Controllable Electrical Power Plug Adapters Made As A ZigBee Wireless Sensor Network

Toshihiko Sasama, Takao Kawamura, and Kazunori Sugahara

Abstract—Using Internet communication, new home electronics have functions of monitoring and control from remote. However in many case these electronics work as standalone, and old electronics are not followed. Then, we developed the total remote system include not only new electronics but olds. This systems node is a adapter of electrical power plug that embed relay switch and some sensors, and these nodes communicate with each other. the system server was build on the Internet, and users access to this system from web browsers. To reduce the cost to set up of this system, communication between adapters are used ZigBee wireless network instead of wired LAN cable[3]. From measured RSSI(received signal strength indicator) information between each nodes, the system can estimate roughly adapters were mounted on which room, and where in the room. So also it reduces the cost of mapping nodes. Using this system, energy saving and house monitoring are expected.

Keywords—outlet, remote monitor, remote control, mobile ad hoc network, sensor network, zigbee.

I. Introduction

MANY advanced features of electric appliances were developed in recent years. By Internet communication, many new appliances can monitor from remote place and remote users can control it. Using these functions, the system saves energy, and monitors children, senior citizens, pets and so on. However, many parts of appliances in houses are still old appliances they don't have the function of Internet communication for several years. And if new appliances exist, each appliance works to standalone unit, they don't communicate with each other and don't share information.

On the other hand, on medical situations, some total monitoring systems were developed. Patients wear wrist bands and ankle straps that was embeded some sensors, a hospital always get information of body temperature, pulse rate, and so on. But, in usual life, people avoid to attach sensors on the body. Because of privacy problems, in many case, camera monitoring is also avoided. However, people care video monitoring in the life on home town, and don't care infrared sensors that were used on automatic door open/close system. Similar tools using infrared sensors are very popular. That mean people don't care limited small sensors that work passively or indirectly, for example, infrared, light, air temperature, and electric power supply. These are not so powerful as camera monitoring, but they can monitor home accidents from multi sensors combination.

In this paper, we develop multifunctional electrical power socket plug adapters. It include some sensors to measure power consumption, light, and air temperature. And they communicate with each other, and send information to the server on the Internet. Adapters have the function to cut power supply to connected appliances by commands from the server or setting schedules. Users access to this server from web browsers, then users can do total monitoring and control of all home appliances that is not only new ages but also old ages. The necessary function of home appliances is easy set up. Then, these adapters communicate using ZigBee wireless network, instead of wired LAN cable. And, we are planning development of an analyzer for everyday sensor information and to search time zones or condition parameters that can cut power supply for energy saving, and, estimation of mounted adapters position from RSSI(received signal strength indicator) between each other. Some studies exist to estimate position[1][2], and they have position error about 2 meter. These accuracies change by walls, tables and some furniture, and it is difficult to calibration. However from these communicate information, neighbors are detected and can divide possibility of layout. It is sufficient to reduce the cost of set up, and it need to just only little manual adjustment.

In one experiment, using this system in the office to cut standby power consumption, total consumption reduced to about 80%[3]. And we study pattern recognition and automatic estimation of appliances[4]. In this paper, we describe the system configuration in section II, and experiment results over two days in our laboratory in section III, and finally describe conclusion.

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II. System

Our developed system is constructed from 2 parts, adapters and the service server. Adapters are mounted on each wall socket and power strip in rooms, and watch connected appliances and switch power supply to it. The service server collect these information from adapters, and send control commands to the adapter. This server has a function of web server, users access this site from web browsers, and monitor and control their appliances.

A. Network Configuration

Fig.1 shows the network configuration of this system. Each adapter communicates with other adapters using ZigBee wireless network, and one adapter that called a coordinator is connect to the Internet. The coordinator behave like a proxy to other adapters, and do polling from inside of LAN to avoid firewall problems. It collect logs of some adapters sensors and send logs to the service server, or receive and relay electrical power supply switching commands from the service server.

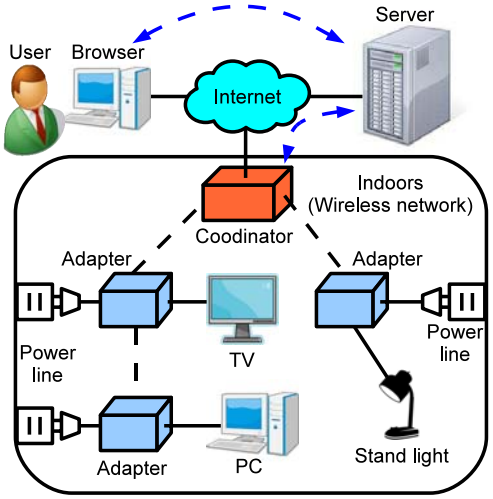

Fig. 1. Network configuration of proposed system

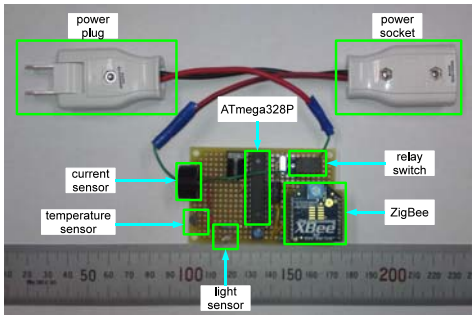

Fig. 2. Configuration of the multifunctional electrical adapter

B. Adapter

Fig.2 shows the configuration of this systems adapter. The adapter used the ATMega328P-PU made by Atmel Co. and programmed using Arduino, the current sensor CTL-6-P-H made by U.R.D Co., and the relay switch Y14H-1C-5DS made by HSIN DA PRECISION Co., For wireless ad hoc network communication, the adapter used XBee made by Digi International. The adapter box size is 80mm(W)x26mm(H)x48mm(D). XBee is one of ZigBee modules. It has short range and low power consumption. We add a light sensor S9648-100 made by Hamamatsu Photonics, and a temperature sensor LM35DZ made by National Semiconductor Co., and a infrared sensor 555-28027 made by PARALLAX Inc. for security monitor and energy saving on it.

One of them is selected as the coordinator to bridge wireless ad hoc network and LAN. It sends message from inside of LAN to the service server on the Internet at regular intervals. Because of low power module, if some shields like walls or furniture exist between adapters, XBee communication capacity rapidly falls. In other situation that large number of adapters are distributed in a building, capacity problem raised too. Then, the clustering/hierarchical routing approaches are used on wireless network[5].

Fig. 3. Screen shot of a web browser displaying top map

Fig. 4. Screen shot of a web browser displaying second map

Fig. 5. Screen shot of a web browser displaying room map

C. Service Server

This system has a web server function as graphical user interfaces for monitor and control of adapters. Users access this web site from web browsers, and control it.

Fig.3 shows the screen shot of layout monitor after login to this system. Users click the space of buildings, and open next map hierarchically. In Fig.4 and Fig.5, room maps and layouts of adapters can be shown. If click an adapter on maps, a monitor page of the adapter is open. Fig.6 shows the screen shot of monitor and control page. a user can turn on/off power supply to target appliance from this page.

III. Experiments

This section shows experiment results our developed adapters. Firstly, 2 adapters are mounted in our laboratory room on some place, and measured RSSI between adapters.

Fig. 6. Screen shot of a web browser displaying sensors graph and control

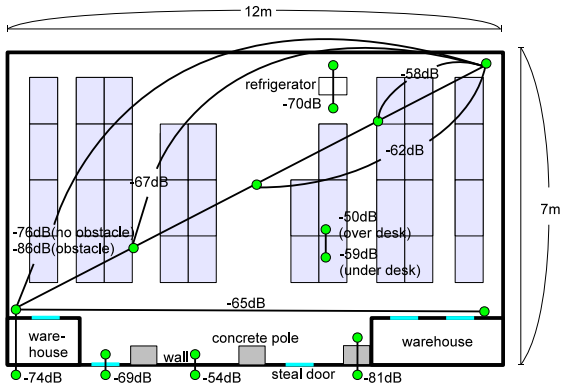

Fig. 7. Measured RSSI(received signal strength indicator)

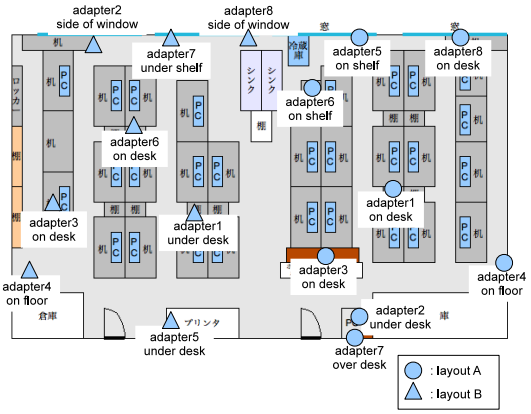

Fig. 8. Layout of mounted adapters in our laboratory room

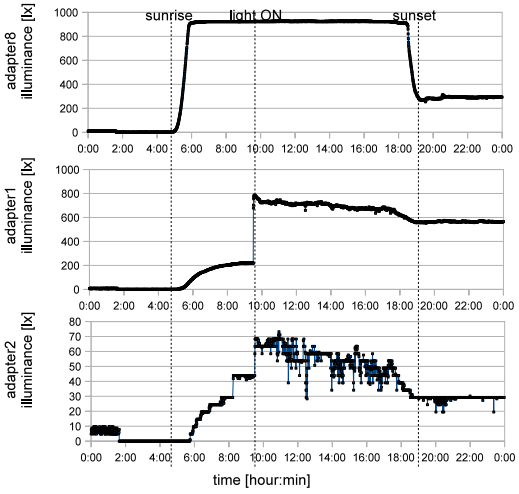

Fig. 9. Illuminance from light sensors on layout A

Fig.7 shows measured RSSI. Influences by distance and metals are large, but degrees of these influences are not directly. Next, 8 adapters are mounted in our laboratory room, and measured each light, temperature, and electrical power consumption in every 30sec. Information are sent to the coordinator in every time, and relayed to the service server on the Internet. Communication networks of this system have no trouble over 2 days.

Fig.8 shows 2 experiment layouts of adapters. In layout A, an adapter 8 is mounted side of window, an adapter 1 are monted on a desk, and an adapter 2 are monted in shadow of a furniture. Fig.9 shows the illuminance of light sensor of these adapters. From this graph, the system can detect sunrise and sunset, and power on/off of room lights. All graph suggests same information, but values of an adapter 2 is low. It means weakness to noise, then this system need to mount at least one adapter on outside of furnitures for light monitoring.

Fig.10 shows the air temperature of these adapters. An adapter 1 mounted near an air conditioner, and an adapter 8 mounted far side of an air conditioner. From this graph, the system can detect power on/off of an air conditioner. All graph shows almost same values.

Fig.11 shows sensor values of other day's morning on layout A. Each sensor values are measured in every 5sec. An infrared sensor output is only 0/1, and it's response is unstable. Then we check response for 3sec continuously, and graphed average of every 1min. This graph suggests that infrared sensors support to detect people in the room, but it is not completely.

Fig.12 shows the electric power consumption of an adapter 3 that connect to a personal computer. From this graph, the system can detect users action using electronics.

On other days, we mount adapters on layout B of Fig.8, and measured sensors in every 5sec. Networks of this system do not have a trouble, too. Fig.13 shows the illuminance of light sensor of an adapter 3 that mounted side of a window. From this graph, the system can detect only sunrise and power on/off of lights. To detect of sunset, the system need another adapters's information.

Fig.14 and Fig.15 shows the electric power consumption of an adapter 5 that connect to the shredder of two days. First day, shredder is not work, and it always use standby electrical power consumption about 0.3W. And next day it work several times.

IV. Conclusion

In this paper, we developed adapters that connect between wall sockets and electronics appliance plugs. This adapter

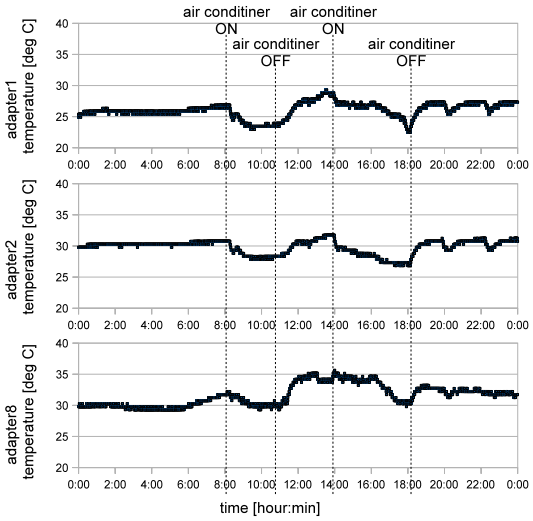

Fig. 10. Air temperature from sensors on layout A

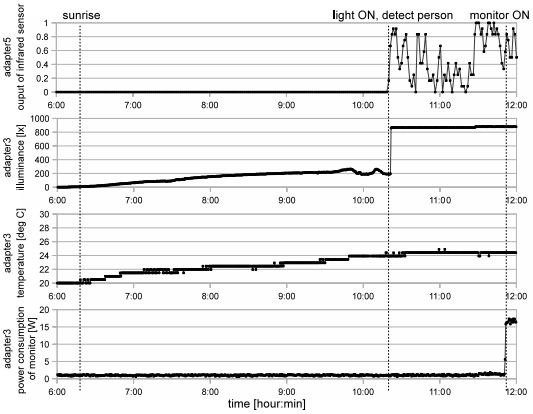

Fig. 11. Values of infrared sensor mounted at a desk side on layout A

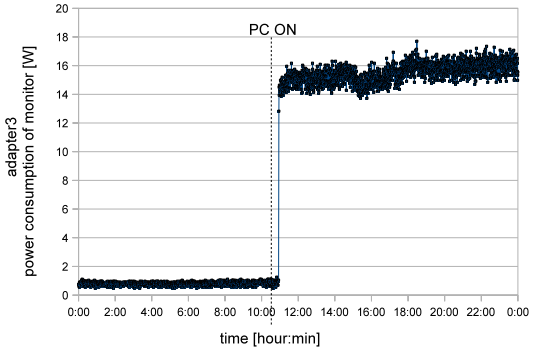

Fig. 12. Electric power consumption mounted to the personal computer

includes some passive sensors and electric power cut switch, then works as a remote monitor in combination with these sensors, and works as a remote controller without chosing target electric appliances. Using ZigBee that is wireless mobile ad hoc networks, it became easy to set up of these adapters.

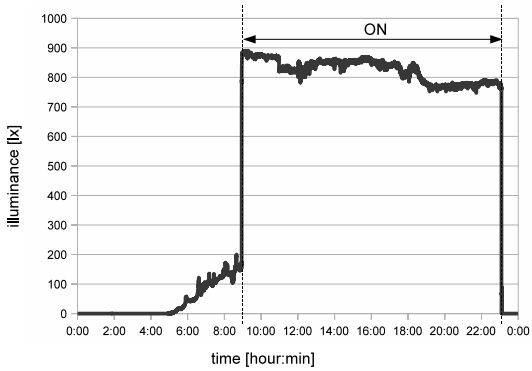

Fig. 13. Illuminance from light sensor mounted on the desk

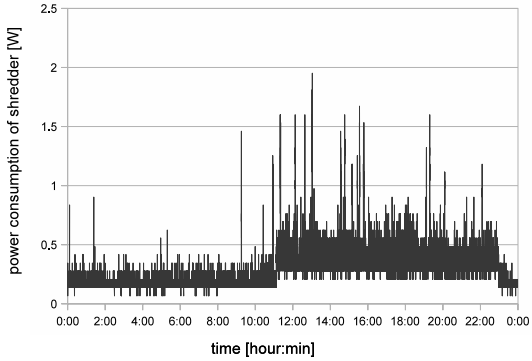

Fig. 14. First day's electric power consumption mounted to the shreder

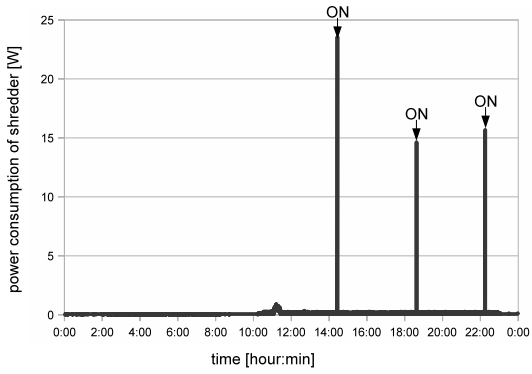

Fig. 15. Second day's electric power consumption mounted to the shreder

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