WIRELESS HOME NETWORK CONTORL MECHANISM FOR STANDBY POWER REDUCTION

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Abstract: Standby power is electric power that a device consumes when not in present use, but plugged in to a source of power and ready to be used. Present estimates indicate that standby power consumption reaches 10 to 15 percent of total residential electrical use. In this paper, we propose a Host-Agent based standby power control mechanism in home network environment. It uses the IEEE 802.15.4 based ZigBee communication protocol between Host and Agent for transmission and secure network. The Agent can acquire the local context information from various embedded sensor and sends the sensing information to the Host. The Host compares this context information from Agent with database and sends the standby power control message to the Agent. To prove the necessity and the efficiency of the proposed control mechanism, we have developed prototype devices and carried out simulation according to control scenario.

1 INTRODUCTION

Standby electricity is the energy consumed by appliances when they are not performing their main functions or when they are switched off. As more and more appliances are being used in households and offices, their energy consumption during standby periods represent a significant share of the total energy used. Household appliances and office equipments such as televisions (TVs), video recorders, audio players, telephone answering and facsimile machines, computers, printers and copiers contribute to this standby loss which is relatively low, with typical loss per appliance ranging from less than 1 W to as much as 25W. According to the IEA, on an average, 10% of a total household (OECD) power consumption is being wasted in the form of standby power (Standby Korea 2010). Moreover due to the special characteristics of home network devices such as set top box, xDSL modem, home gateway, PC and TV can all be connected to the external communication system in standby mode; an increase of standby power consumption is expected. It is apparent that the future market will be dominated by electric/electronic devices with network functions, rather than those devices without network functions. The number of products with standby power consumption is growing rapidly in both quantity and diversity (Standby Korea 2010).

ZigBee is a new low rate wireless network standard designed for automation and control network. The standard is aiming to be a low-cost, low-power solution for systems consisting of unsupervised groups of devices in houses, factories and offices. Expected applications for the ZigBee are building automation, security systems, remote control, remote meter reading and computer peripherals. The ZigBee standard utilizes IEEE 802.15.4 standard as radio layer.

In this paper, we propose a standby power control mechanism in home network environment. Proposed mechanism uses the IEEE 802.15.4 based ZigBee communication protocol between Host and

Agent for context information and control message transmission. Agent acquires the local context information from various embedded sensor and sends to the Host. Host compares this context information from Agent with database and sends the standby power control message to Agent.

This paper is organized as follows. Section 2 explains about related works such as standby power consumption of home network, context-aware concept and low power wireless protocol. Section 3 describes the proposed low power communication and security modules. This section also explains Host-Agent based control system architecture. Implementation results and prototype device of proposed mechanism are presented in section 4. Finally, we have given some concluding remarks and future works.

2 RELATED WORKS

2.1 Standby Power Consumption and Context-aware of Home Network

A new form of standby power called 'Active Standby' is becoming a reality that we have to face. The emergence of active standby power started with the introduction of set top boxes. It is a power mode where the consumer switches off the power (the consumer thinks the power is switched off completely) but the internal circuit still consumes standby power to wait for external cord/cordless signals. By 2020 standby power consumption is projected to be 1/4 of the total household energy consumption, and the main cause of such an increase can be attributed to the home network system. In 1999, IEA has proposed to reduce the standby power of all electronic products below 1W, the so called 1-watt Plan. Several countries such as US government (2001), Australian government (2002) and Korea government (2004) already announced a national strategy to achieve the 1W standby power target (Standby Korea 2010).

Proposed mechanism integrated with various sensors, actuators, wireless networks and context-aware technology will control standby power. In order for adaptation to take place, application must become aware of their surrounding environment, otherwise known as context. In order to enable natural and meaningful interactions between the context-aware home and its occupants, the home has to be aware of its occupants' context, their desires, whereabouts, activities, needs, emotions and situations. Such context will help the home to adapt or customize the interaction with its occupants. By context, we refer to the circumstances or situations in which a computing task takes place. Context of an entity A is any measurable and relevant information that can affect the behaviour of A. Context can be considered and exploited as different levels of abstraction (S. Mayer and A. Rakotonirainy).

2.2 Low-Power Wireless Protocol

The IEEE 802.15.4 wireless standard was developed specifically for remote monitoring and control. The standard defines transmission and reception on the physical radio channel (PHY), and the channel access, PAN (personal area network) maintenance, and reliable data transport (MAC) (Wireless 2003). ZigBee defines the topology management, MAC management, routing, discovery protocol, security management and includes the 802.15.4 portions. ZigBee is designed for applications that need to transmit small amounts of data while being battery powered so the architecture of the protocols and the hardware is optimized for low power consumption of the end device. The coordinator and routing devices should not be battery powered, as these should be able to receive and transmit all the time. Also the network functionality depends on this. The data transfer mechanism depends on the topology. Security and data integrity are key benefits of the ZigBee technology. The ZigBee architecture recognizes two types of devices RFD (Reduced Function Device) and FFD (Full Function Devices). Only the FFD defines the full ZigBee functionality and can become a network coordinator. The RFD has limited resources and does not allow some advanced functions (e.g. routing) as it is a low cost end device solution. Each ZigBee network has a designed FFD that is a network coordinator. The coordinator acts as the administrator and takes care of organization of the network. Typical coordinator has a neighbour table of devices found in the neighbourhood. This leads to extended demands on the coordinator device, as it needs more memory and processing power (J. Gutierrez and et all, 2003)(ZigBee).

3 STANDBY POWER REDUCTION MECHANISM

The goals of proposed standby power control mechanism are like below:

- Standby power consumption ≤ 200mW
- Sensor embedded Agent and operation

- Low power actuator
- Device compatibility
- High authenticity of Host
- Context-aware algorithm application

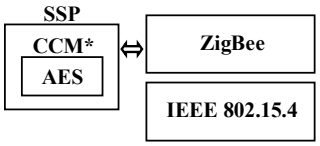
3.1 Low Power and Secure Network

Proposed mechanism uses the IEEE 802.15.4 based ZigBee communication protocol between Host and Agent for context information and control message transmission. Also, security function of specification is applied for data transmission. Communication and security module should consider whether hardware platform and defined operation algorithm are available. In home network environment, the defined functions of communication and security are shown in Table 1. Defined functions are focus on network management and high level security.

Table 1: Function definition for proposed system.

Section	Function Definition
Network Device Management	- Role separation of Host and Agent - Channel scan and selection - Allowing Agent to join - Neighbour table management of Agent - Allocation of unique network address - Disassociation
Routing	- Routing table management - Routing cost calculation - Route discovery and recovery
Broadcast	- Efficient broadcasting algorithm
Authentication	- Security level - Message authentication code
Secure Key Establishment	- Secure key distribution from Host - Key transport mechanism
Encryption /Decryption	- Enc./Dec. according to the security level - Secure key agreement

First of all, security problem should be solved. The attacker can eavesdrop and modify easily because Host and Agent use wireless communication for message transmission. This weakness can be threatened not only standby power control but also entire home network. Therefore, the security technologies of IEEE 802.15.4 and ZigBee specification should be implemented at Host and Agent for secure control network. Figure 1 shows the concept of implemented security service. Used security module of this paper can support all security functions of ZigBee security specification (ZigBee).



SSP : Security Service Provider
CCM* : CTR and CBC-MAC mode *
AES : Advanced Encryption Standard

Figure 1: Security concept of IEEE 802.15.4 and ZigBee.

3.2 Host-Agent based Control Mechanism

Host and Agent are the two main component of our proposed standby power reduction mechanism. Where Agent acquires the local context information using the various embedded sensor and sends this information to the Host. The Host compares this context information from Agent with database and sends standby power control message to Agents. In home network environment, the operation procedure and standby power control method are shown in Figure 2. The Agents can be embedded in electronic devices and wall sockets; Agent can control standby power itself using the context information or drive actuator after receiving control message from Host.

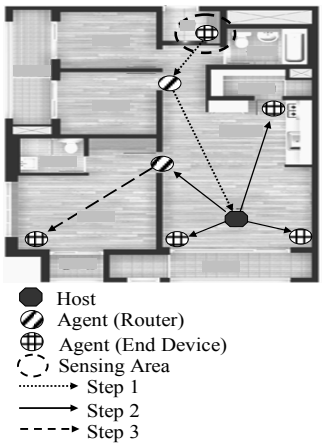


Figure 2: Standby power control mechanism.

The operations and different functions of Host and Agent are described below.

[*Step 1*]

(a) Agent (End Device) sense the specific context information using the embedded sensors such as light, temperature, infrared ray, remote control and humidity.

(b) Agent (End Device) control standby power mode itself using the sensing information according to embedded control algorithm.

Then sensing information is transmitted to the Agent (Router) which can mediate.

(c) Agent (Router) mediates the sensing information to Host.

[*Step 2*]

(a) Host receives the context information from Agent then refer the attribute DB of Agents (Router, End device).

(b) Host transmits actuator On/Off control message to Agents.

[*Step3*]

(a) Agent (Router) can mediate control message to Agent (End device) which can not receive the message itself.

(b) Agent (End device) drives actuator after receiving On/Off control message from Host.

3.3 Sensing Information Acquisition

Proposed control mechanism applies simple context-aware algorithm for power actuator control. Figure 3 shows the embedded sensors of Agent for sensing and Figure 4 shows the structure of Host and Agent module for sensing data transmission.

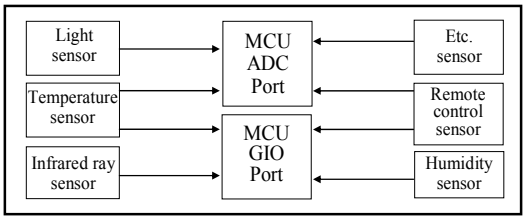


Figure 3: Embedded Sensors in Agent.

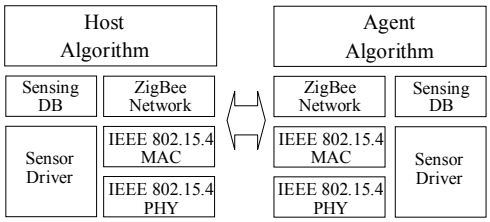


Figure 4: Sensing data transmission.

Table 2: Definition of sensors.

Context -aware	Type of Sensor	Control Application	Sensing Information
Power status	Current	Interception Condition	Current value from CT
Light	Light	Supply Condition	Illumination value
User sensing	PIR	Supply Condition	Movement of user
Using pattern	Current	Supply Condition	ON/OFF of devices

Purposes of embedded sensors shown in Figure 3 are like below:

- *Light sensor / Infrared ray sensor*: to sense the motion of a user.
- *Temperature sensor / Humidity sensor*: to sense the information of circumference environment.
- *Remote control sensor*: to sense control message when remote controller is used.

As shown in Table 2, we have defined type of sensor, standby control application and sensing information according to context-aware information.

4 IMPLEMENTATION

In this section, we define the required items for proposed mechanism implementation for real home network. Also, we analyze standby power reduction effect using the developed prototype devices.

4.1 Network and Security Module

As we explain before, the proposed mechanism of this paper uses IEEE 802.15.4 based ZigBee communication protocol for context information and control message transmission between Host and Agent. Therefore, we have implemented network and security functions according to ZigBee specification (ZigBee). Figure 5 shows the scope of implemented functions at network module and security module.

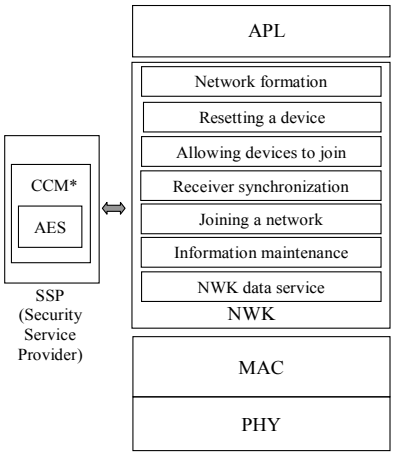


Figure 5: Implemented ZigBee functions.

The proposed control mechanism has been organized based on tree topology. Requirement functions such as routing, address allocation, encryption/decryption and message authentication have been tested as shown in Figure 6.

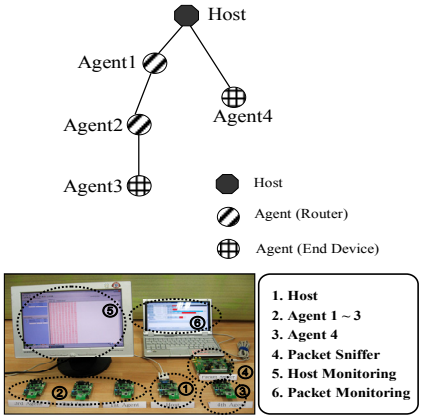


Figure 6: Tree-based test topology.

Specially, security service is very important in this mechanism because Host and Agent use wireless communication protocol. Implemented security functions are like below:

- CCM* for encryption and authentication
- MAC, NWK layer security
- Key establishment
- Lightweight security code
- Encryption/decryption of message
- Message integrity for authentication code
- Symmetric key based system
- Security level

4.2 Prototype Device Development

To develop prototype devices, required items of Host and Agent should be defined. We have considered such as power module, context-aware sensor module and MCU module of Host and Agent. Also, these requirements have implemented in a prototype devices. Table 3 explains required items and implementation result of Host; also, Table 4 explains required items and implementation result of Agent.

Table 3: Requirements and Implementation of Host.

Module	Requirement	Implementation
MCU Module	- minimize power consumption - role of Coordinator - power consumption management	- using the low power consumption MCU - Coordinator function implementation - power management algorithm
Context-aware sensor Module	- movement sensing - environment condition sensing - authenticity of sensing	- using the infrared ray and IR sensor - temperature, humidity and light sensor - sensitivity motion database

Table 4: Requirements and Implementation of Agent.

Module	Requirement	Implementation
Power module	- systematic voltage supply (12V,3.3V) - wall socket size - power consumption less than 0.06Watt - noise	- electronic element voltage supply - Transformer-less type - low power consumption regulator - RC Filter and TNR
Current Sensing Module	- small size - maintenance of linear type - strength till authentic range	- current transformer - maintenance at 0~2A input(CT) - maintenance of CT at 15A input
Actuator Module	- strength till authentic range - chattering countermeasure	- input strength maintenance - Noise countermeasure
Context-aware sensor Module	- movement sensing - environment condition sensing - authenticity of sensing	- using the infrared ray and IR sensor - temperature, humidity and light sensor - sensitivity, motion database
MCU Module	- low power consumption - Interface with ZigBee module - sufficient memory - measurement and control ports	- using the low power MCU - UART communication interface with CC420 - ROM /RAM > 1Mbyte - 12bit ADC Port

Real features of developed prototype device and characteristics are shown in Figure 7 (Host) and Figure 8 (Agent). Host prototype has the light sensor and PIR sensor; it can be located in ceiling. First of all, we have developed wall socket type Agent. Movement type Agent and switch type Agent will be developed. Each type can be used according to control scenarios.

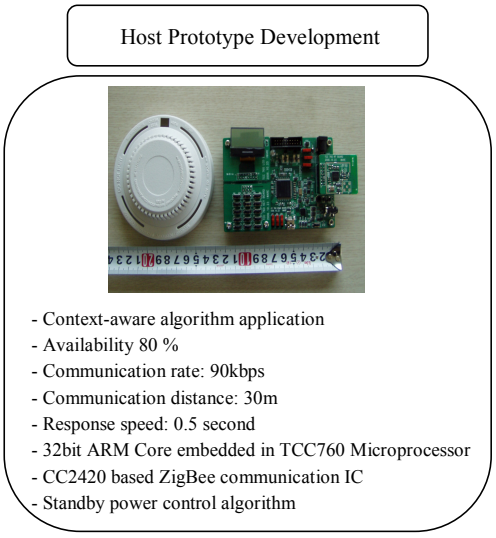


Figure 7: Host prototype and characteristics.

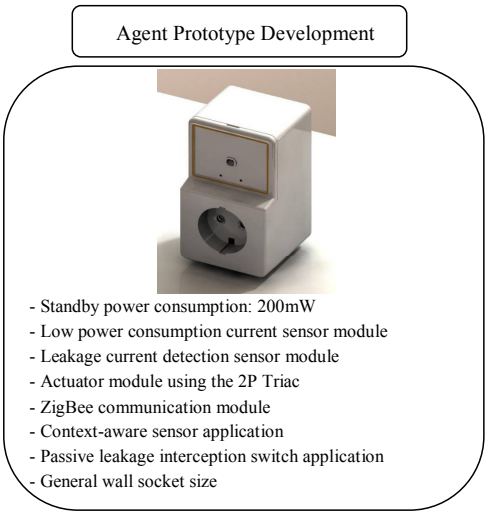


Figure 8: Agent prototype and characteristics.

4.3 Preliminary Results

[Standby power supply scenario]

(a) Hide the lighting sensor of Host (user existence)

(b) Host can sense the user existence using the sensor. Then Host transmits the power supply message to Agent.

(c) Agent supplies the power to PC according to control message from Host.

[Standby power block scenario]

(a) While user uses PC, an electric current increases up to maximum critical condition value. This status will be recognized as working status by Host.

(b) After a user put off the PC, electric current decreases slowly. Agent sends this information to Host; if the electric current less than critical condition, Host sends standby power block message to Agent.

(c) Agent blocks the standby power according to control message from Host.

Table 5: Estimated results.

section	Using Voltage	Working Current	Sleep Current
RF	3.0 V	30 mA	□ 0 mA
MPU	3.0 V	63 mA	□ 0 mA
Current sensor	3.0 V	□ 0 mA	□ 0 mA
Light sensor	3.0 V	□ 0 mA	□ 0 mA
Actuator	3.0 V	□ 0 mA	□ 0 mA
Power Supply	3.0 V	110 mW	80 mW
Total Power consumption	3.0 V	93 mW +110 mW	0 mW +80 mW

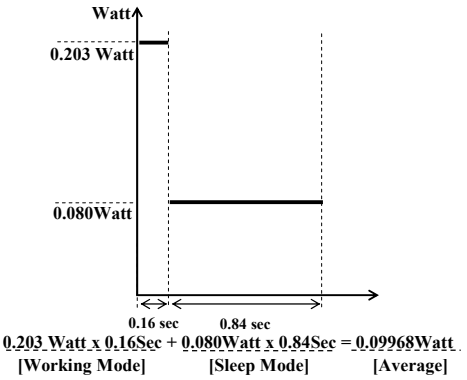


Figure 9: Result analysis.

The estimated standby power value according to the scenario is shown in Table 5 and Figure 9. As shown in these results, electric current of Agent is 0.203W when working state; the other side, electric current of Agent is 0.080W when in sleep state.

5 CONCLUSION

We propose a standby power control mechanism in home network environment. Our proposed mechanism uses the IEEE 802.15.4 based ZigBee communication protocol between Host and Agent for context information and control message transmission. To prove the necessity and efficiency of the proposed mechanism, we have developed prototype devices. Our future work will analyze the mechanism according to various scenarios in home network. Also, authenticity of context-aware algorithm should be enhanced.

REFERENCES

Ministry of Commerce, Industry and Energy, "Standby Korea 2010", from http://www.mocie.go.kr

"Wireless Medium Access Control and Physical Layer Specification for Low-Rate Wireless Personal Area Networks", IEEE Standard, 802.15.4-2003, May 2003.

Jose A. Gutierrez, Edgar H. Callaway Jr and Raymond L. Barrett Jr, "Low-Rate Wireless Personal Area Networks," IEEE Press 2003.

ZigBee Document 053474r13, "ZigBee Specification", from http://www.zigbee.org

Sven Meyer, Andry Rakotonirainy, "A Survey of Research on Context-Aware Homes," Conference in Research and Practice in Information Technology Series, Proceeding of the Australasian information security workshop conference on ACSW frontiers 2003, vol.21, pp.159-168, 2003.