Multimed Tools Appl
https://doi.org/10.1007/s11042-018-5645-x

Data acquisition ad hoc network system based on wireless sensor

Wei Lu [1,2] · **Yuwang Yang** [1]

Received: 7 January 2018 / Revised: 10 January 2018 / Accepted: 10 January 2018

Abstract In order to further explore the networking and application technology of wireless sensor networks, a wireless sensor node based on ZigBee is designed and developed, and on this basis, a novel application of environmental monitoring is carried out in this paper. The proposed building intelligent system mainly consists of environment monitoring platform and mobile APP. This environment monitoring platform dividing into two parts of Host computer and lower computer, and the major collecting parameters of the sensors in the proposed platform are temperature and humidity, light intensity, carbon dioxide, and PM2.5 etc. Moreover, in the APP we designed, the APP interface consisting of menu bar and four sensor modules, which cover login interface, main interface, real-time display interface, system setup, alarm function, data storage, historical data query, port setup and help parts. And the background data is stored in the SQL Server 2008 database. It can overcome the drawbacks of the traditional existing platforms such as low intelligent and difficult0network layout. The results showed that the environmental monitoring is closely connected with people's life. It can make a prediction on the environment pollution alarm and also provide data basis for energy saving in the construction field. Based on the above findings, it is concluded that it has very important significance to promote the construction of sustainable development of the monitoring of indoor and outdoor environment.

Keywords Wireless sensor network (WSN) · ZigBee ad hoc network · Indoor personnel positioning · Building environment monitoring

✉ Yuwang Yang
yangyuwang_scholar@yeah.net

[1] School of Computer Science and Engineering, Nanjing University of Science and Technology, Nanjing, Jiangsu 210094, China

[2] School of Computer Science and Technology, Huaiyin Normal University, Huaian, Jiangsu 223300, China

Published online: 25 January 2018

1 Introduction

In recent years, with the continuous combination of wireless sensor networks and big data technology, the intelligent building system has gradually entered a new stage of development. Wireless sensor network technology is gradually improving the level of intelligent building, and constantly enriches the intrinsic value of intelligent building. With the development of high integration digital devices, the sensor nodes with low cost and small size are gradually appearing and widely used in the buildings [11].

Wireless sensor network is closely linked with people's life in the environmental monitoring. In buildings, monitoring environment information can not only provide data support for energy consumption analysis, but also analyze the change of environment and predict the environmental pollution trend [9]. In terms of building energy consumption monitoring, building energy consumption accounts for a large proportion of energy consumption in China. With the increase of total building in China, the proportion of building energy consumption will be greater. Every year, 99% of the buildings in China are high energy consumption buildings, and only 4% of the 43 billion square meters of buildings in China have adopted energy-saving measures. According to this rate, in the near 2020, the energy consumption of the building will be 2 times more than it is now. In the construction industry, energy consumption is mainly concentrated in the summer heating, winter air conditioning and refrigeration electrical equipment, lighting and other aspects. Through the collection, analysis and processing of data in the building environment, using the optimization algorithm obtains the optimal point under the special constraints, which can provide strategy to reduce energy consumption [10]. The traditional building energy consumption monitoring uses the wired connection way namely connected the sensor nodes with the detection center by cable connection. The disadvantage of this way is that the cost is high, the installation cost is very large, and the reliability is poor. As time goes on, the line will gradually become old, and the signal will not be able to provide reliable and effective data by the influence of the line [6]. Wireless sensor network effectively overcomes the shortcomings of traditional building energy consumption monitoring. By building wireless sensor nodes in the building monitoring area, it can accurately, efficiently and real-time collect the building environment information data by self-organizing networking.

Wireless sensor network is firstly used in the military. Starting in the late 1990s, the United States studied distributed sensor network (DSN), embedded network sensing (CENS), wireless integrated network sensor (WINS), smart dust and some other important wireless sensor network projects [2]. In 1996, the "low energy wireless integrated micro sensor" proposed by American scholars was the beginning of the modern wireless sensor network network. Subsequently, we get the attention of the outside world to wireless sensor network technology, especially the application in military, transportation, environmental monitoring, indoor location, smart home and other fields. In 2001, the American Computer Society (ACM) and IEEE jointly set up the first conference (ISPN) to specialize in sensor networks. In 2003, sensor technology ranked No. 1 among the 10 new technologies published by the American science and technology magazine. In addition, the National Aeronautics and Space Administration, the Ministry of Communications and the Ministry of Energy have started the research project of wireless sensor network. Many famous universities in the United States are also engaged in research on wireless sensor networks. Some large IT companies in the US (such as Intel, Rockwell, HP, Texas Instruments, etc.) have collaborated with many famous universities, and have made important research achievements in many aspects of wireless sensor networks [3].

Environmental monitoring is a typical application of wireless sensor network in civil field. In 2002, the GDI (Duck Island) project, which was used to monitor the living environment of petrel, was considered the most representative at the time [5]. In 2004, some scholars in the United States arranged wireless sensor network nodes in the vineyard. The quality of the grapes was improved by analyzing the collected temperature and humidity information. In 2005, Australian scientists placed wireless sensor network nodes in North Australia, and workers sent the collected signals back to the control center. The distribution and habitat of *Bufo gargarizans* were roughly understood by processing information [1]. In 2007, researchers at the Chongqing University applied wireless sensor networks to the nature reserves of Xishuangbanna. It has realized the function of fire warning in natural reserve, monitoring of ecological environment information, tracking of the law of animal activity route and so on. With the continuous development of wireless sensor networks and related hardware and software maturity, wireless sensor network applications in the field of environmental monitoring will be more and more widely. New technology and new ideas continue to emerge, and it is believed that it will have more extensive application prospect in environmental monitoring field [12].

ZigBee technology is a two-way wireless communication technology with close range, low power consumption, low complexity, low rate and low cost. ZigBee technology has the advantages of low power consumption, low cost, short time delay, large network capacity, effectiveness and competitiveness, security and other advantages, such as conflict strategy between the avoidance data [7].

2 Design of wireless sensor network in buildings

Wireless sensor network plays an important role as a subsystem of building electrical Internet of things. The coordinator node in ZigBee network is connected to the server and then integrated with the building. The overall structure of the network of building electrical equipment is divided into three parts, the application layer, the network layer and the perception layer [4]. The application layer is the user interface between users and the perception layer. Users can use the operation interface to complete business functions. At the same time, users can also use mobile terminal (intelligent mobile phone, tablet computer and so on) to check the state parameters of the electric equipment and control the electrical equipment. The network layer realizes the combination and conversion of Ethernet communication with the wireless network system, information collection interaction, transmission and data processing. The perception layer consists of module carrying different sensors. Its task is the data acquisition and realization of the comprehensive sense of the building electrical equipment. As an important component of the sensing layer, the networking of wireless sensor networks plays a vital role in the whole network.

2.1 ZigBee three structures

The node structure is a typical structure of ZigBee. The sensor nodes generally contain four parts: sensing module, wireless communication module, data processing module and power [8]. The ZigBee protocol stack contains both horizontal and vertical two-dimensional structures. The horizontal communication protocol layer includes the physical layer, the data link layer, the network layer, the transmission layer and the application layer. The vertical protocol layer includes three management platforms. The main function of the management platform is

to coordinate the functions at all levels and to ensure the optimal design of energy management, task management and so on.

The network topology of wireless sensor network is divided into a star network, tree network and mesh network. The star network is the topology with simplest and lowest networking complexity, and the network consists of a coordinator and a number of terminal devices. The coordinator is responsible for initialization of network and maintenance of other nodes joining the network. Data routing between nodes has only one path, and all nodes can only communicate with coordinator. The tree network topology consists of a coordinator, multiple routing devices and multiple terminal devices. Each node can communicate only with its parent and child nodes, in which only the routing channel is passed. The nodes of mesh network topology are similar to tree networks. They also include a coordinator, multiple routing devices and multiple terminal devices. Any two nodes in the network can transmit data between each other. Mesh networks have a strong self - organization and self - repair ability, but need extra storage space.

2.2 Design of ZigBee wireless sensor network networking

The ZigBee protocol stack consists of the physical layer, the media access control layer, the network layer, the transport layer and the application layer. ZigBee mesh network includes star network and tree network. A complete mesh network includes two parts: network initialization and node joining network. Nodes joining the network can be divided into nodes joining the network through the coordinator and nodes joining the network through the existing parent nodes. ZigBee nodes self-organization networking must satisfy the following aspects. First, nodes are fully functional device (FFD) nodes, and have the ability of ZigBee coordinator. Second, there is only one coordinator in ZigBee network.

3 Scheme of building environment monitoring system

The application of wireless sensor network in environmental monitoring is very important. Environmental monitoring has many characteristics, such as many monitoring points, long monitoring time, complex monitoring situation and so on. Aiming at the shortcomings of traditional environmental monitoring methods, such as difficult network layout and low node intelligence, this paper introduces the overall scheme and hardware development of building environment monitoring system.

3.1 Sensor requirements

The sensors involved in this paper include temperature and humidity sensors, light intensity sensors, carbon dioxide sensors, and PM2.5 sensors.

The temperature and humidity sensor uses the DHT22 digital temperature and humidity sensor, which connects a high performance 8-bit single chip microcomputer. It consists of a capacitive humidity sensor and a NTC temperature measuring element. GY-30 light intensity module is a digital signal output light intensity sensor. It uses BH1750FVI chip and I2C bus interface to facilitate system integration. The CO_2 sensor is a MG811 type CO_2 gas sensor with high sensitivity and strong stability. The influence of temperature and humidity is less. The ceramic probe can be inserted in the design, the replacement is convenient, the heat insulation performance is better, the

service life is long, and the stability is reliable. The PM2.5 sensor module uses the SHARP optical dust sensor GP2Y1014AU0F. Inside the sensor, there are infrared light emitting diodes and phototransistors, which work by the principle of photosensitivity.

3.2 Scheme of building environment monitoring system

The whole system is divided into two parts: the host computer and the lower computer. Among them, the host computer is monitoring platform for building environment. The monitoring platform has the functions of data protocol conversion, data processing, graphic display, data storage, data query, real-time alarm, remote monitoring and others; the lower computer is sensor node, which has the data acquisition, data transfer, data upload and other functions. The system design requirements are as follows:

Ensure the safety of the system and provide the user login interface; provide different permissions for different users; test whether the platform can display real-time data and use the curve display; remotely control nodes in the network, sensor module on / off; query historical data, display and print in tabular form; alarm of monitoring data over threshold; add, modify and delete user information; communicate with serial and set serial port parameters.

As the network erect, the coordinator is the core of the whole ZigBee network and plays a vital role. It connects all the other nodes in the network. In the environmental monitoring system, the coordinator node is responsible for sending the instructions sent by PC machine to the designated nodes in time. Besides, it also sends the information collected by other nodes to the host computer. The work-flow of the coordinator node is shown in Fig. 1.

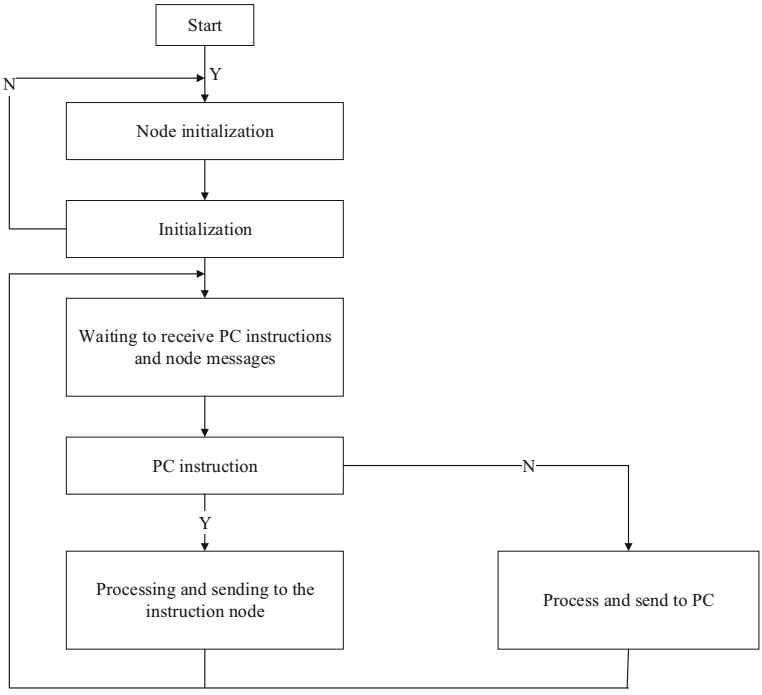


Fig. 1 Coordinator node working process

The router nodes are responsible for connecting the coordinator and the terminal in the ZigBee network. When the terminal node is too far away to connect to the network, the routing node plays a central transmission role. The message received by the routing node is divided into three types: the message from the terminal node, that the routing node message will be forwarded to the coordinator node; sending a message to yourself, then processed by routing node; the message is sent by the coordinator node to the terminal node, and then the routing node is forwarded to the terminal node.

The terminal node, as the terminal node of the ZigBee network, has neither the forwarding function nor the function of controlling the other nodes. Terminal nodes work simply, only collecting data and uploading them to the coordinator node or routing node. When the coordinator has instructions, the coordinator is treated in accordance with the instructions. The work flow is shown in Fig. 2.

3.3 Design of building environment monitoring system software

After the completion of the hardware platform, the development of the building environment monitoring system is carried out. Wireless sensor nodes collect environmental information in the monitoring area, through the ZigBee network, send data to the routing node, and finally send to the network coordinator node. The coordinator node is connected to the computer through the serial port, and then the data is uploaded to the monitoring platform of the host computer environment. The software of the building environment monitoring system is written

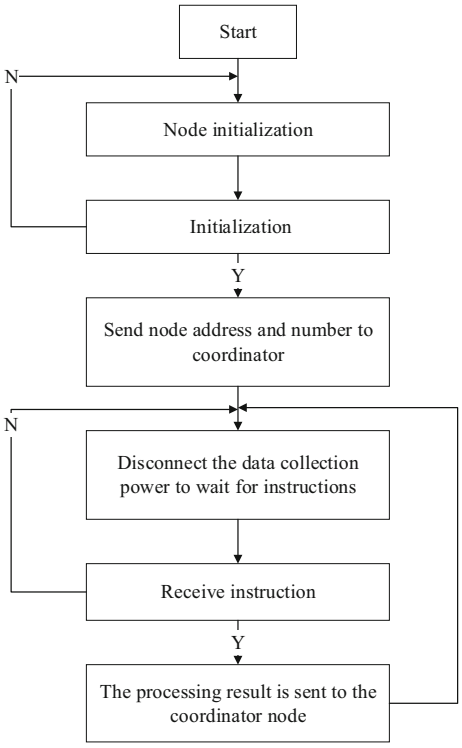


Fig. 2 Terminal node working flow chart

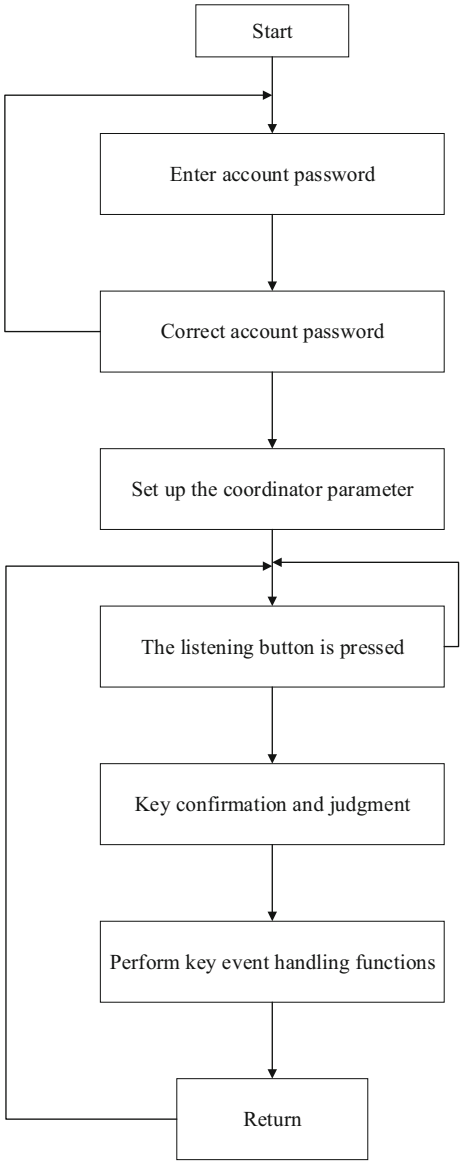


Fig. 3 Flow chart of environmental monitoring system

in the C# language under the VS2010 development platform. The background data is stored in the SQL Server 2008 database.

The interface structure of the whole environmental monitoring system includes: login interface, main interface, real-time display interface, system setup, alarm function, data storage, historical data query, port setup and help parts.

Figure 3 is the flow chart of the environmental monitoring system. First of all, we open the monitoring software, input the correct account password and enter the main interface. In the menu bar's serial port settings, we set the coordinator serial number, baud rate, data bits and

other parameters. Then, we monitor whether the function button is pressed: if there is no press button, it will be monitored always. If there is a function button pressed, then conduct key judgment and confirm that the key is pressed. Enter the event processing function for the processing, then judge the return and monitor again.

The data is transmitted to the environment monitoring platform by the coordinator node through the serial port. The data protocol includes the word head, the floor number, the node number, the environment information and the stop bit. When a packet is received, first of all, we detect whether the prefix is FE, and then intercept the floor number and node number, so as to read and store the node location information. Then, the information of the environment is read, finally the stop position is judged, and the reception is finished.

The data received by the terminal sensor is forwarded through routing, and after the coordinator node receives the data, it is stored in the local database SQL Server 2008. The tables in the database are divided into: user login information table, node temperature and humidity information table, node light intensity information table, node carbon dioxide concentration information table, node PM2.5 concentration information table, historical data query table, and alarm threshold table.

3.4 Software implementation of building environment monitoring system

The user login interface is the first interface after starting the host computer monitoring software. After the user inputs the user name and password, the user enters the main interface after the verification is correct.

The main interface consists of a menu bar and four sensor modules. The menu bar includes system management, alarm setting, help and port settings. Due to collecting four kinds of information, such as temperature and humidity, light intensity, carbon dioxide concentration and PM2.5, four sensors modules are added to the main interface, so as to conveniently view specific environmental information. Among them, the button uses the MenuStrip control

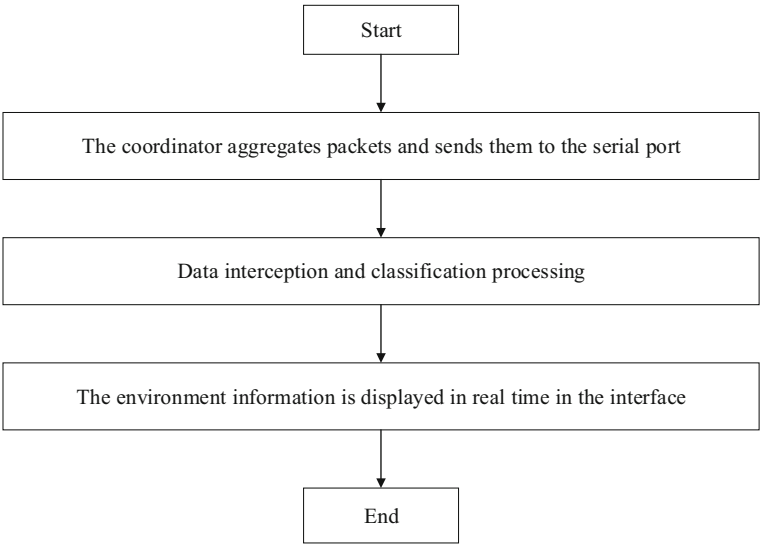


Fig. 4 Data real-time display process

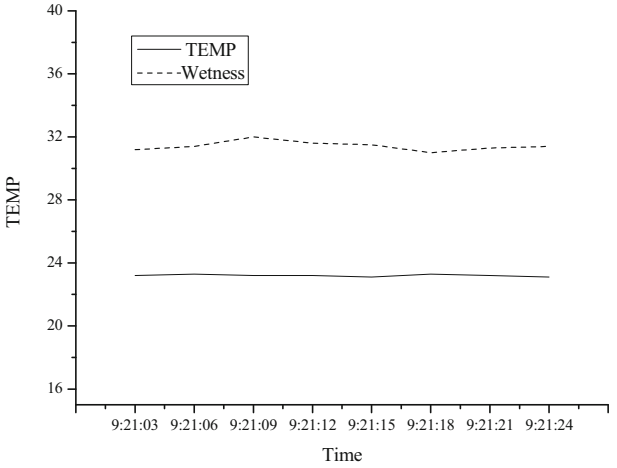
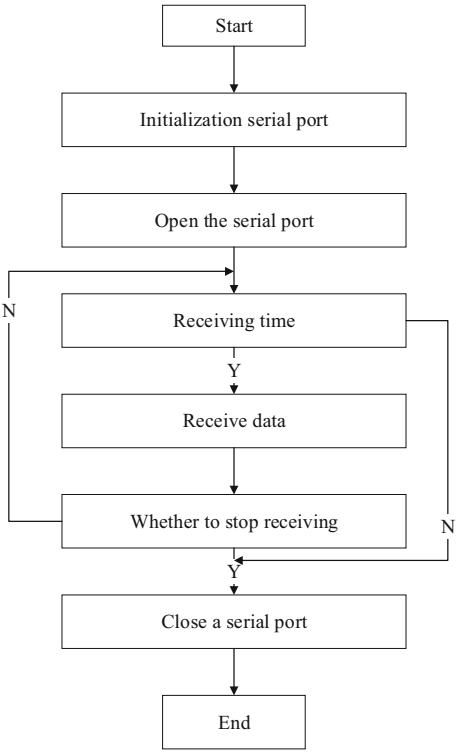


Fig. 5 The curve display interface

addition and the button is added to the Button control. The process for displaying is shown in Fig. 4. The data is displayed in real time curve, as shown in Fig. 5.

The system settings are mainly related to user information. It includes the function of adding, modifying and deleting users.

Fig. 6 Serial data receiving process



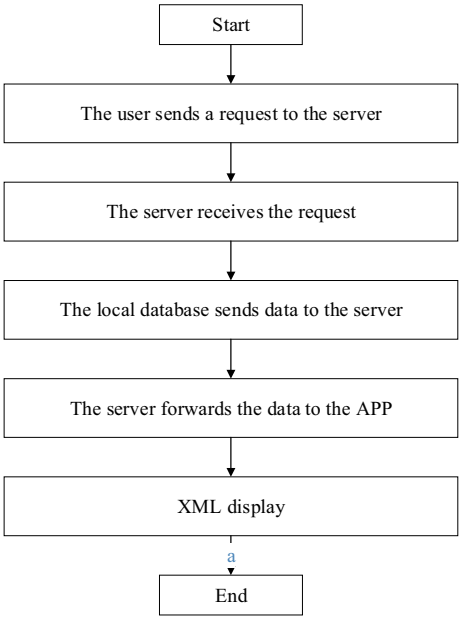


Fig. 7 Connection and communication with remote server

After collecting sensor information on each terminal node, in order to facilitate the search and analysis, the collected environmental data is stored and used in the SQL Server 2008 data table.

The coordinator in the network is connected to the computer through RS232. Therefore, port settings interface can set parameters such as port number, baud rate, data bits, check bits, stop bits and so on. Figure 6 is a serial data receiving process.

With the continuous development of intelligent building and wireless sensor network, intelligent home APP is getting more and more applications in real life. Especially for building environment monitoring, we can conveniently and intuitively monitor the environmental information of the monitoring area through mobile phone APP, which will greatly promote the construction and development of intelligent community. Android, as an open source operating system, makes more and more intelligent devices adopt Android systems. Its advantages are good scalability and rich hardware support. The local database needs to connect to the remote server, APP connects and communicates with the remote server and the user sends a request to the server through the mobile phone. The server receives a request and then operates on the local database following the instructions in the SQL statement, receives the data returned by local database, and then uses XML display on the client, as shown in Fig. 7.

In the mobile APP, the bottom is the environment information, and from left to right, they are temperature, humidity, light intensity and PM2.5 in order. The debug results on the virtual machine are shown in Fig. 8.

4 Conclusion

With the integration of wireless sensor network and big data technology, building intelligent system has entered a new stage of development. Wireless sensor network

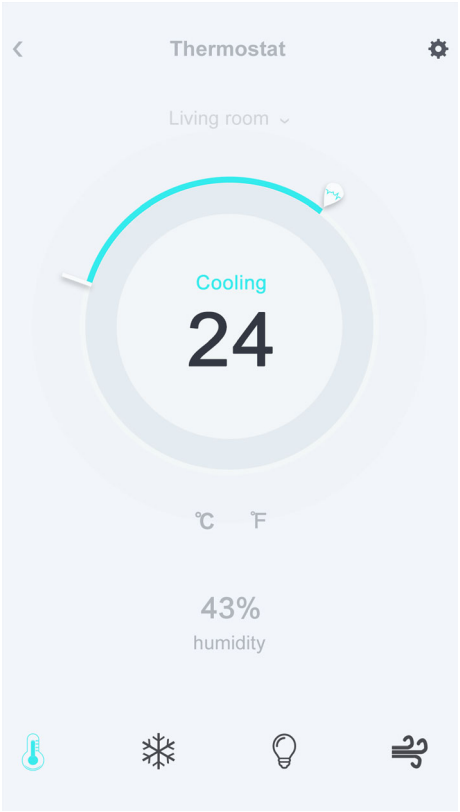


Fig. 8 APP temperature display interface

has been widely applied. In view of the particularity of building space, this paper studies the networking of wireless sensor network and the application of environmental monitoring in the building.

Based on the analysis of ZigBee network topology, protocol stack and node functions, this paper analyzes the ZigBee wireless ad hoc network, and conducts ZigBee networking simulation and experiments. It verifies the self-organization and self-healing of ZigBee wireless sensor self-organizing network. The building intelligent system environment monitoring platform and mobile APP are designed and developed. Environmental monitoring is closely related to people's life. It can predict and alarm the environmental pollution, and also provide data basis for energy saving and consumption reduction in the field of architecture. As a result, achieving building indoor and outdoor environment monitoring is very important for promoting sustainable development of buildings.

References

1. Arjunan S, Sujatha P (2017) Lifetime maximization of wireless sensor network using fuzzy based unequal clustering and aco based routing hybrid protocol. Appl Intell 34(6):1–18
2. Fang X, Nan L, Jiang Z, Chen L (2017) Fingerprint localisation algorithm for noisy wireless sensor network based on multi-objective evolutionary model. IET Commun 11(8):1297–1304

3. Li L, Li X, Lu Z, Lloret J, Song H (2017) Sequential behavior pattern discovery with frequent episode mining and wireless sensor network. IEEE Commun Mag 55(6):205–211
4. Martinez K, Hart JK, Basford P, Bragg G, Ward T, Young DS (2017) A geophone wireless sensor network for investigating glacier stick-slip motion. Comput Geosci 105:103–112
5. Masazade E, Kose A, Masazade E, Kose A (2017) A proportional time allocation algorithm to transmit binary sensor decisions for target tracking in a wireless sensor network. IEEE Trans Signal Process 21(1):1–12
6. Mirzaie M, Mazinani SM (2017) MCFL: an energy efficient multi-clustering algorithm using fuzzy logic in wireless sensor network. Wirel Netw 32(8):1–16
7. Nasseri M, Kim J, Green R, Alam M (2017) Identification of the optimum relocalization time in the mobile wireless sensor network using time-bounded relocalization methodology. IEEE Trans Veh Technol 66(1): 344–357
8. Pérez CA, Valles FS, Sánchez RT, Buendía MJ, López-Castejón F, Cervera JG (2017) Design and deployment of a wireless sensor network for the mar menor coastal observation system. IEEE J Ocean Eng 42(4):966–976
9. Sarkar A, Murugan TS (2017) Cluster head selection for energy efficient and delay-less routing in wireless sensor network. Wirel Netw 23(1):1–18
10. Wei W, Song H, Li W, Shen P, Vasilakos A (2017) Gradient-driven parking navigation using a continuous information potential field based on wireless sensor network. Inf Sci 408(C:100–114
11. Zhang Z, Glaser SD, Bales RC, Conklin M, Rice R, Marks DG (2017) Technical report: the design and evaluation of a basin-scale wireless sensor network for mountain hydrology. Water Resour Res 53(5):4487–4498
12. Zhu YH, Li E, Chi K (2017) Encoding scheme to reduce energy consumption of delivering data in radio frequency powered battery-free wireless sensor networks. IEEE Trans Veh Technol PP(99):1–5