Design Smart Home Energy Management Systems based on ZigBee

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Abstract: wireless sensor networks are rapidly gaining popularity. Today, organizations use IEEE 802.15.4 and ZigBee to effectively deliver solutions for a variety of areas. The SHEMS (*Smart Home Energy Management System*) includes both energy consumption and renewable energy generation. That consists of the system server, the family controller (modules), the composition of routers, switches, communication device, wireless transceiver, all kinds of detectors, sensors, actuators and other major parts . the SHEMS not only supplies power as the way the common power strips do but also controls sockets using ZigBee wireless communication . By Using SHEMS, users can recognize and reduce the amount of energy consumption, and the appliances can be controlled considering the energy efficiency. The advantages of our system are low cost, robustness and simple deployment. In this paper We tried to review the papers published in this field and By comparing the similarities and differences between research and experiments to reach a comprehensive conclusion.
Keywords : Smart Home, Smart Energy, ZigBee, IEEE802.15.4, wireless sensor network

Introduction

Moving towards the smart energy management will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential [1][2]. Using plenty of the power strips caused high power consumption along with unnecessary power consumption such as standby power in particular [5]. Standby power is electricity used by appliances and equipment while they are switched off or not performing their primary function [11]. The standby power occupies approximately 10% to 15% of the total power consumption of OECD (Organization for Economic Cooperation and Development) member nations according to the IEA (International Energy Agency). The standby power can be reduced by not only decreasing the standby power of electrical appliances themselves but also using the power strips providing solutions to this standby power problem. In spite of substantial efforts for research and development of the power strip to date, there is few power strips used efficiently reducing only small amount of the standby power [5]. The current energy crisis requires significant reduction in energy consumption in all areas. Energy saving and RES (renewable energy sources is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat) are considered as methods of solving the problem [6]. In an existing home, there are few technologies for energy saving, so residents have to manually control the energy leakage status. Therefore, we define a smart home, where includes many technologies such as ZigBee with Wi-Fi, PLC (Data communication over power line networks has a number of similarities with communication using wireless transmission. This probably goes back to fact that neither power lines nor wireless channels were designed for carrying communication signals. As a result, a number of techniques successfully used in wireless communications have found their way into power line communications), and SUN (IEEE 802.15.4g Smart Utility Networks is a global wireless networking standard enabling interoperable communications between smart grid devices, including smart meters and smart home appliances), for energy saving and management such as smart plugs (SPs), occupancy sensors, and notification schemes for energy leakage [7]. The SHEMS combination of sensors, controllers and other devices through wireless technology to connect and collect data information processing, using a sensor to collect indoor temperature, light and other data in the embedded terminal for information read and processed, and make the appropriate action. The whole process involves ZigBee-based wireless sensor network and GPRS (The is the general packet radio service for short; it is a mobile data service available on the GSM mobile phone users. GPRS can be said to be a continuation of the GSM (Global System for Mobile Communications, originally Groupe Spécial Mobil*e*, is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second-generation (2G) digital cellular networks used by mobile). The transmission rate of GPRS can be increased to 56 or even 114Kbps) mobile communications modules of the application [4]. ZigBee communication module is the most appropriate network module for manufacturing the

wireless power strip to reduce the standby power because this is able to construct a low-cost and low-power network based on IEEE 802.15.4 standard [5]. ZigBee network model services have been proposed in different domains of our everyday such as in homes, offices, streets, building and school [2]. ZigBee smart energy certified products must be based upon a ZigBee Compliant Platform (ZCP). The majority of the nodes in the network should be based on one stack profile or the other to get reliable performance. If the smart energy profile resides in combination with a private profile, the product should be ZigBee Manufacturer Specific Profile (MSP) licensed and must be smart energy ZCP certified. This additional certification provides a guarantee that the fundamental stack is behaving correctly and the application is not abusive to the network. As an ecosystem, the Agreement offers everything future product and service companies need todevelop ZigBee products [1]. The wireless sensor network in the home area can be distributed in different various services throughout our daily lives. Developing assassin applications model and services for ubiquitous home network will confer important business value [2]. Wireless sensor networks (WSNs) based smart grid in residential area were developed to monitor energy consumption profiles for the purpose of demand-supply balancing and improving the energy efficiency and reducing the electricity expenses [3]. In this paper : First, we consider the standard definition IEEE 802.15.4 (ZigBee), Second, we describe the structure and components of home energy management system.

IEEE 802.15.4 (ZigBee)

At our system, the common wireless communication protocols include Radio Frequency Identification (RFID), ZigBee, Infrared Data Association (IrDA), Bluetooth and Wi-Fi. RFID and IrDA are not suitable for this system due to the short transmission distance and difficulty in node expansion. The performance comparison among ZigBee, Bluetooth and Wi-Fi is shown in Table 1. As each communication protocol has its suitable application occasion, ZigBee is chosen as the communication protocol in the our system [9]. ZigBee was conceived in 1998, standardized in 2003, and revised in 2006. The name refers to the waggle dance of honey bees after their return to the beehive. It is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. The IEEE 802.15.4 working group is mainly responsible for the development of physical layer and MAC layer protocol, the protocol reference and use existing standard, high-level application, testing and marketing etc . The work will be responsible for the ZigBee alliance [4]. Though its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics, ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys) [8]. As for the noise interference issue, ZigBee uses direct sequence spread spectrum (DSSS) to reduce the environmental interference. It uses Carrier Sense Multiple Access-Collision Avoidance (CSMA/CA) channel access mechanism, dynamic frequency selection and transmission power control to avoid channel collision [9]. ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi. ZigBee chips are typically integrated with radios and with microcontrollers that have between 60-256 KB flash memory. ZigBee operates in the industrial, scientific and medical (ISM) radio bands: 2.4 GHz in most jurisdictions worldwide; 784 MHz in China, 868 MHz in Europe and 915 MHz in the USA and Australia. Data rates vary from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band) [8]. Zigbee message consists of 127 bytes [4]. The ZigBee network layer natively supports both star and tree networks, and generic Mesh networking [4][8]. Especially the Mesh structure, it has the reliability of network robustness, strong [4]. ZigBee networks include the following device types :

• Coordinator

This device starts and controls the network. The coordinator stores information about the network, which includes acting as the Trust Center and being the repository for security keys.

• Router

These devices extend network area coverage, dynamically route around obstacles, and provide backup routes in case of network congestion or device failure. They can connect to the coordinator and other routers, and also support child devices.

• End Devices

These devices can transmit or receive a message, but cannot perform any routing operations. They must be connected to either the coordinator or a router, and do not support child devices [1].

Table 1- Comparison of ZigBee, Bluetooth, and Wi-Fi characteristics

Characteristics	ZigBee	Bluetooth	Wi-Fi
IEEE standard	802.15.4	802.15.1	802.11 a/b/g
Max signal rate	250 kb/s	1Mb/s	54 Mb/s
Nominal range	10–100m	10m	100m
Max number of nodes	>65,000	8	2007
Power consumption	Low	Very low	High
Protocol complexity	Simple	Most complex	Complex
Cost	Low	Low	High

STRUCTURE SMART HOME ENERGY MANAGEMENT SYSTEM

Several conditions are required to reap advantages from the ubiquitous home network. For instance, computing systems should integrate diversified sensing information to perceive the current situation in the home area. Also, they should be able to control various consumer home devices. The home system may become complex, as the number of sensors and devices offered increases. Therefore, home network systems should be designed distributing various tasks into proper computational units to reduce complexity. Using a wireless sensor network with actuator functionality, our system can automatically gather physical sensing information and efficiently control various consumer home devices. We call this system the "Smart home control system". The system can efficiently distribute various tasks related to home network to corresponding components and implement real ubiquitous home services via smart sensors and controller deployed in home areas [1]. Smart home system can provide you with remote control, home appliances (air conditioning, water heaters, etc.) control, lighting control, indoor and outdoor remote control, curtain automation, burglar alarm, telephone remote control, programmable timing control and computer control and many other features and tools make life more comfortable, convenient and secure. You can also commute advance to home air conditioning open, so that hot water heater burned in advance, cooked fragrant rice cooker; and all this is achieved are simply playing a simple phone call [4]. We have developed a smart node that has sensing, processing and networking abilities. Three type sensors are included in the smart node: light, temperature and humidity sensors [1]. The main function of the temperature sensor is to measure the temperature of an outlet to avoid overheating and fire resulting [9]. PIR (passive Infra-Red) sensors are used to detect human movement. For example, while inhabitants are out of the home, if an unexpected movement occurs, motion is detected by the movement detector sensors; this event is then forwarded to the smart home control system. Various optional sensor and actuator modules can be equipped with our smart. To collect diversified sensing information and control consumer home devices, we developed the several additional optional modules equipped with our smart node. They are directly controlled by the microprocessor in our smart node. Using the additional modules, the smart node is divided to the generic sensor and actuator nodes. The advanced sensing modules are weather, bio, gas and motion detection sensors that can measure the pressure, the accelerated velocity, the pulse rates, the body heat, a gas leak and the motion, respectively. The actuator modules are Infra-Red and relay modules. The Infra- Red module supports IR (Infra-Red) remote control [1]. We consider the home easily controllable with an IR remote control of a home device. The home has automatic standby power cut-off outlets. A typical automatic standby power cut-off outlet has a waiting time before cutting off the electric power. It consumes standby power during that time. To eliminate the waiting time, we turn off the home device and the power outlet simultaneously with an IR remote control through the ZigBee hub. This method actively reduces the standby power. The SHEMS provides easy way to add, delete, and move home devices to other power outlets. When a home device is moved to the different outlet, the energy information of the home device is kept consistently and seamlessly regardless of location change [11]. The relay modules can switch power on/off in electronic devices and control a motor. These actuator modules enable the role of smart nodes to be changed from just a physical information detector to an electronic device controller [1]. Each node should have multi path routing protocol to establish the wireless network between smart nodes. We proposed routing protocols are difficult to accommodate to dynamic topology variations and to interact with our home control system. We develop a new On-demand based routing protocol named as "DMPR (Disjoint Multi Path Routing

Protocol)". That based on the Kruskal's algorithm [1][2]. The Device Binding System that bindings are connections between endpoints. We survey that the remote control has bindings to all devices [1]. We describe how smart devices can interact with and be controlled by our home system, and how they can form multi path networks wirelessly. The smart space should attempt to minimize the amount of manual overhead that is required to configure, control, and manage those services and devices. Hence, we believe intelligent behavior and decision making capabilities are essential in the realization of smart spaces. We have developed the smart sensor nodes that are classified into two different types of a generic sensor and an actuator. The Generic sensor typed nodes try either to detect the general physical sensing measurements such as temperature, humidity and light or check for the special events such as gas leaks, human movement and window status detection. Whereas, actuator typed nodes can directly control consumer home devices. The generic sensor and actuator nodes are managed by the Sensing Component and Control Component. Each smart node should have a special computational entry, which can understand commands transmitted from the home system and recognize its tasks according to its sensing or actuator functionality, to interact with our home system. We develop the Interaction Component on smart nodes as a part of our system for this purpose. Since each node is equipped with special capabilities such as gas detection, relay switching and IR controlling, each node may perform different actions according to its capabilities. Our Interaction Component is design to distinguish these different capabilities and perform adaptive operations. It can respond with appropriate responses to commands transmitted from the home control system [2]. The ZigBee WSN based energy monitoring and smart home controlling system consists of two main parts: home control and energy monitoring network, gateway node. The system consists of end device nodes, router nodes, and one coordinator node. Electric meter circuits are integrated with router or end device nodes to form the Smart Power Outlets (LSPO). These LSPO nodes are distributed in different places of the home area. Each LSPO can be used to control and monitor energy consumption for one to four appliances (The appliance receives information from home gateway by ZigBee module and then generates corresponding signals to manipulate the smart appliances. In order to reduce costs and improve network efficiency, appliances can be classified as smart appliances and non-smart appliances according to the function. Smart appliances, such as air conditioning, only need to realize switching function. Non-smart appliances, such as television, not only realize switching function, but also require complex instruction to realize some other functions. Since the remotely controlling information appliances based on Ipv6 in a home network has become a major request for nowadays consumers. For this reason, all appliances have IP address based on the IPv6, they can be directly connected to external network. The mobility of the terminals can be managed through IPv6 mobility support. In this way, users can complete the operation over the Internet in public places to improve the system's flexibility and maneuverability [10]). In our design, we use mesh topology WSN network which has decentralized nature. All message exchanges between devices pass through the coordinator and routers to the destination devices. The gateway node is designed to provide the accessibility to energy monitoring smart home system from external networks. Users can access the system from remote sites through the Internet or mobile networks. They can carry out the control and energy monitoring tasks even though they are away from home. The gateway is programmed with Mini-Web server firmware which can support Graphic User Interface for users to access their smart home system easily. Web-server program has been designed with database containing energy consumption data and status of all appliances collected from individual nodes, by this way, the gateway can store and update energy consumption and status of each device in the system. Mini web-server can supports automatic remote access process to enable energy provider to collect real time energy consumption from customer side [3]. The SHEMS functions as not only existing power strips, but power interruption by communication with the server or the motion sensor using ZigBee wireless communication [5]. The smart home consists of two parts: energy consumption and energy generation. The energy consumption in home is caused mainly by home appliances and lights. Outlets and lights are equipped with an energy measurement and communication unit (EMCU). The EMCU in outlets and lights reports the measured values to the home server periodically through ZigBee. The outlets and lights in home can be controlled for energy saving either automatically by the home server or manually by the users. The energy generation part consists of a solar power generator and a wind power one, which are two of the most popular RES. Solar panels on the roof are connected to the inverter, which converts dc power to ac one. Each solar panel is equipped with a PLC modem to monitor the status of all solar panels for maximum power generation. The energy gateway (EG) gathers all the status information from the solar panels based on PLC and from the inverter. The status information of each solar panel enables users to maintain the performance of solar power generator. The EG also gathers the wind power status from the wind inverter. The home server aggregates all the power generation information and utilizes it for home energy management. The home server can manage and control home energy use according to the circumstances in real time. It estimates the renewable energy generation based on the weather information from the weather forecasting web service, which provides solar radiation, cloud amount, wind speed, and so on [6]. The SHEMS is a smart residential

core. Thus, it is in the smart house in an important position. The system design chose the first platform, there are three main modules: the sensor node WSN ZigBee module, embedded server terminal module, GPRS communication module and RFID (is a non-contact automatic identification technology, it through space coupling automatic target recognition and access to relevant data, to identify work without human intervention) devices. Mobile terminal can be remotely via GPRS network connected to the embedded server terminal center console, center console handle connections, through ZigBee module sends information to the appropriate processing ZigBee module, the node consoles receive command with an appropriate treatment. [4].The SHEMS is to monitor and control the energy consumption and to minimize the energy leakage in a smart home [7]. A recent study found that 10 % of energy saving was achieved with a monitoring system providing real-time energy information [11]. The architecture of a smart home, where consists of home area network (HAN), smart plugs (SPs), occupancy sensors, SHEMS, mobile devices, an internet router, and energy service providers (ESPs). HAN includes several types of wireless home area network, such as , ZigBee with Wi-Fi, PLC and SUN. Wi-Fi is used among mobile devices, the SHEMS, and the appliances, PLC does among the SHEMS and lights, ZigBee does among the SHEMS and appliances, SUN does among SHEMS and SPs. A SP is matched for one appliance, and collects the power consumption of the appliance, and sends the data to the SHEMS through SUN. And, occupancy sensors transmit the detected data to SHEMS using ZigBee. Users can monitor the energy consumption of the home appliances using their mobile devices, and control the appliances through SHEMS and SPs. ESPs (Energy Service Providers) provide energy management and saving services such as DR (demand response changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized) and real-time pricing (RTP) [7]. Smart home energy control system's design provides intelligent services for users [2], Gives more efficient energy-saving [11], Can optimize home energy use and result in energy cost saving [6], Has very good effect [4], Can be provided more easily and efficiently [7], And offers a new way of life devoted to a greener, better intelligent to everyone [10], The advantages are low cost, robustness and simple deployment [3], Can be easily implemented [9].

Conclusions

These days, the energy saving technologies became the one of the key research items in the world to reduce carbon dioxide emission, which causes global warming and climate changes. Ubiquitous home networks excite new possibilities. The most effective way to reduce lighting energy is to turn lights off. The second most effective way is to turn them down. The SHEMS can do both for you, and initiative serves these needs by providing an adoptable and sustainable experience by linking new and useful digital technologies to the needs of consumers. The system can help consumers to increase the efficiency of electric utility by shifting their non-urgent appliances to the Off-Peak hours; turning off appliances during non-using time to reduce electricity expenses. Energy savings and user happiness are two major design considerations for modern system. You can use many technologies such as ZigBee with Wi-Fi, PLC, RFID,GPRS,SUN for your systems. By considering the information of energy consumption and generation simultaneously, the system can achieve home energy conservation and save the energy cost. The system helps a user decide what device to purchase and how to use it.

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