Design of Intelligent Safety Monitoring System for Power Supply Bureau Based on ZigBee Technology and Information Fusion

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Abstract. Safe operation of the power supply bureau is very important. A design scheme of intelligent security monitoring system for power supply bureau based on ZigBee technology and information fusion is proposed. Through the ZigBee wireless communication technology, the wireless self-organizing network service is provided for the security operation of the power supply bureau, and the various sensor nodes of the system are connected with the coordinated control node, and a feasible system reliability design solution is proposed in combination with the actual application environment.

1. Introduction
Safety monitoring is an eternal subject that power companies have been researching and exploring. The application of ZigBee and information fusion technology to monitor the working environment of the power supply bureau can not only realize the flexibility of the wireless sensor network and the diversity of signal measurement, but also realize the effective monitoring of the complex working environment in the shortest time. In order to solve the problem of security monitoring of power supply bureau, the research and design of power supply station monitoring system based on ZigBee technology and information fusion is carried out, focusing on the two core problems of operation mechanism and system reliability in monitoring system. In-depth research was carried out and corresponding solutions were given [1-5].

2. Data Processing And Communication Key Technologies In Power Station Security Monitoring

2.1 Information fusion technology
Information fusion is a multi-hop self-organizing network system that uses computer technology to combine sensors from multiple sensors [6]. It is a multi-hop self-organizing network system that connects sensors deployed in the target area through wireless communication to analyze and comprehensively process the observed information. The composition of the information fusion network is mainly divided into three parts: information monitoring center, backbone communication network and wireless sensor network [7-8]. Among them, the monitoring center is a monitoring network composed of several PC terminals. Each PC terminal is equipped with a corresponding monitoring software system, which can integrate and process various real-time information collected in the construction site environment of the power supply bureau [9]. The backbone communication
network carries the construction of the communication network environment of the main body of the power supply station monitoring system based on the wireless sensor network, and is the main bearer communication technology facility for completing various data transmissions such as monitoring network information transmission, monitoring control command transmission and the like. The wireless sensor network is a terminal network for information collection and information monitoring. It is the most front-end communication link in the whole monitoring system, and it is also the most important communication link. The wireless sensor network is composed of several wireless sensor nodes, and each sensor node communicates with each other through a wireless communication protocol to complete data collection and transmission.

2.2 Technical introduction of ZigBee

As a two-way wireless communication technology, Zigbee technology has the advantages of low cost, low power consumption, simplicity, short distance, etc. It is widely used in the fields of remote control and automatic control [10-11].

The ZigBee protocol architecture consists of service entities at each level. The next layer provides services for the upper layer, the data service entity is responsible for the data transfer service, and the management entity is responsible for managing the service. Each service entity provides a corresponding interface to its upper layer through a corresponding service access point (SAP), and implements its own functions according to primitive rules. The Coordinator, Router, and End Device are three logical devices in the Zig Bee network. The Zig Bee network consists of numerous router nodes and numerous terminal devices and a coordinator device group. The Zig Bee protocol standard defines three topologies: Star Extension Star, Tree Topology Cluster Tree and Mesh Topology Mesh. As shown in Fig.1[12-15].

![ZigBee mesh topology](image)

Figure 1. ZigBee mesh topology

3. Analysis Of The Results Of The Safety Monitoring System

3.1 Sensor data fusion

Sensor data fusion is a method of combining sensed data from multiple sensors to produce more accurate, complete, and reliable information that cannot be achieved with a single sensor. Nakamura et al. define three key operations based on Complementary, Redundant and Cooperative for data fusion. Among them, the complementary operation combines a large number of sensors for sensing scene factors such as temperature to realize the integrated perception of the overall environment; the redundant operation is to use the different sensors to perceive the same scene factors and comprehensively use multiple sets of data. To improve the accuracy of the data; and collaborative operation is to integrate sensor data in different environments to acquire new information for multi-faceted collaborative judgment. Data fusion processing can be divided into two levels: cloud level and network node level. Sensor nodes, power supply infrastructure, edge nodes, sink nodes, and underlying computing devices (such as mobile terminals) belong to network node level data processing, while upper level computing devices such as servers are cloud level data processing. In network node-level data processing, data fusion is performed directly at the data aggregation node and the edge node, which can effectively reduce the data transmission cost. Since data transmission
requires a lot of energy, redundant operations can reduce the amount of data that needs to be transmitted. However, since the nodes often only contain local information of the target environment, complex operations such as cooperative operations are not applicable[10]. In cloud-level data processing, environment-perceived results can be better integrated by performing more complex sensor data fusion operations. Moreover, since the cloud device can provide a relatively rich computing resource, the GSPSOBP algorithm can be applied to a large amount of data obtained from the underlying node.

When applying the GAPSOBP algorithm, it is first necessary to determine the structure of the BP neural network based on the topology map of the wireless transmission network. The wireless sensor network forms clusters according to the LEACH algorithm, and each cluster is regarded as a BP neural network structure. The number of nodes in the cluster is the number of input layers of the BP neural network, and the number of output layers, that is, the number of cluster heads is 1. The number of hidden layers is determined according to formula 1. The number of hidden layers is determined by trial method.

\[ I = \sqrt{(m + n)} + \alpha \quad (0 < \alpha < 10) \]  

Where: n is the number of input layers, and m is the number of output layers.

### 3.2 Power consumption problem

Wireless sensor networks are typically designed to operate in a battery-powered manner, primarily because wireless sensors are often deployed in locations that are difficult to reach directly when deployed. Therefore, once the wireless sensor network node is deployed successfully, it will be difficult to maintain and replace the battery of these deployed sensor nodes, so information fusion faces a common problem in the design process, namely power consumption.

#### 3.2.1 MCU’s calculated power consumption

On most wireless sensor nodes, the computational load is time-varying, so there is no need for the microprocessor to maintain peak performance at all times. CMOS technology is the foundation of MCU, and its energy consumption can be divided into dynamic energy consumption and static energy consumption. The dynamic energy consumption formula of static CMOS is:

\[ E_{\text{switch}} = \alpha f C_{\text{total}} V_{dd}^2 \]  

Where, \( C_{\text{total}} \) is the total capacitance of the gate output node, \( V_{dd} \) is a CMOS power supply, \( f \) is the clock frequency and \( \alpha \) is the frequency of change of the input node per clock cycle.

In a wireless sensor network, because the wait event occurs when the sensor is in an idle state most of the time, the power supply component consumes leakage energy for a long period of time. One way to reduce idle-state energy consumption is to completely shut down unused electronics in the idle state, but the energy savings through this approach are not very efficient due to the potential long delays and the additional energy consumption required to start these devices. Energy can only be saved by reducing the leakage current in the idle state. So the leakage energy of the processor becomes an important parameter in the model. Since the energy loss caused by the leakage current is exponentially related to the supply voltage Vdd, the formula is as follows:

\[ E_{\text{leakage}} = \left( V_{dd} I_0 e^{\frac{V_{dd}}{V_{th}}} \right) T_{\text{bit}} \]  

Where \( V_{th} \) is the threshold voltage of the device, \( V_T \) is the thermal voltage, \( I_0 \) is the leakage current, \( T_{\text{bit}} \) is the calculation time per bit and \( n^- \) and \( I_0 \) are related to the processor.

The energy consumption per bit can be expressed as the sum of the digital switch and the leakage energy, as shown in the following equation:

\[ E_{\text{bit}}(V_{DD}, C_{\text{bit}}, T_{\text{bit}}) = E_{\text{switch}} + E_{\text{leakage}} T_{\text{bit}} \]  

Where \( E_{\text{switch}} \) is the dynamic energy loss of static CMOS, \( C_{\text{bit}} \) is processing the conversion energy per bit, \( T_{\text{bit}} \) is the calculation time per bit and \( E_{\text{leakage}} \) is leaking energy.
Available from equations (2) and (4):

\[ E_{bit}(V_{DD}, C_{bit}, T_{bit}) = \alpha f C_{total}V_{dd}^2 + \left\{ V_{dd} I_0 e^{\frac{V_{dd}}{V_{th}}} \right\} \] (5)

It can be seen from equation (5) that by changing \( V_{dd} \), the node will reduce the dynamic energy consumption of the MCU at a square speed; for the dynamic change of \( V_{th} \), the node will reduce the power consumption exponentially. At the same time, in order to make the wireless sensor nodes work longer and lastingly, the wireless sensor nodes are designed to work in sleep mode during the design process, that is, all sensor nodes are in a sleep state most of the time, only periodically wake up. Monitor whether the current actual working environment requires the collection and measurement of environmental parameters.

3.2.2 Dynamic power management. Dynamic Power Management (DPM) is a control power management technology that dynamically allocates power through user requests, allowing the system to go to sleep when it is not working. While ensuring the normal operation of the system, most devices are working in low power consumption status. The precondition for the application is that the load of some functional modules of the system is in a non-uniform state during normal working hours. When the load of the device in a period of time is longer between the two requests, the device is in an idle state, and the dynamic power management technology can set the device to sleep state, which can save energy, and the system works normally and sleeps. There is a certain amount of power consumption when converting between states. The power management algorithm should be designed just right, and the ratio of the energy consumed by the conversion time to the energy consumed by the sleep state should be considered. That is, although the device is for a while Idle, the normal idea is to set the device to sleep state, but the energy consumed after transitioning to sleep state is less than the energy consumption from the idle state to the sleep state. In this case, no state transition is necessary.

3.2.3 Dormant scheduling mechanism. Dynamic Power Management (DPM) is a control power management technology that dynamically allocates power through user requests, allowing the system to go to sleep when it is not working. While ensuring the normal operation of the system, most devices are working in low power consumption status. The precondition for the application is that the load of some functional modules of the system is in a non-uniform state during normal working hours. When the load of the device in a period of time is longer between the two requests, the device is in an idle state, and the dynamic power management technology can set the device to sleep state, which can save energy, and the system works normally and sleeps. There is a certain amount of power consumption when converting between states. The power management algorithm should be designed just right, and the ratio of the energy consumed by the conversion time to the energy consumed by the sleep state should be considered. That is, although the device is for a while Idle, the normal idea is to set the device to sleep state, but the energy consumed after transitioning to sleep state is less than the energy consumption from the idle state to the sleep state. In this case, no state transition is necessary.

3.2.4 Dormant scheduling mechanism. Scheduling is a task in which the operating system distinguishes tasks by allocating time. In actual systems, scheduling is to run or interrupt thread processes. Since different scheduling algorithms have different attributes, which may be more favorable for some threads, in order to select an algorithm to be suitable for a specific situation, each scheduling algorithm must be compared to determine the impact on the system. The criteria commonly used to determine the impact of scheduling algorithms on the system are as follows: (1) CPU usage, if the CPU processes data all the time, its usage rate is high, and the CPU usage is generally required to be 40% to 90%; (2) Throughput refers to the number of threads completed in a unit of time, as a measure of the workload of the system; (3) Turnaround time is the time interval from the submission to the completion of a process, including the time to wait into memory, the waiting time in the ready queue, the time to execute on the CPU, and the time to operate on I/O; (4) Waiting time. The time it takes for a task to
wait in the queue for scheduling by the CPU is called waiting time. It is related to the CPU scheduling algorithm. The scheduling algorithm is reasonable, which requires less waiting time for task execution, otherwise it will take a long time; (5) Response time. In the system, the time from the submission of the request to the first response is called the response time, the scheduling algorithm affects the response time, and the scheduling algorithm has a reasonable task response time.

In general, we need to maximize CPU usage and throughput, while turn around time, latency, and response time need to be minimized. But in most cases, what is more needed is the optimization of the average metric. Of course, depending on the specific application, it is also possible to optimize the maximum or minimum value instead of the average value.

In the single-threaded model, the system enters the sleep state, the node is in the disconnected state, and wakes up to the normal working state through the interrupt. The node is set on the software; the communication is performed during networking, and only the data is collected during the sleep state, so that the work can be reduced.

3.3 Monitoring system reliability design
(1) The watchdog module is added to the nodes running on all sensor nodes. Because the sensor nodes are hardware-based, the microprocessor-based hardware structure is used according to the actual operation of the microprocessor. The test found that the typical AVR chip is an example. The typical program runs at a frequency of 1 000 times/s, that is, every 1 ms, the system will crash once. Therefore, in the design process, it is difficult to ensure that the sensor nodes work stably for a long time. In this paper, the watchdog guard command is added to all the embedded programs running on the sensor node [9]. By setting the watchdog's overflow period, the management and monitoring of the program for long-term stable operation are realized, and the embedded sensor node is ensured. Can work stably for a long time.

(2) The wireless sensor node adopts a low-power design strategy in the design process, so the sensor node is in a sleep state for most of the time. In the design process, the sensor node is set to start the state monitoring process every 30 minutes. Therefore, when the sensor node moves from the sleep state to the state monitoring process, the reliability of the state monitoring is very high. If the sensor node cannot correctly monitor the working state in the current operating environment due to signal interference or unstable operation of the sensor monitoring module, this may cause the sensor node to erroneously sleep, resulting in some sensitive and important parameters not being collected in time. And transmission, for this reason, in the design process, the sensor node is set to a reliability monitoring implementation step when entering the state monitoring process. If the sensor node does not monitor the correct working status information for three consecutive times, it automatically determines that the current working environment is abnormal, and automatically starts all working modules of the sensor node, so that the sensor node has various accidents under the mine. It can wake up all working modules in time to provide accurate monitoring data for the upper monitoring system.

(3) Data exchange between the sensor node and the backbone network is a difficult and weak environment designed in the entire monitoring system. Once various emergencies occur in the mine environment, the data aggregation point of the sensor node and the backbone communication network must ensure good communication capabilities. Otherwise, the trunk network will be disconnected from the sensor network at the front end, thus losing the ability to monitor the actual application environment. Therefore, in the design process, by setting the data point of the wireless sensor network to be redundantly arranged, there are multiple different data aggregation access points between the wireless sensor network and the backbone communication network, thereby improving the reliability of data aggregation access [4]. Sexually, while taking full advantage of the wireless transmission characteristics of wireless sensor networks, the physical coverage of wireless sensor networks is extended as much as possible to avoid excessive dependence of the entire communication network on the backbone communication network based on wired conditions. Because of the various accidents in the mine, the wired communication network is the most vulnerable and most vulnerable network infrastructure, and if the physical range of the wireless network can be extended as much as possible,
the wireless transmission technology can be better improved. In addition, the number of nodes in the wireless sensor network can be increased to improve the accuracy and reliability of environmental parameter measurement, and also to improve the life cycle of the entire wireless sensor network.

4. Experiment and analysis

4.1 Node energy test

The test of the energy of the design node is calculated by measuring the current of the communication node using a multimeter to calculate the energy consumption of the node. Experiments establish two communication nodes, test the processor module and wireless communication module of the node, and select the CC2530 for the RF chip. Three nodes were selected in the experiment: the Telosb node, the MSP430 node, and the Mica2 node were compared with the node under the same conditions. The node processor sets the DEEP-STOP mode to achieve low power consumption, and the processor on the communication module acts as a coprocessor to set the PM3 mode for low power consumption. The test results and related characteristic parameters are shown in Table 1.

| Working status node          | This node | MSP4 30 | Telos b | Mic a2 |
|------------------------------|-----------|---------|---------|--------|
| Minimum working voltage (V)  | 1.1       | 1.8     | 1.8     | 2.7    |
| Emission current (mA)        | 17        | 26      | 19.5    | 25.4   |
| Receiving current (mA)       | 10        | 25.9    | 21.8    | 15.1   |
| CPU sleep current (uA)       | 42        | 1.5     | 2.6     | 20.0   |
| CPU activity current (us)    | 65        | 0.724   | 1.8     | 8.0    |
| MCU wake-up current (us)     | <3.0      | <1.0    | <6.0    |        |
| Flash read current (mA)      | 0         | 0       | 4.1     | 9.4    |
| Flash write current (mA)     | 0         | 0       | 15.1    | 21.6   |

In the energy node test, it is assumed that the system is in a sleep state for most of the time, and there is only a small amount of data transmission. Since the actions of collecting, processing, and transmitting and receiving data are extremely fast, it is ms-level, so we work according to the system for 1 s. To calculate. The system operating current consumption is 65mA, the sleep state current consumption is 42A, and the transmit/receive current is 17/10m A. Thus, the system power consumption per hour is: \[
(65 + \frac{10+17}{2}) + \frac{3599}{3600} \times 42 \times 10^{-3} = 0.06379 \text{mAh}.
\] The design considers that the node sends data at a fixed time interval, most of which is in a dormant state, and the sleep current of the processor and the RF chip are very small. This node has a small system energy consumption in an environment with relatively long sleep time, which has great advantages.

4.2 Power control algorithm experiment

As a sink node, a color LCD device is added for observing data needs. Since LCD power consumption accounts for 68% of the entire node, when designing a node, starting from software programming, integrated dynamic power management technology and voltage management technology to realize LCD liquid crystal Display power consumption is reduced. In the operating system, the number of clock ticks running in the user state and the system state after the CPU is started is obtained by the global variable. The time is 100 ms as the sampling time, and the idle time is obtained by calculating the task execution time, and the idle period of the sampling period is 100 ms. According to the data trend of the idle ratio in three consecutive sampling periods and whether the idle mode timer idle expires, the operating state of the processor is judged, and a decision to control the LCD is made. The experiment uses two methods: (1) System normal working power consumption test; (2) The system uses dynamic power management technology and voltage management technology power consumption test.
In the power consumption test of the aggregation node, the node works for 5s. When the power control algorithm is not used, the system current consumption is 97mA, the sleep state current consumption is 53mA, and the transmit/receive current is 18/15mA. The system consumes power: \[ \frac{5}{3600} \times \left( 98 + \frac{18+15}{2} \right) + \frac{3599}{3600} \times 5 \times 53 \times 10^{-3} = 0.423954 \text{mAh} \]
\[ + \frac{3599}{3600} \times 5 \times 45 \times 10^{-3} = 0.357576 \text{mAh} \]

The program controls the image processor so that the input signal field frequency is slightly higher than 40 Hz, so that the image is not flickered, the number of refreshes of the LCD storage capacitor is reduced, the read/write rate of the frame buffer memory and the clock frequency of the bus are slowed down. The goal of power consumption.

5. Conclusion

In this paper, the research on the safety monitoring system of the power supply bureau is combined with the following overall design schemes: one is wireless sensor network technology; the second is ZigBee embedded technology, and the sensor network low power consumption is analyzed. The wireless sensor network management system is designed in detail and the low-power operation mode of the sensor network is analyzed. The system has multiple functions, which are embodied in various aspects such as acquisition, analysis and storage of data.

The security monitoring system designed with ZigBee technology and information fusion technology still needs to be improved in the process of sensing information, but it can still improve the security protection capability of the power supply bureau, improve the availability and durability of the power grid system, and make the power grid system run more efficient, stable and safe.

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