Design of Mine Ventilators Monitoring System Based on Wireless Sensor Network

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Abstract. A monitoring system for a mine ventilator is designed based on ZigBee wireless sensor network technology in the paper. The system consists of a sink node, sensor nodes, industrial personal computer and several sensors. Sensor nodes communicate with the sink node through the ZigBee wireless sensor network. The sink node connects with the configuration software on the PC via serial port. The system can collect or calculate vibration, temperature, negative pressure, air volume and other information of the mine ventilator. Meanwhile, the system accurately monitors the operating condition of the ventilator through these parameters. Especially, it provides the most original information for potential faults of the ventilator. Therefore, there is no doubt that it improves the efficiency of fault diagnosis.

1. Introduction

The data are transmitted through the cable for most condition monitoring systems of mine ventilators at present, but it is difficult to implement in some industrial fields [1]. Because the number of mine ventilators monitoring parameters is large and monitoring nodes are widely distributed, it is particularly necessary to design a condition monitoring system based on the wireless sensor network. Application of the wireless sensor network can eliminate non-implementation and inconvenience of traditional cable transmission.

The system is designed to monitor the operating condition of mine ventilators and warn early. It is basically divided into two parts, that is, hardware and software. Hardware consists of a sink node, sensor nodes, industrial personal computer, and several of sensors. Software includes ZigBee protocol stack and configuration software. The stack of nodes is TI's Z-Stack and the main chip is TI's CC2430.

2. Design of wireless sensor network node

The design is a mine ventilators monitoring and warning system, which can collect or calculate vibration, temperature, negative pressure, air volume and other information of mine ventilators. The system consists of an industrial personal computer, a sink node, many sensor nodes, at least four temperature sensors, two vibration sensors and one pressure sensors.

Figure 1 shows the schematic diagram of the monitoring system. A ZigBee star network is built up by a sink node and the sensor nodes. The sink node is responsible for receiving data from each sensor node. The data is transferred to the monitoring and warning system on a PC via the serial port. The monitoring system is used for displaying real-time, alarming, etc.
2.1. The sink node design

The sink node consists of a power supply module, a serial module, CC2430 modules and other components. The CC2430 is a true System-on-Chip (SoC) solution, which is specifically tailored for IEEE 802.15.4 and ZigBee applications. The CC2430 combines the excellent performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU, 32/64/128 KB flash memory, 8 KB RAM and many other powerful features. It combined with the industry leading ZigBee protocol stack (Z-Stack) [2].

The CC2430 operating voltage is 3-3.3V, and therefore the voltage should be reduced to 3.3V from 5V by the voltage conversion module. 5V AC/DC power adapter is used. The serial port module consists of MAX3232E and the peripheral circuits. Taking the distance into account, a MAX485 circuit is designed, which makes the distance between the sink node and the PC extended to more than 1200 m. So the operability of the system is improved.

2.2. Sensor nodes design

The block diagram of sensor nodes is shown in figure 2. The sensor nodes consist of sensor node master chip CC2430 module, key control module, power conversion module, external sensor interface module, bridge circuit to measure temperature, I/V conversion circuit and antenna interface. The sensor module is responsible for collecting data.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Schematic diagram of the monitoring system (1 industrial personal computer, 2 sink node, 3 sensor node, 4 temperature sensors, 5 pressure sensors, 6 vibration sensors).

**Figure 2.** Block diagram of sensor nodes.

Because the system is required for real-time monitoring all the time, especially vibration and pressure sensors need 24V DC power supply, therefore, the sensor nodes are supplied by 24V DC power. The benefit of 24V DC power supply is not required to consider low-power design and power management. In power conversion module we choose DC/DC power module BSD5-24D15, whose input voltage is 18V-36V, output voltage is ±15V, accuracy of output voltage is ±1%. Therefore, BSD5-24D15 can meet the power needs of various types of chips. The bridge circuit is responsible for converting the resistance output signal of PT100 temperature sensors into a voltage signal in order to measure temperature.

As the voltage signal can only be collected for CC2430, we must convert the current output signal of vibration, pressure sensors into a voltage signal. Therefore the conditioning circuit is designed, where 4-20mA current signal is converted to 0-3V voltage signal for CC2430 sampling. The conditioning circuit of the 4-20mA current signal is shown in figure 3, and the circuit consists of the operational amplifier LM324 and other components. In figure 3, P1 is interface for the current output signal of sensors, P3 and P4 are Potentiometers. P0.2 of CC2430 is used to collect the signal. Taking
the versatility of the sensor node into account, each node is designed to collect two temperature signals and two 4-20mA signals.

![Figure 3. The conditioning circuit of 4-20mA current signal.](image)

3. Application of communication protocols

The software development environment of this system is IAR EW 7.30, and protocol stack is TI's Z-Stack. Figure 4 shows system flow of Z-Stack. The main work processes of Z-Stack can be divided into several stages which are system start, disable all interrupts, driver initialization, OSAL initialization and startup, polling tasks and so on. When the operating system is performed, it will check the readiness of each task according to priority. If some task is ready, OSAL calls the corresponding event handler to handle the event until poll and perform all of the ready tasks.

![Figure 4. The flow chart of Z-Stack.](image)

According to IEEE 802.15.4 and ZigBee standards, Z-Stack is divided into the following layers: API (Application Programming Interface), HAL (Hardware Abstract Layer), MAC (Media Access Control), NWK (ZigBee Network Layer), OSAL (Operating System Abstract System), Security, Service, ZDO (ZigBee Device Objects). Among them, Z-Stack has created HAL, MAC, NWK, OSAL, Security, Service and ZDO layer by TI. These functions don’t have to be modified basically. Users only need to create customized task and event handler of API layer [3].
Z-Stack polls the events by tasks. It constitutes such a scheduling mechanism “event-task-operating system”. Operating system is responsible for scheduling multi-task. Each task contains more than one event. The steps to add a new task are shown in figure 5. Three modifications are as follows:

- Add new tasks to the task initialization function: osalInitTasks().
- Add several events to the new tasks.
- Add two related handler for each newly created user’s task, that is, initialization handler and event handler: APP_Init(), APP_ProcessEvent().

The following example is about temperature acquisition. When corresponding event occurs the event handler will be executed. Part of the code of SensorApp_ProcessEvent is as follows:

```c
if (events & SENSORAPP_MSG_SEND_EVT)
{
    #if (!defined(ZDO_COORDINATOR))
        dt[0] = Read_Temperature();
    ......
    SerialApp_SendData(dt, len);
    #endif
    return (events ^ SENSORAPP_MSG_SEND_EVT);
}
```

Multiple tasks can be added with the same method. Network formation process is shown in figure 6. The sink node is responsible for the formation of the network including selecting channel, broadcasting information to the network and assigning address for sensor nodes in this network. Sensor nodes send their own addresses and data after they join the network. PC receives data through the serial port in order to warn and monitors online.

### Figure 5. The steps to add a new task.

### Figure 6. Network formation process.

## 4. Monitoring software development

We need to design monitoring software for monitoring equipment operating condition and alarming for abnormal behaviors. The software includes the following functions:

- show real-time the data of each node;
- show real-time signal curve and historical trend curve of the sensor node;
- parameter settings, including alarm limits, etc.;
- alarming, report generation and report inquiry;
- database management.

KingView 6.53 is selected as the development platform for the condition monitoring system of mine ventilators. KingView 6.53 is developed by Beijing wellincontrol technology development Co., Ltd. The system monitors the operational condition of mine ventilators, and can implement alarms for abnormal behaviors. The main interface of mine ventilator monitoring software is shown in figure 7.
In this part, the condition monitoring system of the mine ventilator is abstracted. Running state of mine ventilator is shown in the form of animation, and the operating conditions point is shown in the relation curve between air velocity and pressure, and the monitoring parameters are shown in the monitoring tables. Theses models truly reflect the real-time operating conditions of a mine ventilator.

Figure 7. The main interface of mine ventilators monitoring software.

5. The communication program between KingView and the sink node
As KingView doesn’t have CC2430’s driver, it is necessary to develop the driver according to the selected chip. Communication can be achieved by the following three methods [4].

- Users can develop our own communication drivers by KingView driver development package, which is suitable for professional manufacturers.
- Users can communicate by means of DDE means, which is more complex and less real-time.
- KingView provides a common communication protocol of microcontrollers, which is relatively simple and good real-time [5]. Therefore the third method is adopted in this paper.

First the parameters of communications port need to be set, and then the device addresses and registers in KingView should be defined according to the formats of the common communication protocol. This communication program is designed based on ASCII code by C language in this paper. The flow diagram for KingView reading data from CC2430 is shown in figure 8. According to the common communication protocol, when KingView read data, if it is normal then CC2430 is responded as format 1, otherwise CC2430 is responded as format 2. The two formats are shown in table 1.

Table 1. Two formats responded by CC2430.

| Type       | Data packet |
|------------|-------------|
| format 1   | Prefix      |
|            | Device address | The number of data bytes | Data | XOR | CR |
| format 2   | Prefix      |
|            | Device address *XOR | CR |

KingView on the PC can communicate with CC2430 by this program, and successfully read data from the sensor nodes. The main functions of this communication program based on ASCII code are as follows:

- void initUART (void) //CC2430 serial port initialization
- #pragma vector = URX0_VECTOR_interrupt void UART0_IRQ(void)  //interrupt function
• void uartsends(uchar buff[], uchar num) //send data through the serial port
• void CC2430_KingView() //communication program between the sink node and KingView

![Flow diagram for KingView reading data from CC2430.](image)

**Figure 8.** The flow diagram for KingView reading data from CC2430.

### 6. Conclusions
The monitoring system for a mine ventilator is developed based on ZigBee wireless sensor network technology in the paper. We have designed the sink node and the sensor nodes according to system requirements, and have developed the program for data collection and wireless transmission based on ZigBee 2006 stack (Z-Stack). Meanwhile the software for warning and monitoring is developed by KingView. The system can collect vibration, temperature, negative pressure and other information of mine ventilators. And the system can accurately monitor operating condition of the equipments through the parameters. This design has the following characteristics:

- Wireless sensor network is applied in the condition monitoring system for mine ventilators, which guarantee efficiently and safely producing.
- The system solves the following problems: difficult to implement, poor system expansion for traditional cable transmission.
- Because of its low manufacturing cost for nodes, the system has obvious economic benefits.

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