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Research Article

Design of Centralized Heating Monitoring System Based on Wireless Sensor Networks

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Current centralized heating monitoring system has realized the collection and control of working condition data in heating power stations, but there are still some shortcomings, such as the inability to collect data on the working conditions of user sides, and the inability to meet the further demand of heating enterprises for the refinement of heating network monitoring data. A wireless sensor network is a fully distributed sensor system with no central node, which can intensively deploy many sensor nodes to monitoring area through random placement, and integrates sensors, data processing and communication modules to form a self-organized network system. Therefore, in order to realize the intelligence of heating system and improve the flexibility of node data collection, the monitoring system can use wireless sensor network technology to realize wireless collection of node data, and display the collected data on a man-machine interface in real time. On the basis of research results from previous scholars, this paper expounds the research status and significance of centralized heating monitoring system design, elaborates the development background, current status and future challenges of wireless sensor network technology, introduces the methods and principles of wireless network communication protocol and heating and heat balance flow analysis, proposes a structural model of a centralized heating monitoring system based on wireless sensor networks, carries out the design of perception and convergence nodes, analyzes the layout of wireless sensor networks, explores the design scheme of centralized heating monitoring system based on wireless sensor networks, conducts the hardware and software design of the monitoring system, implements the software testing and hardware debugging of the centralized heating monitoring system, and finally discusses the relationship between data transfer related tasks and task scheduling. The study results show that the application of the centralized heating monitoring system based on the wireless sensor networks can not only more conveniently monitor, control and manage the entire heating networks, but also make full use of the centralized monitoring and quantitative management functions of the wireless sensor networks. This achieves dynamic tracking and monitoring of heating operation, real-time diagnosis of hidden dangers in heating operation, and safe, normal and energy-saving operation of the centralized heating system. The study results of this paper provide a reference for further researches on the design of centralized heating monitoring system based on wireless sensor networks.

1. Introduction

Centralized heating has become a main method for house heating in many areas. Centralized heating technology is currently relatively mature, has high safety, can effectively reduce environmental pollution, and is easy to achieve scientific management of heating. However, traditional centralized heating has problems such as uneven heating, local overheating, and outdated monitoring systems [1]. Therefore, centralized heating monitoring systems developed based on information technology have been widely promoted and applied. The current centralized heating monitoring system realizes the data collection and control of the heating power station, but there are still some shortcomings [2]. The wireless sensor network technology collects processes and displays the operating data of the thermal station, automatically adjusts, detects faults, diagnoses and alarms, calculates cumulative heat consumption, and prints reports.

For example, it cannot realize the user-side data collection and cannot meet the further requirements of the heating enterprise for the refinement of the heating network monitoring data. Therefore, it is important to use more advanced information technology to design a centralized heating monitoring system with more comprehensive functions, more accurate data, and more sensitive operations [3]. In order to realize the intelligence of heating and improve the flexibility of node data collection, the monitoring system can use wireless sensor network technology to realize wireless collection of node data, and display the collected data on the man-machine interface in real time [4].

The wireless sensor network is a self-organized system structure composing a large number of micro sensor nodes deployed in monitoring areas through radio communication. Its purpose is to cooperatively perceive, collect and process the information from the monitored objects and feedback them to observers [5]. These sensor nodes integrate sensors, data processing and communication modules, which are connected through wireless channels and form a self-organized network system [6]. The protocol stack is designed after the investigation of the remote monitoring environment of the urban heat pipe network and the in-depth research on the commonly used communication technologies of wireless sensor networks, and is used for data collection at the user end of the heat network. Some or all of the nodes in the sensor network can be moved and the topology of the sensor network will also dynamically change with the movement of nodes [7]. Wireless sensor network integrates sensor technology, embedded technology, distributed information processing technology and network communication technology. It can monitor, perceive and collect information of various environmental objects in real time collaboratively, and transmit the information to the system user host for analysis and processing [8].

On the basis of research results from previous scholars, this paper expounds the research status and significance of centralized heating monitoring system design, elaborates the development background, current status and future challenges of wireless sensor network technology, introduces the methods and principles of wireless network communication protocol and heating and heat balance flow analysis, proposes a structural model of a centralized heating monitoring system based on wireless sensor networks, carries out the design of perception and convergence nodes, analyzes the layout of wireless sensor networks, explores the design scheme of centralized heating monitoring system based on wireless sensor networks, conducts the hardware and software design of the monitoring system, implements the software testing and hardware debugging of the centralized heating monitoring system, and finally discusses the relationship between data transfer related tasks and task scheduling. Specifically, Section 2 introduces the methods and principles of wireless network communication protocol and heating and heat balance flow analysis; Section 3 proposes a structural model of a centralized heating monitoring system based on wireless sensor networks; Section 4 explores the design scheme of centralized heating monitoring system based on wireless sensor networks; Section 5 discusses the relationship between data transfer related tasks and task scheduling; Section 6 is conclusion.

2. Methods and principles

2.1. Wireless network communication protocol. As the network scale becomes larger, the delay caused by the long back-off time will increase exponentially; and choosing a suitable back-off time strategy can increase opportunistic routing transmission and reduce the end-to-end transmission delay. Suppose the back-off time interval of node i is a_i, the delivery rate between sending node i and node j is a_j, and the forwarding probability of node i continuing to forward to the destination node k after receiving the packet is a_k, then the back-off time A_i is:

$$A_i = \frac{1}{b}\sum_{i=1}^{n}\frac{a_k\left(\|a_i\|^2\right)}{a_j[c(a_i)-c(a_k)]} \tag{1}$$

Where $c(a_i)$ and $c(a_k)$ are the processing time of data packets at nodes i and k, which are determined by the sending node in the data packet; b is a random number that changes with time to prevent node back-off time and the selected node conflicts with other backups.

Assuming that the setting of sensor nodes is basically a relatively uniform random distribution, for any non-empty sub-area b_i in the monitoring area B, $N(b_i)$ represents the number of objects falling in the monitoring area B, then the probability of $N(b_i) = m$ is:

$$P\{N(b_i)=m\} = \frac{1}{l}\frac{(c_i\|b_i\|)^m(b_i-d_i)}{\left[h_i-e^{-m\|g_i\|}\right]f_i[(o_i-p_i)]} \tag{2}$$

Where c_i is the intensity of the random process; d_i is the area of area B; f_i is the input vector, which is the influencing factor; g_i is the output vector, which is the temperature value corresponding to each influencing factor in the time series; l is the correlation coefficient between the influencing factor and the indoor temperature; o_i and p_i are the average values of input parameters and output parameters.

In a wireless heat metering network system, suppose that the heat meter source node needs to transmit q-bit data to the concentrator after multiple hops, and the wireless transmission power can be adjusted. Data transmission needs to be forwarded by q-1 intermediate heat meter nodes, so the total energy consumption $C(q_i)$ of the node transmitting q_i bit data to the concentrator is:

$$C(q_i) = \frac{(q_i-r_i)\cdot(q_i-s_1)}{\sqrt{(q_i-s_2)^2+(q_i-s_3)^2}} \tag{3}$$

Where r_i is the correlation coefficient between the i-1-th hop intermediate node and the i-th hop intermediate node; s_1, s_2, and s_3 are constant factors related to energy consumption, respectively.

The monitoring system uses the existing public facilities in the city to construct a monitoring network. According to

the characteristics of convenient cable wiring inside the heating station, a field bus is used to lay out the local area network. The wireless low-speed network of the wireless sensor network is used at the user end of the centralized heating and the wireless sensor network includes a monitoring center. The sensor nodes are installed on the roof of the building on the user side of the centralized heating that needs to collect data, and the convergent nodes are installed in the heating station. Each sensor local area network is composed of a sink node and multiple sensor nodes. After the nodes are turned on, they automatically form a tree-like hierarchical network with the sink node as the root node. The user-side working condition data of the centralized heating collected by the sensor node is aggregated to the data relay aggregation node by means of wireless jump transmission. The thermal station sensor collects the field working condition data in the thermal station and converge it to the data relay convergent node by the field bus. The protocol stack is designed after the investigation of the remote monitoring environment of the urban heat pipe network and the in-depth research on the commonly used communication technologies of wireless sensor networks, and is used for data collection at the user end of the heat network.

2.2. Flow analysis of heating balance. Considering that the heating network pipes will dissipate heat to the surrounding space uninterruptedly, resulting in significant high-temperature hot spots on the pipe shell or certain components, which constitutes a suitable environmental heat source. The terminal generates an available temperature difference to drive its output power. When the impedance of the load and the thermoelectric module match, the maximum output power D_i can be expressed as:

$$D_i = \left[\frac{z(t_i)}{x(t_i) - y(t_i)}\right] \frac{t_i(u) - v_i(u+1)}{t_i(u) - w_i(u+1)} t_i \in [t_i(u), t_i(u+1)] \tag{4}$$

Where t_i is the material insulation coefficient; u is the pulse interval; v_i is the pulse time interval; w_i is the temperature difference between the hot and cold ends; x is the cross-sectional area of the thermoelectric arm; y is the length of the thermoelectric arm; z is the number of thermocouple pairs inside the thermoelectric device.

When a heat meter is installed in the heating user and the hot water flows through the heating user, the heat meter can calculate and display the heat absorbed by the heating user E_i:

$$E_i = \int_{i=1}^{n} \frac{B_i|C(i)|^2 + D(i)|F(i)|^2}{G(i)|H(i)|^2} \tag{5}$$

Where B_i is the heat absorbed by the heating user; $C(i)$ is the mass flow of water flowing through the heat meter; $D(i)$ is the volume flow of water flowing through the heat meter; $F(i)$ is the heat flowing through the density of the water in the table; $G(i)$ is the difference in enthalpy between the inlet and outlet temperatures of the heating user; $H(i)$ is the time.

During the operation of the centralized heating system, there is unavoidable parameter perturbation due to friction and changes in resistance and capacitance; the system parameters at this time behave as the nominal parameters with an additional amount of change. If the system sensitivity function J is the ratio of the system output change to the controlled object change, then the compensation sensitivity function $J(i)$ is:

$$J(i) = \sum_{i=0}^{t}[K(i)L(i)] = \sum_{i=0}^{t} \frac{M(i)N(i)}{O(i)P(i)} \tag{6}$$

Where $K(i)$ is the nominal transfer function of the controlled system; $L(i)$ is the multiplicative perturbation; $M(i)$ is the perturbation bound function; $N(i)$ is the amplifier coefficient; $O(i)$ is the input voltage control signal; $P(i)$ is the voltage signal returned by the position feedback.

The server collects and stores data from each client site in real time, and monitors the operation of each site in real time. The control layer is located in the substations of each thermal power company. After the software is started, it is initialized first. The node is in a sleep state by default, waiting to receive data. When the node receives data through the radio frequency module or its own sensor senses the data, it is awakened, processed data and sent to the next node when the sending cycle arrives or the cluster head node. The automatic processing is the ability to automatically perform self-adjustment control or alarm by means of text messages, phone calls, sound and light, email, etc., and notify the computer room management personnel in time. In this protocol, the sensing node has four states: sensing, forwarding, sensing and forwarding, and inactive. The protocol also divides the time frame into a data transmission phase, a refresh phase, a recombination phase caused by a refresh, and an event-triggered recombination phase. The sink node exchanges data with the cluster head node through the radio frequency module, and communicates with the host computer through the serial port. Therefore, the sink node can be awakened by radio frequency data, and it can also be awakened by serial port data. The processed data is placed in the sending buffer. When the data sending cycle comes, the data in the buffer is sent out through the radio frequency module, or the data is sent to the upper computer.

3. Structure model of the centralized heating monitoring system based on wireless sensor network

3.1. Sensing and convergence node design. The wireless ad hoc network in the centralized heating monitoring system is a wireless communication network composed of wireless communication nodes such as monitoring terminal nodes, building byte points, community nodes, and relay nodes distributed in different locations in the centralized heating area. The temperature data reported by the wireless temperature sensor is first stored on the relay module, and then the temperature data is reported to the database server through the gateway according to the patrol instruction of the central

monitoring system. It is widely used in technical fields such as communication, electronics, measurement and control with its strong self-organizing network capability and unique multi-hop routing and transmission advantages [9]. The wireless temperature sensor has two working states, heating period and non-heating period, and set up unmanned house management. As a host, it can complete the wireless sending and receiving of instructions and data information according to the terminal's realization function; as a route, it can refer to parameters such as wireless link quality and route hops to select an optimal path for data transmission. Therefore, in the entire wireless sensor network, without base station support, any communication node can interact with neighboring nodes for data (Figure 1). Therefore, the wireless sensor network is a true self-maintenance and self-management multi-hop network.

The software control makes the sensor node sleep for most of the time, wake up every once in a while and the system uses hardware address allocation method to allocate node addresses. Daily management tasks include report generation and printing, centralized heating metering management, controller working parameter setting, remote data collection, summary and comprehensive analysis of operating data. Some circuits will be turned off, and only the timer and interrupt will be retained, and the timer will be started in the dormant state. The process scheduling module completes the control flow of the operating system, and it is related to the initialization of the entire wireless sensor and the system operating state. The energy consumption management unit supports the energy consumption status control of processors, radio frequency transceivers, sensors and other components. Some data collection nodes can also act as routing nodes and act as relay bridges. Its function is to connect data collection nodes beyond the influence range of the central data collection node. Therefore, the functions of each node are distinguished by different physical address information. When the main collection node performs a query operation, it needs to determine the physical address of the destination node in the first place.

The central monitoring station needs to receive the data packets sent by centralized station and display the data for monitoring personnel and heating users to access and view. The former sends the data collected by the interface to its own application layer for frame structure organization, which realizes the data collection function; the latter sends the application layer data application serial communication program to the serial port of the module sends data to the network through its data transfer function. The module is more convenient to use, can automatically complete all information exchange with the network, and can be directly connected to various configuration software without special drivers [10]. The sensor part is in a dormant state when there is no data collection. Once the collected heating information needs to be transferred, the sensor starts to work, transfers the heating packages to the wireless sensor network and then resumes the dormant state. Once the node data comes in, it will immediately pass the information to the monitoring center through the module to process the incoming data. The pressure sensor is small in size, lights enough in weight, and adopts a stainless steel sealed structure, which can work in harsh environments with a high degree of corrosion.

3.2. Layout of wireless sensor network. The centralized heating monitoring system can monitor heating information and record operating parameters of centralized heating in real time, and carry out over-limit alarms for parameters such as temperature, pressure and flow. Daily management tasks include report generation and printing, centralized heating metering management, controller working parameter setting, remote data collection, summary and comprehensive analysis of operating data, and historical data backup. Through the automatic control of the centralized heating, the monitoring system will make the entire system heat evenly, meet the comfort requirements, reduce heat consumption, and achieve the purpose of energy saving. The management layer is located in the main station of the thermal power company and consists of a network with industrial control machines as the core (Figure 2). The industrial control machines operate around the clock. The industrial control machine is not only the server of the dispatch center, but also the client relative to the collection and control stations. The server collects and stores data from each client site in real time, and monitors the operation of each site in real time. The control layer is located in the substations of each thermal power company. It collects, stores, monitors and processes signals from smart sensors in real time, completes the network transmission of collected data, and can set parameters such as over-limit alarms at any time.

Adding a data analysis thread to the main process can play a role in the first-level monitoring of the physical quantity of the pipe network. The processor receives the physical quantity collected by the terminal device and compares it with the threshold first. Control commands and transfer the heating information to the server to display error information on the control center web page. Since four threads are running in the main process and frequent data interaction and transmission are required between the threads, a global variable structure is defined in the main process, and the variable values required by each thread are obtained from the global area. In order to prevent conflicts in multi-threaded operation of the global area, each thread uses semaphores to mutually exclusive access to global variables. The central monitoring station needs to receive the data packets sent by centralized station and display the data for monitoring personnel and heating users to access and view. The content of the beacon frame includes information such as the network number of the network and the communication channel occupied by the network. The control center obtains the corresponding network number and channel information according to the received beacon frames of different networks, and selects the appropriate network number and communication channel to establish a new wireless sensor network [11].

Automatic monitoring is real-time online monitoring in the unattended situation, and can automatically deal with abnormal situations. The automatic processing is the ability to automatically perform self-adjustment control or alarm by means of text messages, phone calls, sound and light,

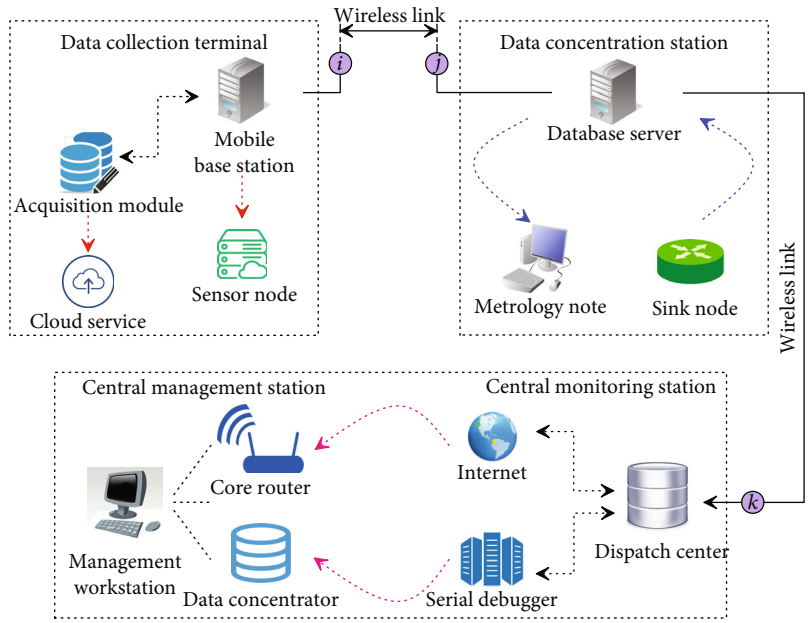

Figure 1: Structure model of the centralized heating monitoring system based on wireless sensor network.

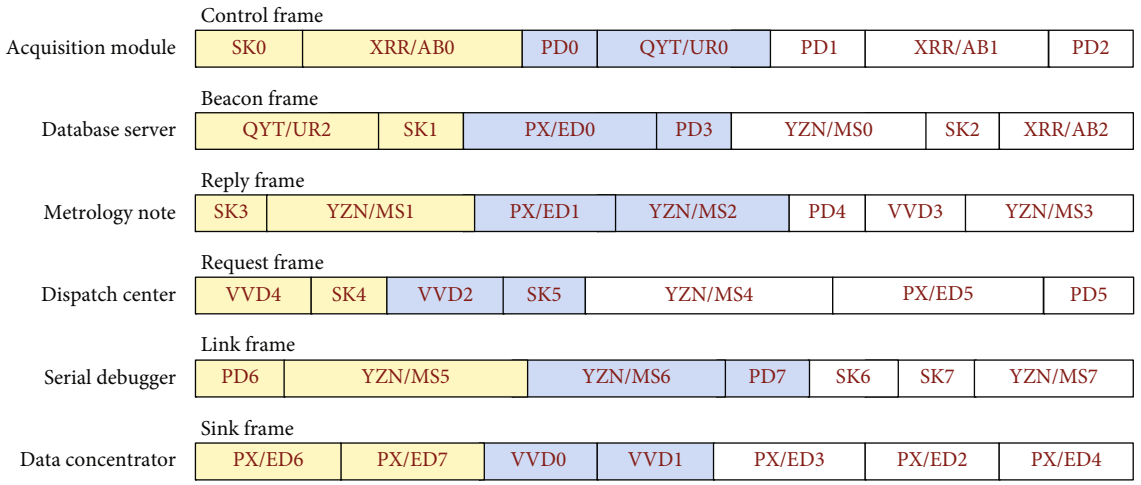

Figure 2: Sensing and convergence node design for the layout of wireless sensor network.

email, etc., and notify the computer room management personnel in time. The real-time performance and stability are mutually restricted. Too high real-time performance will inevitably reduce stability; therefore, the system can flexibly configure real-time performance. In the case of limited system resources, as the collection parameters increase, the load on the data collection terminal and the data collection management center will also increase, which affects the real-time performance and even stability of the system, and therefore requires scalability of the system [12]. The data processing part is the core of the entire network. The main tasks it completes are information processing, storage, data transmission and reception, and control of the components of the data collection part. This system requires the setting of thresholds and ranges for important parameters of the computer room environment.

4. Design scheme of centralized heating monitoring system based on wireless sensor network

4.1. Hardware design of centralized heating monitoring system. In the centralized heating monitoring system, the wireless sensor node data collection part includes temperature sensors, humidity sensors, light intensity sensors, smoke sensors, water immersion sensors, etc., which collect temperature, humidity, light, fire alarm, and water immersion parameters in the computer room. The research and development of a single sensor node self-organizing dynamic multi-directional wireless data transmission sensor network cannot work alone, because its wireless communication distance is limited, and it is impossible to directly send the

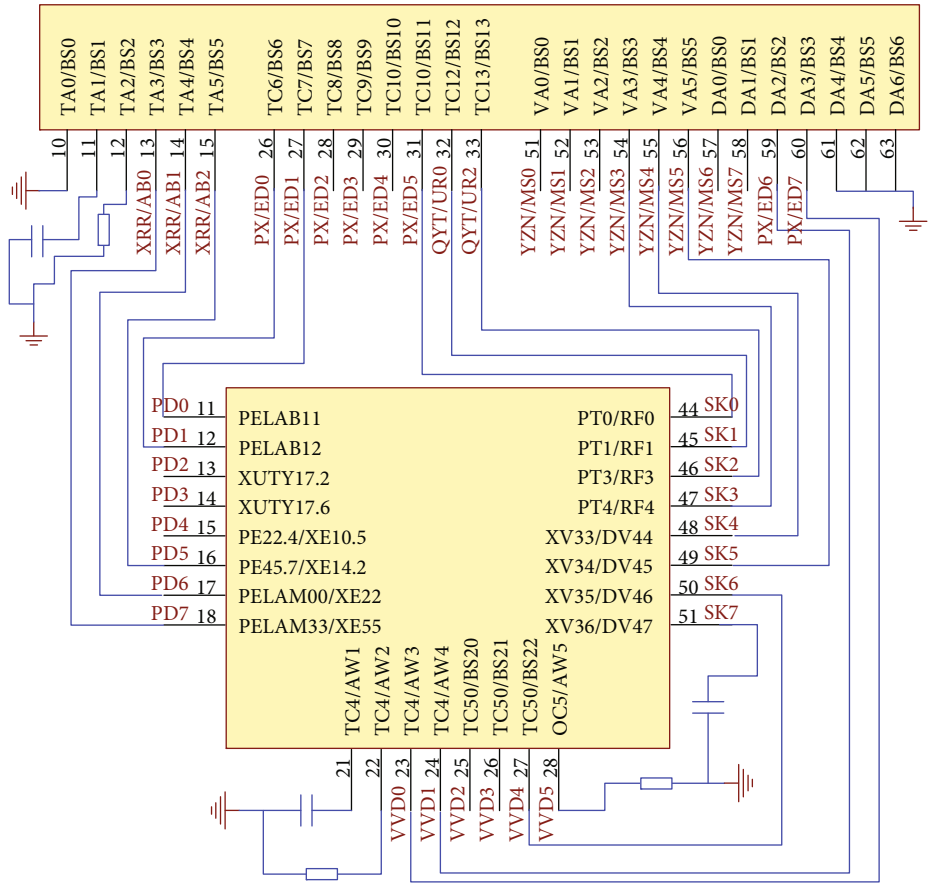

Figure 3: Design result of core monitoring circuit in the centralized heating monitoring system based on wireless sensor network.

collected monitoring data to the computer network system. This requires a certain protocol and technology to interconnect multiple sensor nodes to form a wireless data transmission sensor network to realize data forwarding through neighboring nodes and change short-distance to long-distance transmission [13]. The upper-level computer management software is deployed on the monitoring host. It is designed to transfer the temperature information by the wireless sensor network, forming an intuitive monitoring view, and real-time alarming according to the preset alarm strategy (Figure 3). The wireless sensor network subsystem and the upper computer system rely on the gateway to interconnect. A gateway node is a wireless sensor node with relatively complex functions. It can naturally communicate with other heating information in the sensor network and it can also design a hierarchical data transfer mode for multi-level gateway nodes.

The wireless household on-off solenoid valve adopts a normally-open on-off solenoid valve to control the on-off of the heating water to realize the regulation of the heating temperature, and keep it normally open when it is not controlled or when the power is cut off, and does not control the heating water flow. When the heating water is closed, the wireless household on-off solenoid valve activates the automatic protection function, and automatically opens the heating water according to the temperature to ensure the normal heating of the user. The temperature data reported by the wireless temperature sensor is first stored on the relay module, and then the temperature data is reported to the database server through the gateway according to the patrol instruction of the central monitoring system [14]. The wireless household on-off solenoid valve control is used in conjunction with the wireless temperature sensor, and the point-to-point binding is realized by setting on the central control system. When the wireless temperature sensor receives the switch command sent by the central monitoring system through the wireless repeater, or controls the switch of the wireless household on-off solenoid valve according to the temperature data and time period, realizes the on-off control of the heating household water inlet solenoid valve to achieve the regulation of heating temperature (Figure 4). The wireless temperature sensor has two working states, heating period and non-heating period, and set up unmanned house management. The wireless gateway is connected to the server in a wired manner, and the wireless gateway can be set with different Ethernet addresses, as long as it is on the same network segment as the database server.

In order to save energy, terminal monitoring nodes are dormant most of the time. When the monitoring heating information is not been packed and not been transferred, they turn off the node communication module and data acquisition module to save energy. After the coordinator receives the data packet, it will return the original route and send the confirmation message to the terminal

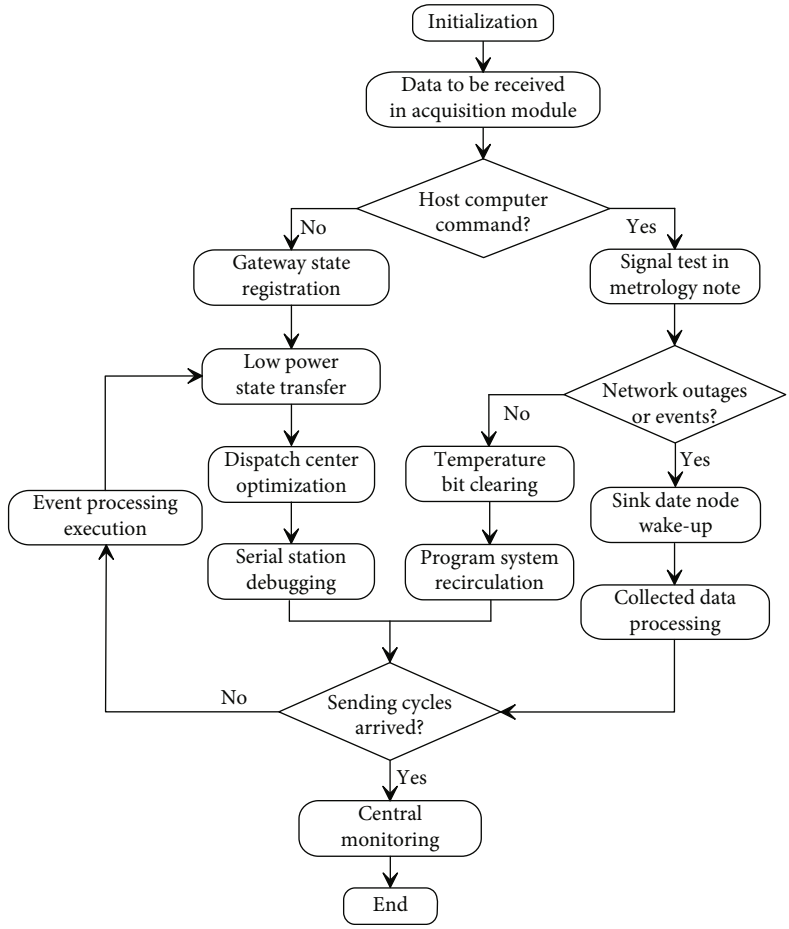

Figure 4: Design scheme flowchart of centralized heating monitoring system based on wireless sensor network.

monitoring node to realize handshake communication with the monitoring node. If the heating information does not transfer confirmation, the coordinator continues to send data until it receives the confirmation message. The main job of the coordinator is to transfer heating information, upload them to monitoring hosts, and forward commands from the monitoring center. In addition, considering that in the same centralized system, different heating pipes have different energy requirements and consumption. In order to balance the electricity consumption of each heating pipe, the centralized heating monitoring system uses a clustering network to perform mean clustering on the sensor network. The system then combines the remaining heating information and uses the global optimization capability of the genetic algorithm to select the appropriate cluster heating pipe. As a result, the sink node is a sensor node with rich memory resources, strong computing power, and sufficient energy supply.

4.2. Software design of centralized heating monitoring system. Since wireless sensor networks are usually highly related to applications, each protocol has its own uniqueness and shortcomings. Through the analysis and comparison of the protocol and the actual situation of the system itself, a set of routing protocols for multi-hop adaptive routing path selection are designed. In the parent node selection of the same level, the only parent node will be selected according to the estimated value of the received signal power level in the current street. The maximum number of relay router hops for transmitting messages is inversely proportional to the maximum number of nodes connected to a router node. Therefore, each node can only have one parent node, but it can have multiple child nodes (Figure 5). The heating information is related to the establishment and maintenance of routing and the basic functions to be realized by routing protocol are routing. After simple processing operations, the microcontroller unit uses the channel access mechanism specified by the network protocol to transfer heating information to the system via the radio frequency transceiver unit. It sends the target pipe address and transmission path instruction to the subnet heating pipe in centralized system and the heating pipe that receives the instruction corresponds to its own address to determine whether to execute it. The client's data reading process corresponds to the server's data writing process, and the client's data writing process corresponds to the server's data reading process.

The star structure is relatively easy to implement, but its functions are limited. If the central node fails, the entire network will be paralyzed. The tree structure can form a network with a relatively wide coverage, but if one route fails,

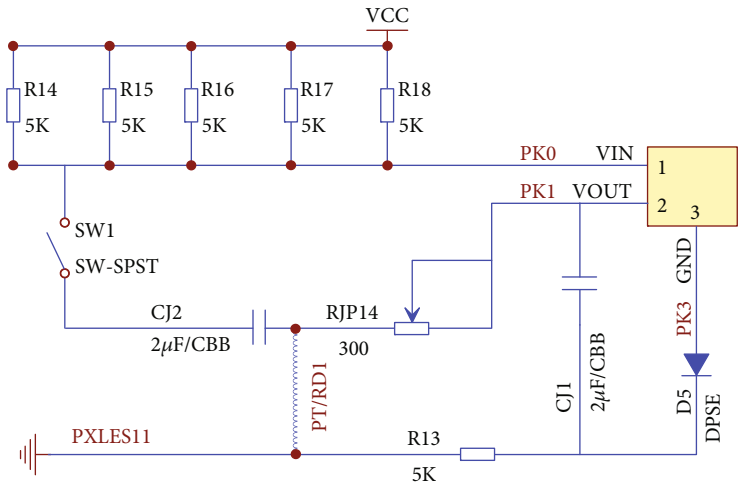

Figure 5: Design result of core interface circuit in the centralized heating monitoring system based on wireless sensor network.

there is no route that can be replaced. This kind of function is usually used as the communication interface between heating information and centralized system. It is the interface that transfers the control right to the application program when the protocol stack is running, if the application program needs to perform corresponding processing. In the mesh network topology, nodes have dynamic networking and automatic routing functions. All sensor node devices in the network not only complete the task of data collection, but also forward the data of other nodes and transfer heating information to the centralized system. The greater the number of router node hops, the greater the vertical coverage area of the network, and the greater the data delay at the terminal data collection node; the greater the maximum number of nodes that the router can connect to, the greater the horizontal coverage of the network. In the actual development process, the developer adds the user's application logic to the required interface, defines the user's data processing process, and calls it at the appropriate time through the corresponding interface function to realize the application code [15].

According to the location of the centralized heating equipment, an appropriate number of terminal temperature collection control nodes and router nodes are arranged in different areas. After doing the corresponding judgment processing, it forwards the collected device temperature to the centralized system, and finally uploads the temperature data to upper computer monitoring software. The heating information is related to the establishment and maintenance of routing and the basic functions to be realized by routing protocol are routing [16]. The maximum number of relay router hops for transmitting messages is inversely proportional to the maximum number of nodes connected to a router node. Therefore, the larger the maximum router hop number is set, the fewer detectors and routing nodes that each router node can connect to them. The greater the number of router node hops, the greater the vertical coverage area of the network, and the greater the data delay at the terminal data collection node; the greater the maximum number of nodes that the router can connect to, the greater the horizontal coverage of the network. However, the probability of data transmission conflicts between router nodes has also increased, and the delay of data transmission has also increased. Therefore, the system needs to set appropriate network parameters according to the scale and structure of the communication centralized heating to optimize the performance of the entire monitoring network.

5. Discussions

5.1. Relationship between data transfer related tasks and task scheduling. The application of the centralized heating monitoring system can not only more conveniently monitor, control and manage the entire heating network, and coordinate scheduling, but also can give full play to the computer's centralized monitoring and scientific quantitative management functions. The heating information is related to the monitoring system in the centralized heating program, and the eating program need to optimize the censor layout styles for the operation of the centralized heating pipes. The main task of the coordinator is to transfer heating information, upload them to monitoring hosts, and forward commands from the monitoring center. The wireless household on-off solenoid valve control is used in conjunction with the wireless temperature sensor, and the point-to-point binding is realized by setting on the central control system. After simple processing operations, the microcontroller unit uses the channel access mechanism specified by the network protocol to transfer heating information to the system via the radio frequency transceiver unit. The sink node uses the routing algorithm to forward data to the management node through multiple hops to realize the exchange of information [17]. Therefore, the design of sensor networks must take improving the heating pipes of the centralized system as primary goal (Figure 6).

The data collection function will display the operating status of all circulating pumps, make-up pumps, electric regulating valves and other operating equipment on site in real time, and parameters of the heat exchange unit. The frequent alarm function will display the abnormal conditions

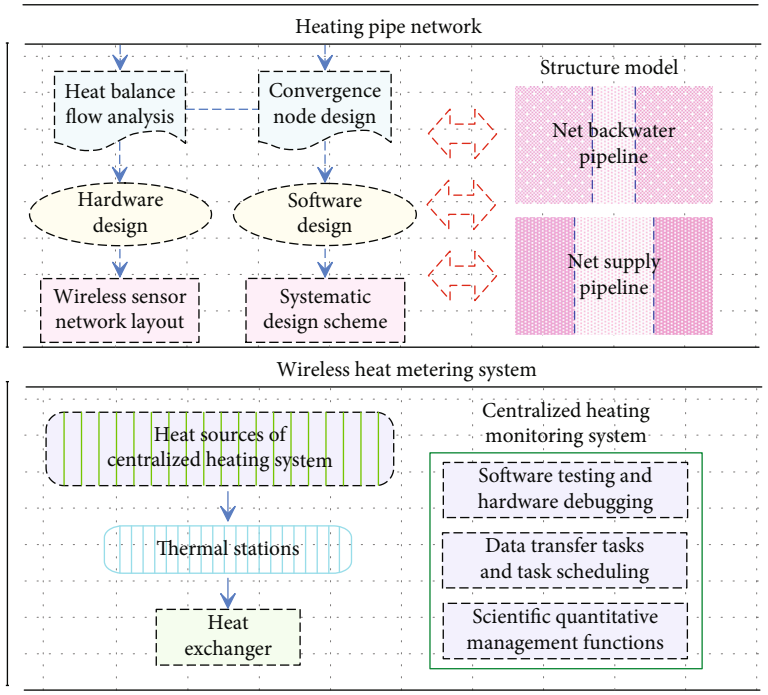

Figure 6: Relationship between data transfer and task scheduling of the centralized heating monitoring system.

or alarms of the on-site heat exchange unit from time to time and promptly notify the station patrol personnel to solve the problem on the spot, and the operator can confirm and manage the alarm information that appears from time to time. The remote setting function will send equipment operation instructions remotely and remotely set the parameters of the field equipment, which provides a very convenient means for equipment maintenance. When the data collection equipment changes, the software can update the instrument and wireless sensor network node information in real time, and has the adaptive capability of equipment update. The application of the centralized heating monitoring system can not only more conveniently monitor, control and manage the entire heating network, and coordinate scheduling, but also can give full play to the computer's centralized monitoring and scientific quantitative management functions. This realizes dynamic tracking and monitoring of heating operation, real-time diagnosis of hidden dangers in heating operation, and enables the heating system to operate safely, normally and energy-saving.

The coordinator first needs to select idle channels for the entire network, and then generate beacon frames and send them regularly, and at the same time process other device association or disassociation requests, data transmission, etc. The association operation refers to the process of registering with the coordinator and identity authentication when a device joins a specific network. The time allocation of super-frames is defined by the network coordinator, which mainly includes active periods and inactive periods. All communications in the network must be carried out during heating process; and during the optimizing stage, the device can revoke the heating information [18]. The physical layer is designed to realize the transparent transmission of various heating information between data link entities on a physical transmission medium. The transmission mechanism of each data transmission also depends on whether the network supports beacon transmission. When there is no low-latency device in the network, the system can choose not to use beacon transmission in data transmission. In this case, although data transmission a beacon is not used, but when the network is connected, a beacon is still needed to complete the network connection.

5.2. Software testing and hardware debugging of the centralized heating monitoring system. The management layer uses a carrier sense algorithm to avoid shared channel conflicts caused by multiple nodes sending data at the same time. In addition, the management layer searches for the next hop address based on the address information provided by the network layer to cooperate with the physical layer to complete the single-hop data transmission. Sensor nodes are divided into router nodes and leaf nodes. Among them, heating pipes and heating devices are designed to address allocation, and the leaf nodes are at the end of this local area network and do not have the function of address allocation [19]. The network layer implements routing management in the protocol, and its functions also include address allocation and routing table management for new nodes in the process of wireless sensor network ad hoc networking. From the function, it uses the network to complete the two data aggregation of the sensor local area network and the internal field bus of the heating station, and the aggregation node automatically completes the registration and login to the network after a period of time (Figure 7). The structure

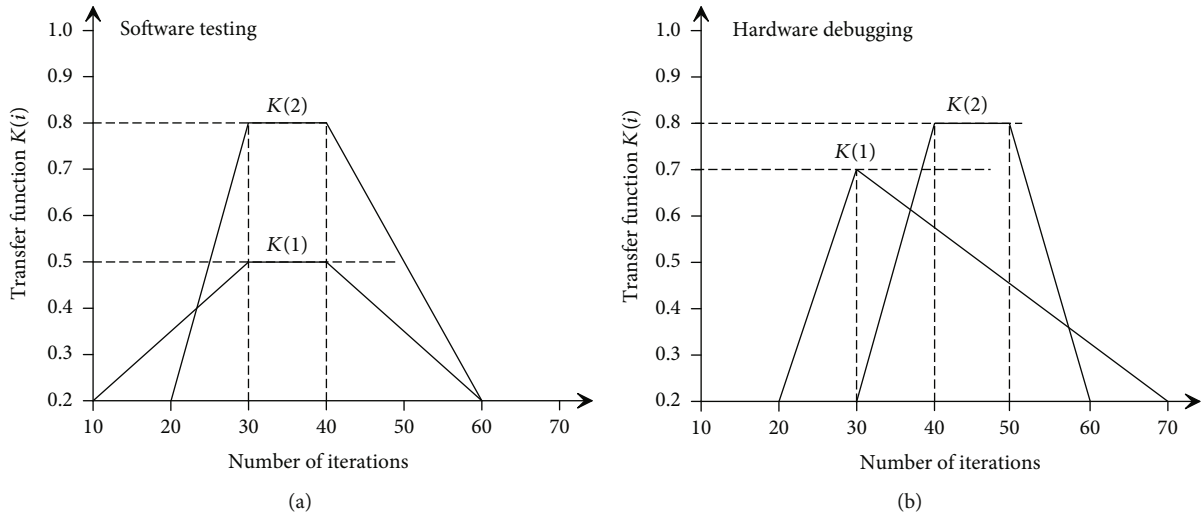

Figure 7: Transfer functions of numbers of iterations in software testing (a) and hardware debugging (b) of the centralized heating monitoring system.

defines the menu description string members, and the menu description string is sent through the serial port to display the menu items. The protocol stack of the heating pipe and the centralized system is different according to the heating devices. The sensor node is divided into a router node and a leaf node according to the address that can be allocated and the address that cannot be allocated.

The heating operation management software collects the temperature, pressure, flow, heat, valve opening, outdoor temperature and other data of the thermal station site, weighs and calculates the operation of the entire network, and issues control instructions to the on-site control equipment. The on-site controller is equipped with a communication interface, which is used to realize the data transmission with the dispatch center and the signal transmission of the on-site heat meter, soft water and other equipment. The on-site controller not only accepts the instructions issued by the central control machine and adjusts the control, but also can work independently within the specified range [20]. It collects processes and displays the operating data of the thermal station, automatically adjusts, detects faults, diagnoses and alarms, calculates cumulative heat consumption, and prints reports. The monitoring system converts the collected analog signals such as temperature, pressure, and flow into digital signals to optimized the basic function of the heating surrounding environment, circulation pump and primary network valve, and maintain the stability of the system. After the data collection front-end computer obtains the data of the user's heat meter, the data must be analyzed first to remove the abnormal data, and the processed information will be archived in the data server.

The wireless sensor network protocol uses the routing algorithm to initiate the message node, and establishes an appropriate routing path by querying neighboring nodes. This query propagates in the network like a wave until the destination node is found and a response is obtained. This response reaches the message originating node in the reverse direction and save important routing data all the way. After a period of time, this new routing message will become old and expired, and new routing information will be needed to ensure that the routing result is based on the new information [21]. The interruption or failure of any node will cause some nodes to leave the network. Since the transmission path between nodes is processed in a preprogrammed manner, no matter whether there are other nodes within the communication range, the information will be transmitted according to a predetermined procedure. Therefore, the potential for communication time is very high. Finally, the tree network must provide configurable range attributes to indicate how many resources the wireless network device has to support the tree topology. This range attribute includes the maximum number of layers of the tree structure and the maximum number of allowed child nodes.

6. Conclusions

This paper introduces the methods and principles of wireless network communication protocol and heating and heat balance flow analysis, proposes a structural model of a centralized heating monitoring system based on wireless sensor networks, carries out the design of perception and convergence nodes, analyzes the layout of wireless sensor networks, explores the design scheme of centralized heating monitoring system based on wireless sensor networks, conducts the hardware and software design of the monitoring system, implements the software testing and hardware debugging of the centralized heating monitoring system, and finally discusses the relationship between data transfer related tasks and task scheduling. The centralized heating monitoring system based on the wireless sensor network can monitor measure and record the operating parameters of the centralized heating in real time, and carry out over-limit alarms for parameters such as temperature, pressure and flow. The heating operation management software collects the temperature, pressure, flow, heat, valve opening, outdoor temperature and other data of the thermal station site, weighs and

calculates the operation of the entire network, and issues control instructions to the on-site control equipment. The sink node exchanges data with the cluster head node through the radio frequency module, and communicates with the host computer through the serial port. Therefore, the sink node can be awakened by radio frequency data, and it can also be awakened by serial port data. The processed data is placed in the sending buffer. After simple processing operations, the microcontroller unit uses the channel access mechanism specified by the network protocol to transfer heating information to the centralized monitoring system via the radio frequency transceiver unit. The study results show that the application of the centralized heating monitoring system can not only more conveniently monitor, control and manage the entire heating networks, but also make full use of the centralized monitoring and scientific quantitative management functions of the wireless sensor networks. This achieves dynamic tracking and monitoring of heating operation, real-time diagnosis of hidden dangers in heating operation, and safe, normal and energy-saving operation of the centralized heating system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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