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Forest Fire Positioning Monitoring System based on Wireless Sensor Networks

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Abstract. *To solve the problem of traditional forest fire monitoring system, a system for forest fire positioning monitoring based on wireless sensor networks is proposed. The system mainly includes the fire parameter collection node, routing node, the gateway node and the fire remote monitoring center. The parameter collection node is responsible for collecting the fire parameters and sending them to the routing node. The routing node packs parameters, and send them to the gateway node, then parameters are sent to the Internet through intelligent gateway, finally parameters are transmitted to the remote fire monitoring center. Experiments have shown that the system is more feasible and more effective than those of the existing ones, and accurate rate reaches 97.5%.*
Keywords: Forest Fire; WSN; CC2530; Information acquisition; Monitoring interface

1. **Introduction.** In recent years, forest fires occurred frequently, which poses a serious threat to forest ecosystem. The forest fire burned a large number of trees, which will not only reduce forest area, cause serious damage to the forest structure and forest environment, but also will lead to a serious decline in forest species, many birds died because there is no suitable forest environment for their survival[1, 2]. Therefore, how to monitor forest fires accurately and timely has become an urgent problem.

The traditional ways of forest fire monitoring are by ground patrol, tower monitoring, air patrol, remote video surveillance and satellite remote sensing monitoring[3], Although these monitoring methods can prevent forest fires in a certain degree, they require a lot of manpower and resources, its effect is not obvious and it has limited coverage. There are many shortcomings in the aspects of resource integration, system complexity, effective working life and the accuracy of fire alarm prediction, they can not meet the current needs of forest fire prevention[4]. And forest fire location mode still stays at a low level, mainly reflect in the positioning error, poor real-time, large funds and so on. Therefore, it is urgent to research new forest fire positioning system which is suitable for forestry sustainable development, cost less money and with high precision. Because of its low cost, large coverage, low energy consumption, convenience and flexible networking features, wireless sensor network provides a new idea for forest fire monitoring, and has been applied to national defense construction, industrial automation, agricultural production and environmental monitoring and many other industries, its development prospect is very wide. Therefore, how to apply wireless sensor network to forest fire positioning monitoring system has become the focus of scholars at home and abroad.

2. **Overall System Design.** The forest fire monitoring system designed in this paper integrates the functions of data collection, data transmission, data processing and alarming, it can monitor the forest fire situation in real time. The system is divided into four parts, as shown in Figure 1.The first part is the fire parameter collection node, which is responsible for the fire parameters collection and transmission in the monitoring area. In order to reduce energy consumption,the"listening/sleeping" mechanism is adopted. The second part is the routing node, which is responsible for packet the data collected by several nodes and sent them to the gateway node. The third part is the gateway node, which is responsible for receiving fire monitoring data sent by each routing node in the monitoring area, and forwards it to Internet. Because of so many forest obstacles, according to the packet loss rate to select and switch intelligently Ethernet, optical fiber, WiMAX, 3G four kinds of data transfer mode are used. The fourth part is the remote fire monitoring center, it is mainly responsible for processing the fire monitoring data from Internet, implementing fire position, and displaying fire parameters of the monitoring area in a real-time, enquiring the historical fire data and alarm and other functions.

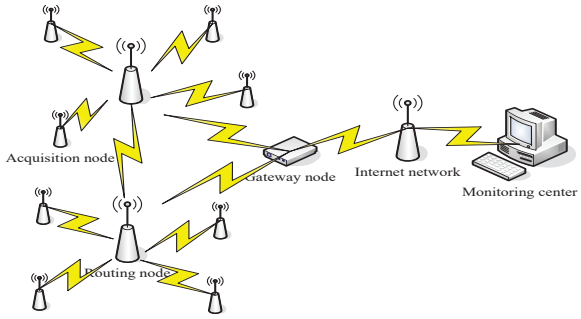

FIGURE 1. System structure diagram

3. **Hardware Circuit Design.**

3.1. **Software and Hardware Design of Fire Parameter Acquisition Node.** The node of fire parameter collection is composed of two parts: sensor module and ZigBee module. The sensor module includes temperature, humidity sensors and combustible gas concentration detection sensors, which transmit the collected fire parameters to the ZigBee module, and then transfer them to the routing nodes by the ZigBee module.

3.1.1. *Circuit Design of Zigbee Module.* It selects the CC2530 chip as the core of the ZigBee module in this paper, CC2530 chip integrated microcontroller, ADC, wireless communication module in one, it can support the latest Zigbee protocol and has the advantages of low power consumption, low cost and high reliability.In view of the complicated communication environment and short communication distance of nodes in the forest, the CC2591 chip is used as the power amplification chip to amplify the node transmit power and increase the communication distance of nodes. In order to find the physical location of the abnormal data nodes accurately, this paper uses the UBLOX-6010-BNX1722 chip with higher sensitivity and stronger compatibility as the GPS module to locate the nodes. The main circuit of the Zigbee module is shown in Figure 2.

3.1.2. *Design of temperature and humidity acquisition module.* In this paper, SHT10 is used to collect temperature and humidity parameters in monitoring area. It has the advantages of high precision, high speed, low power consumption, strong anti-interference ability etc. SHT10 can output fully calibrated digital signals. The principle is shown in Figure 3.

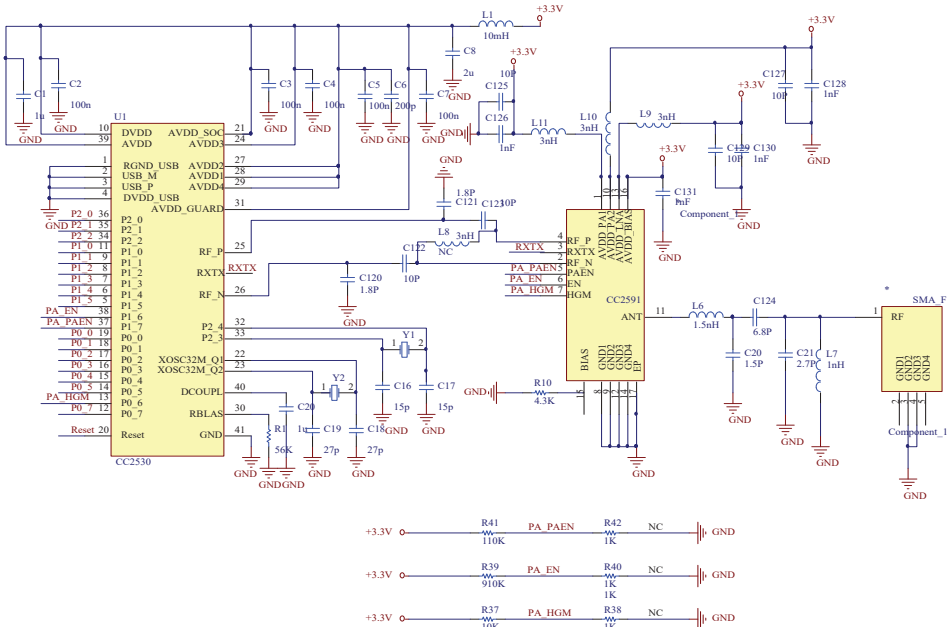

FIGURE 2. The main circuit diagram of the Zigbee module

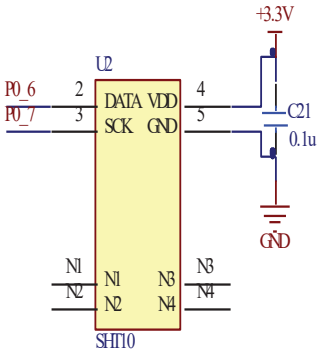

FIGURE 3. The schematic diagram of temperature And humidity sensor SHT10

3.1.3. *Design of combustible gas concentration detection module.* In this paper, MQ-2S chip is used as a sensor element to monitor the concentration of combustible gas in the forest monitoring area[4]. The sensors monitor the density of a variety of flammable gases in forest areas. And they have low cost, long service life, strong stability, quick response recovery and can be applied to monitor a variety of occasions. The circuit diagram is shown in Figure 4.

3.2. **Hardware design of gateway node.** The gateway node is the key part of the forest fire monitoring system. The main function is to receive data, temporarily store data and transmit data. The gateway node receives the parameter information sent by the fire parameter collection node through the ZigBee module and then is sent to the Internet through the intelligent switching method after processed by processor. In this paper, the S3C6410 chip based on ARM11 kernel and 16/32 bit RISC is used as the micro controller of the gateway node. The chip has many kinds of hardware interfaces, and it has low cost, stable performance and high cost performance. It is very suitable for mass production. After the redesigning of the S3C6410, the peripheral block diagram is shown in Figure 5.

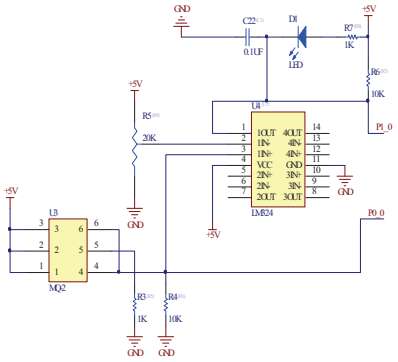

FIGURE 4. The schematic diagram of combustible gas concentration sensor MQ-2S

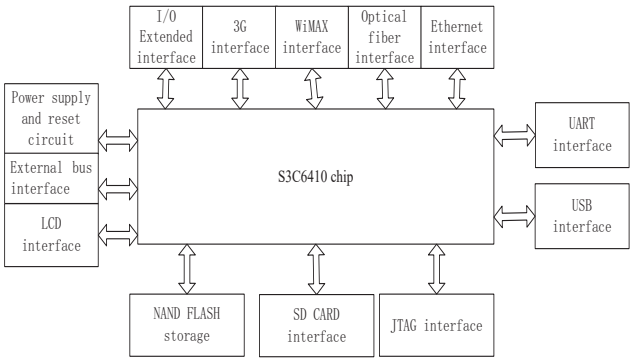

FIGURE 5. The peripheral block diagram after redesigning the S3C6410

4. **Software design.** When the fire parameter acquisition node is in the open power supply, CC2530 firstly initializes hardware and tries to enter the wireless sensor network[5]. After numbers of attempts and eventually it enters into the network, the node will regularly collect temperature, humidity and the combustible gas concentration information in the monitoring region and transmits it to the upper node, the program flow diagram is shown in Figure 6.

When the net is in the open power supply, CC2530 initializes hardware and sets up a network. After receiving the information which the fire parameter acquisition node needs to join, the gateway node will decide whether to allow the fire parameter acquisition node to join or not according to the actual needs, the program flow chart is shown in Figure 7.

5. **Location algorithm and routing.** The wireless sensor network cluster routing strategy based on the improved DV-Hop algorithm is applied to the wireless sensor network model which is composed of multiple stable sensor nodes and base stations.In WSN, energy is the important index of network. The first part of the network energy consumption is data transmission, and another part is the process of data processing[6]. During the data transmission, energy consumption is mainly decided by the communication distance. For data processing, data fusion is a key technology. Energy constraints are deduced by the distance between the nodes. We change the original cluster head election method based on the improved DV-Hop algorithm and combined with the data fusion technology to improve the traditional LEACH protocol[7, 8].

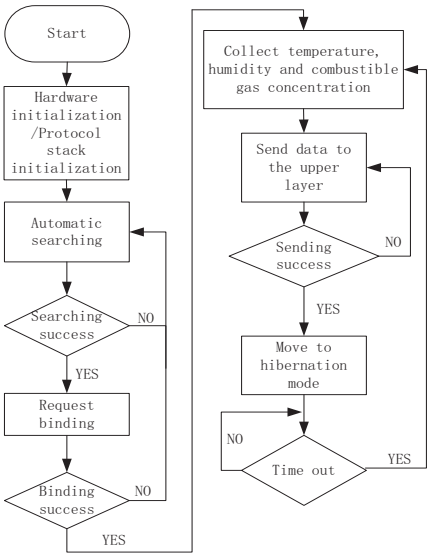

FIGURE 6. The program flow chart of fire parameter collection node

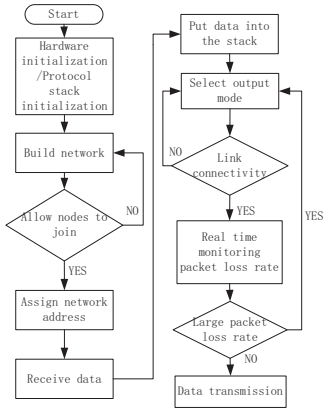

FIGURE 7. The program flow chart of gateway node

6. **System test.** The safety level of the temperature is shown in Table 1, and the safety level of the concentration %LEL is shown in Table 2.

TABLE 1. Safety level of temperature

Temperature factor	$< 30°$	30°-45°	45°-55°	$> 55°$
Grade	1-0.8	0.8-0.7	0.7-0.6	< 0.3
Danger grade	Safety	Caution	Notice	Warn
Safety grade	I	II	III	IV

When the fire data exceeds the threshold, the system can carry out real-time fire warning so as to detect the fire area in the forest.

When fire alarms occur, the data analysis module uses an improved DV-HOP localization algorithm developed independently. In the classical DV-Hop algorithm, regardless of the actual distance of adjacent nodes, the count is recorded as 1 hop within the radius of communication[9]. The average hop distance calculated from these hop information is

TABLE 2. Safety level of concentration %LEL

Concentration level	< 30%LEL	30%LEL-50%LEL	50%LEL-80%LEL	> 80%LEL
Grade	1-0.8	0.8-0.7	0.7-0.6	0.6
Danger grade	Safety	Caution	Notice	Warn
Safety grade	I	II	III	IV

different from the actual value, which will eventually lead to more measurement errors. In view of the above problems, the improved algorithm starts with the number of hops and matches the actual distance between neighbor nodes, thus greatly improves the positioning accuracy. Although the actual distance between neighbor nodes is unknown, most of the nodes have detected signal intensity function, and there is a certain relationship between the neighbor nodes and the actual distance of RSSI, so it can be used in order to improve the positioning accuracy of RSSI ranging technology. In order to overcome the influence of the external environment on the RSSI ranging model, the algorithm uses the anchor nodes to estimate the parameters of the ranging model so as to make it more environmental usability[10]. Location analysis of fire location is carried out according to the collected data. Simulation results show that the method reduces the positioning error, as shown in Figure 8. The fire history data query module is mainly based on the choice of time period to find the time for a specific node of temperature, humidity, concentration of combustible gas and fire data, and line charts presented in tabular form, in order to study the fire warning trend in the region.

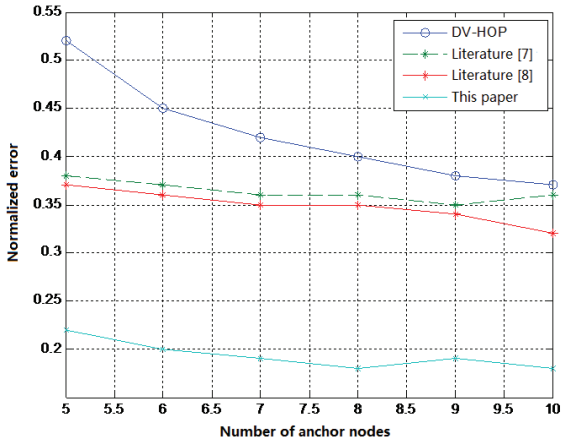

FIGURE 8. Error analysis of fire location

In order to detect the fire alarm sensitivity and accuracy of the system, we carry on the simulation experiments with the simulation of experimental data of the 40 groups, including 20 groups of normal data and 20 groups of abnormal data (the data of caution, warning and alert are abnormal data, we need to pay attention to fire protection), then send data to the system for observing the operation status of the system, as shown in Figure 9. As we can see from the Figure, only one set of data is judged to be in error, calculating with an accuracy of 39/40=97.5%.

7. **Conclusions.** In this paper we designed each module of Forest Fire Positioning Monitoring System based on wireless sensor network, including hardware and software design of fire parameters acquisition node, gateway node and Interface design of remote fire monitoring center. This paper elaborates the design of various parts, describes the structural

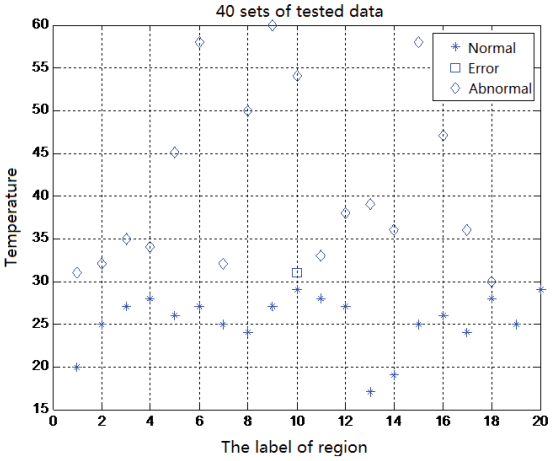

FIGURE 9. Analysis of the system sensitivity

design of every part and schematic diagram of circuit design. Test experiments shown that this system can detect forest fire in time, its accuracy rate can up to 97.5%, it can provide a strong support for forest fire prevention and rescuing, which proves its validity and reliability and then achieve the expected research and design goals.

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