Development of Information and Communication Technology-Based Energy Management System Platform for Household Use

Hidekazu MIYOSHI*, Masami UEDA, Takashi YANO, Yuuichirou NOZUE, So-ichiro FUKUI and Takefumi SHIMOGUCHI

Sumitomo Electric Industries, Ltd., a leading company in the broadband network equipment market in Japan, has developed an energy management system targeting homes and small offices by applying information and communication technologies which have been accumulated in the Sumitomo Electric Group. This energy management system is comprised of a intelligent power strip and a power distribution board, both of which can measure electric power consumption and communicate with other devices, a cloud server which manages electric power data collected by sensor devices, and an energy management controller which plays a central role in this system. The major features of this system are 1) supporting various network interfaces, such as power line communications and low power wireless communications, as well as flexible data processing architecture designed for multiple communication interfaces, 2) an intelligent power control mechanism that can reduce power consumption without sacrificing quality of life, and 3) the OSGi open platform which enables easy accommodation of various service applications. This paper also reviews the proof-of-concept experiment held in Japan 2010, where several influential Japanese companies, including Sumitomo Electric, have jointly demonstrated the positive effect of the energy management system. We believe that the energy management service and other new types of home services that utilize information and communication technologies will improve the way of life. We highly expect that the prototype system we have developed can contribute to the future deployment of these services.

Keywords: green by ICT, HEMS, EMS, home gateway, OSGi, smartgrid, microgrid

1. Introduction

Sumitomo Electric Industries, Ltd., a leading-market-share company in Japan's broadband network equipment market, has developed a prototype energy management system for general consumer users, by applying its more than 20 years of experience in information and communication technologies. The major features of this system are 1) supporting various network interfaces, such as power line communications and low power wireless communications, as well as flexible data processing architecture designed for multiple communication interfaces, 2) an intelligent power control mechanism that can reduce power consumption without sacrificing quality of life, and 3) the OSGi open platform which enables easy accommodation of various service applications. The following is a report on our development efforts.

The Kyoto Protocol, adopted in December 1997, requires advanced countries to reduce their combined emissions of six greenhouse gases between 2008 and 2012 to at least 5% on average (6% for Japan) below 1990 levels. In Japan, the first commitment period started in April 2008. The Kyoto Protocol Target Achievement Plan, approved in a Cabinet meeting in April 2005, was fully revised in March 2008. The revision reflected the national government's increased commitment to making a concerted effort to implement global warming mitigation measures.

Meanwhile, there is a growing trend to strengthen energy-saving regulations among standardization organizations. For example, the International Telecommunications Union (ITU) set up the Focus Group on ICT and Climate Change, while the European Commission set power consumption and standby power reduction targets for each kind of equipment. In Japan, the Top Runner program led by the Ministry of Economy, Trade and Industry has begun to operate as a mandatory energy-saving standard, additionally covering communication devices such as routers and switches.

Under these circumstances, in 2009 Sumitomo Electric, as a company operating in the information and communication technology (ICT) industry, commenced developing an ICT-based energy management system and service platform technologies targeting general consumers, hoping to contribute to society in some form.

In general, ICT equipment includes PCs, other networking devices and audio visuals at home, as well as - in offices - servers and storages typically installed in data centers. Meanwhile, ICT-related energy-saving approaches are categorized into (1) energy saving in ICT equipment (green of ICT) and (2) energy saving of entire systems by use of ICT technologies (green by ICT). Sumitomo Electric concentrated its development efforts on the second category, which is expected to lead to greater energy-saving effects[7].

In the present paper, Section 2 outlines the system. Section 3 describes features of Sumitomo Electric's newly developed system: multi-sensor network support and platform technology that facilitates networked equipment control and installation of multiple items of service application software. Section 4 reports on our participation in a proof-of-concept test. Lastly, Section 5 summarizes the present paper and presents expected future development.

2. System Overview

Figure 1 shows an example configuration of the newly developed system. The home energy management system (HEMS) controller that performs the primary role in the system acquires various sets of energy information from sensors at home (**Photo 1**). Sensor product types include: (1) smart power distribution board (**Photo 2**) capable of measuring entire household's power consumption, (2) intelligent power strip (**Photo 3**), which measures power consumption of specific electrical/electronic appliances and turns power on/off from a remote location, (3) various sensor devices including water metering sensors, and (4) CT clamp sensor capable of relatively flexibly measuring power consumption. Another feature is that introducing the system involves no wire installation since the system employs short-distance wireless (Z-Wave[(3)]) and power line communication (PLC) methods.

The HEMS controller collects (and temporarily stores) data sent from sensors to transfer it at regular intervals to the management server provided as cloud-computing services (for long-term storage). The management server receives and performs statistics processes on energy information transferred from HEMS controllers installed in individual homes. The statistics processes compute the average, maximum and minimum energy consumption values for different lengths of time (day, week, month and year) and, sorting out households into virtual communities according to specific factors (for example, address, household size, housing size and presence/absence of power generating unit), produce data such as community comparisons and differences between individual households and community average.

The HEMS controller and management server with stored energy information (including statistics) enables visual data to be shown on a display terminal such as a PC

Photo 1. HEMS Controller

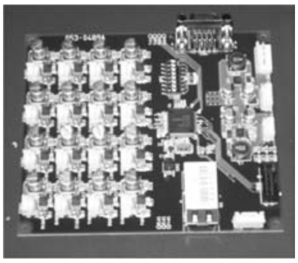

Photo 2. Controller of Smart Power Distribution

Photo 3. Intelligent Power Strip

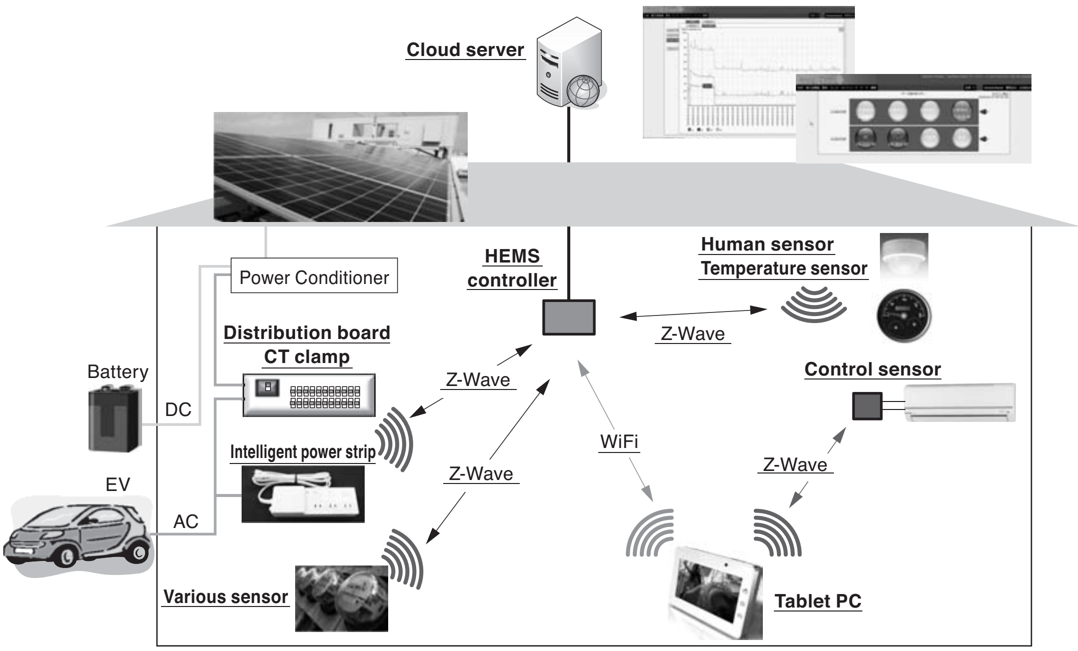

Fig. 1. Example Configuration

monitor and a tablet-type PC (**Fig. 2**). The tablet-type PC is an Android OS(12)-based terminal (with 7-inch display) provided with wireless LAN capability (**Photo 4**), which has a touch screen for operation. Moreover, the management server is accessible via the Internet, enabling, for example, the user to view the user's household energy information away from home.

The intelligent power strip is capable of turning power on and off as instructed by the HEMS controller. For example, when the user on the road is reminded that he or she forgot to turn off the air conditioner, he or she can easily turn it off by remote control if the user's terminal can access the Internet. In that case, the control request is transmitted from the user's terminal via the management server to the HEMS controller.

Additionally, the HEMS controller performs autonomous power control using its own criteria. The controller is also suitable for controlling power in response to the management server's request for power usage reduction. The system is designed to help future building of smart communities, in which demand response is a notable feature. Moreover, we view the HEMS controller not just as a discrete product. As part of the development, we also plan to implement HEMS's capabilities as bundled software in home gateways and tablet terminals.

The features of the present energy management system are summarized below:

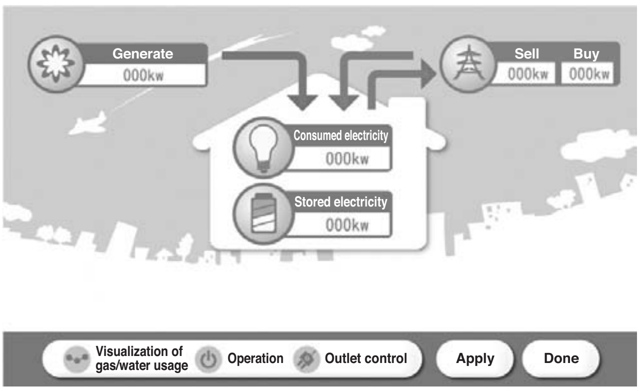

Fig. 2. Energy Visualization System

Photo 4. Tablet PC with Android OS

(1) Acquisition (and temporary storage) of energy information
(2) Energy information transfer to management server (long-term storage and intelligent control incorporating data analysis)
(3) On/off control of electrical/electronic appliances (external or autonomous control)

3. System Features

3-1 Multi-Sensor Network Compatibility

(1) Diversified network environment

In implementing services such as power control for household use, it is important to collect information from sensors and to control various types of equipment, including electrical/electronic appliances. These sensors and equipment are placed in various locations in the home, necessitating construction of a home network interconnecting them. In the sensor networking and home automation fields, a wide range of communication means - and protocols designed to use them - have been proposed, incorporating wireless (ZigBee[2] and Z-Wave[3]) or wired (HomePlug[4]) methods. However, these communication means and protocols have not come into general use. It is therefore necessary to develop a network at low cost, because in home monitoring and control applications many types of connected devices are present, though a small volume of information is exchanged in such applications. Moreover, the connection of sensors and other devices from different manufacturers requires a communication protocol that supports multi-vendor environments. As a solution to these challenges, standardization organizations promote the development of standards in order to build home networks for monitoring and control purposes.

The National Institute of Standards and Technology[1] (NIST) of the United States is working for the communication standardization including wireless and power line communication technologies for smart grid applications. ITU-T G.hnem[5] also holds discussions on PLC standardization, with future network system advances in mind. These standardizations, however, do not necessarily guarantee connectivity with existing technology. Furthermore, conventional communication methods tend to be specific to certain devices. In regard to wireless methods, for example, ZigBee is often used for meter reading, while Z-Wave is used for sensor networks and home control. Accordingly, it is currently difficult to use a unified communication method for connecting home monitoring and control sensors and devices to external devices via the Internet. It is therefore necessary to incorporate a gateway capability, so as to meet specific individual needs.

(2) Multi-networking capabilities

Sumitomo Electric has developed a multi-protocol HEMS controller that supports various communication methods and protocols, in order to accommodate various sensor networks. To comply with multiple communication standards, we designed architecture such that an intermediary data structure, independent of a particular standard or technology, is implemented in the database that stores a class of commands and acquired data. The present prototype supports such communication methods as Z-Wave, PLC (HomePlug), wireless LAN and Ethernet. Its flexible architecture adapts to additional interfaces.

3-2 Networked Equipment Control for Human-Friendly Energy Saving

(1) Tradeoff between energy saving and user experience

In general, energy saving is incompatible with user convenience. The greater the energy saving, the lower the user convenience. Maintaining user convenience would result in failure of energy saving. Consequently, demand is high for a scheme that ensures energy saving without loss of living comfort.

Meanwhile, some people declare that users should turn off information and communication equipment when they finish using them, for the purpose of saving energy in the office and at home. For example, users can turn off their PCs when going home from the office or when going to bed at home. Another recommendation is to power down the network server shared at home. However, requiring that individuals turn off devices each time when the need to do so arises is not so convenient. Specifically, with shared devices (for example, networking devices such as routers and switching hubs, networked printers and networked servers), the user must confirm that there are no other current users before turning off. This is highly inconvenient. As a result, in many cases, these shared devices are left on, which leads to the waste of power. Human-dependent energy-saving approaches appear to be generally ineffective.

(2) Usage-based control among electronic devices

If the HEMS controller takes into account usage-based associations among electronic devices, it should be possible to conserve energy while maintaining a satisfactory level of convenience. Take the example of a networking device shared by multiple terminal devices. When all terminal devices that use the networking device are turned off, turning off the networking device does not affect user convenience. The networking device could be turned on when at least one terminal device is turned on. Device on/off control performed according to the state of another device, as described here, is known as networked control. One requirement for networked control is to clarify the associations among specific devices regarding their usage, and to perform control based on that information.

Figure 3 shows an example of controlling four electronic devices. Device A uses devices B and C; Device D uses only device C. Assume for example an initial state in which electronic devices A, B, C and D are all turned on, and at one point the HEMS controller determines that device A has been turned off. Since device B is used only by device A, the HEMS controller turns device B off. Device C is not turned off by the HEMS controller because it is also used by device D. (The controller turns device C off if at a later time device D is turned off.)

This automatic networked control is performed similarly when these devices are turned on, taking into account the associations among the devices. Thus, networked power control based on device usage relations can be attractive for both energy saving and user convenient.

3-3 Support for Multiple Service Applications

Home broadband connection is provided via a small unit known as the home gateway (HGW) at the source. HGW is exceptionally important, because its role can be a backbone switch in home network and a server providing various application services. Various sensor devices can be connected to the HGW. One possible idea here is application software that acquires diverse bits of information (such as power consumption) from the sensor devices and uses the acquired information for various purposes. Moreover, packets captured from the network provide a variety of network status-related information, which is valuable for troubleshooting, diagnostics and capacity planning. An example of the former is home monitoring services, including those for elderly people, using information collected from door sensors and electric light on/off information. An example of the latter is network maintenance services. In this regard in the United States, major carriers such as Verizon Wireless and AT&T have found new business opportunities and are working on providing a wide range

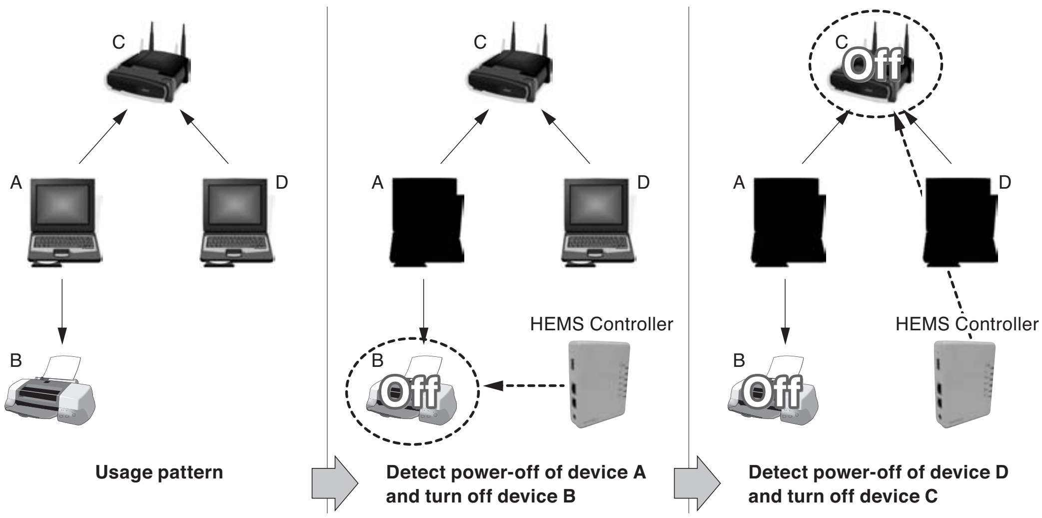

Fig. 3. Example of Power Control by HEMS Controller

of home network services[6],[8].

The design concept of the prototype HEMS controller was to implement capabilities for serving as HGW. We used the Open Services Gateway initiative[9] (OSGi) as a framework for providing application software. OSGi, promoted by the OSGi Alliance, offers common technical specifications intended to provide broadband services for various mobile and communication devices. As a basic service-providing framework, it is designed to realize application installation, starting/stopping services, application update and deletion and the like, without rebooting individual devices.

4. Participation in Proof-of-Concept Experiment Project

We took part in an industry-academia proof-of-concept experiment project to verify the effectiveness and possible applications of the prototype described in the previous sections. The following is a review of the project.

In fiscal 2010, the Shijo Smart Apartment Proof-of-Concept Experiment project was organized by i-Energy WG[10] (Chief: Professor Matsuyama at Kyoto University) of the Research Promotion Council of Keihanna Info-Communication Open Laboratory. Kyoto University played a leading role, and several companies participated in the project[11]. The project rented a 33 m^2 apartment in Kyoto. A total of 50 smart strips developed by member organizations were attached to some 30 types of electronic devices. While test subjects lived in the room, power consumption data were collected from the electronic devices. The project verified the energy-saving effects by introducing a system which visually represents acquired data.

One objective of the experiment was to verify the operation of the architecture designed to use the bundle section on OSGi to absorb differences in communication means and protocol specifications that were separately developed by individual companies. The experiment proved that different types of smart strips could be coexisted concurrently. Another objective was to verify the energy-saving effects of visually representing power consumption data. In the test, a married couple lived in the room for two months. Visual representation of power consumption data enabled them to easily reduce their power consumption by 10%, in comparison with that recorded for the period without visual representation. Moreover, the maximum power reduction of 23% was achieved, demonstrating the energy-saving effects of visual data representation.

Details of the apartment proof-of-concept experiment were released to the press in August 2010. Furthermore, in September 2010, an i-Energy WG symposium was held, which showed the apartment used in the experiment and approaches taken by individual member companies. **Figure 4** presents an overview of Sumitomo Electric's system as demonstrated at the symposium.

5. Conclusion

This paper outlines the basic features of the HEMS controller and prototype system developed for use at home and in small offices. The HEMS controller acquires power consumption information via intelligent power strips and other sensor devices, and provides visual data representation. Additionally, the controller performs power conservation control while maintaining user experience using its own intelligent power-control mechanism. Platform design assumed that certain controller functions would be placed in a server and provided as cloud computing services. Since multiple wired and wireless methods are used for communication with sensors, the architecture was designed to handle these methods in a unified manner. Moreover, we developed a multi-platform architecture to accommodate various items of application software, such as crime prevention, security and network maintenance, as well as to provide energy saving. We participated in an industry-academia proof-of-concept experiment project, actually operated the newly developed prototype system, and verified its effectiveness.

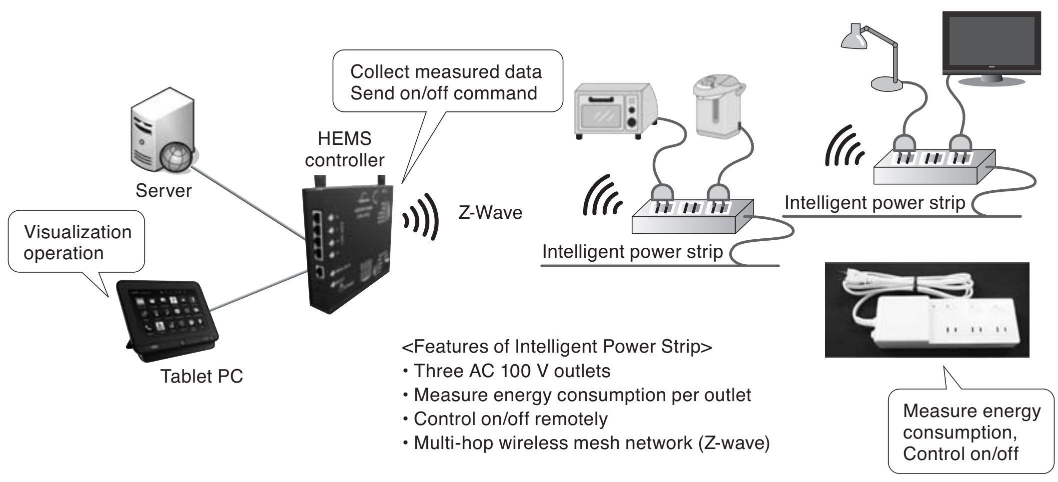

Fig. 4. Overview of Sumitomo Electric's System Demonstrated in the Proof-of-Concept Experiment

Regarding power control, we conducted a general analysis. Since society must address the challenge of reducing greenhouse gas emissions, it is expected that renewable energy systems, such as solar and wind power generation, will be rapidly installed in homes, building, and plants; accordingly, rechargeable batteries will be increasingly installed in various facilities. Consequently, the importance of energy management technology and systems is expected to increase, not only for energy saving, but also for energy generation and storage, covering unstable power generation sources. We intend to expand the newly developed energy management system to meet the challenge of providing advanced HEMS systems that respond to future social needs.

Japan is an increasingly aging, low birthrate society, where elderly people living alone are expected to increase in future. Under such circumstances, it appears that service application software will become important for realizing a safe, secure and comfortable living environment through crime prevention, monitoring and/or home automation services. To that end, we will work on bringing the platform technology described in this paper into wider use.

Using the newly developed system as a foundation, we will develop new products applying ICT technologies that are helpful in building a safe, secure and sustainable society.

* Z-Wave is a trademark or registered trademark of SIGMA DESIGNS, INC.
* Wi-Fi is a trademark or registered trademark of Wi-Fi Alliance.
* Android is a trademark or registered trademark of Google Inc.
* ZigBee is a trademark or registered trademark of ZigBee Alliance.
* HomePlug is a trademark or registered trademark of HomePlug Powerline Alliance, Inc.

References

(1) NIST: National Institute of Standards and Technology <http://www.nist.gov/>
(2) ZigBee Alliance <http://www.zigbee.org/>
(3) Z-Wave Alliance <http://www.z-wavealliance.org/modules/AllianceStart/>
(4) HomePlug Powerline Alliance <http://www.homeplug.org/home/>
(5) G.hnem Home Networking Aspects on Energy Management, ITU-T SG15
(6) Verizon News Release <http://newscenter.verizon.com/press-releases/verizon/2010/new-verizon-home-monitoring.html>
(7) Green IT Initiative, Ministry of Economy, Trade and Industry
(8) CEPro, AT&T Acquires Xanboo, Developper of Home Automation Platform, December 06. 2010 <http://www.cepro.com/article/att_acquires_xanboo_enters_home_automation_biz/>
(9) Open Services Gateway Initiative Alliance <http://www.osgi.org/>
(10) i-Energy WG <http://www.i-energy.jp/>
(11) Eco-life in a Smart Apartment Room with an Integrated Smart Tap Network <http://www.i-energy.jp/data/2010-08-25-press.pdf>
(12) Android <http://www.android.com/>

Contributors (The lead author is indicated by an asterisk (*).)

H. MIYOSHI*

• Assistant General Manager, Information & Communication Laboratories
Engaged in designing power network systems.

M. UEDA

• Manager, Information & Communication Laboratories

T. YANO

• General Manager, Product Marketing Division, Sumitomo Electric Networks, Inc.

Y. NOZUE

• Deputy General Manager, Product Marketing Division, Sumitomo Electric Networks, Inc.

S. FUKUI

• Manager, Product Marketing Division, Sumitomo Electric Networks, Inc.

T. SHIMOGUCHI

• General Manager, Home Network Products, Sumitomo Electric Networks, Inc.