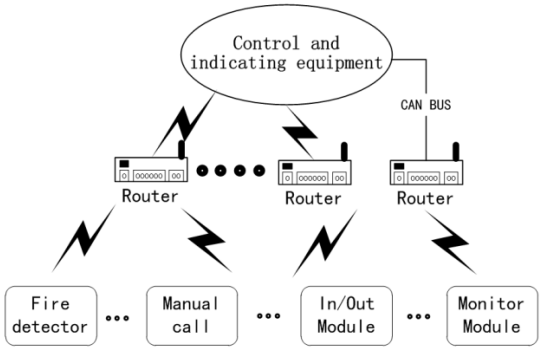

Fig. 1 Architecture of Wireless Fire Alarm System

3. Module Hardware Design

The Router and field modules in this system are designed and constructed as shown in Figure 2. The core control chip adopts TI MSP430 low-power chip, and wireless transmission function is based on MRF49XA RF chip. According to

"Technical Requirements for Micro-Power Radio Equipment", the wireless network is designed to work on 433MHz public free band, in line with the requirements of the National Radio Regulatory Commission. It supports frequency multiplexing of multi-points and frequency hopping technology, with high ability of frequency use. All modules support two-way transceiving and sleep/wake-up functions.

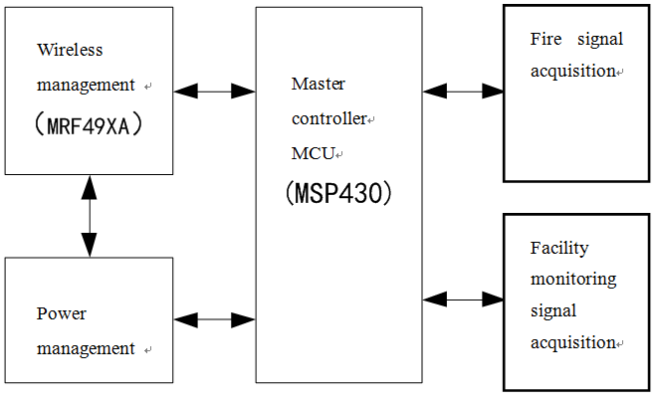

Fig. 2 Modules

4. Wireless Communication Design

4.1 Communication characteristics of wireless automatic fire alarm system

Communication of wireless automatic fire alarm system in wireless has very distinct characteristics:

1) Low data in single communication. The data required for the transmission by the automatic fire alarm system include the fire detection and alarm information and integrated fire control information. Most data types can be expressed as switch status, and length of each data is usually within a few bytes.

2) High real-time requirement. According to the requirements of GB4717-2005 *Fire Alarm Control Units*, the time from the detector's issuing a fire alarm signal to the controller's receiving should be controlled within the 10s, and when any module in the system fails, fire alarm controller should detect the fault in 100s.

3) Recurrent fault monitoring communication. To realize real-time monitoring of the status information of each module in the system and to meet the business requirement of acquiring the module fault condition within 100s, the system needs to query the module status at a fixed period.

4) Occasional fire alarm signal transmission. As a disaster, fire occurs at very low frequency in a certain building. Therefore, the transmission of fire alarm signals is incidental.

5) Power consumption constraints. Unlike wired system, modules in wireless alarm system are typically battery-powered, with limited energy. The battery life on actual site is usually required to last 1 year, so the wireless system's communication works under the constraints of limited energy.

For the above characteristics, the system fully compresses the communication data frame, and proposes polling protocol that can reduce communication energy consumption.

4.2 Communication frame design

Based on the wireless automatic fire alarm system communication features of low data in single communication but high real-time requirement, the communication frame is designed as shown in Figure 3. One frame of data contains a total of 10bytes. The small amount of data helps to reduce the transmission power consumption. In the date, lead byte and sync byte are fixed byte; type, status, and data fields all use 1 byte; source address and destination address of the address fields occupy one byte each. Type and status of various types of detectors and fire-fighting facilities are bit-encoded into 1 byte, with a total of 256 kinds of type and 256 kinds of status.

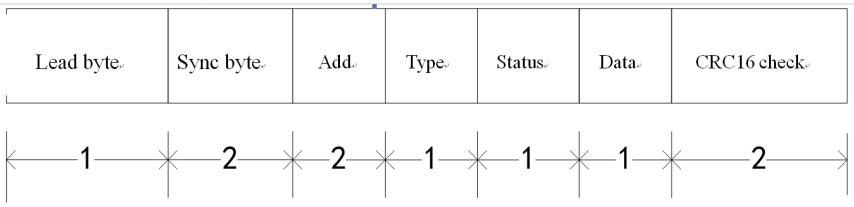

Fig. 3 Communication Frame

4.3 Interval inserting polling logic design

Based on the system communication feature of power consumption constraints, the more frequent the communication is, the faster the battery power consumes; while according to features of real-time communication and recurrence, the more the network points are, the more communications will occur in one polling cycle. Thus, the network size and power consumption optimization is a pair of mutual restraint parameters.

In one polling cycle, a same frequency network divides TDA of each field module by TDMA, sets a series of query fields according to module quantity of the network and assigns to each field module. Each field module is waked up by the arrival of its own query field. After the relay module has carried out 1 status query of the field module, the latter will re-enter the sleep state.

To realize real-time detection of fire, each field module wakes up the MCU to detect fire at regular intervals, and wireless function remains asleep. Without fire, it will immediately re-enter the sleep state; if a fire is detected, wireless function will be waked up and maintained.

In the time interval between querying two adjacent address modules, the relay module will insert a single fire query instruction to all the fire trigger modules. Due to the wake-sleep policy setting, only the fire trigger modules in fire alarm state remain awake and can answer the query.

The above polling logic design has three characteristics:

1) The polling cycle can be lengthened as much as possible, so that in the absence of regular monitoring of fire, the number of module communications will decline, thus reducing the communication power consumption.

2) The main load of network traffic moves to the relay module. As the relay module uses fire power supply, there is no power consumption constraint, realizing high practicality on the actual site.

3) When a fire occurs, through the use of interval between two polling queries, insert a fire polling instruction to avoid potential fire alarm transmission delay after lengthening of polling cycle, and alarm signal transmission will still be able to meet the real-time requirement.

5. Test

Each physical part of the system is shown in Figure 4. A test has been carried out according to fire safety standards with the wireless fire alarm system deployed in a building. The test results are shown in Table 1.

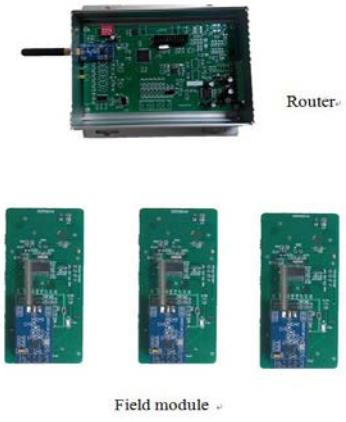

Fig. 4 Real Picture of Wireless Automatic Fire Alarm System

The field module communication radius can reach up to 35m in case of 1- wall barrier. A same frequency network can cover a total space of approximately 1,000 m^2. The communication radius will be longer in places without direct barrier wall. Also, the field module's operating current is less than 93μA; with 2400mAH battery, the maximum working life can be up to 3 years, which can meet the actual needs of 3-in-1 and other small places. The system's communication packet loss rate is as low as 1/11110, which means loss may occur once out of a thousand times of communication at most. And even if packet loss occurs, through inserting retry command into the interval between polling of two modules, lost packets can be regained. In addition, the timeliness of the system can be guaranteed. At the scale of 1 relay module managing 100 field modules, the fire alarm reporting time can be controlled within 5s, and the field module's failure discovery time can be controlled within 10s.

Table 1 Test Results

Parameter		Test Data
Field module communication radius within building	No direct barrier	50m
	1-wall barrier	20m～35m
	2-wall barrier	17m～25m
Average packet loss rate		＜1/11110
Average operating current of relay module		28mA
Average operating current of field module		＜93μA
Alarm response time		＜5s
Fault response time		＜10s

The test data shows that this system has sufficiently low operating current, short information transmission delay, and low packet loss rate, thus meeting the requirements on wireless fire alarm system of low power consumption, real-time transmission, and low error rate.

6. Conclusions

In summary, this paper analyzes the characteristics of automatic fire alarm system setting, proposes 433M wireless automatic fire alarm system architecture, designs and develops system module hardware, and designs a communication interval inserting polling logic that can effectively reduce the average power consumption based on analyzing and summarizing the characteristics of wireless automatic fire alarm system's communication behavior, thus completing the design and development of this wireless fire alarm system. Compared with 2.4G communication technology, this system uses the wavelength advantage of 433M RF signal, with strong diffraction ability. Compared with other low-megahertz RF communication wireless fire alarm network, the system features potential wired system integration and low average communication power consumption, whose application will help improve the fire safety level of 3-in-1 places, multi-property street shops, brick or wood relics and ancient buildings, temporary buildings and other places.

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References

[1] Kim Byoung-kug, Hong Sung-hwa, Hur Kyeong, et al, 2010. Journal of Energy-efficient and rapid time synchronization for wireless sensor networks. IEEE Transactions on Consumer Electronics 56, p. 2258.