Evaluation of Occupancy-Based Electricity Management System

Yong Kuk Park, Min Goo Lee, Kyung Kwon Jung, June Jae Yoo
Embedded Software Convergence Research Center, Korea Technology Institute
Seongnam-si, 463-816, Korea

ABSTRACT

This paper presented an occupancy-based smart plug system for appliance energy saving in smart home. We measured current consumption of appliances in real time using smart plugs, and check the occupation of residents using occupancy sensors installed on the door and room. The proposed system saves electric energy to switch off the supply power of unnecessary usages in the unoccupied spaces. Experiments conducted have shown that current usage of appliances can be measured by using smart plugs and presence can be checked by using occupancy sensors.

Keywords: Smart house, Electricity monitoring, Occupancy sensor, PIR sensor, Wireless sensor network

1. INTRODUCTION

Conservation of energy is necessary for economic and social prosperity. It is important to optimize the usage of energy in homes and make the users aware of their energy consumption. There are various systems in the house which consume lots of electrical energy. With an increase in the usage of the modern devices on one side and the shortage of the energy supplies on other side, it has become mandatory to use the energy more effectively and if possible conserve it in smarter ways than before.

The high energy required by home appliances and air conditioning systems, makes our homes one of the most critical areas for the impact of energy consumption on natural environment. In a modern household, hardly any device runs without electricity. Understanding household energy usage in-home is vital for the planning of energy consumption and conservation. Household are an important group when addressing energy conservation. Many researchers pointed out that changing life style is important to reduce the energy consumption.

The smart metering and Home Energy Management Systems (HEMS) are being given increasing attention both in commercial enterprises. HEMS are much advertised and promoted as 'high potentials' for domestic energy savings, with some (commercial) energy monitors claiming 10–20% savings [1].

Smart meter is a very general term for a more advanced metering device, which provides more detailed information on consumption to the customer and is mostly able to communicate with the electricity supplier via some network for the purpose of accounting, billing and monitoring. Capabilities range from simple display a meter, which gives a user feedback on current and past consumption, to high-tech meters which are capable of interacting with home automation systems and for instance are able to switch on a device when the supplier indicates cheap energy prices [2], [3].

This paper presents the architecture, design, and evaluation of energy monitoring system, a smart plug for gathering electricity usage and controlling AC in a smart house using occupancy status.

2. SYSTEM OVERVIEW

The overall design of the smart energy monitoring system is shown in Fig. 1. The design divides the system three parts. The three pieces of this decomposition are the smart plugs, the occupancy sensor module, and the home gateway.

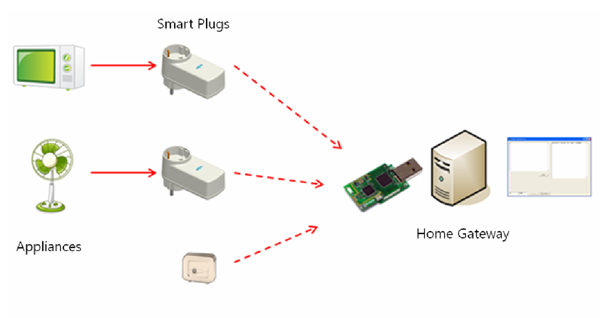


Fig. 1 System overview

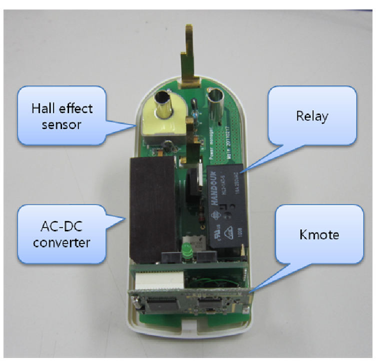
A. *Smart plugs*

An essential component of smart plug is the device that performs the energy measurement and control. This device consists of four components – Hall effect sensor, AD/DC power supply, microcontroller with radio, and relay as shown in Fig. 2.

To obtain real, reactive, and apparent power measurements, a dedicated IC is usually used to perform the necessary analog-digital conversions. In this paper, we use the Hall effect sensor to convert current to voltage. These devices use the Hall effect to measure current and can be either clamp-on (non-contacting) or in-line. Inline Hall effect sensors intercept the AC current and couple it with an internally calibrated Hall effect element. This approach is compact and precise. More importantly, the high voltage AC input is electrically isolated from the low voltage output inside the in-line Hall effect sensor.

The sensor network module is implemented from a commercial product (Intech co., Kmote-B) which is a clone of Telosb platform, including a microcontroller (Texas Instruments co., MSP430, 8MHz), an IEEE802.15.4 compliant RF transceiver chip (Texas Instruments co., CC2420) [4-6].

(a) Appearance



(b) Configuration
Fig. 2 Smart plug

B. *Occupancy Sensor Module*

Figure 3 shows the photo of the developed sensing module. The sensing module is implemented from a commercial product (Intech, Kmote-B) which is a clone of Telosb platform, including a microcontroller (Texas Instruments, MSP430, 8MHz), a IEEE802.15.4 compliant RF transceiver chip (Texas Instruments, CC2420), and a PIR sensor (PerkinElmer Optoelectronics, LHI878).

Fig. 3. Occupancy sensor module.

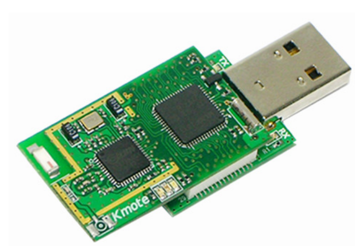
To reduce the power consumption, the hardware was modified to enable the use of wake-up and low-power mode. When the PIR sensor detects the movements of a person in a certain working range, it makes the microcontroller enter into the normal operation from low-power mode.

C. *Home Gateway*

The role of the home gateway is to store packets from the smart plug to a database as show in Fig. 4. We choose a small size PC for easy development of client program and convenient management of the in-house monitoring system.

The home gateway reads the packet from base module and writes it with additional information into the database. The UI program is implemented under the MS Windows XP using MFC.

(a) Home Gateway (Fit PC)



(b) Base module (Kmote)
Fig. 4 Home Gateway

Fig. 5 is the energy control UI.

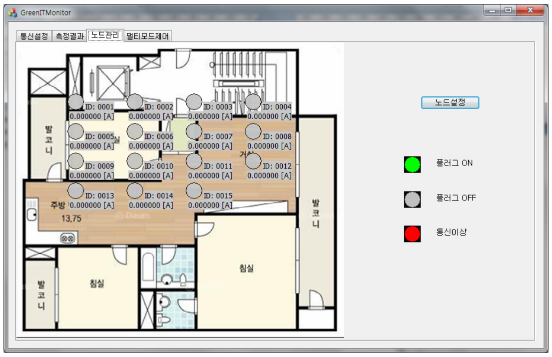


Fig. 5 Energy control program UI

3. EXPERIMENTS

Fig. 6 illustrates the experimental measurement set-up. The smart plug measures the current per 0.5 second, and transmits the wireless data to the energy control wallpad per 5 seconds. We measure the current consumption and electric power. It was based on the result of saved data in the energy control wallpad. Table 1 is list of appliances.

Fig. 6 Floor plan

Table 1. Appliances

Node ID	Appliances
1	Air Conditioner
2	Water Purifier
3	Fan
4	Air Purifier
5	PC
6	TV
7	Internet Modem
9	Microwave Oven
10	Printer
11	Electric Rice Cooker

Fig. 7 is power consumption traces from electrical appliances under measurement of appliances.

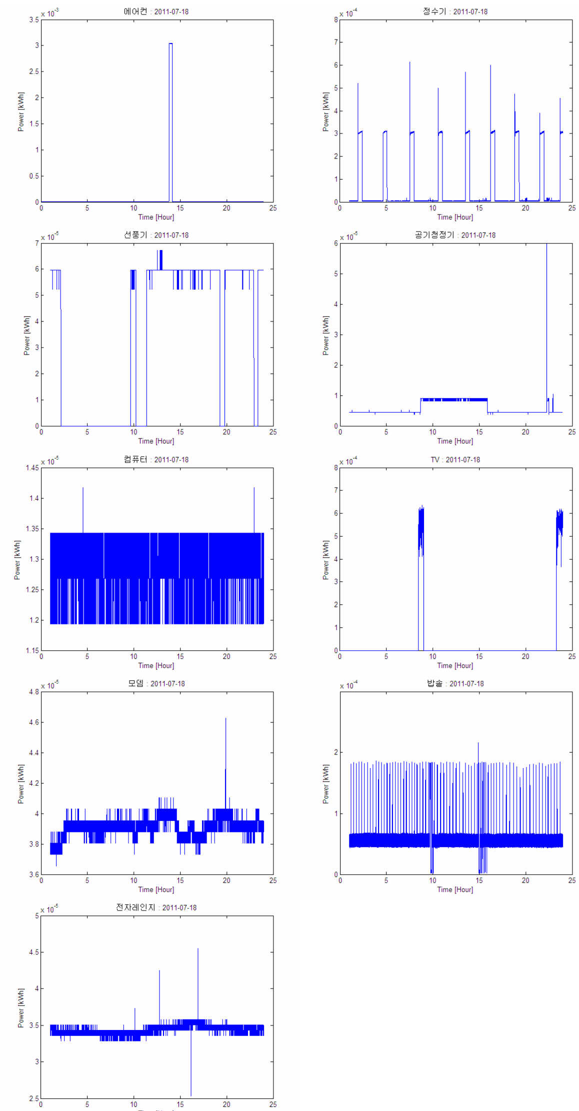


Fig. 7 power consumption

Fig. 8 is occupancy decision process. Occupancy state lasts 10 minutes after occupancy sensor fired.

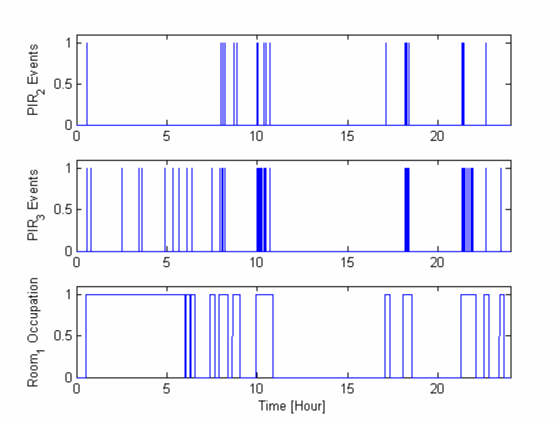


Fig. 8 Occupancy decision

Fig. 9 shows occupancy based energy saving results. In the absence state, we can reduce wasted electrical energy using power relay off.

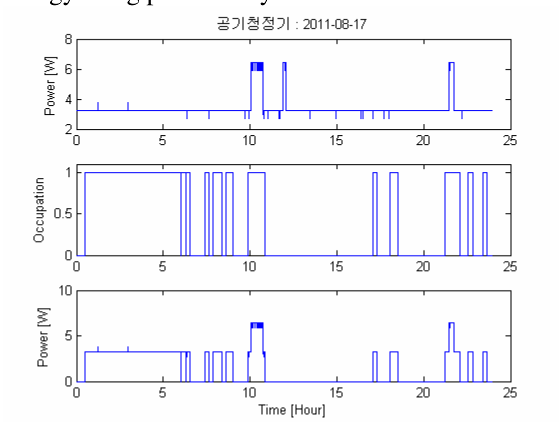


Fig. 9 Occupancy based energy saving

Fig. 10 is comparison result of power consumption. P_{Normal} is measurement power, and $P_{Occupation}$ is saved power controlled using occupancy sensor modules.

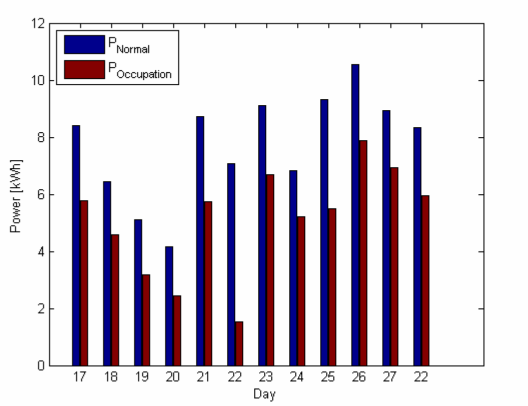


Fig. 10 power consumption

4. CONCLUSIONS

This paper presented an occupancy sensor-based power management system for appliance energy saving in smart house. We measured current consumption of appliances in real time using smart plugs, and checked the occupation of residents using occupancy sensors installed on the door and room. The proposed system saves electric energy to switch off the supply power of unnecessary usages in the unoccupied spaces. Experiments conducted have shown that electric energy usage of appliances can be saved about 34% checked by using occupation.

5. ACKNOWLEDGMENT

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6. REFERENCES

[1] I. Demirkol, C. Ersoy, F. Alagoz, “MAC protocols for wireless sensor networks: a survey,” IEEe Communications Magazine, Volume 44, Issue 4, pp. 115 – 121, 2006.
[2] S. Meguerdichian, F. Koushanfar, M. Potkonjak, M. B. Srivastava, “Coverage problems in wireless ad-hoc sensor networks,” INFOCOM, vol. 3, pp. 1380 – 1387, 2001.
[3] J. Bezdek. “A convergence theorem for the fuzzy ISODATA clustering algorithms,” IEEE Trans. on Patt. Anal. and Mach. Intell, vol. PAMI-2, pp. 1-8, 1980.
[4] Bernard Sklar, Digital Communications: Fundamentals and Applications, Prentice Hall, 2001.
[5] Maxfor homepage, http://www.maxfor.co.kr/
[6] Leon W. Couch, Digital and Analog Communication Systems, Prentice Hall, 2001.