2012 International Conference on Intelligent Information and Networks (ICIIN 2012)
IPCSIT vol. 23 (2012) © (2012) IACSIT Press, Singapore

Intelligent Energy Conservation System Design Based on Hybrid Wireless Sensor Network

Hung-Cheng Chen [1 +], Teng-Fa Tsao [2], Chun-Liang Hsu [3]

[1] Department of Electrical Engineering, National Chin-Yi University of Technology, Taiwan

[2] Department of Electrical Engineering, Nan Kai University of Technology, Taiwan

[3] Department of Electrical Engineering, St. John's University, Taiwan

Abstract. This paper attempts to design and implement an active intelligent energy conservation system utilizing hybrid wireless sensor network (HWSN) which incorporates ZigBee wireless sensor network (WSN) with Bluetooth control network (BCN). This research also proposes an ontological information agent built in back-end server to provide the system with intelligent control strategy in order to effectively achieve the goal of energy conservation. With the proposed agent, the feedback control commands are decided and then delivered through Bluetooth control network to control the power-consuming facilities. After practical operating the intelligent energy conservation system for 4 whole months, totally 22.44% electricity power is saved with the help of intelligent energy conservation system. The effectiveness of the intelligent energy conservation system with ontological information agent is encouraged.

Keywords: energy conservation, Wireless Sensor Network (WSN), ontological information agent, ZigBee, Bluetooth

1. Introduction

With limited territory, large population, and rare natural resource, Taiwan mostly depended on import to provide energy needs up-to 97%. To solve the energy shortage and green house problem, all nations reach to the common sense to positively promote energy-saving activity [1]. To save the electrical energy we have to manage all the environmental parameters such as temperature, humidity, luminance, and quality of air in the living space and probably adjust all the power-consuming facilities dynamically [2-5]. For example, if the temperature in the living space is lower than 26℃, the air conditioner would keep closed, and if there is no person in the space all the facilities ought not be opened. Reference [3] investigated the luminance regulation techniques so as to improve the efficiency of lighting energy conservation. Reference [4] proposed the study on the difference of energy conservation management between building and indoor-decoration Luminance. It also revised the luminance energy conservation standard with the statistics of luminance loading and electricity density /per area unit of office in Taipei city so as to improve the luminance energy conservation strategies.

From the description above, we attempt to design an intelligent energy conservation system with ontological information agent which is an intelligent agent technique proceeding data mining, events analysis, and quickly response system [6]. The system displays all the sensor information and environmental parameters on the server computer screen, and through the comparison between the real-time collected data with database to make decision and proceed feedback control to all power-consuming facilities. This study constructs HWSN using 2.4GHz ZigBee and Bluetooth, in which ZigBee is used to design the interface between end-device environmental detection sensors and middle-way station, while Bluetooth is designed as the communication interface between the controlled facilities and middle-way station. Finally, the system is

+ Corresponding author. Tel.: +886-4-23924505ext7255; fax: +886-4-23924419.
E-mail address: hcchen@ncut.edu.tw.

built in a campus building as a target for the effectiveness evaluation of the intelligent energy conservation system.

2. Design Concept of Intelligent Energy conservation System

The energy conservation system could collect all the environmental parameters in an energy-consumption space such as room, house, office, factory, community, or any space. The collected parameters which include number of people, light luminance, temperature, CO_2, power usage, and humidity would influence the operation strategy of the energy conservation system. These parameters are sent to middle-way station through ZigBee and then to server computer through Ethernet. The server will decide the feedback control command based on the proposed ontological information agent for the purpose of energy conservation. The feedback control command is then sent to controlled facilities via middle-way station using Bluetooth wireless communication for the regulation of air quality, temperature, light luminance, and control of affair machines and facilities. The design concept is shown in Fig. 1. The sensors of temperature, CO_2, luminance, humidity, power usage in this energy conservation system are designed with modules to meet different situations of power consumption such as power system, lights, air conditioner, official affairs machines and facilities. The information streams use a large number of WSN technology so as to construct an active and intelligent energy conservation system. All sensor modules are designed with microprocessor as the core of control system. Consumers could combine some certain modules to set up the energy conservation system case-by-case in their own need.

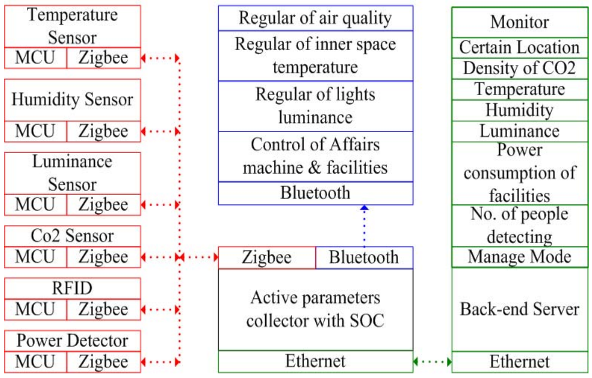

Fig. 1: Design concept of intelligent energy conservation system.

Based on the design concept, the system structure of the energy conservation system shown in Fig. 2 consists of four parts as follow:

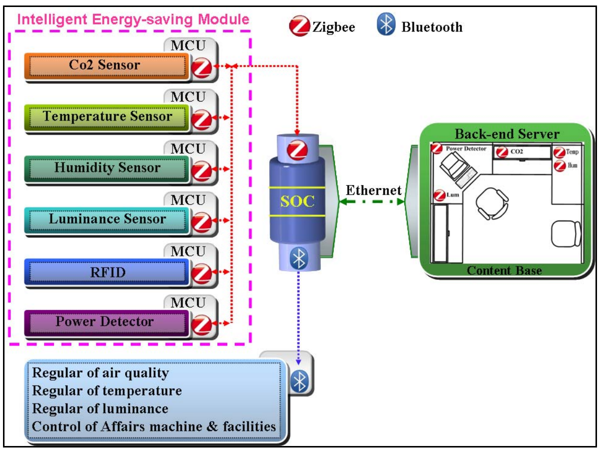

Fig. 2: System structure of intelligent energy conservation system.

(1) Environmental condition sensing (environmental parameters collection)

The various WSN sensor modules with ZigBee data transmission interface for sensing temperature, humidity, luminance, CO_2, and number of people are well-designed. Those environmental parameters would be detected and sent to the embedded middle-way station and server computer as judged factors to be determined whether the system should proceed feedback control based on the proposed ontological information agent. These WSN modules are placed at proper location to match up the condition of environment.

(2) Practical installation of WSN in power-consuming locations

In this study, we implement ZigBee as the environmental sensors interface to collect the environmental parameters of energy conservation system, and Bluetooth as the interface of controlled facilities. All sensors are designed in module-type so that those sensors could be reorganized by customers according to their environmental features. In addition to the sensors, the communication-net mechanism could be organized by the user-defined packet protocol of information. So far, the sensor network has been installed at the frequently used place in our campus, such as experimental laboratory, computer classroom, huge offices, and conference room.

(3) Ontological information agent in server computer

The interface of feedback control of server is responsible for collecting all environmental parameters from the sensors of energy conservation system established in certain power-consuming space. All parameters are stored in a database which can be mined for operation situation judgment indexes of feedback control. In addition, there is designed ID for each end-device node, which could be user-defined according to the located position of the sensor node. That means the interface of system parameters is in a visual-mode display and users could easily monitor the condition of controlled facilities in the power-consuming space.

(4) Feedback control on power-consuming facilities

For the energy-saving purpose, the power-consuming facilities will be monitored and controlled by server. Once the abnormal condition occurred, the facilities should be controlled through the Bluetooth wireless control network. The controlled nodes can be divided into single-switch and multi-switch that are controlled by the ontological information agent on server computer.

3. Intelligent Information Processing and Decision Making

In this research, an ontological information agent with solution integration and agent techniques for intelligent information processing is proposed, which not only helps the whole system find out proper and integrated processing results, but also supports proxy access of information solutions through a two-tier solution finding process, as showed in Fig. 3. The architecture involves two main modules, namely case-based reasoning (CBR) [7, 8] and solution predictor [8, 9], and shows how it interacts with the system interface. The solution finder is designed to serve as the central control for making control strategy to effectively achieve the goal of energy conservation. To ensure that all the knowledge used in CBR and solution prediction can be automatically generated, we have introduced a solution predictor into the system. They will be described in the subsequent subsections.

As stated above, the solution finder is a system control manager. After receiving a query from the interface system, it tries to produce an answer following a two-tier algorithm, which includes predicted solution retrieval, CBR, and solution integration. We briefly summarize this process here.

- Predicted solution retrieval: Firstly, solution finder checks whether any predicted results exist in query model base. If yes, it directly produces the answer retrieved from the question-answer pair. If none, solution finder starts CBR to find out query solution.
- CBR: If the given query is already existent in ontological database access cases (ODAC), solution finder directly outputs its answer part. If none, solution finder performs case adaptation to solve the query.
- Solution integration: The last mechanism of finding solutions is to trigger solution integrator to integrate solutions from external experts. If this integrated solution is credited with a high degree of satisfaction by the user, it will be stored in the ODAC serving as a new case.

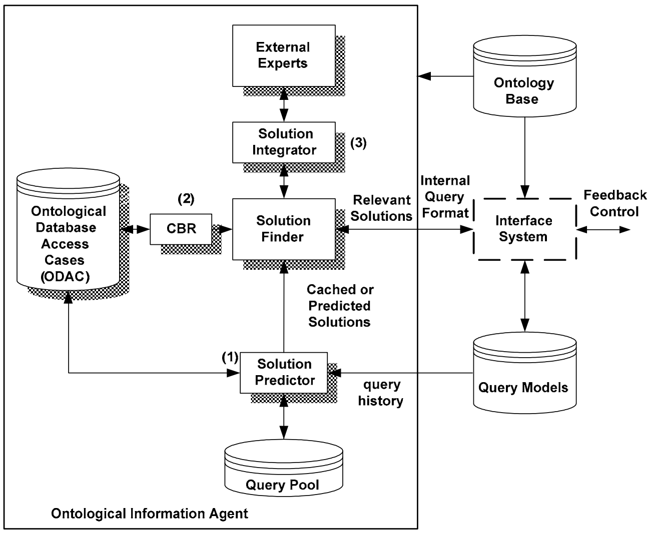

Fig. 3: System architecture of ontological information agent.

4. System Installation and Effectiveness Evaluation

In this study we select the Electrical Engineering and Information Building in our campus as a target for the effectiveness evaluation of the intelligent energy conservation system. The sensors have been located at experimental laboratory, computer classroom, huge offices, and conference rooms, where are mostly power-consuming spaces. The ZigBee network is located in a scatted net domain structure as shown in Fig. 4. There are totally three net domains in the 2nd floor of the building and each net domain has its own PAN ID.

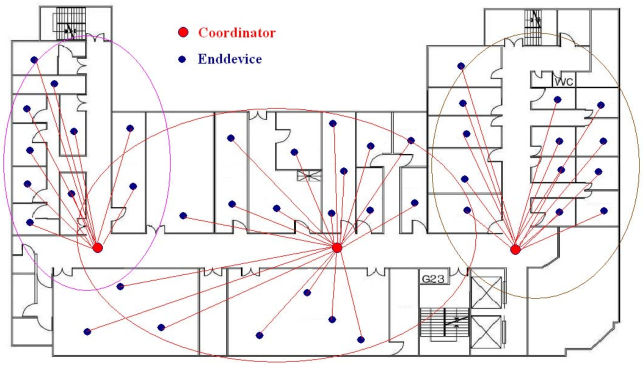

Fig. 4: Installation of sensor nodes in the 2nd floor of Electrical Engineering and Information Building.

We have practically located the ZigBee wireless sensors in different teaching laboratories or room spaces in which temperature and humidity sensors are mounted. In order not to generate abnormal data, the sensor nodes should avoid to locate too close to the outlet of air conditioner. The number of the located sensor nodes depends on the size of space area. In this study 40 sensor nodes provided with both temperature and humidity detection function are distributed into 3 ZigBee net domains as shown in Fig. 4. Since coordinator is responsible to receiving all environmental parameters transmitted from sensors nodes (end device) any time, the power supply of coordinator directly uses civilian electricity. As for the end device, all the environmental parameters are sensed and sent to coordinator per 80 seconds. Once the parameters are sent out, the end devices would enter into sleep mode to save power consumption. Therefore, we adopt three No.3 batteries to provide the power supply for end device.

After practical operating the intelligent energy conservation system for 4 whole months, the total electricity power consumption is analyzed in Table 1 for system effectiveness evaluation. From Table 1, we could easily compare the results of power conservation with and without the energy conservation system. It is obvious that totally 22.44% electricity power is saved with the help of intelligent energy conservation system. The potential energy conservation system is now duplicated at all of the other buildings in our campus. We hope we could offer more complete data of total power conservation after the hybrid wireless communication network and related sensors network are built. At this moment, the effectiveness of the intelligent energy conservation system is encouraged.

Table 1. Efficiency analysis of energy conservation system

Device \ Condition	With energy conservation system	Without energy conservation system
Lighting	40w * 232 Group=9.280kw/hr	7.424 kw/hr
Air conditioner	10kw * 19 Group=190kw/hr	142.5 kw/hr
Computers	400w * 153 Group=61.2kw/hr	52 kw/hr
Service Machines	120w * 35 Group=4.2kw/hr	3.36 kw/hr
Total Energy conservation (%)	100%-(7.424+142.5+52+3.36)/(9.28+190+61.2+4.2)=22.44%	

5. Conclusion

The active intelligent energy conservation system is originally designed and implemented utilizing hybrid wireless network. The various environmental detection sensor modules are also constructed for collecting all environmental parameters. In order to effectively achieve the goal of energy conservation, a two-tier ontological information agent is built in back-end server to provide the system with intelligent control strategy. With the proposed agent, the optimal feedback control commands are decided and then delivered to control the power-consuming facilities. After practical operating the intelligent energy conservation system in a campus building for 4 whole months, total 22.44% electricity power is saved with the help of intelligent energy conservation system. The effectiveness of the intelligent energy conservation system with ontological information agent is encouraged.

6. Acknowledgements

This research was originally creative works and sponsored by The National Science Council of Taiwan Government under project Granted No. NSC-100-2623-E-167-001-ET and NSC 100-2632-E-252-001-MY3.

7. References

[1] Taiwan Ministry of Economic Affairs Bureau of Energy. Energy Technology Research and Development White Paper, First chapter Senate. Available at http://www.moeaec.gov.tw/Policy/PoMain.aspx? PageId= energytechwhitepaper, 2007.

[2] Living 3.0. Intelligent Living Space Demonstration Center - Taiwan. Available at http://www.living3.org.tw, 2008.

[3] T.Y. Wu. *A Study on Energy conservation of Old College Buildings - Illuminating Systems Using the Index of Daily Green Buildings Energy Consumption Evaluation Criterion*. Master Thesis, Department of Civil Engineering, National Chiao Tung University, Taiwan, 2006.

[4] H.T. Chuang, *The study on the difference of Energy conservation Management between Building and Indoor-Decoration Luminance - Example with Taipei Offices*. Master Thesis, Department of Interior Design, Chung Yuan Christian University, Taiwan, 2002.

[5] H. C. Chen, and L. Y. Chang. Design and Implementation of a ZigBee-Based Wireless Automatic Meter Reading System. *PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review)*, 2012, **88** (1b): 64-68.

[6] G.L. Wang, G.H. Cao, and T. La Porta. Proxy-Based Sensor Deployment for Mobile Sensor Networks. *Proc. of 2004 IEEE International Conference on Mobile Ad-hoc and Sensor Systems*. FL, USA, 2004, pp. 493-502.

[7] S.Y. Yang, P.C. Liao, and C.S. Ho. A User-Oriented Query Prediction and Cache Technique for FAQ Proxy Service. *Proc. of 2005 International Workshop on Distance Education Technologies*. Banff, Canada, 2005, pp. 411-416.

[8] S.Y. Yang, and C.L. Hsu. An Ontological Proxy Agent with Prediction, CBR, and RBR Techniques for Fast Query Processing. *Expert Systems with Applications*. 2009, **36** (5): 9358-9370.

[9] S.Y. Yang, P.C. Liao, and C.S. Ho. An Ontology-Supported Case-Based Reasoning Technique for FAQ Proxy Service. *Proc. of the 17th International Conference on Software Engineering and Knowledge Engineering*. Taipei, Taiwan, 2005, pp. 639-644.