Intelligent Building Fire Warning System With WSN

Gang Su
Department of Electronic and Information
Tianjin Institute of Urban Construction
Tianjin, China
sgltu@163.com

Hong Zhou
Faculty of Engineering and Surveying
University of Southern Queensland
Toowoomba, Australia
hong.zhou@usq.edu.au

Rui Gao
Department of Electronic and Information
Tianjin Institute of Urban Construction
Tianjin, China
gaorui223@yahoo.com.cn

***Abstract*—Fires disasters in a higher frequency often cause huge casualties and property damages. There are many problems in the existing wired fire alarm system, such as long construction period, large investment, maintenance problems, omissions, higher rate of false, etc. Cables are one of the weakest links. Once broken when the fire occurs, they will lead to signal failure in a large scope. Therefore, wireless fire alarm system is urgently demanded. With the development of WSN technology, it's possible to use wireless technology in fire alarm system. Currently, ZigBee technology is one of the most promising solutions with the features of low-rate, low–consumption and low-cost. In this paper, scheme of wireless fire monitoring network based on ZigBee is proposed. Fire information fusion system based on artificial neural network and fuzzy is setup. Reliability and accuracy of fire forecasts are improved.**

Keywords-WSN; ZigBee; intelligent; building; fire warning

I. INTRODUCTION

Building Fire Alarm System (BFAS) is a very important facility in early detection of fire. The reliability of system is the bottleneck of restricting the application, especially high omission rate and high false alarm rate. In traditional wired fire alarm system, probes are connected with controller through insulated copper wires within tube. If the installation of such system is completed, there are many defects, such as high cost, high power consumption, low anti-interference ability, complex design and construction, difficult to maintain, and so on. Even cause destruction of the building structure. Furthermore, because hard-wire connection is used, the lines are easy to aging or corrosion. It seriously affects the reliability of fire alarm system. It's inevitable that wired fire alarm system is replaced by wireless[1].

In this paper, WSN technology based on ZigBee with character of short distance, low speed, low cost, low power consumption is used in intelligent BFAS. Wireless sensor network node which combined with ZigBee and fire data fusion technology is designed. The nodes use temperature sensor, smoke sensor and CO sensor to capture the fire data at the same time in each stage when the fire broken, Build-in MCU in the node is used for data fusion. If fire is determined, alarm signal is send to the host, and fire process programs are executed. If suspected fire is determined, pre-alarm signal is send to the host. After receiving pre-alarm signal, the monitoring host start the data fusion network feature level and fuzzy logic decision level to make decision. In this design, wired fire alarm system is replaced by wireless. Complexity is reduced. Reliability and stability are improved. When nodes are installed, it needn't to wiring through the wall. Construction cost is reduced. This design is especially for ancient architectures and old buildings to install intelligent BFAS. Because data fusion technology is used, omission rate and false alarm rate are reduced, and reliability is improved.

II. OVERVIEW OF ZIGBEE

The ZigBee is a new short-distance, low data-rate wireless network technology. It is built on the IEEE 802.15.4 low-rate wireless personal area networks (WPAN) standard. The complete ZigBee standard stack architecture is shown in Figure 1. The IEEE 802.15.4 defines the physical layer (PHY) and media access control (MAC) layer. The stack above the network layer is defined by ZigBee alliance, it includes network layer and application layer standard[2][3].

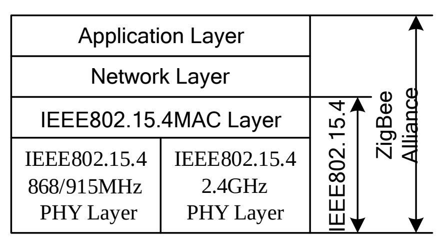

Figure 1. ZigBee standard stack architecture

The ZigBee devices can be divided in full function devices (FFD) and reduced function devices (RFD) .The FFD have all the operations and the RFD do not have. According to the function, the FFD device can work as a ZigBee coordinator or router in ZigBee network, and the RFD device can only be the ZigBee end devices.

The goal of the ZigBee alliance is to define a very low complexity, low-power consumption and low-data rate wireless network technology. So it can meet the demand of the BFAS system. The advantages of the ZigBee technology include followings:

- Low cost and low complexity.
- Low data bund rate: 10Kbps~250Kbps date rate fits the BFAS system.

• Low power consumption: the normal ZigBee device can work 6 months to 2 years with two AA batteries.

• High network capability: 65000 nodes per network.

• Stability and safety: CSMA/CA method for channel access. AES-128 Advanced Encryption Standard cryptography and trust-center based authentication for security.

III. LAYOUT OF NETWORK NODES

When the network nodes are laid in the building, the following requirements need to be met:

1) Monitoring network must be able to cover all areas of building

In order to ensure that various areas in the building can be monitored, each area must be laid a certain number of detector nodes. In the design of network parameters, as a ZigBee network can contain up to 65,000 nodes, network parameters *m*, *n* and *x* must meet the following relationship:

$$(1+n^2+n^3+\cdots+n^{(x-1)})(n+m)<65000 \qquad (1)$$

m-the maximum number of each router node can connect to the terminal nodes

n-the maximum number of each router node can connected to the router nodes

x-the maximum number of router hops during the massage transmit

2) Ensure the performance of the monitoring network to meet the requirements of communication

When network nodes are laid, performance of fire alarm delay and fault reporting delay must meet the requirements. Communication performance of monitoring network is closely related with the size of the network and the density of network nodes. If the nodes were laid too close, probability of conflicts between nodes were increased, and delay were increased. These factors will affect the performance of network. If the size of network too large, the more router hops the massage through when it were send from node to coordinator, the more the delay. It also affects the performance of network. Therefore, the number of nodes and router hops must be reasonably designed.

3) Minimize the number of network devices in the case of ensuring network coverage

Considering these factors, the layout of nodes in medium-sized buildings is shown as Figure 2.

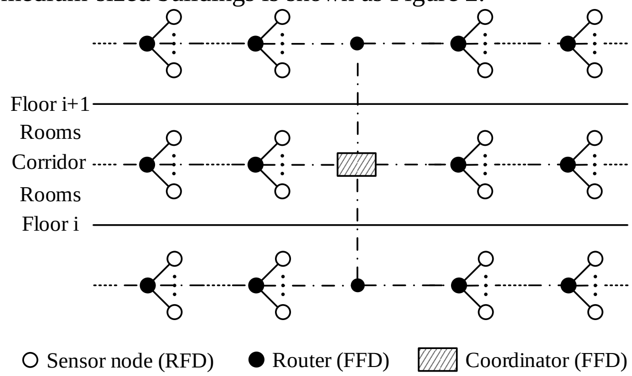

Figure 2. Layout of network

IV. DATA FUSION SYSTEM STRUCTURE

In this paper, in order to improve the rapid detection of fire, accuracy and ability to adapt to the environment, reduce the probability of omission and false alarm of fire, multi-sensor data fusion technology is used. Data fusion system for automatic fire detection is constructed.

The terminal equipments are looked as information fusion level of data fusion. Terminal equipments collect field data regularly. In order to reduce the amount of data transmission, the system makes local decision of fire through the field data. If fire occurred, the system alarm to the host directly. If the system makes local decision of suspected fire through the field data, pre-alarm signal is sent to the host. The system waits for the monitoring host command.

In this system, the change of environmental temperature, smoke concentration and CO concentration are monitored to make the decision of fire. Data layer, feature layer and decision-making layer are adopted. The original data acquisition and preprocessing are completed in data layer. The output signals from data layer are used for data fusion in feature layer. Visible fire, buried fire and non-fire source are identified. The various characteristics come from feature layer are full used in decision-making layer, and the final result of fire is obtained. The structure of data fusion is showed in Figure 3.

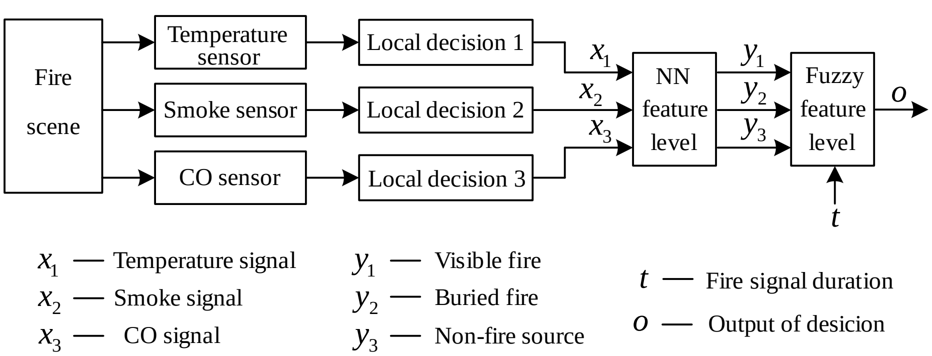

Figure 3. Structure of data fusion

V. HARDWARE DESIGN OF NODE

ZigBee sensor node is the basic unit for information collection. Figure.4 is the structure of the ZigBee sensor node module. The sensor probes are made up of temperature sensor, smoke sensor and CO sensor. The sensors in end nodes collect the signals from the environment and the original signals will be processed by the signal processing module. Then the processed signals will be uploaded to the ZigBee module. The ZigBee module send the information to router nodes or the coordinator.

In the course of the designing, the chip CC2430 is used. It's a System-on-Chip solution specifically tailored for IEEE 802.15.4 and ZigBee application. It's a low price, small size and low power consumption chip for ZigBee communication[4]. It integrat RF transceiver, CPU, and 128K flash memory. Very few external components are required in the CC2430 typical application. It also includes A/D converter, some Timers, AES128 Coprocessor, Watchdog Timer, 32K crystal Sleep mode Timer, Power On Reset, Brown Out Detection and 21 I/O ports. I/O ports can be used as the SPI ports, GPIO and so on. The chip CC2430 provides the most competitive ZigBee solution.

These sensor nodes except the coordinator have the same basic structure. These ports are assigned to the sensors and peripheral equipments. The coordinator will not connect with the sensor, which will extend USB port to connect with the processor[5][6].

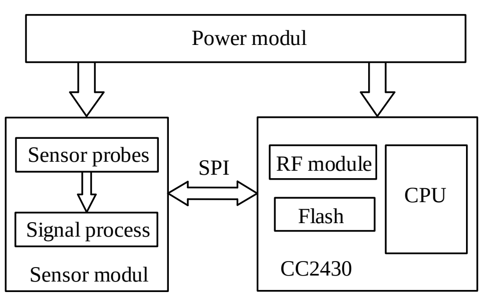

Figure 4. Structure ZigBee sensor node module

VI. SYSTEM SOFEWARE DESIGN

The software design include network operation software design and data fusion software design.

1) Network operation software design

Network operating software mainly solves the problems of networking of system and data transmission. In the software design of the system, The CC2430 Evaluation board is used. This Evaluation board is based on the ZigBee protocol stack software package which offers functionality for ZigBee coordinator, ZigBee router or ZigBee end devices and all the network topologies. Application layer of ZigBee stack is programmed in C language.

The programs of ZigBee coordinator node (FFD) include: initializing the CC2430, setting up a network, waiting for the ZigBee end devices join, managing network nodes, receiving and processing the data from ZigBee end devices and so on. The data processing flow is shown in Figure.5 .

The program of ZigBee end device nodes (RFD) include: initializing the CC2430, joining the network, receiving the data from sensor (or other device) and sending data to coordinator after being analyzed and processed. The data processing flow is shown in Figure.6.

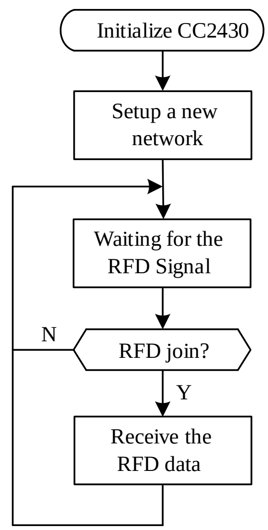

Figure 5. Flow chart of coordinator

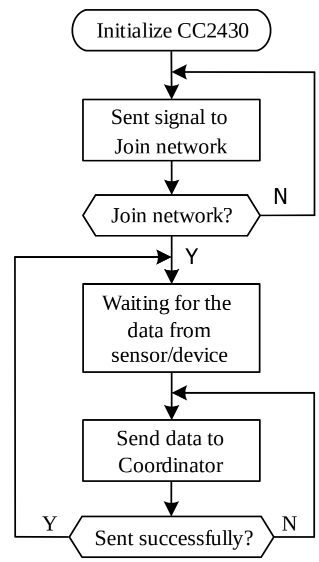

Figure 6. Flow chart of end nodes

2) Data fusion software design

The energy of WSN is limited. The size of data transmissions and MCU computations directly affect the lifespan of batteries in end nodes and router nodes. The function of BFAS is sending information to the monitoring host timely and reliably. It's unnecessary to sending information and making data fusion when the fire not occurs. This greatly reduces the amount of data transmissions and microprocessor operations, and the lifespan of batteries are extended greatly.

To the end nodes, it's difficult to deal with complex data processing. But they can be used in harsh environment with their small volume and low prices. Monitoring host has strong analysis ability and rapidly processing speed. So data collection and local decision are completed by the end nodes, while complex data processing and controlling to the nodes, etc. are completed by the monitoring host[7]. Figure 7 is the end node data fusion software program flow chart. Figure 8 is the monitoring host data fusion software program flow chart.

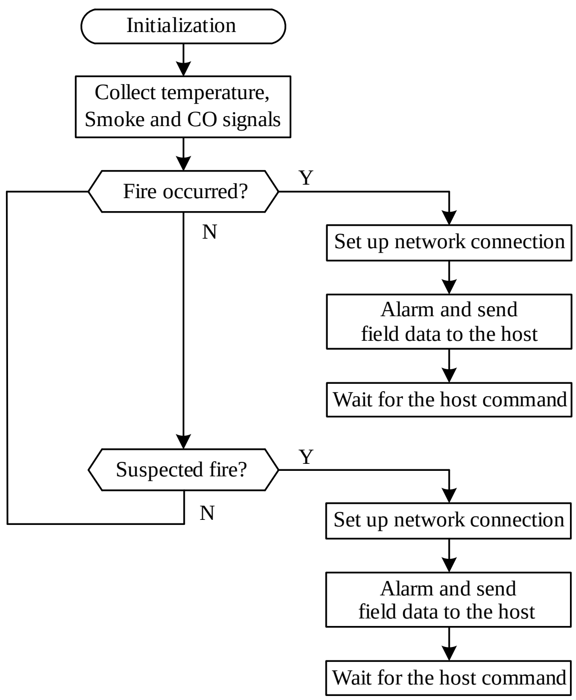

Figure 7. Flow chart of end node

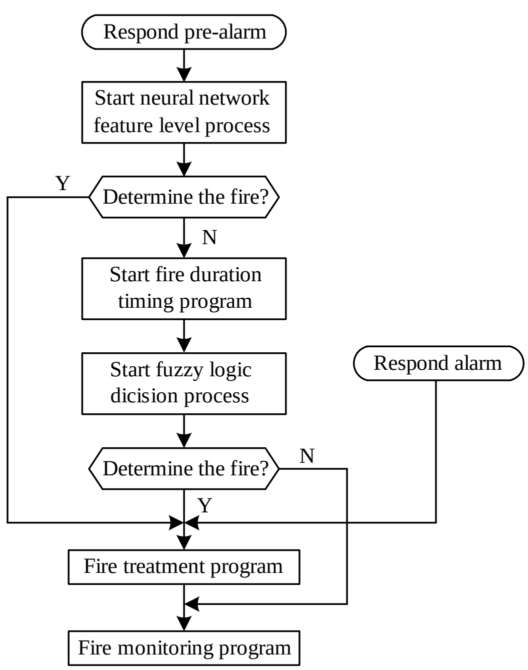

Figure 8. Flow chart of monitoring host

VII. SYSTEM TEST

A laboratory building is selected as a test object. Construction area of the building is 7800 m^2. There are 5 floors in the building. The height of each floor is 4 m. there are 12 standard rooms evenly distributed in corridor sides in each floor. The area of standard room is 13×8 m^2. Four end nodes are laid in each room according to formula (1). Seven routing nodes are laid in each corridor. The stable communication distance between adjacent nodes which separated by 20 cm thick concrete wall is 10 m. The stable communication distance without obstacles is 30 m. In order to ensure the fire information is send rapidly and the numbers of hop are not too much, the coordinator node is laid in the middle of the building. The delay time from the farthest nodes under the conditions of obstacle and message conflicts is 0.78 s. A variety of simulated fire status can be judged accurately.

VIII. CONCLUSION

This article discusses the intelligent building fire alarm system design with ZigBee wireless technology. The thought is proposed that Wireless communication technology and information fusion technology are used in BFAS. High omission rate and high false alarm rate which generally exist in current systems are reduced. Wireless communication technology is used in the field of fire alarm, which avoids lines aging, corrosion, being worn and other unreliability factors in wired fire alarm system. Using multi-sensor information fusion technology to process the on-site information and make the judge of fire. The signal processing model is closer to the fire scene nature. Massage delay is short.

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