Design of Monitoring and Control System of Electrical Equipment in Buildings based on Internet of Things

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Abstract

To realize the remote control and parameter monitoring of different electrical equipments, such as air conditioning equipments, lights and water pumps, etc., an Internet of Things for building electrical equipments is constructed and its network topology and functional structure are explored in this paper. In this Internet of Things, there exist three main functional blocks the wireless measurement and control block, the room controller and the environment block. The issues on the self-organization and protocol of the wireless sensor network, which is used for information exchange in these functional blocks, are also studied. What is more, an equipment- management system, which can communicate with the room controllers via Ethernet, is provided on the management computer to realize the remote control of building electrical equipments. At last, an example is given to show how the electrical equipments can be connected to the Internet of Things and be controlled remotely.

Keywords

Internet Of Things; Wireless Sensor Network; Building Electrical Equipment.

1. Introduction

Along with the increase of building electrical equipments, traditional energy saving control theories and methods for single equipment/system have been unsuitable for the global optimization of all the building electrical equipments. Although the Building Automation System (BAS) can realize the monitor and remote control of all public electromechanical equipments, such as the central air conditioning system, water supplying and sewerage system, power transmission and distribution system, lighting system, etc.. But the BAS often needs to be imported aboard because of its strict demands of hardware and software. Even if some manufacturers have developed their own BASs, their products have not been able to be commercial. Furthermore, the lower openness and extendibility of the BAS make its investment unfavorable in the long run.

A new technology -- "Internet of Things", enable the Internet to reach out into the real world of physical objects. Since all the electrical equipments can be connected to the network, it is possible to gather and share the mass data like the equipment states, environmental parameters and so on. It also provides a new way to control and optimize more and more building electrical equipments.

The Internet of Things for Building Electrical Equipments (ITBEE) is a complex network. It highly integrates communication system, calculation system, control system and physical system into a complicated, dynamic and human- oriented system. In the ITBEE, different electrical equipments are connected to the same network through different mediums (wire or wireless) and forms (fixed or mobile). In this unified framework, electrical equipments can get messages (commands, sensor information, etc.) from the network and provide service (information gathering, calculation, equipment control, etc.) for it. Especially when the wireless networks are introduced, it becomes more convenient to construct the ITBEE. Nowadays, in the field of energy-saving control, it becomes very significant to study how to construct the ITBEE to the make building electrical equipments operate with low energy consumption and to provide a safe, comfortable and convenient living or working environment for people.

As a developing technology, the structure design and application of “Internet of Things” is still in the exploring stage in recent years. Being interested in the safety and reliability of the Internet of Things, Kottenstette et al. [1] have presented it a theoretical network architecture based on the concept of passive adaptation. Besides, some scientists built customer- focused network architecture according to the random multiagent system of Internet of Things [2], [3]. Karsai [4] has designed a totally parallel system using the model-driven approach to realize the communication between the Internet of Things and the models. All these researches provide a useful reference for the architecture design of ITBEE. The ITBEE not only has the common features of network, e.g. complexity, dynamics, reconstruction and reconfiguration, but also has its special characteristic named as “human-centered feature”. To the authors’ knowledge, no work has studied the topic of ITBEE, so it is a challenging but meaningful thing to study the architecture and application of the ITBEE and to solve the theoretical and technical problems existing in the ITBEE. For this purpose, this paper makes some useful attempt. The network topology and functional structure of the ITBEE are explored in this paper to realize the remote control and parameter monitoring of different electrical equipments.

2. Architecture of Internet of Things for Building Electrical Equipments

Fig. 1 shows the architecture of the ITBEE. In the following, we will introduce it in two aspects network topology and functional structure. Its network topology structure is composed of an industrial Ethernet, a wireless network, WAN and the GPRS/GSM network, etc. In the aspect of the functional structure, as shown in Fig.1, electrical equipments (Mi), e.g. air conditioners, lamps, pumps, have two-way communications with their room controller (Ci) by the wireless networks with the help of the measurement and control block (Wi) embedded in the equipments. Each Mi has its own Wi, which collects the states and parameters of Mi and sends these information to Ci, at the same time, receives commands from Ci to control Mi. An environment block (Ei) gathers environmental information around the room, such as environment temperature, humidity, lightness and infrared

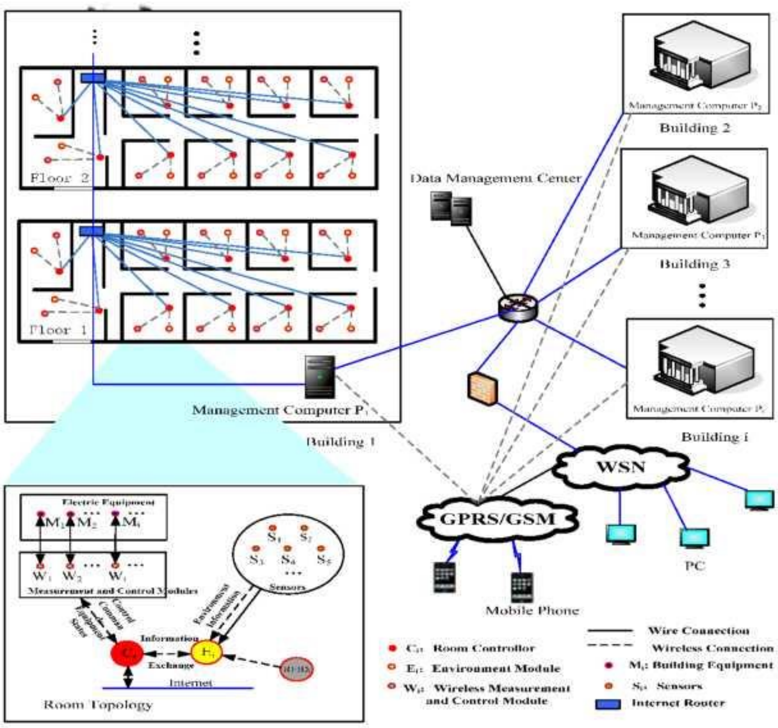

Fig.1 Architecture of Internet of Things for Building Electrical Equipments

2.1 Equipments ’ Connection with Network

If we want to control hundreds of electrical equipments in a building by a global optimization approach, these equipments must be physically connected into our Internet of Things, in which each equipment has a corresponding Mi. The block Mi uploads information to the room controller and at the same time receives commands from it through a wireless network. The structure of the wireless measurement and control block for electrical equipments is shown in Fig. 2. Sensor information, carbon dioxide concentration, personnel identity information RFID and the other expanding information if needed. Environmental information in E_i can also be sent to Ci via a wireless network. Each Ci receives data of Ei and Wi, and then send it to a management computer (P) through Ethernet. In other words, the room controller (Ci) not only has the two-way communications with Wi and Ei through a wireless network, but also realize the bi-directional data exchange with P. After receiving the data collected by Ci, the P manages these data in a database, makes decision according to the results from the energy optimization algorithms, and finally sends control commands to Ci to control the electrical equipments through Wi. At the same time, the management computer also provides users a friendly equipment-managing interface in the Browser/Server (B/S) framework, by which the authorized users can observe the interested information (environment parameters, equipment status, etc.) by means of Internet or mobile phone remotely.

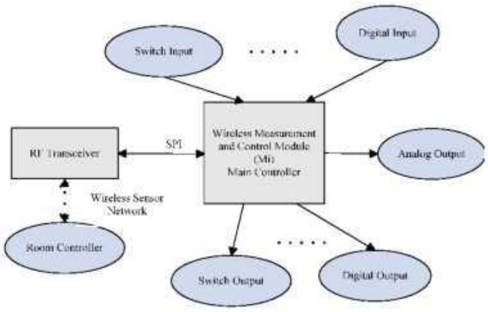

Fig. 2 Structure of Wireless Measurement and Control Block for Electrial Euipments

For such devices that can be controlled by switch signal as lamps, solid state relays (SSR) and buttons are fixed on M_i. So once the block has received the switch commands, on/off control action for lamps could be realized automatically. The main controller in Mi achieves on-off manipulation of the devices by use of the zero-crossing conduction/cutoff characteristics of SSR through the I/O port. Moreover, the port must be read again to confirm the state of device. Manual operation, which has been assumed to own the highest priority, can also be achieved by the buttons on the block. For example if a lamp is operating and at some time the "off" button is pressed down at the interface, M_i will cut off SSR to turn off the lamp. Simultaneously, the block reports the changed state to C_i. And, C_i will transmit it to the P immediately. Next, the "off" state will be shown in the management interface on the management computer. For those equipments controlled by digital signal, e.g. air conditioners, their blocks can control their operation like a remote-control unit. Similarly, the gathered state information will be sent to Ci.

2.2 Room Controller (C)

Room controller (Ci) equipped with RF transceiver, as shown in Fig.3, can obtain environment information of every room from E_i, and get the messages of equipment parameters by two-way communication with W_i. In addition, it is responsible for giving orders to W_i to manipulate the related equipment, and executing instructions given by the P via Ethernet. For instance, when a person walks into a room, Ci in this room will detect the change, and then start up the lighting system automatically and adjust the air-conditioner to the most suitable temperature. On the contrary, when he leaves the room after a while, Ci will ask for the management computer. If the computer answered that the person had left the building, then C_i will shut down the lighting and air- conditioning equipments automatically. The main controller in C_i is MC9S12NE64 or MEGA64. The main controller of RF transceiver is UM2455, which is a kind of the wireless transceiver chips.

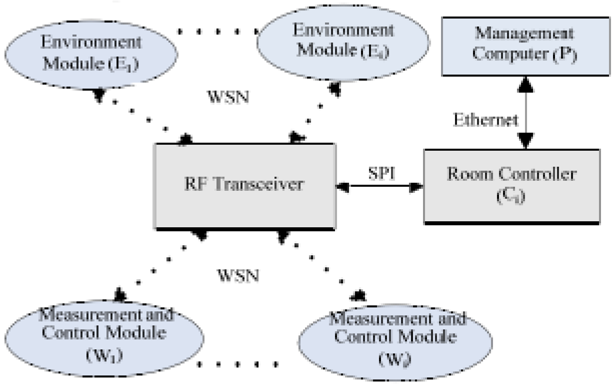

Fig. 3 Relationship of Room Controller and other Modules

2.3 Environment Block (E_i)

Environment block is used to gather environmental temperature, humidity, illuminance and infrared sensor information, carbon dioxide concentration, personnel information and so on. Thanks to its powerful popularity, the block can be further expanded to collect other information for special requirements. If some parameters become unimportant, some function of this block can also be simplified. Environment block, which has joined the wireless sensor networks by RF transceiver, exchanges with Ci and receives personal identification RFID information. The main controller in E_i is MEGA64. UM2455 is employed as the controller of a RF transceiver. Fig.4 demonstrates the architecture of E_i.

2.4 Construction of Wireless Sensor Networks (WSN)

In the ITBEE, WSN plays a very important role as a key means of communication between C_i and E_i, C_i and W_i. Since the wireless network is applied, it does not need to run wires and cables in the field. Our Internet of Things can be installed easily due to the powerful self-organizing ability of WSN. Nodes with self-organizing capability in the network can arrange and manage automatically, and finally form a multiskip network with the help of the topology control mechanism and the internet protocol. For example, once a new W_i or E_i appears, these blocks can distinguish WSNs, and find a node with the strongest signal to enter. When a certain node loses for reasons of power failure or disturbances, the WSN can be rebuilt automatically.

Construction of WSN in a room has two stages. At first, a WSN must be established logically. After initializing, Wi and Ei broadcast an asking frame in the wireless network, and Ci or routers nearby will send messages (including short address of the asking block) to respond. Having received the replied frame, the block will choose a node to join in, and extract its own address from the replied frame. The second stage is the registration of blocks. Due to the dynamics of WSN, the allocated address maybe modified. As a result, Ei and each Wi must register to their C_i. Having stored of these messages in a table, the room controller replies the packet. Once Ei and Wi have received the responded packet, it means that the registration stage is finished successfully.

3. Design of Equipment Management System

In this paper, B/S mode and .Net layered framework are applied for design of the equipment management system. With access to the Internet, users anywhere in the world can view the environmental parameters and the working status of building electrical equipments, and manipulate the operation of equipment remotely. The equipment management program based on Web server is divided into three parts: receiving data and sending commands, construction of database and Web publishing. Developed with C# and Winsock programming techniques, the first part program is not only responsible for monitoring the specified ports, distinguishing UDP Socket connection request of each room controller, but also sending orders decided by a host to the corresponding Ci. SQL Server 2000 is chosen as a database management tool in our scheme. Five tables with different functions are designed as required, which are called environment information table, equipment table, log table, access information table and system configuration information table. Amounts of the environmental parameters, equipment states and the like are stored in the first two tables. The log table is used to record system maintenance information. The access permission of every user can be checked from the fourth table. System configuration is described in the final table. Limited to the space, only data form of environment information table is listed in Table 1.

Table 1. Form of Environment Information Table

Name	Type	Null	Default Value	Comments
Rnum	text		0	Room ID
Uname	varchar(20)			User ID
Upass	varchar(21)			Password
Tem	float		0	T emperature
Hum	float		0	Humidity
Light	float	Allowable	0	Illuminance
CO2	float		0	CO2 Concentration
Person	text	Allowable	0	Person Information
Dflag	char	Allowable	0	Equipment Flag

Having finished the database construction, we assign an IP address to the P and each Ci. The P carries on receiving UDP Socket connection request sent by Ci, and saving information also sent by Ci into database. Similarly, the equipment management system processes the gathered data in real-time, and displays various parameters and charts. When a user opens the Web browser and enters URL address of homepage, it is easy to access the environment and equipment information of each building. Furthermore, it is feasible to control the electrical equipments remotely as long as you are authorized.

4. Application Example

It is a good idea to take the remote control of electrical equipment in a room as an example to illustrate how the ITBEE can be realized. The steps are listed as below:

1) In the room XX308, as shown in Fig.4, each device has its own W_i. all W_is and E; in XX308 register to the C_i in the same room first. After the registration, the equipment states are uploaded to the Q via WSN. As well as, E_i transmits environmental information.

2) An IP address is assigned for every Q and P. After initializing, the equipment management system can realize the two-way communication among them through Ethernet.

3) If one user logs in the system successfully, the management interface of the room XX308 which the controlled equipments lies in can be found with the help of the navigator on the left screen. For example, when the user presses down an on/off button of an air-conditioner, the control procedure begins to run and give an order to the Ci of XX308.

4) Having received the order, the Ci of XX308 finds the Wi of the air-conditioner, and delivers the control command to it.

Fig. 4 Interface of Equipment Management System

5. Conclusion

An Internet of Things for building electrical equipments is designed in this paper. Environmental parameters and equipment states are collected by the environment block and the wireless measurement and control blocks embedded on the electrical equipments, such as air-conditioner, lights, water pumps, etc. These data are also sent to the room controller by means of WSN. The self-organization characteristic and protocol problem of WSN are solved ideally. In addition, we provide an equipment management interface in the B/S framework on the management computer to realize the remote control and monitoring of the electrical equipments. By integrating information of each room controller, the management computer can improve the measurement accuracy and achieve fault diagnosis for the electrical equipments.

References

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[4] Gabor Karsai, Sandeep Neema and David Sharp, “Model-driven architecture for embedded software: A synopsis and an example,” Science of Computer Programming, vol. 73, pp26-38, 2006. Finally, W; can complete the “on/off” operation of the air- conditioner by means of SSR successfully.