Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 5 (2011) 794–797

Procedia Computer Science

International Symposium on Intelligent Systems Techniques for Ad hoc and Wireless Sensor Networks (IST-AWSN)

Real-time Energy Monitoring and Controlling System based on ZigBee Sensor Networks

Woong Hee Kim, Sunyoung Lee, Jongwoon Hwang*

KIST Europe Forschungsgesellschaft mbH
Stuhlsatzenhausweg 97
Universitaet des Saarlandes,
D-66123 Saarbruecken, Germany

Abstract

The use of smart home technology in the home or building offers significant potential for energy savings. In this paper, we propose an energy management system based on wireless sensor networks. The proposed system is composed of two main components: a wireless sensor network and an intelligent home gateway. Wireless sensors are used for sensing and transmitting electricity data and remote monitoring and control of home appliances are provided to users through the intelligent home gateway. The system enables users to save energy by monitoring and controlling home appliances through web and mobile devices.

Selection and/or peer-review under responsibility of Prof. Elhadi Shakshuki and Prof. Muhammad Younas.

Keywords: home network, energy management system, ZigBee

1. Introduction

Advancement in the field of ubiquitous computing opens a wide range of possibilities for the design of energy efficient systems in future smart homes. Ubiquitous computing and integrating a large number of sensors, actuators, and computing devices into our everyday environments have great potential to contribute energy efficiency in our everyday life. Energy efficiency is becoming increasingly important in industry as well as in the residential sector. However, due to the complexity and diversity of computing devices, integrating energy efficiency into ubiquitous computing is still in its infancy. Adding each new device into the environment requires a great deal of work. After deciding which particular device to integrate, the smart home developer must determine how to configure it and interface with it. Then the device must be connected and physically integrated it into the environment.

Realizing energy efficiency in homes involves far more than connecting devices to the environment. The smart home environment make use of a wireless sensor network platform to integrate numerous heterogenous devices. These devices should cooperate with other devices independently to provide intelligent services for users in the smart home.

*Corresponding author
Email address: hwang@kist-europe.de (Jongwoon Hwang)

1877–0509 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and/or peer-review under responsibility of Prof. Elhadi Shakshuki and Prof. Muhammad Younas. doi:10.1016/j.procs.2011.07.108

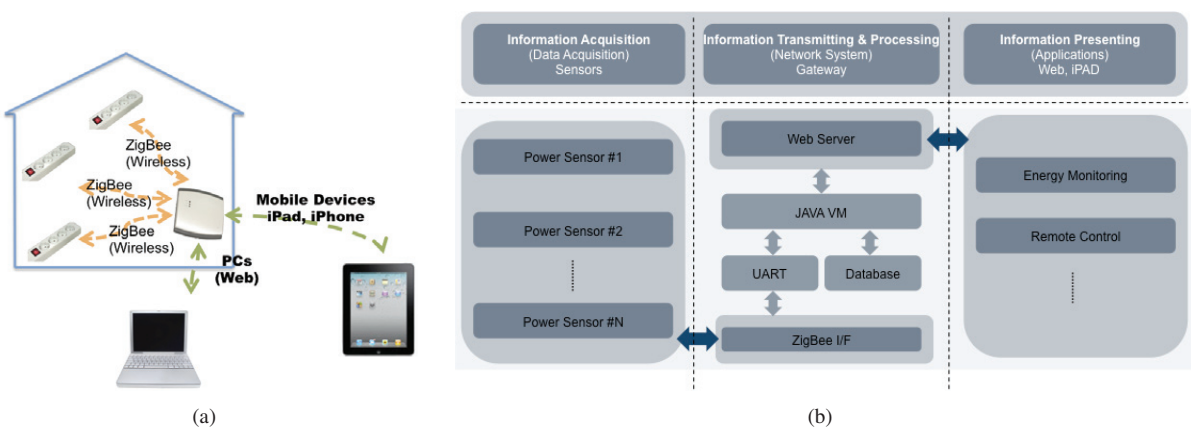
Also, information among the various heterogenous devices must be shared and connected in order to build effective intelligent services. Manufacturers of computing devices use many different communication protocols. Therefore, the integration of household appliances (white goods) and consumer electronics is not straightforward at any layer of the sensor network platform. Additionally, apart from the technical difficulties of the integration, due to the complexity of the systems, users are often unable to fully understand their systems. To fully take advantage of smart home technologies, any energy management system should transparently integrate all household appliances and make available all important information to users both for energy savings and user convenience.

To this end, we propose an energy management system using ZigBee sensor networks and an intelligent home gateway. The proposed system continually senses and updates electricity data in order to provide real-time electricity consumption information to users. Users can remotely monitor and control household appliances to save energy. To confirm the feasibility of the proposed system, wireless sensors with ZigBee, to measure AC (Alternating Current), and applications for users are implemented. This paper is organized as follows. In section 2, the background and related works on home energy management and home network and ZigBee are explained. Section 3 describes the proposed system in detail. The implementation results are presented in section 4. Finally, section 5 concludes the paper.

2. Background

There have been two approaches for electric power management in homes from smart grids and home network [9, 10, 11]. A smart-grid measures and reads the consumption of electricity remotely using a smart meter and communication network [6]. It provides real-time or near real-time information on the consumption of electricity to utility companies or service companies. However, most of the systems and projects of smart metering for homes in smart grid are only focusing on measuring the total amount of energy consumption or electricity at a home and communication infrastructure for data transaction. If we could measure or monitor the electricity consumption of each home appliance, better intelligent services could be provided such as tracking energy consumption, statistical analysis, and rule-based configuration. In the home network area, the data of energy consumption from each home appliance are collected using sensor networks. Several systems for monitoring and controlling power consumption have been proposed [1, 7]. Their main contribution has been to design and implement energy measurement and control systems. In our approach, both energy management and control services are included . The proposed system focuses on deploying a wireless sensor network and implementing energy management and controlling service as prototype services in a smart home.

3. Proposed Energy Monitoring and Controlling System



(a) (b)

Figure 1. (a) Concept of the proposed system, (b) Overall system architecture

A universal framework of electric energy management system for homes is proposed. The figure 1(a) shows the concept of the proposed system. The proposed system consists of three technical components, information acquisition, information processing, and information presenting, as shown in figure 1(b). Sensors measure the actual power consumption and transmit this information and the on/off status of electronic products (e.g., household appliances) to the information processing module via the ZigBee communication protocol [3]. When the information processing module receives the power consumption information and the on/off status, it stores them into a database. It responds to the users' requests for monitoring the status and the power consumption information.

The ZigBee is used as a communication protocol. It is a promising wireless communication protocol for low rate communication and home automation [1, 2]. Conventional wired and wireless communication interfaces like the Ethernet, IEEE 1394, Wi-Fi, PLC(Power Line Communication) and bluetooth could be used for the home network. Wireless network interfaces are preferred to wired communication ones, because they are easy to deploy and install. Additionally, ZigBee has a much higher maximal number of cell nodes than other protocols. For example, Bluetooth has only 8 nodes as the maximal number of cell nodes, but ZigBee could have over 65000 nodes [4].

Wireless sensors are used to measure AC and control power outlets. Because these sensors should be universal or independent from home appliances or electronic products, we designed our sensor as an additional device for conventional power outlets between power lines and electronic products. Our approach is similar to [1], but it is focusing on on-off control and providing limited services. A wireless sensor in the proposed system is composed of mainly three parts, which are a controller with an ADC(Analog-to-Digital Converter), a ZigBee transceiver, and a sensing unit. In the proposed system, a wireless sensor network with star topology is constructed. However, the topology of the network could be changed to other topologies such as a mesh network.

The Data processing module receives the information of the electricity consumption from each sensor through a ZigBee communication interface. It then stores this information in a database and responds to requests from users. A web server in it receives users' service requests and transfers them to the sub-technical components. The final goal of the proposed system is to provide users with smart services such as tracking energy consumption, price comparison, statistical analysis, and rule-based configuration. All of these services could be implemented within this module.

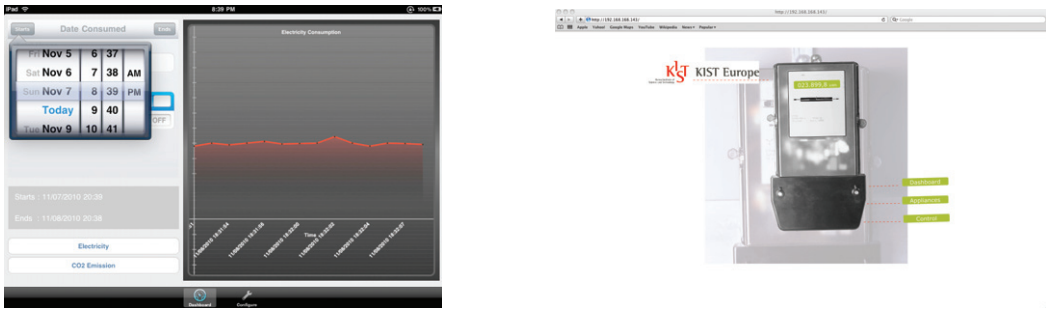
The proposed system as a prototype system has two applications or services, monitoring of electricity consumption and remote on/off control. The information on instantaneous electricity consumption is presented in the monitoring service. If a device consumes more electricity than usual, it could give an alarm to its users. With remote on/off services users could turn on and off home appliances.

4. Implementation and Results

A wireless sensor has three technical components, a MCU(Microcontroller Unit) with a ADC, a sensing unit, and a ZigBee transceiver. The sensing unit is the most important part in a sensor. A hall effect-based sensor, ACS712 from Microsystems Inc. [5], is used to measure AC in our system. We tested the sensors from a 100 Watt load to 1000 Watt load.In this testing, we assume the power factor is 1. A SMPS (Switch Mode Power Supply) is integrated to supply power, which means it does not need DC batteries. A Relay is included for remote on/off controlling.

A ZigBee dongle with USB interface is connected to a PC, which serves as an intelligent home gateway. The application is OS independent, because it is implemented in Java. The incoming data from each sensor contain the actual status of the device, the power consumption and a unique sensor ID. We store the received data in a PostgreSQL database. The system receives several values per second from the sensors which are stored in the database for later use in a web interface or mobile application. Functional routines are implemented on Java VM (Virtual Machine) in the proposed system, because we will integrate OSGi [8] based middleware into our system in the future. When a user wants to switch on/off a device from a web interface or mobile application, the reaction time is below one second.

As a prototype system, two services, monitoring and remote on/off control, are implemented in our system. The figure 2 shows the implemented services. Users can set the range of dates to check energy consumption of a specific home appliance. Monitoring and controlling services are example services in the proposed system. Further works will include smart or intelligent services like statistical analysis, tariff comparison, recommendation for usage,time-based on/off-control, etc.



(a) (b)

Figure 2. (a) Application implemented in a iPad, (b) Implemented Web application

5. Conclusion and Future Work

Awareness of electricity consumption in the home or building is a first step towards saving energy. The combination of alternative energy and pervasive technologies for monitoring and controlling energy consumption is a powerful vehicle for reducing energy demand. With effective feedback about energy consumption and control of household appliances, users can be motivated and encouraged to change their behavior on energy use such as turning off lights or reducing heat. These small changes in behavior can lead to significant energy savings.

This paper presents a smart energy management system for homes and buildings. The proposed system can monitor and measure electricity usage in real-time. With the proposed system, users can remotely control real-time electricity usage through web and other mobile devices such as smart phones or smart pads. Our future work will focus on expanding the current system to include the following functionalities: automatic home appliance detection and context inference. The automatic identification of appliances and detection of the location of appliances are important for developing efficient energy management systems. Automatic detection of appliances can offer easy and usable services and information on the location of appliances is used for providing various context-await. A user's behavior, based on data from electricity consumption, can be used to infer the current or future context of users. For example, a user's intention to operate certain appliances at certain locations can be determined from the context inference engine of the system. We also plan to evaluate our system in a real-world context. We are currently building a living lab to conduct user studies which will provide us with insights into our future research direction.

References

[1] J. Han, H. Lee, and K. Park. Remote-Controllable and Energy-Saving Room Architecture based on ZigBee Communication. IEEE Trans. On Consumer Electronics, Vol. 55, No. 1, pp. 264-268, Feb. (2009)
[2] K. Gill, S. Yang, F. Yao, and X. Lu. A ZigBee-based Home Automation System. IEEE Trans. On Consumer Electronics, Vol. 55, No. 2, pp. 422-430, May (2009)
[3] IEEE 802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs). Sept. (2006)
[4] J. Lee, Y. Su, and C. Shen. A Comparative Study of Wireless Protocols: Blutooth, UWB, ZigBee, and Wi-Fi. The 33rd annual Conference of the IEEE Industrial Electronics Society(IECON), Nov. 5-8 (2007)
[5] Allegro MicroSystems, Inc.: Fully Integrated, Hall Effect-Based Linear Current Sensor IC with 2.1 kVRMS Isolation and a Low-Resistance Current Conductor. ACS712 datasheet. (2010)
[6] European Commision: Eoruopean Smart Grids Technology Platform. European Communities (2006)
[7] Y. Bai, and C. Hung. Remote Power On/Off Control and Current Measurement for Home Electric Outlets Based on a Low-Power Embedded Board and ZigBee Communication. Proceedings of the 2008 International Symposium on Consumer Electronics, Algarve, Portugal, 14-16 Apr. (2008)
[8] OSGi Alliance, http://www.osgi.org
[9] B. Botte, V. Cannatelli, and S. Rogai. The Telegestore project in Enel's metering system. In Proc. Int. Conf. on Electricity Distribution (CIRED) (2005)
[10] Korea Smart Grid Institute, http://www.smartgrid.or.kr
[11] MeRegio, http://www.im.uni-karlsruhe.de/Default.aspx?PageId=470&lang=en