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Research on the Wireless Industry Monitoring System

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Wireless monitoring is an indispensable part of the industry site. As the increasingly complicated site situation, higher demand for the wireless industry monitoring system has been proposed. This paper, based on ZigBee wireless network technology, designed a wireless industry monitoring network system composed by coordinators, routers and terminal nodes. In this way, software and hardware were designed, made and debugged, and terminal nodes, routers and coordinators were programmed and debugged, which realized the industry monitoring by the system.

1. Introduction

With speeding up industrial automation, industrial production tends to be a continuous, comprehensive and complicated process in a large scale. During industrial production and management, many physical quantities, technical parameters, performance data require real-time detection, monitoring management and automatic control. Thus, the industrial monitoring and inspecting system is an important part of industrial production.
The increasingly advanced industrial automation technology poses higher demand for monitoring on the real-time data transmission, open data interface and safe data chaining. In this industrial condition, it has become an urgent need to build a reliable data transmission network. Therefore, the short-distance wireless network technology under industrial control has become the hot issue in relevant researches for recent years, leading to the emergence of wireless network technologies based on Bluetooth, Wi-Fi and ZigBee. ZigBee, with a relatively simple network protocol(Cui and Chen, 2013), can be operated on MCU with limited calculation and storage capability, which is pretty applicable to cost-efficient situation. Also, ZigBee, with flexible network building, can achieve multi-hop data transmission via routers with big network capacity. As a result, researches on ZigBee-based industrial monitoring and inspecting system are very critical for industrial production and improvement of production efficiency.

2. ZigBee Technology

2.1 Overview of ZigBee technology

ZigBee, as a new short-distance and low-bitrate wireless network technology, is mainly used for short-distance wireless connection. With its own wireless protocol standard, ZigBee realizes communications though coordination between thousands of tiny sensors. Only with a little energy, can the sensors relay data via radio wave from one sensor to another, leading to very high communication efficiency. ZigBee is distribution-friendly owing to its small nodes and automatic network building. And its emphasis on the group cooperation of many nodes, the network can easily repair itself, and any node effect will not impose detrimental effect on the complete task. Thus, ZigBee is very suitable for building the wireless monitoring and inspecting system.

2.2 Analysis of ZigBee equipment

ZigBee is a technical manual of LR-WPAN based on PHY and MAC defined by IEEE802.15.4 formulated by ZigBee alliance. ZigBee alliance calls PAN coordinator, coordinator and ordinary equipment defined by IEEE802.15.4 as “ZigBee coordinator”, “ZigBee router” and “ZigBee terminal nodes”.
ZigBee coordinator is the central of the whole network, with its major role of starting the network by choosing a relatively vacant channel to form a PANID. Also, it will help establish the security layer of the network and handle the binding of application layer. After the whole network starts and completes configuration, ZigBee

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coordinator will become an ordinary router. ZigBee mainly serves to relay to expand the signal transmission area, so it is usually active. And ZigBee terminal nodes can be in the asleep or awaken state, so they are used to supply the electricity.

2.3 ZigBee network topology

ZigBee, based on each independent working nodes, constitutes the star-shaped, tree-shaped and mesh network, leading to different functions of nodes. To cut down cost, most nodes in the system are sub-nodes, which is just a subset of the function in terms of network building communication called reduced function device(RFD). And the other nodes communicate with sub-nodes under control， collect data and post control and connect routers, which are called FFD. Details can be seen in Figure 1.

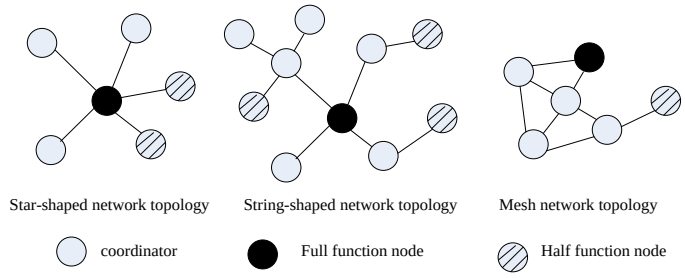

Figure 1: Figure of ZigBee network topology

Regardless of the type of network topology structure, each independent network has a unique identifier, namely network number (PAN identifier). PAN identifier is used for communication among network equipment and the communication activation via 16-bit short address code.

3. Design of the System

3.1 Overview of the system

Wireless monitoring system based on standard communications protocol, with several sensors and equipment with digital communications capability scatted in the industrial spot as the network nodes, connects on-the-spot sensors to the equipment, then the equipment to the workshop and industrial equipment to make the whole system connected as a whole for information communication and completion of monitoring and inspecting. The framework of this system is shown in Figure 2.

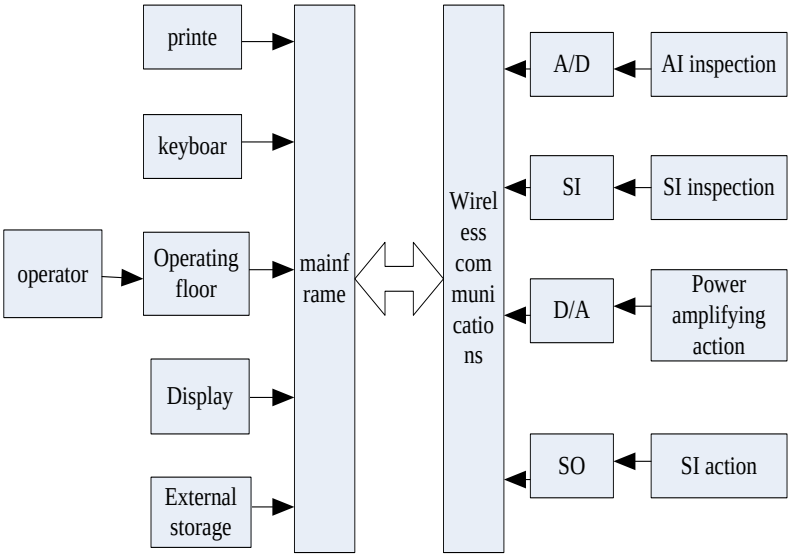

Figure 2: Wireless industrial monitoring and inspecting system

In Fig. 2, data input signals mainly contain analog input (AI) and switch input (SI). AI channel receives the continuous information on the spot (such as voltage, current, temperature and humidity). The input must be magnified, segregated and A/D transformed to become digital value to enter the computer. SI channel receives “on/ off” (such as contactless switch and relay switch for valve and equipment condition of on or off).

3.2 Design plan of the monitoring system

This wireless industrial monitoring system was built based on ZigBee network in line with the requirement of the industrial spot for the monitoring system. This system is mainly composed by the upper computer, coordinator, router and terminal nodes, as shown in Figure 3.

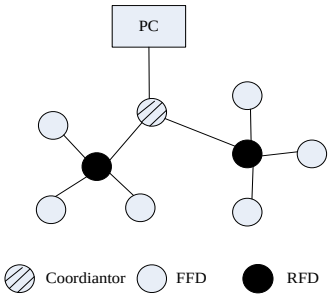

Figure 3: Figure of the monitoring network

4. Design of hardware of the system

The design of the hardware of the monitoring system contains the following three main parts: terminal nodes, routers and coordinators.

4.1 Figure of hardware of terminal nodes

In practice, owing to long-time operation of terminal nodes, hardware system must be simple in structure to effectively reduce power consumption. Thus, the hardware of terminal nodes must be streamlined as shown in Figure 4.

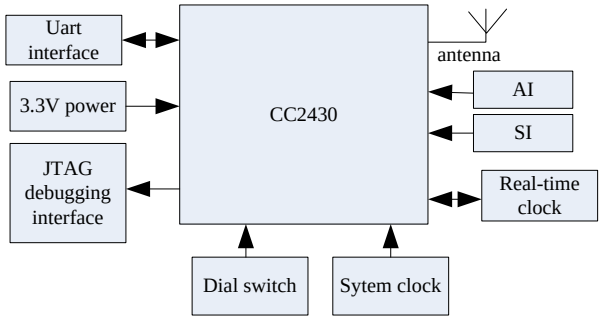

Figure 4: Design of hardware of terminal nodes

In Figure 4.1, terminal nodes contain CC2430 system on chip, 32MHz system clock, 32.768kHz real-time clock, debugging interface, antenna, power, SI and AI collecting.

4.2 Figure of hardware of router nodes

The designed monitoring nodes are of small volume, low power consumption, simple structure and user friendliness. But limited by the power consumption, volume and cost, the nodes are not very sensitive in sending and receiving signals with about 100-meter communications distance and small network building coverage, which significantly harms the network application. To increase the network coverage(Gao, et al., 2015), this system designed router nodes of high power as shown in Figure 5.

4.3 Figure of hardware of coordinators

The figure of hardware of coordinator nodes is shown in Figure 6. In practice, coordinator nodes require long-time operation for their tasks of network maintenance, data uploading, order commanding and system monitoring and controlling. Also, due to several peripheral equipment and high power consumption of coordinator nodes as a whole(Wang and Li, 2014), the child nodes had better to operate with external power source or power with large capacity to ensure the continuous working for a long time.

In terms of communications, RS485 can achieve the communications between coordinators and monitoring mainframe in the following way. Coordinators poll monitoring terminal nodes and router nodes, and then the monitoring terminal nodes send the industrial spot information to the monitoring mainframe via coordinators.

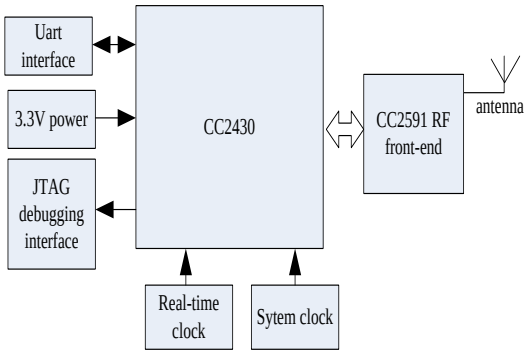

Figure 5: Figure of hardware of routers

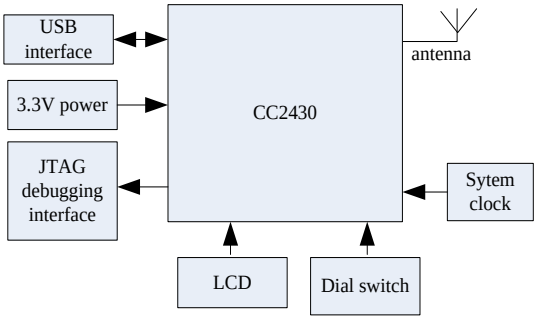

Figure 6: Figure of hardware of coordinators

5. Design of the system software

According to the requirement of the industrial monitoring system FOR ZigBee network building, the working process of coordinators, routers and terminal nodes were designed with corresponding flow charts.

5.1 Design of software of router nodes

In the system, router nodes serve to relay in ZigBee network to realize data transmission among terminal nodes, router nodes and coordinator nodes via the router. NLME_START_ROUTER is used to initialize new network equipment to ZigBee router or to reconfigurate a superframe of ZigBee router. Figure 7 shows the algorithm of the basic ZigBee router.

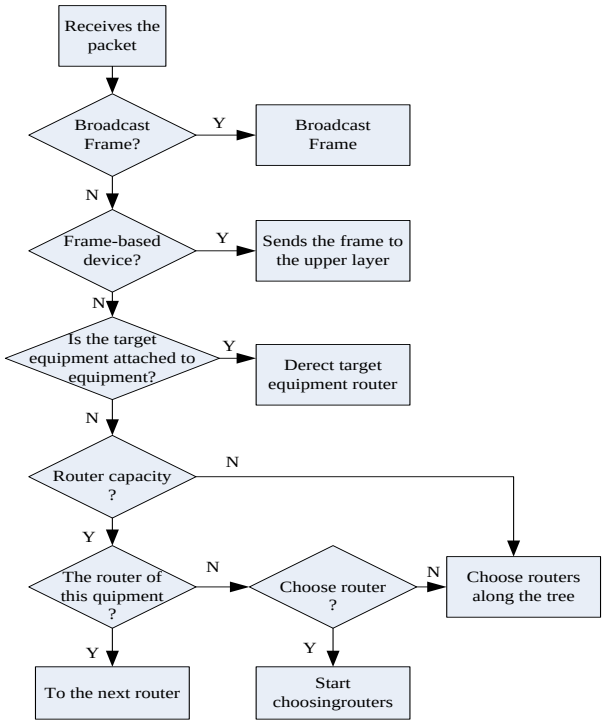

Figure 7: Algorithm of the basic router

5.2 Design of software of terminal nodes

Terminal nodes are mainly used to collect the data of industrial production line, send the data to father nodes and then to the coordinator and receive the order sent by the coordinator. The main flow chart of terminal nodes is shown in Figure 8. With electricity, terminal nodes initialize software and hardware at first, and then

find the existing accessible network. After the terminal nodes enter the network(Wang, 2012), their father nodes cannot be designated, but decided in line with the principle of lowest router cost in the protocol stack.

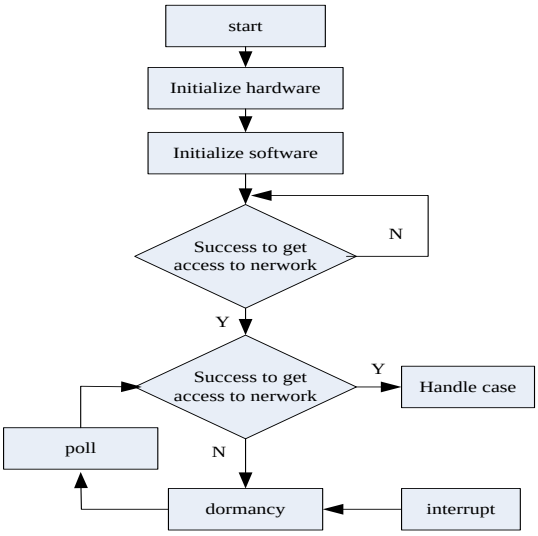

Figure 8: Flow chart of software of terminal nodes

With electricity, terminal nodes initialize hardware, protocol stack, and start global interrupt, and then initialize terminal nodes condition (initialize RFDState=1), command frame and operate protocol stack. Terminal nodes condition means the condition of sensor nodes in normal operation, including seven conditions represented by numbers from 1 to 7. They are application to enter the network, confirmation of network access, data transmission, confirmation of sending, starting dormancy, reentering the network and confirmation of reentering the network.

6. Test of the system

With the premise of normal circuit board, debugging starts. AI is collected; then the upper computer sends a SI for turning on the light; at last the serial debugging assistant is used to see whether terminal nodes respond or not. At the same time, LCD on the circuit board shows collection value, terminal nodes and the ID number of and coordinators. This paper mainly collects AI with the standard output of transmitter as 4-20mA. I/V is used to transmit it into voltage signal. Details is shown in Table 1.

Table 1: Table of voltage collection data

Lcd value	voltmeter	Difference value	Relative error	Lcd value	voltmeter	Difference value	Relative error
0	0	0	0.00	1.259	1.255	0.004	0.32
0.1	0.1	0	0.00	1.729	1.724	0.005	0.29
0.253	0.254	-0.001	-0.39	1.938	1.945	-0.007	-0.36
0.312	0.311	0.001	0.32	2.046	2.041	0.005	0.24
0.389	0.387	0.002	0.52	2.124	2.131	-0.007	-0.33
0.465	0.466	-0.001	-0.21	2.313	2.309	0.004	0.17
0.586	0.584	0.002	0.34	2.419	2.424	-0.005	-0.21
0.625	0.623	0.002	0.32	2.503	2.509	-0.006	-0.24
0.764	0.761	0.003	0.39	2.608	2.615	-0.007	-0.27
0.864	0.867	-0.003	-0.35	2.742	2.748	-0.006	-0.22
0.962	0.959	0.003	0.31	2.827	2.84	-0.013	-0.46

This test is mainly to debug the hardware circuit and software in the experiment through collecting AI and design and debug ZigBee network communications. Table 1 shows that the basic demand for wireless monitoring and inspecting system has been met.

7. Conclusion

According to the actual situation of the environment of the industrial production, this paper puts forward the design scheme of the wireless monitoring and control system. Experimental results show that each module of the wireless monitoring and control system can work normally, the terminal node module can accurately capture the analogy value，the coordinator module can receive a terminal node ID number, location, and RF transmit power. And according to the command of the monitoring host, it can perform the locking action. The system is stable, reliable, practical, and can be widely used.

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