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A context-aware multi-model remote controller for electronic home devices

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Abstract In the past few years, household remote control products have continuously emerged, and more equipment could be controlled at remote distance. With continuous growth in the number of home remote control devices, the number of remote controllers at home is increasing. In addition, with the increase of PC and notebook computer demands, technologies for controlling computer devices or digital home appliances within the home networks have been launched, such as UPnP (Universal Plug and Play), OSGI (Open Service Gateway Initiative), HAVI (Home Audio/Video Interoperability), and Jini. Because there are too many standards of home network, it is difficult to define a universal standard conformed to others. Many researches have focused on linking the various protocols of these devices, but most of them used the Web or PDAs to control the devices. In such situation, users must rely on computer equipment and face the battery problem of handheld devices.

This study aims to develop a cross-heterogeneous network remote control system. In order to relieve the problem of excessive remote controllers, we built a context-aware multi-model remote controller for electronic home devices to relieve the user of a nuisance of enormous amount of remote controllers.

Keywords GUI · ZigBee · LonWorks · UPnP

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1 Introduction

It is a common experience of being unable to conveniently control home appliances, such as TV, air-conditioner, etc., even after repeatedly pressing the unresponsive buttons. The lack of response is usually due to incorrect angles of use; users then automatically adjust the angle and press once again, and become well trained. In addition, when operating an air-conditioner with a remote control, one can learn its current status, such as room temperature and air flow intensity, from the remote control LCD, but in fact, such status information is not from the air-conditioner, but from the automatic computation of the remote controller. In other words, IR remote controllers have the previously mentioned problem, and are also restricted to one-way use. Since different brands of remote controllers are not compatible with each other, which ends in a growing number of personal controllers, and is very inconvenient, and will remain this way until remote controller communication standards are consolidated [1, 2].

Nonetheless, digital home appliances enable close associations between the IT industry and households, bringing the dream of a truly digital home closer to reality. In terms of daily life, home appliances of the future will have partial functions of a computer, linkable to a home network. Current home networks have multiple transmission medias, such as WLAN, ZigBee, ECHONET, LonWorks, UPnP, Jini, and X10 [3–8], and manufacturers that design products lack joint standards to follow, leading to problems of network protocol interoperability. In terms of user interface, such incompatible circumstances create difficulties, thus many studies have discussed this problems and proposed solutions to enable home control network protocol synergy [9–14]. Most control terminals are desktops, notebook computers, handheld computers, personal digital aides (PDA), mobile phones, which use wireless network technology (IEEE 802.11) or Bluetooth [15–19], which belong to high-bandwidth high-power consumption system. Also, these techniques are not suitable for home control network, whose design purpose is not to transmit large video data but simply to transmit brief control signals, once every several hours or even days. Such an idea existed before, but was hard to realize, primarily because IR remote controller saves so much power that wireless network remote controller hardly substitutes and spreads, power consumption of wireless network remote controller is better than handheld phone that lasts only 3 or 5 days per recharge, $2 \sim 4$ batteries can afford only $1 \sim 2$ months, while more than half of IR remote controllers with equivalent charge can sustain over a year, without replacing battery in about 1–2 years or even longer.

Based on the above, this study proposes an integrated design of a smart home control systems for heterogeneous home devices, using ZigBee as the transmitting and receiving device for a remote control signal and communication messages [20], targeted to control both digital and traditional home appliances. In a wired home control network, a power line carrier control is the most direct and economic control medium; thus, the LonWorks technology was used in this study to interconnect or control various devices in a digital home control network, and the UPnP network protocol was applied. This study also incorporated an IRDA control technology to coordinate home appliance devices that cannot be controlled by the other three technologies. Thus, four control mechanisms, UPnP, LonWorks, ZigBee, and IRDA, were used to build the heterogeneous home control network prototype, along with a self-designed management control platform. When a home appliance device is added, its information would be automatically detected, a management control platform would convert these control methods into the XML format, and transmit to the ZigBee controller. The ZigBee and automatic switching of a graphic user interface could allow users to control all electronic devices in the home with one single remote controller [21]. Since a traditional IRDA has no two-way communication function, a function recommendation system is also designed for the remote control [22–24], which requires neither a powerful operations processor, nor excessive memory capacity. Therefore, the remote controllers could achieve the advantages of low cost, power saving, and easy operation.

This paper is organized as follows. Section 2 discusses the ZigBee, LonWorks, and UPnP technologies. Section 3 describes the overall frame of a smart home control system, introduces the remote controller and control center system, and details the component segment. Section 4 is implementation and results. Section 5 offers conclusions.

2 Related work

2.1 IEEE 802.15.4/ZigBee

ZigBee is a kind of wireless network automation and distance control application technology targeted at low data transmission rates, low power consumption, and low cost. Initially, ZigBee was developed to support low data rates, low power consumption, a safe and reliable and low-cost wireless network. To address this need, ZigBee Alliance developed standardized application software in wireless IEEE 802.15.4. ZigBee still acts as the official testing and certification agency of ZigBee equipment. ZigBee is the sole standard-based technology to meet most distance detection, control, and sensor network applications. The ZigBee standard is likely to gradually supersede Bluetooth in future marketplaces that require low power usage. ZigBee operates in the ISM band of 2.4 GHz, adopts a direct sequence spread spectrum, and is expandable for as many as 255 units. It can transmit data in 10–75 m, at the rate of 10–250 kbps, decreasing with distance. The main advantage of ZigBee is power saving: one ZigBee device battery can last months to years. ZigBee is much like Bluetooth, but the main difference is that Bluetooth transmission rate is 1 Mbps, suitable for complicated applications. Thus, in simpler applications, such as home appliance control, ZigBee can be a substitute.

ZigBee's block structure consists of layers, including a physical layer, a network layer, and an application layer. ZigBee's physical layer is as per 802.15.4 definition, while its network and application layers are defined by ZigBee Alliance. The complete block structure of ZigBee is shown in Fig. 1.

The network layer is to establish and manage network mechanisms, with functions of Self-Configured and Self-Healing routing. In the network layer, ZigBee defines three roles: (1) WPAN Coordinator: in charge of network establishment and network address allocation; (2) Router: responsible for searching, setting up and repairing of