Journal of Theoretical and Applied Information Technology
20th March 2013. Vol. 49 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

DESIGN AND IMPLEMENTATION OF WIRELESS SENSOR NETWORK MANAGEMENT SYSTEM BASED ON WEBGIS

[1] LIU HAIBO, [1] ZHANG FANG

[1] College of Mathematics & Computer Science, Hebei University, Baoding 071002, China

E-mail: [1] liuhaibo@hbu.cn

ABSTRACT

With the rapid development of wireless sensor network (WSN), how to effectively and conveniently manage the WSN has become an urgent problem. According to the actual requirement of WSN management, the WSN management system based on WebGIS is designed and implemented. Many functions are designed for the system, such as monitoring scheme management and monitoring, monitoring data collection and analysis, real-time display of scanning data with graph and table, visual management of WSN based on WebGIS and so on. The system can monitor, collect and analyze real-time monitoring data, and it can also modify and send monitoring command in monitoring process. These successfully guarantee the system's real-time visual management and environmental adaptability. The system is developed by B/S mode and JavaServer Faces framework. OpenLayers is used to finish the WebGIS client. PostgreSQL acts as database service. These ensure the platform independence, extensibility, security and reliability of the system. The effective and convenient management of WSN is realized.

Keywords: *Wireless Sensor Network, Management System, WebGIS, OpenLayers, PostgreSQL*

1. INTRODUCTION

At present, sensors have been used in many fields, such as industrial production, ocean exploration, environmental protection, medical diagnosis, biological engineering and so on. [1, 2] As a physical device, sensor can not only detect the external signal, physical conditions and chemical composition information, but can also transfer them to other devices. [3, 4] The WSN has become the most useful tool for human to recognize and transform nature.[5,6] But the development of WSN management system seriously lags behind the WSN's. The existing system has many problems, for instance, bad real-time [7], poor security [8], low tolerance for network fault [9], and it can not accommodate to the change of the environment.

2. SYSTEM DESIGN

WSN consists of sensor nodes, sink nodes and management node. A lot of sensor nodes and sink nodes are scattered randomly inside or nearby the monitored area. They can organize into a network by themselves. The monitoring data collected by a sensor node are transported through other sensor nodes. In the process of transmission, monitoring data may be operated by other sensor nodes, and be routed into sink nodes, then they can arrive at the management node finally. [10]

Considering the features of the WSN, resource constrained [11], frequent fault [12], wide distribution [13], and huge amounts of data [14], the WSN management system is designed and implemented according to the actual requirements. Many functions are designed for the system such as monitoring scheme management and monitoring, monitoring data collection and analysis, real-time display of scanning data with graph and table, wireless network visual management based on WebGIS and so on. It can modify and send the monitoring command in monitoring process. The real-time visual management and environmental adaptability are successfully guaranteed by the functions. Sensors are configured and managed, monitoring schemes are released and executed, and monitoring data are collected and analyzed by the system. So the effective and convenient management is realized.

2.1 System Architecture Design

The system is composed of sensor layer, server layer and user layer. This mode has several features such as efficient flexibility, extensibility, and security. Electromagnetic spectrum signal is detected and scanned in sensor layer. Monitoring scheme management and monitoring, monitoring data collection and analysis, node detection, command sending and other functions are supported in server layer. Further more, the server layer

Journal of Theoretical and Applied Information Technology
20th March 2013. Vol. 49 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

provides users with operation interfaces, such as real-time display of scanning data with graph and table, visual management based on WebGIS, display of data analysis result and so on. The system architecture is shown in Figure 1.

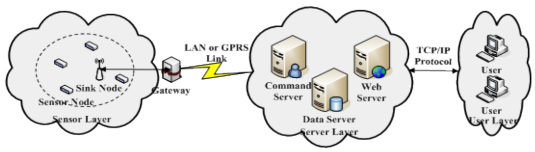

Figure 1: System Architecture

Considering mostly existing systems are based on specific environment, and their generality and platform independence are poor, so they cannot be used on other platforms. Moreover, there are large amount of users with different operation capacity, and most of them only input or query data. For these reasons, the system adopts Browser/Server (B/S) structure. In this structure, user's working interface is provided by Web browser, and a small part of transaction logic is implemented in browser while most transaction logic is implemented in server. [15]

2.2 System Security Design

The system is used on varieties of circumstance, therefore its security requirement is different. It uses grade mechanism which assigns users with different level of privilege. In user layer and server layer, the security issue flow is applied to users' identity authentication, and firewall is used to filter network garbage data, so the system guarantees the security and stabilization of data transmission during the network connection. [16] For user login, we use a method combining the account, password and authentication code to strengthen user audit, in order to ensure user validity. We fully utilize the system log to record user's operation information such as login, query and accessing. System administrator regularly inspects system log and status, together with user operation information to prevent possible illegal intrusion. In addition, user with different privilege level can access corresponding data and execute data statistics and analysis. The system uses redefined data communication format and protocol between server layer and sensor layer. The data are encoded and checkout before they are transported.

2.3 System Interface Design

The system interface is easy to use, and it is divided into management, data display and WebGIS interface. Management interface is used to create, edit, delete, monitor monitoring scheme and other operations. Data display interface is used to display analysis result and scanning data collected by server layer. Multiple data display mechanisms are provided such as table, bar, line, and pie diagram. A special interface called WebGIS interface is implemented to cater for sensor devices' characteristic of geography distribution. This interface makes the demonstration of the data more intuitionistic.

2.4 System Functions Design

After thorough analysis of every step of WSN management, the whole system is divided into 3 modules and 12 sub-functions by using system analysis method, function decomposition and modularization. System functions are shown in Figure 2.

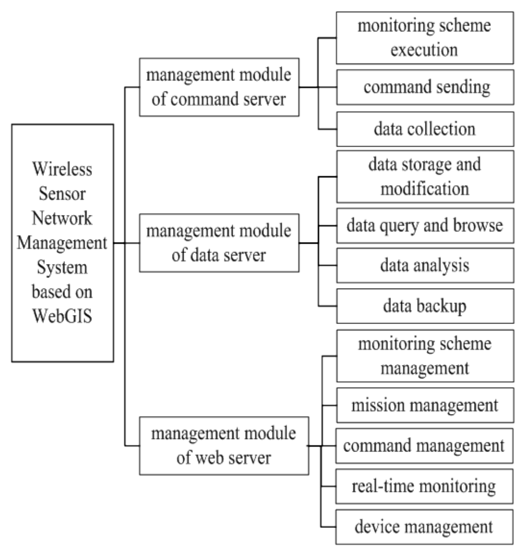

Figure 2: System Function Modules

1. Management Module of Command Server

It provides monitoring scheme execution, command sending, data collection and other functions. About function of monitoring scheme execution, implementation detail of monitoring scheme is analyzed by the command server. Commands recorded in the monitoring scheme are divided into different categories according to execution time. Instant command means a command which will be executed immediately, and it can interrupt other command which is executing; Relay command means a command which will be executed by some devices according to the time sequence; Loop command means a command which will be executed repeatly over a period of time. Meanwhile, commands can be divided into setting and query command according to execution properties, and they are used to Configure and query sensors attributes or working pattern.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

After loading monitoring schemes from database, the command sending function analyses them, and sends the commands recorded in schemes to the corresponding sensor nodes or sink nodes. Command sending algorithm is shown as follows:

Input: Monitoring Schemes
Output: Command Lists
Step 1 Load the next monitoring scheme P.
Step 2 If P has required execution then go to step 3, else go to step 12.
Step 3 Load the next mission M at program P.
Step 4 If M has required execution and hasn't been completed then go to step 5, else go to step 10.
Step 5 Load the next monitoring command C at mission M.
Step 6 If absolute (beginning time of C - now) <=10s then go to step 7, else go to step 9.
Step 7 If C is instant command then it should be added into the instant command list. Else if C is relay command then it should be added into the relay command list. Else if C is loop command then it should be added into the loop command list.
Step 8 C is formatted to binary sequence according to redefined format.
Step 9 Go back to step 5 until there is no command left at mission M.
Step 10 Go back to step 3, until there is no mission left at scheme P.
Step 11 Send the binary commands which are recorded in the lists. Check out the commands which exceed the time limit of transmission, then delete them, and make the state of the command is timeout.
Step 12 Go back to step 1, until there is no scheme left.

The data collection function collects all the data reported by sensor nodes or sink nodes, then they will be submitted to data server. The data are divided into feedback data of setting command, device status data and scanning data. The communication between sensor nodes and management node is shown in Figure 3.

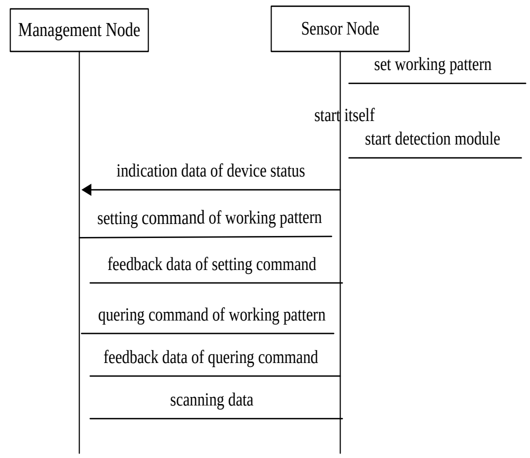

Figure 3: Communication Between Sensor Nodes and Management Node

2. Management Module of Web Server

It provides users with friendly and visual operation platform. The user requirements are handled by the server, and then the output will be return to the client. Some functions are achieved such as real-time monitoring, monitoring scheme, mission, command and device management.

a. Real-time monitoring management provides real-time pictures based on WebGIS according to GPS data reported by sensor nodes. It can query the device status, edit the instant monitoring command, and show the real-time data by the WebGIS.

b. Monitoring scheme management manages all the monitoring schemes. The management operations include creating, modifying and deleting scheme, together with refreshing the scheme list, changing the scheme status from normal to being monitored.

c. Mission management deals with all the missions which are planned by the scheme, including several functions such as creating, modifying and deleting mission. Mission is constructed by commands having same type of job on logic. Missions are divided into panoramic, frequency range, and channel scanning mission, together with positioning mission according to function logic. The working state, pattern and process of sensor nodes and sink nodes are controlled by missions.

d. Command management handles all the commands which are executed by mission. Commands are divided into periodic and aperiodic commands. The periodic command

Journal of Theoretical and Applied Information Technology
20th March 2013. Vol. 49 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

will be executed at a certain time every day within specific period. The beginning, end time and the beginning, end day must be set for the command. The aperiodic command will be executed one time at a certain day. The beginning, end time and the day must be set for the command.

e. Device management manages the information of sensor nodes and sink nodes. It can manage the queue of device management command, check out legality of command and set device status.

3. Management Module of Data Server

Data server is composed of a database server. It can store, modify, query, browse, analyze and back up the data. It is the bridge between command server and Web server. Through Web server, users create monitoring scheme, edit the command and store them into data sever. The command server loads and operates the monitoring schemes and commands stored in the data server, and then stores the result returning from the sensor nodes into the data server. The Web server loads feedback data and result stored in data server, and shows them to users.

2.5 Database Design

There are thousands of sensor nodes in the network, and a huge number of data. So the reasonable database structure and fast data access speed are very important for the system. After a in-depth research, 34 database tables, 11 views and 12 triggers are created. The main relation of tables and views is shown in Figure 4.

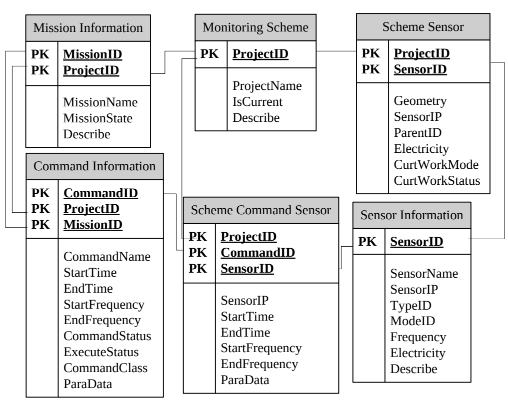

Figure 4: RELATION OF TABLES AND VIEWS

3. SYSTEM IMPLEMENTATION

3.1 The Choice of System Development Tools

To achieve the platform independence, command server is programmed with JAVA language, and the communication between command server and sensor nodes is implemented with JAVA Socket technology. The user interface of management module of Web server is developed by JavaServer Faces. The efficiency of developing program is improved by the use of PrimeFaces. The user experience is enhanced by the usage of Ajax and XML technology. The OpenLayers is used to finish the development of WebGIS. Data server is implemented by PostgreSQL which is a powerful and complex freedom software database system. PostGIS is one of the most famous open source GIS database, and it is used to store the spatial data.

3.2 Difficulties of System Implementation

a. How to control the work flow in the way of programmatic. Through in-depth study, the work flow and data flow are subdivided carefully, and then each step is controlled by program, so this difficulty is solved.

b. How to receive and store a huge number of scanning data from thousands of sensor nodes, and show them to users. The communication protocol between command server and sensor is redesigned, so as to reduce the count of the communication and the length of command. In order to decrease the pressure of data receiving, several threads are created by the command server, and the data are distributed to the threads. The client adopts Ajax technique. Ajax provides function of asynchronous communication with server, and the user will disentangle from circle of request/respond. With the aid of Ajax, the system can asynchronously load data from the data server. This can avoid data be loaded to client at once, or else the operation will be overtime. When the result is returned, we use JavaScript and CSS to renovate user interface, but not refresh the full page.

c. How to solve sensor fault, network fault and power restriction of WSN. To ensure the system can detect the faults and power status, many mechanisms are used, such as power early warning, non-response retransmission, delay retransmission and non-response alarm.

3.3 System Characteristic Functions

a. The real-time display of scanning data with graph and table.

Object oriented technology and script separation technology of flash are adopted to realize the real-time display of scanning data with graph and table. In order to ensure the dynamic creation of graph and table in Web pages, generation technology of dynamic element is utilized to draw coordinate axis,

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

axis text and auxiliary lines. In order to ensure real-time data display, communication among sensors, command server, data server and Web server is developed by socket technology. Further more, the drawing functions are recreated according to the data point parameters, so as to improve the drawing efficiency.

b. The display, edit and monitoring of WSN by using WebGIS.

The WebGIS is implemented by OpenLayers and PostGIS. PostGIS is used to store the spatial data, and the WebGIS client is developed by OpenLayers. Not only zooming in, zooming out, panning and other common operations are completed, but also surface, line, element selection and layer stack operations are finished. In addition, the real-time monitoring graph and WebGIS are combined to enhance the user experience. The WebGIS is shown as Figure 5.

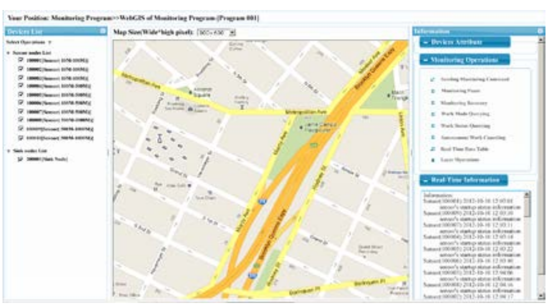
Figure 5: WEBGIS INTERFACE

c. Data format and protocol of custom communication.

Because of plenty of sensors, there are large number of communication data and scanning data. In order to reduce the count of communication and the length of command, the data format and communication protocol are redesigned.

3.4 System's Running Environment

System running environment involves hardware and software environment. The hardware part involves command, data, and Web server. The software part includes Linux Ubuntu 12.04, PostgreSQL 9.0 and Apache Tomcat 6.0.

4. SUMMARIZATION AND FUTURE WORKS

In this paper, we introduce the design and implementation of the WSN management system. The framework and hierarchy structure of the system are described in detail. The platform independence, visualization, extensibility, security and other items are achieved efficiently by the usage of Java, flash, multithread and socket technologies. The system provides information management and display functions, such as sensor, WebGIS, configuration, and state information. The functions make the system adapt to the complex and volatile environment where WSN works, and it makes the management of WSN more effective and convenient. The technology and method for the design and implementation of WSN management system are provided, and they have important value for research and application.

In order to make this system can be applied in more environments, the follow-up work is studying the extensibility deeply, investigating into practical application adequately, and adding more functions.

ACKNOWLEDGEMENT

This work is supported by the College Science Research Project of Education Office of Hebei Province (No. Z2010121).

REFERENCES:

[1] Xiaoji LI and Chen CHEN, "A Dynamic Guaranteed Time Slots Allocation Scheme In Wireless Sensor Networks", *Journal of Computational Information Systems*, Vol. 6, No. 7 , 2010, pp. 2305- 2311.

[2] Tingting XIE, Yongxuan LAI, and Hong CHEN, "Energy-efficient Approximate Skyline Computation in Sensor Networks", *Journal of Computational Information Systems*, Vol. 3, No. 5, 2007, pp. 1821- 1826.

[3] Mantian XIANG and Lihong LI, "A Connectivity Based Distributed Algorithm for Localization in Wireless Sensor Network", *Journal of Computational Information Systems*, Vol. 4, No. 1, 2008, pp. 63- 68.

[4] Zhijun XIE and Lei WANG, "Rapid Coverage Decision Algorithm for Query Process in Wireless Sensor Networks", *Journal of Computational Information Systems*, Vol. 3, No. 5, 2007, pp. 1815- 1820.

[5] LI Jian-Zhong, LI Jin-Bao, and SHI Sheng-Fei, "Concepts, Issues and Advance of Sensor Networks and Data Management of Sensor Networks", *Journal of Software*, Vol. 14, No. 10, 2003, pp. 1717-1727.

[6] Li Jianzhong and Gao Hong, "Survey on Sensor Network Research", *Journal of Computer Research and Development*, Vol. 45, No. 1, 2008, pp. 1-15.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[7] Wang Feng, Liang Yan, and Cheng Yongmei, "Study of Sensor Management in Sensor Networks", *Computer Measurement & Control*, Vol. 15, No. 2, 2007, pp. 278-280.

[8] Qingzhang CHEN and Zhongzhe TANG, "Research on Encryption Algorithm of Data Security for Wireless Sensor Network", *Journal of Computational Information Systems*, Vol. 7, No. 2, 2011, pp. 369- 376.

[9] ZHANG Jie and SHI Weiren, "A Design of Data-Collection and Monitoring System Based on Wireless Sensor Networks", *CHINESE JOURNAL OF SENSORS AND ACTUATORS*, Vol. 22, No. 6, 2009, pp. 861-864.

[10] WEN Ying-You and FENG Yong-Xin, "Sensor Distribution Optimization Based on Extending-tree in Sensor Network", *ACTA AUTOMATICA SINICA*, Vol. 31, No. 5, 2005, pp. 737- 742.

[11] CHENG Xiao-liang and DENG Zhi-dong, "Residual energy real-time monitoring of wireless sensor network", *Journal of Central South University (Science and Technology)*, Vol. 40, No. 1, 2009, pp. 84-90.

[12] Xiao renyi and wu guozheng, "A survey on routing in wireless sensor networks", *progress in natural science*, Vol. 17, No. 3, 2007, pp. 261-269.

[13] ZHAO Zhong-hua, "Wireless Sensor Network Management Technology", *Computer Science*, Vol. 38, No. 1, 2011, pp. 8-14.

[14] LIU Lin, YU Hai-bin, and ZENG Peng, "Data Management Techniques in Wireless Sensor Networks", *Computer Engineering*, Vol. 34, No. 2, 2008, pp. 62-65.

[15] Haibo LIU and Fang YUAN, "Design and Implementation of Mobile Communication Network Optimization System based on Data Warehouse", *Journal of Computational Information Systems*, Vol. 4, No.1, 2008, pp. 43-50.

[16] Hai-bo Liu and Yong-gang Wei, "The application of web GIS in E-government", *2010 International Conference on E-Business and E-Government (CEE 2010)*. 2010, pp.519-522.