Application of Wireless Sensor Network in Smart Buildings

Mingze Xia[1(✉)] and Dongyu Song[2]

[1] Heilongjiang University (HLJU), Harbin, China
hlju_xia@yeah.net
[2] Harbin Institute of Technology (HIT), Harbin, China
songdy.381@qq.com

Abstract. The development of technology in large strides has enabled wireless sensor network to extensively supersede traditional wired sensor network (WSN), which is accompanied with its application to every aspect of life and production. In terms of smart buildings, presently the mainstream direction in the research is combining wireless sensor network with IOT technology and internet technology, etc. In this paper, based on ZigBee wireless sensor network (WSN) combined with Java, Android, etc., developed to monitor building real-time environmental data of intelligent building system, and can achieve the combination of automatic and manual household appliance control platform.

Keywords: WSN · Smart buildings · ZigBee technology · Java Web MySQL · Android

1 Introduction

So-called smart buildings [1] are product of combining traditional architectural technology with internet technology and communication technology, etc. Mainly oriented towards office buildings, schools, hospitals, traffic, residences, shopping malls, etc., which are outfitted with smart and automatic functions to make our life, work, study and entertainment more comfortable and sustainable.

Wireless sensor network (WSN), a distributed sensing network, is the result of combining sensor with wireless communication technology. Its features of small volume, low power dissipation and a strong ad hoc network capacity, etc. have made it gradually replace traditional wired sensor network and become the mainstream direction for present scientific research and development for use. The sensors are widely or even randomly dispersed over monitored area, and the information collected by sensor is transferred via ad hoc and multiple hop wireless communication modules with low power dissipation to upper computer for related processing. The today's wireless communication technology is extensively applied to military, agricultural, traffic, and medical domains [2], etc. People's demands in everyday life dramatically boosted upgrading of traditional sensors, with multimedia sensor emerging as the times require in such domains as medical treatment and traffic, etc. The collected information is no

X. Gu et al. (Eds.): MLICOM 2017, Part I, LNICST 226, pp. 315–325, 2018.
https://doi.org/10.1007/978-3-319-73564-1_31

longer traditional temperature and humidity, etc. but is multimedia information such as audios, videos and pictures, etc. Combination of wireless communication modules (GPRS, Bluetooth, ZigBee, etc.) with sensors substituted traditional wired sensor network to save substantive resources. With advantages of high scalability, ad hoc property, low power dissipation, high integration, etc., wireless sensor network is fully applied in monitored regions with sparse population and complicated geologic environment [3].

2 Introduction of ZigBee Technology

ZigBee technology is a LAN wireless communication technology with low power dissipation, low latency, a strong ad hoc network capacity and quick reaction rate. Its communication protocol is based on 802.15.4 standard, and network topological architecture is mainly divided into three types: star topology, tree topology and mesh topology, wherein the star topology consumes the least energy. In ZigBee technology, the primary routing protocol algorithms are Cluster - Tree, AODVjr, and Cluster - Tree + AODVjr. Many scholars improved the three routing protocols to create many new and more efficient routing protocols, which will not be described in details here. The ZigBee network mainly comprises three parts: co-ordinator, router and end device, which are selected according to network topology styles. For example, the star network structure needs no router. The co-ordinator must be a global functional device, while end device allows two-way selection and can be both a global functional device and a device with simplified functions. Compared with Bluetooth and WIFI, notwithstanding relatively shorter transmission distance, this leads to lower dissipation of energy for ZigBee network. Besides, in terms of quantity of network connections, ZigBee network support more than 65,000 nodes [4–7].

3 Application of ZigBee Technology in Smart Building System

The smart building system based on ZigBee technology can realize automation and intellectualization of buildings by dint of low power dissipation, low cost and high integration of ZigBee. Terminal node is integration of sensor and ZigBee module to transfer the collected data to coordinator node which integrates data and submit it to upper computer. In the meanwhile the coordinator node issues the device operation directive of upper computer to control nodes to finish control of home appliances. The general frame is as shown in Fig. 1:

3.1 Acquisition of Sensor Data

The acquisition process of sensor data in intelligent building system is to transfer data collected by sensors to coordinator nodes through ZigBee module for summarization

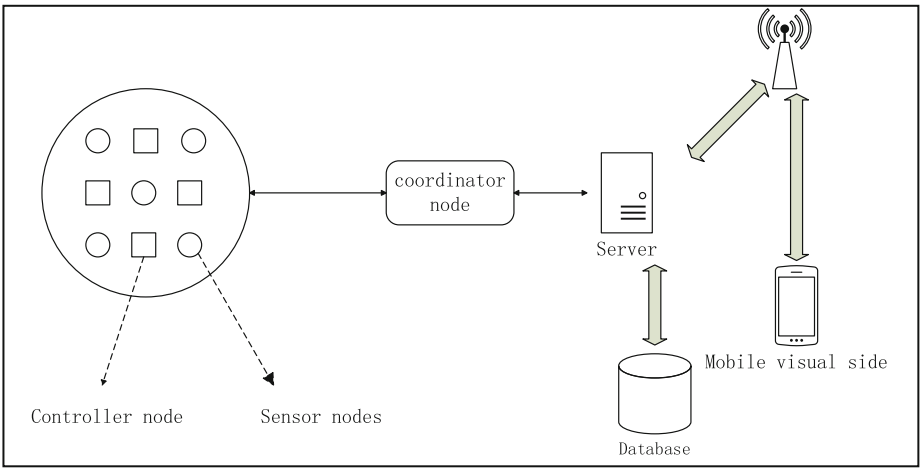

Fig. 1. General frame

and processing. The coordinator sends the processed data through the serial port, WIFI, GPRS and other networks to the designated ports on the server and monitor the start of server of this port starts. The data packets are processed and stored in the database by a communication protocol in advance. Its architecture is mainly divided into 3 parts.

(1) Information acquisition and transmission layer: By using ZigBee network, various environment data information sensors are formed into an information acquisition and transmission network. The sensors are distributed at specific detection points in the monitoring area. The ZigBee module transfers the collected data to the coordinator node.
(2) Information summarization and upload layer: The ZigBee coordinator sends the data uploaded by the lower computer to the ARM chip so that the data can be summarized and processed according to specific network protocols. Finally, it is uploaded to the designated server IP via the serial port, WIFI or GPRS (depending on the environment).
(3) Information analysis and processing layer: The data uploaded by the lower computer is parsed by monitoring the service of designated port server. The analysis is based on the network protocol corresponding to the information summarization and upload layer. The parsed data stream is then stored in the database for the use of the server and visual end.

3.2 Communication Protocol

Communication protocol refers to rule and regulations that both parties must comply with in order to complete communication or service. The protocol defined the format used by data unit, information and meaning that information unit should include, connection mode, sequence of information transmitting and receiving so as to ensure data in the network to be transmitted to a certain place smoothly.

Network protocol in this paper includes message header, data layer and message ending. Message header mainly includes lead code, data length, equipment tag, message type, etc. and represents the beginning of a piece of message. Message ending includes weighted sum verification and ending symbol.

The function of data layer is to cover the type of sensing data of a piece of message and data value so as to form a data package. On the server, it is analyzed into different data flows and saved to different lists in database. Specific network protocol is shown in the Fig. 2:

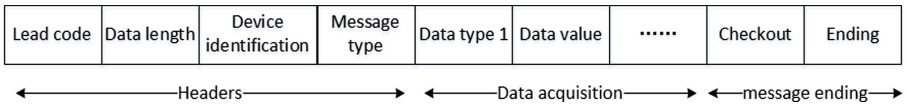

Fig. 2. Specific network protocol

3.3 Hardware Design

The smart building system based on wireless sensor network adopts ZigBee module on wireless collection transmission terminal. ZigBee chip is CC2530, which supports global free wave band of 2.4 GHz. The network type is star network and mesh network, with the largest network capacity being 65, 535 nodes, transmission range being 800 m and emissive power being 4.5 dbm. The core controller of coordinator adopts STM32F103RBT6 chip, which is a 32-bit microcontroller launched by STMicroelectronics NV, with 64 pins. It has a Flash capacity of 128 k bytes, working temperature of −40 °C–85 °C and is packaged by way of LQFP.

In agricultural detection system based on ZigBee, the simple hardware circuit diagram for coordinator node is as shown in Fig. 3.

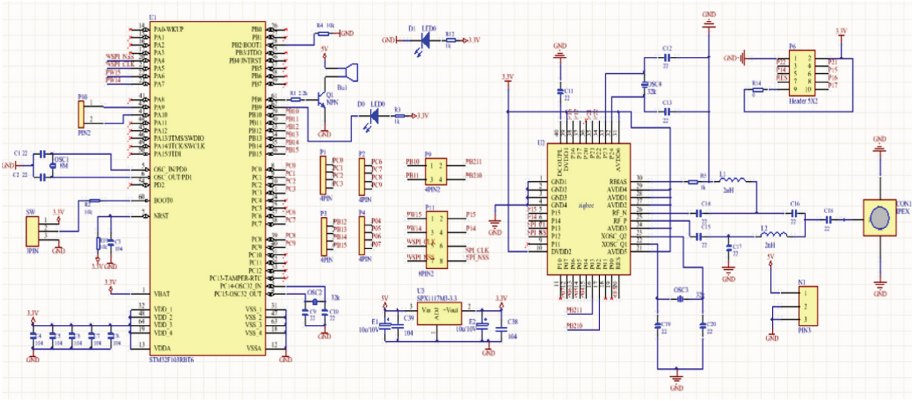

Fig. 3. Coordinator node

The simple hardware circuit diagram for sensor node is as shown in Fig. 4.

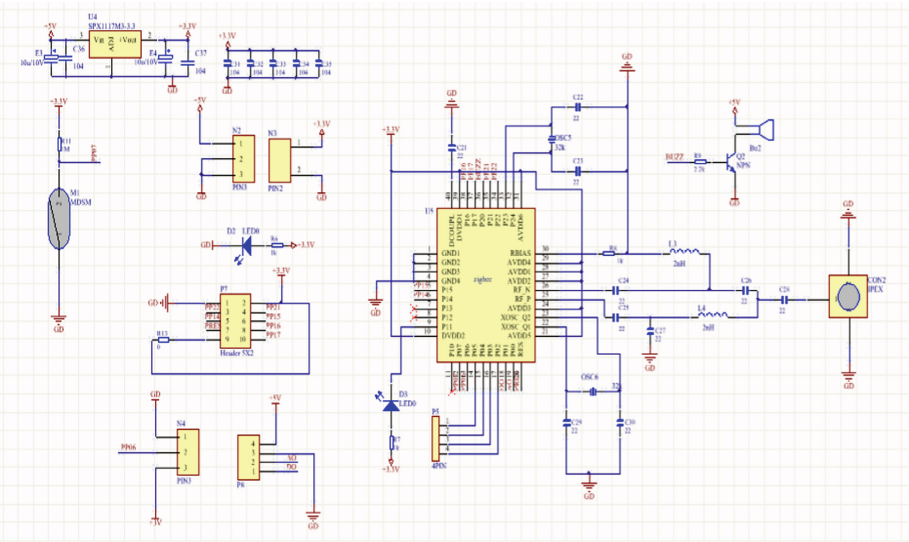

Fig. 4. Sensor node

3.4 Software Design

Software end mainly comprises three aspects: processing and storage of collected data, server of visual terminal, and visual terminal (Android mobile).

Processing and storage of collected data adopt C++ language and MySQL database, with primary functions as follows: hardware unit transfers via network the collected date to daemon written with C++ for resolving using communication protocol commonly defined with hardware unit to get the desired data. The data is not only collected environmental data, but also includes IP address of data source i.e. collection terminal. Lastly the information is stored in MySQL database.

In data processing course, the daemon process filters and screens the data. Data size received by the daemon process is huge, but data error may appear owing to limitation of hardware equipment, network time delay, network capacity, network throughput capacity. The daemon process calculated calculates all data of one type of sensor and gets the average value of sensing data at one time node. When there is great difference between data uploaded by the sensor and average value, the daemon process will abandon such item of data and insert the average value to database. Moreover, the daemon process also makes comparison according to the preset sensing range of sensor in database so as to screen the wrong data.

Visual server is developed using lightweight Java-Web, with three major functions:

(1) Real-time data, history data and equipment status value are issued to visual terminal.
(2) Collect and store the information fed back by the visual terminal. Related control operations for the equipment are finished via the feedback.
(3) Combine real-time data and fixing algorithm (threshold algorithm, etc.) to finish control of equipment.

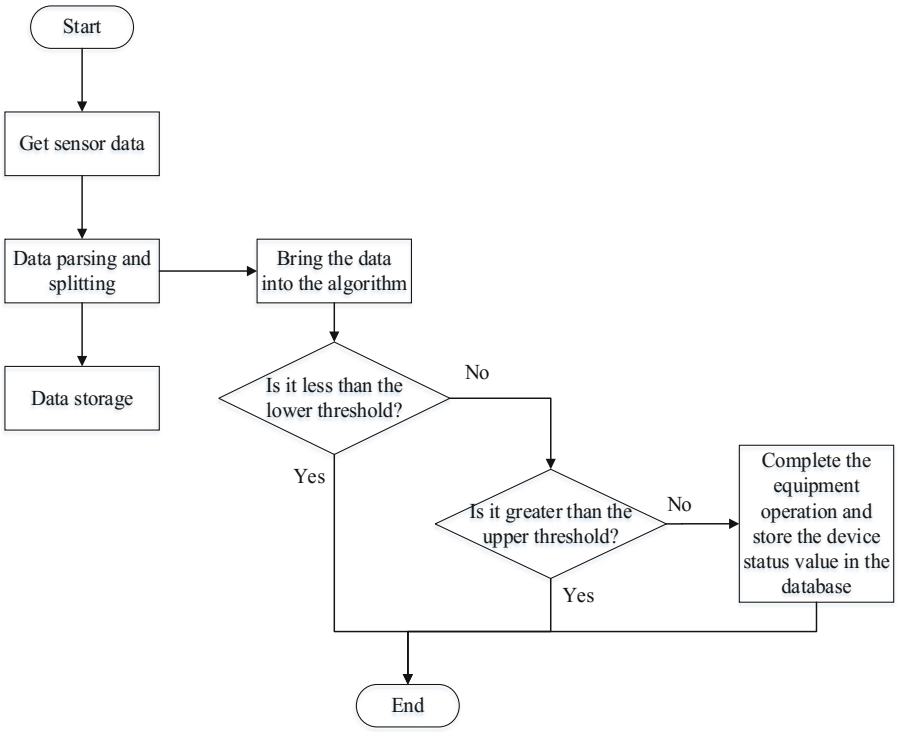

Fig. 5. Data acquisition flow chart

Wherein the priority for (2) and (3) is (3) is higher than (2), i.e. the server terminal makes algorithm evaluation and controls the equipment with priority, then modifies the equipment state via the operational data fed back by visual terminal. The flowchart is as shown in Figs. 5 and 6:

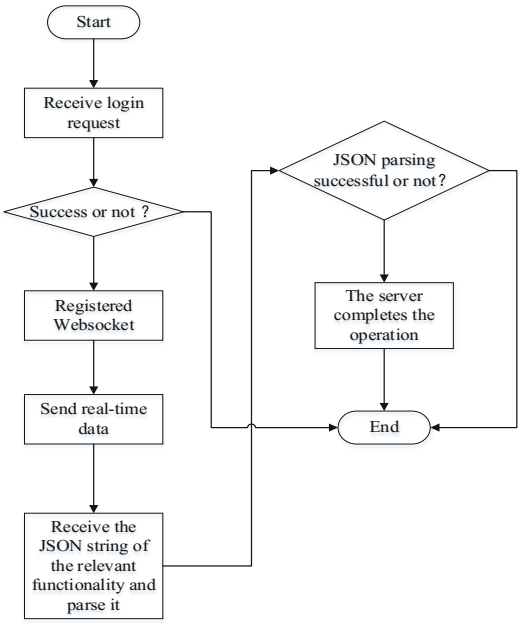

Fig. 6. Visual terminal flow chart

The database mainly comprise five tables: i.e. collector table, collection area table, environmental data table, user information table and equipment state table, etc. Wherein the collector table (collector) stores relevant information of collector, including: ID, IP address, heartbeat frequency, equipment mac address, etc. Table definitions are as shown in Table 1 below:

Table 1. Collector table (collector)

Field name	Data type	Whether is master key	Whether is external key	Description
collectorId	Int	Yes	No	Collector ID
rate	Int	No	No	Heartbeat frequency
last	Datatime	No	No	The last uploading time
mac	Varchar(32)	No	No	Mac address of equipment
binding	Int	No	No	Binding state
areaId	Int	No	No	ID for bound collection area
areaName	Varchar(50)	No	No	Name of bound collection area

Collection area table, also called office area table (area), mainly stores: area ID, area name, area address, area description, ID of bound user, etc. The Table definitions are as shown in Table 2 below:

Table 2. Office area table (area)

Field name	Data type	Whether is master key	Whether is external key	Description
areaId	Int	Yes	No	ID of collection area
areaName	Varchar(50)	No	No	Name of collection area
address	Varchar(12)	No	No	Address of collection area
setTime	Datetime	No	No	Time of creating
userId	Int	No	No	ID of bound user
userName	Varchar(50)	No	No	Name of bound user
unit	Float	No	No	Area

The environmental data table (data) mainly stores relevant information of sensor and collected data, etc., mainly comprising: data ID, collector ID, sensor type, sensor value, time of uploading sensed amount, upper and lower limits of sensed amount, etc. The table definitions are as shown in Table 3 below:

Table 3. Environmental data table (data)

Field name	Data type	Whether is master key	Whether is external key	Description
Id	Int	Yes	No	Data ID
collectorId	Int	No	No	Collector ID
sType	Int	No	No	Sensor type
sValue	Varchar(2)	No	No	Sensor value
Date	Datetime	No	No	Time of uploading sensed amount
rMax	Decimal(8, 2)	No	No	Maxima of measuring range
rMin	Decimal(8, 2)	No	No	Minima of measuring range

User information table (user) mainly comprises all personal information of users, through which, collector can be bound. For example, the user in office block on the second floor is bound with relate sensor and home appliances of the second floor, so he cannot control the equipment on the third floor. The table definitions are as shown in Table 4 below:

Table 4. User information table (user)

Field name	Data type	Whether is master key	Whether is external key	Description
userId	Int	Yes	No	User ID
userName	Varchar(50)	No	No	User name
type	Int	No	No	User type
pwd	Varchar(32)	No	No	User code
realName	Varchar(50)	No	No	Real name
tele	Varchar(12)	No	No	Tel.
email	Varchar(30)	No	No	Email
userAddress	Varchar(20)	No	No	Address

Equipment table is similar to collector table, mainly storing: equipment ID, equipment name, current state of equipment (0, 1), ID of bound office area, etc. The table definition is as shown in Table 5 below:

Table 5. Equipment table (equipment)

Field name	Data type	Whether is master key	Whether is external key	Description
equipmentId	Int	Yes	No	ID of home appliance
rate	Int	No	No	Heartbeat frequency
last	Datatime	No	No	The last uploading time
mac	Varchar(32)	No	No	Mac address of equipment
state	Int	No	No	Current state value
areaId	Int	No	No	ID for bound collection area
areaName	Varchar(50)	No	No	Name of bound collection area

The visual terminal is App software developed based on Android OS, which runs on mobile and tablet computer, with major functions of: checking real-time data; checking history data; checking equipment status and control equipment. The user cannot only check real-time data of current sensor on the visual terminal, but also can obtain history data via history data interface, and get the current state of home appliances, thereby making secondary regulation according to actual condition.

3.5 Test of Smart Building System

Test showed that the fundamental functions of wireless smart building system based on ZigBee can be realized. Test of networking and communication succeeded, environmental data was successfully inserted into database, the database data is shown in

Fig. 7. The visual terminal displays normally. The issuing time of data is averagely 2 s. The time interval between issuing of control directive and finishing of actual control operation is averagely 3 s, indicating functions of wireless smart building system are basically enabled.

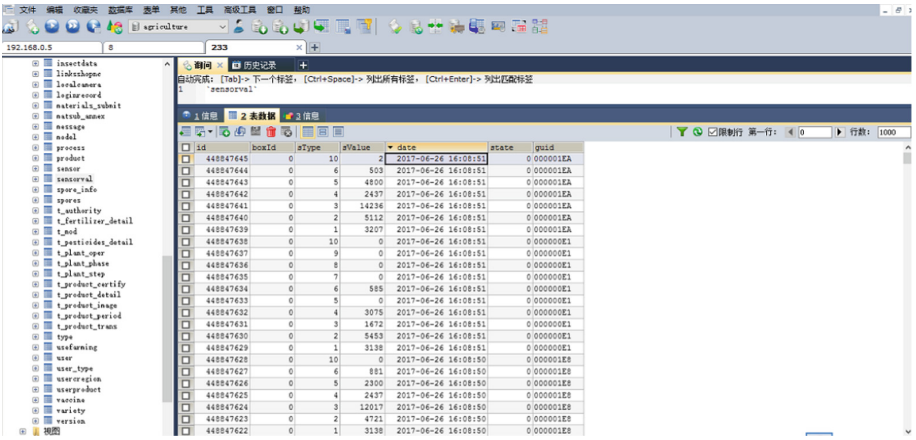

Fig. 7. Database data

4 Conclusion

The increasingly higher economic level is coupled with increasing of people's demands for life quality. The rise of IOT and development of e-technology provide a better foundation for smart home and smart buildings, etc. via use of sensors, server and other electronic devices clustered in a large scale, the smart buildings provide convenience for people in entertainment and work, etc. The paper introduces a wireless smart building system which combines ZigBee wireless networks and mobile development technology and is applicable to office environment. Next, the author will continue to research networking communication of wireless sensor network, data transfer, and practical application and expanding, etc. to underpin technically the smart building domains such as building automation and office automation in a better way.

References

1. Minoli, D., Sohraby, K., Occhiogrosso, B.: IoT considerations, requirements, and architectures for smart buildings-energy optimization and next-generation building management systems. IEEE Internet Things J. **4**, 269–283 (2017). IEEE Press
2. Zhang, Z., Hu, X.: ZigBee based wireless sensor networks and their use in medical and health care domain. In: Seventh International Conference on Sensing Technology (ICST), pp. 756–761. IEEE Press, Wellington (2013)

3. Tan, X., Sun, Z., Akyildiz, I.F.: Wireless underground sensor networks: MI-based communication systems for underground applications. IEEE Antennas Propag. Mag. **57**, 74–87 (2015). IEEE Press, New York
4. Xiaoman, L., Xia, L.: Design of a ZigBee wireless sensor network node for aquaculture monitoring. In: 2nd IEEE International Conference in Computer and Communications (ICCC), pp. 2179–2182. IEEE Press, Ghaziabad (2016)
5. Chi, H.R., Tsang, K.F., Wu, C.K.: ZigBee based wireless sensor network in smart metering. In: 42nd Annual Conference of the IEEE Industrial Electronics Society, pp. 5663–5666. IEEE Press, Florence (2016)
6. Naruephiphat, W., Promya, R., Niruntasukrat, A.: Remote air conditioning control system base on ZigBee wireless sensor network for building. In: 2015 International Computer Science and Engineering Conference (ICSEC), pp. 1–6. IEEE Press, Chiang Mai (2015)
7. Islam, T., Rahman, H.A., Syrus, M.A.: Fire detection system with indoor localization using ZigBee based wireless sensor network. In: 2015 International Conference on Informatics, Electronics & Vision (ICIEV), pp. 1–6. IEEE Press, Fukuoka (2015)