IEEE 802.15.4와 임베디드 리눅스 기반 디지털 가전기기 제어를 위한 UPnP 확장

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IEEE 802.15.4 and The UPnP Expansion for Digital Electrical Appliance Control based on Embedded Linux System

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요 약

본 논문에서는 인터넷 홈 네트워크 가전 제어를 위해 PLC라인의 가전 제어는 IEEE 802.15.4를 통하고 디지털 가전제어는 UPnP를 확장하여 인터넷 게이트웨이를 통하여 인터넷망으로 서로간의 모든 기능 및 컨트롤이 가능한 시스템을 구축을 연구한다. UPnP Bridge는 댁내의 홈 네트워크의 장치를 검색하여 메시지를 전송하고 장치들을 발견시 이벤트를 발생하여 장치들의 정보를 추가하며, 인터넷으로 연결된 외부 클라이언트는 다른 댁내의 인터넷 홈 가전 제어를 위해 ZigBee와 UPnP가 확장된 인터넷 게이트웨이 내의 UPnP IGD DCP를 통하여 액션 실행 요청을 하면 UPnP IGD DCP는 인터넷 게이트웨이 내의 UPnP IGD Bridge에게 요청을 하고 그에 맞게 댁내의 정보 기기 및 가전의 UPnP Device에게 Invoke Action을 취함으로서 컨트롤이 가능하게 된다. IEEE 802.15.4 기술은 20Kbps(868MHz)와 40Kbps(915MHz), 그리고 250Kbps(2.4GHz)를 지원하는 WPAN 기술로 낮은 전력을 소모하며, 초저가의 센서 네트워크를 구현하기에 홈 네트워크를 구축하는데 최적의 방안을 제공한다.

Key Words : Embedded, Embedded Linux, UPnP, Internet Gateway

ABSTRACT

Electrical appliances of home network base on Embedded Linux System via the Internet can be controlled Using ZigBee System and the UPnP expansion like ones in the same home network without modification of existing the UPnP. In this paper, we propose Internet Gateway that consists of ZigBee and the UPnP IGD (Internet Gateway Device) DCP (Device Control Protocol) and the UPnP Bridge for control electrical appliance of Internet home network with a low data rate and low power consumption. The UPnP IGD DCP is configurable initiation and sharing of Internet connections, advanced connection-management, management of host configuration, and supports transparent Internet access by non-UPnP-certified devices. The UPnP Bridge searches for local home network devices by sending control messages. Control Point of the UPnP Bridge searches for devices of interest on the Internet and can deliver the control devices on other home networks to device within its home network. With our approach, devices can control home electrical appliances and ZigBee(IEEE 802.15.4) System via internet through IGD DCP on other home network with control commands of the UPnP. ZigBee(IEEE 802.15.4)) technology is a low data rate, low power consumption, low cost, wireless networking protocol targeted towards automation and remote control applications.

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Ⅰ. Introduction

Home network is started for share of resources, remote education, remote treatment, home automation, and multimedia services at home. There are lots of multiple wire, wireless home network technologies and sensor networks nowadays[1][2]. An effective middleware is needed to control the home appliances regardless of any kinds of home network technologies and sensor networks applied, which is like ZigBee (IEEE 802.15.4) and the UPnP (Universal Plug and Play)[3].

ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology. ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. In addition, ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. ZigBee compliant wireless devices are expected to transmit 10-100 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF worldwide (2.4GHz global, 915MHz Americasor 868MHz Europe). Thedatarate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz. IEEE and ZigBee Alliance have been working closely to specify the entire protocol stack. IEEE802.15.4 focuses on the specification of the lower two layers of the protocol(physical and data link layer). On the other hand, ZigBee Alliance aimsto provide the upper layers of the protocol stack(from network to the application layer) for inter operable data networking, security services and arange of wireless home and building control solutions, provide inter operability compliance testing, marketing of the standard, advanced engineering for theevolution of the standard. This will assure consumers to buy products form different manufactures with confidence that the products will work together.

The UPnP is that extends the plug and play concept to the networking based on the standard Internet Protocol[4]. The UPnP is architecture for pervasive peer-to-peer network connectivity of intelligent appliances, wireless devices, and PCs of all form factors.

The UPnP presents home network middleware for local home electrical appliances based on internet protocols that is available access and control electrical appliances just in local home network. It is designed to bring easy-to-use, flexible, standards-based connectivity to ad-hoc or unmanaged networks in the home, a small business, public spaces, or attached to the Internet. The UPnP is distributed, open networking architecture that leverages TCP/IP and the Web technologies to enable seamless proximity networking in addition to control and data transfer among networked devices in the home, office, and public spaces[5].

ZigBee System searches many kinds of Sensors in home that sensor's event send IGD DCP and can control each sensors. The UPnP IGD DCP is configurable initiation and sharing of Internet connections, advanced connection-management, management of host configuration, and supports transparent Internet access by non-UPnP -certified devices. The UPnP Bridge searches for local home network devices by sending control messages. Control Point of the UPnP Bridge searches for devices of interest on the Internet and can deliver the control devices on other home networks to device within its home network.

With our approach, devices can control ZigBee System and home electrical appliances via internet through IGD DCP on other home network with control commands of the UPnP. Electrical appliances of home network and many kinds of Sensors at home via the Internet can be controlled with the UPnP expansion like ones in the same home network without modification of existing UPnP.

In this paper, we propose Internet Gateway that consists of ZigBee System and the UPnP IGD (Internet Gateway Device) DCP(Device Control Protocol) and the UPnP Bridge base on Embedded Linux System for control electrical appliances and Sensors of Internet home network.

Ⅱ. UPnP and Zigbee Overview

The UPnP is broad scope targeting to home networks, proximity networks, and networks in small businesses and commercial buildings. It enables data communication between any two devices under the command of any control device on the network. The UPnP is independent of any particular operating system, programming language, or physical medium. The UPnP supports zero-configuration networking and automatic discovery, whereby a device can dynamically join a network, obtain an IP address, announce its name, convey its capabilities upon request, and learn about the presence and capabilities of other devices. DHCP and Domain Naming System(DNS) Servers are optional and will be used if available on the network. Furthermore, a device can leave a network smoothly and automatically without leaving any unwanted state behind[6].

The UPnP learns from the Internet's success and heavily leverages its components, including IP, Transmission Control Protocol(TCP), Universal Datagram Protocol(UDP), Hyper Text Transfer Protocol(HTTP), and Extensible Markup Language(XML). The UPnP involves a multi-vendor collaboration for establishing standard Device Control Protocol(DCPs). Similar to the Internet, these are contracts based on wire protocols that are declarative, expressed in XML, and communicated via HTTP.

The UPnP is not technology that is also an outcome of a cross-industry UPnP Forum, which has in November 2002 more than 500 industry members. The primary task of that forum is to produce Device Control Protocols(DCPs) that describe standard methods for device interaction using XML. The UPnP specification is still in a preliminary stage; major issues like security have not yet been addressed.

2.1 UPnP Protocol Stack

The UPnP network device implementers use protocol standards, such as GENA(General Event Notification Architecture), SSDP(Simple Device Discovery Protocol), and SOAP(Simple Object Access Protocol), to enable automatic discovery and description(Figure 1 show). UDP is used for discovery and events because it is multicast. TCP handles description, control, and control point uses HTTPMU to ask what devices are present.

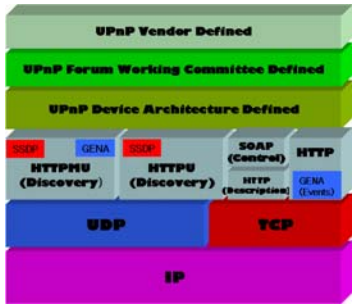


Fig. 1. The UPnP Protocol Stack

2.1.1 GENA

Generic Event Notification Architecture(GENA) was defined to provide the ability to send and receive notifications using HTTP over TCP/IP and multicast UDP. GENA formats are used in UPnP to create the presence announcements to be sent using Simple Service Discovery Protocol (SSDP) and to provide the ability to signal changes in service state for UPnP event. A control point interested in receiving event notifications will subscribe to an event source by sending a request that includes the service of interest, a location to send the events to and a subscription time for the event notification.

2.1.2 SSDP

Simple Service Discovery Protocol (SSDP), as the name implies, defines how network services can be discovered on the network. SSDP is built on HTTPU and HTTPMU and defines methods both for a control point to locate resources of interest on the network, and for devices to announce their availability on the network. By defining the use of both search requests and presence announcements, SSDP eliminates the overhead that would be necessary if only one of these mechanisms is used. As a result, every control point on the network has complete information on network state while keeping network traffic low. Both control points and devices use SSDP. UPnP control point, upon booting up, can send an SSDP search request (over HTTPMU), to discover devices and services that are available on the network. The control point can refine the search to find only devices of a particular type(such as a VCR), particular services (such as devices with clock services) or even a particular device.

2.1.3 SOAP

Simple Object Access Protocol(SOAP) defines the use of Extensible Markup Language(XML) and HTTP to execute remote procedure calls. It is becoming the standard for RPC based communication over the Internet. By making use of the Internet's existing infrastructure, it can work effectively with firewalls and proxies. SOAP can also make use of Secure Sockets Layer(SSL) for security and use HTTP's connection management facilities, thereby making distributed communication over the Internet as easy as accessing web pages. Much like a remote procedure call, UPnP uses SOAP to deliver control messages to devices and return results or errors back to control points.

2.1.4 HTTP/HTTPU/HTTPMU

HTTPU(and HTTPMU) are variants of HTTP defined to deliver messages on top of UDP/IP instead of TCP/IP. These protocols are used by SSDP, described next. The basic message formats used by these protocols adheres with that of HTTP and is required both for multicast communication and when message delivery does not require the overhead associated with reliability.

Some of the explanations of higher-level protocols and the workings of UPnP assume a basic knowledge of the HTTP protocol. More information on HTTP can be found through the references listed at the end of this document.

2.1.5 XML

Extensible Markup Language(XML), to use the W3C definition, is the universal format for structured data on the Web. Put another way, XML is a way to place nearly any kind of structured data into a text file. XML looks a lot like HTML in that it uses tags and attributes. Actually, it is quite different in that these tags and attributes are not globally defined as to their meaning, but are interpreted within the context of their use. These features of XML make it a good fit for developing schemas for various document types. The use of XML as a schema language is defined by the W3C.

XML is a core part of UPnP used in device and service descriptions, control messages and eventing.

2.2 ZigBee and IEEE 802.15.4

ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology[7].

ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but dose not require data transfer rates as high as those enabled by Bluetooth. In addition, ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. ZigBee compliant wireless devices are expected to transmit 10-75 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF world wide(2.4GHz global, 915MHz Americans or 868 MHz Europe). The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz.

IEEE and ZigBee Alliance have been working closely to specify the entire protocol stack. IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol(physical and data link layer). On the other hand, ZigBee Alliance aims to provide the upper layers of the protocol stack(from network to the application layer) for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability compliance testing, marketing of the standard, advanced engineering for the evolution of the standard. This will assure consumers to buy products from different manufacturers with confidence that the products will work together.

IEEE 802.15.4 is now detailing the specification of PHY and MAC by offering building blocks for different types of networking known as "star, mesh, andclustertree." Figure 2 shows 3 types of topologies that ZigBee supports: star topology, peer-to-peer topology and cluster tree. Network routing schemes are designed to ensure power conservation, and low latency through guaranteed time slots. A unique feature of ZigBee network layer is communication redundancy

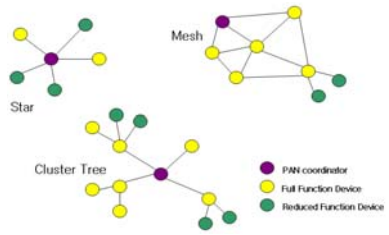


Fig. 2. Topology Models

eliminating “single point of failure” in mesh networks. Key features of PHY include energy and link quality detection, clear channel assessment for improved coexistence with other wireless networks[8].

2.3 ZigBee vs. Bluetooth

ZigBee looks rather like Bluetooth but is simpler, ha a lower data rate and spends most of its time snoozing. This characteristic means that a node on a ZigBee network should be able to run for six months to two years on just two AA batteries. The operational range of ZigBee is 10-75m compared to 10m for Bluetooth (without a power amplifier). ZigBee sits below Bluetooth in terms of data rate. The data rate of ZigBee is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz whereas that of Bluetooth is 1Mbps[9].

ZigBee uses a basic master-slave configuration suited to static star networks of many infrequently used devices that talk via small data packets. It allows up to 254 nodes. Bluetooth’s protocol is more complex since it is geared towards handling voice, images and file transfers in ad hoc networks. Bluetooth devices can support scatter nets of multiple smaller non-synchronized networks (piconets). It only allows up to 8 slave nodes in a basic master-slave piconets set-up. When ZigBee node is powered down, it can wake up and get a packet in around 15 msec whereas a Bluetooth device would talk around 3 sec to wake up and respond.

Ⅲ. Design of ZigBee System and the UPnP for Internet connectivity

3.1 Design of ZigBee System and the UPnP for Internet connectivity

To provide actual home network service for which communication home electric appliances and ZigBee system are connected, services can be provided even when users are outside as well as when they are home. ZigBee system consists of several components. The most basic is the device. A device can be a full-function device (FFD) or reduced-function device (RFD). A network shall include at least one FFD, operating as the PAN coordinator. An RFD is intended for applications that are extremely simple and do not need to send large amounts of data. All of ZigBee System can connect each sensors and communication. However, many problems occur when sensors are accessed and controlled by the internet.

ZigBee system architecture lends itself well to the discovery, configuration and management of Sensor devices. Figure 3 ,4 and figure 5 show ZigBee System. Figure 3, 4 shows ZigBee main control system and protocol stack.

Figure 5 shows that each sensor connects main receive Sensor system which sends sensor’s data to ZigBee System. ZigBee System can control in internet which sends protocol message to the UPnP IGD of the UPnP Gateway system.

Home network usually consists of private networks because of lack in IPv4 address and security, and home network and internet network are basically separated. Standardization of IPv6 is actively progressing[10]. However, control middle wears such as JINI and the UPnP suggested controlling technological problems that have not been solved yet and devices within home network appliances works normally when devices are controlled inside home network. However, many problems occur in accordance with each technology when devices are controlled by the internet network outside.

The UPnP architecture lends itself well to the discovery, configuration, and management of an IGD

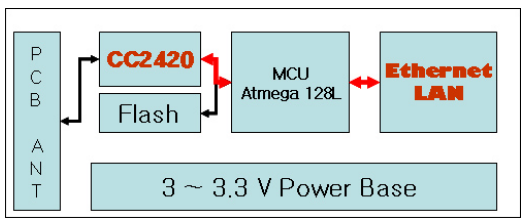


Fig. 3. ZigBee Main Controller System

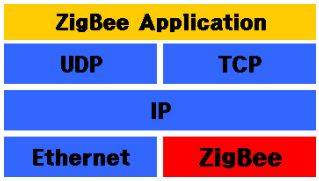


Fig. 4. ZigBee System Protocol Stack

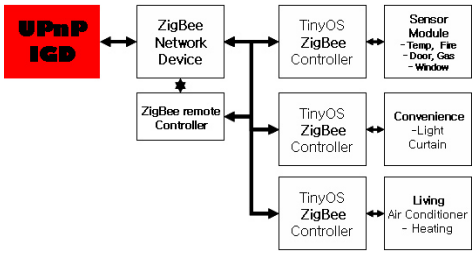


Fig. 5. ZigBee Network Architecture

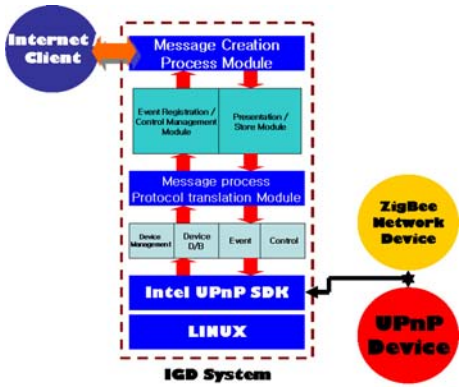


Fig. 6. UPnP Internet Gateway System Architecture

(Internet Gateway Device). An IGD is an IP addressable device typically residing at the edge of a home or small-business network. An IGD interconnects at least one LAN with a WAN interface for Internet access. An IGD also provides local addressing and routing services between one or more LAN segments and to and from the Internet. In this paper, we propose Internet Gateway that consists of the UPnP IGD(Internet Gateway Device) DCP (Device Control Protocol) and the UPnP Bridge for control electrical appliance of Internet home network.

3.2 The UPnP IGD DCP

The IGD DCP(Device Control Protocol) is designed to help internet network and home communication electric appliances to be connected to at the UPnP internet Gateway. It creates a device list web document and stores information on environment of home communication electric appliances. It includes CGI modules and demon modules to expand functions of web server and specialized functions according to time of information storage. It delivers control order to the UPnPBridge.

The IGD DCP has a four-pronged focus: Configurable initiation and sharing of Internet connections, advanced connection-management features, management of host configuration services (DHCP), and support for transparent Internet access by non-UPnP-certified devices.

3.3 UPnP Bridge

The UPnP Bridge focuses on providing and control of information on devices of home communication electric appliances. It has device list information of home network that adds device information when a device discovery event occurs and delivers device search message in implementation. It controls device by receiving control order that delivers SOAP message to corresponding devices and resultant messages to DCP. It delivers event messages of devices to DCP through inside control point.

Ⅳ. The Results of Experiments

ZigBee System constructed ZigBee controllers and one network device. ZigBee controller send sensor data after collected many sensors and control systems. For construction of system and test, sample communication sensor systems that show figure 7. ZigBee sensor system was based on TinyOS which collected many sensor data and PLC event data. ZigBee network device system was designed by author who designed ZigBee network device for high speed and attributed system (show figure 5).

The UPnP expansion internet gateway system was developed based on Linux (show figure 6). For construction of system and test, sample communication electric appliances that show the same actions as the device of the UPnP were replaced by embedded system in which Linux was embedded to control functions. This study provides one jointly-used IP to internet gateway system developed with Linux for the notebook in which wireless Windows XP Professional

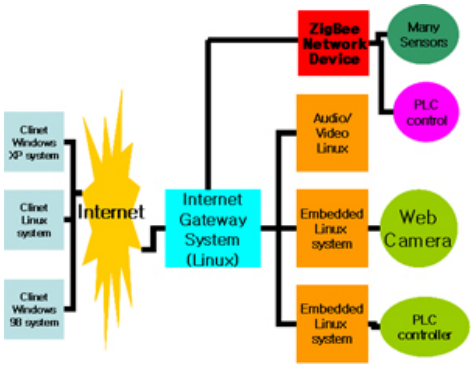


Fig. 7. The UPnP Internet Gateway System Test Model

is embedded by applying cable and wireless environments at the same time. Embedded Linux system devices replaced by home electric appliances with the same function as the UPnP Devices consist of private IP. The following Figure 7 shows construction of the system.

Internet users can confirm and control devices such as cameras, lamps and audios connected to home networks by approaching to home network constructed with private networks through internet gateway. Among them, if users select one device, the results of presentation on corresponding devices are delivered through internet gateway, through which users can control and monitor devices. This device control is presented as follows shown in Figure 8 and Table 1:

Figure 9 shows the results of experiments for ZigBee Network device system and the UPnP Expansion. The data which it receives from ZigBee Network device via internet which is can control and check. It sends each control signal to ZigBee Network device for many sensor systems and control digital appliance of PLC line and also can control the UPnP devices through The UPnP IGD.

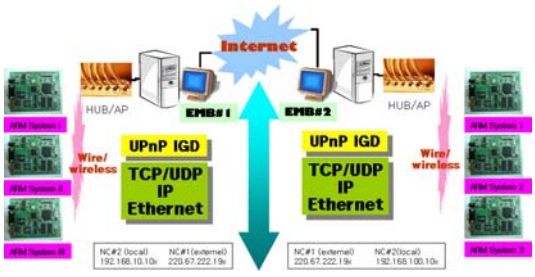
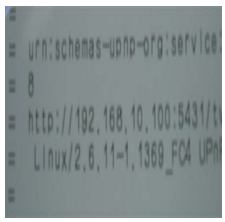


Fig. 8. The UPnP Expansion Realization

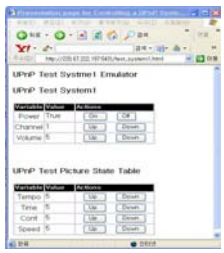
Table 1. The Results of Experiments

(a) UPnP Test ARM Board



(b) Electrical appliance Connect IP Via Internet Gateway

(c) Connection Via Control Point



(d) UPnP Electrical appliance Control Via Internet

Fig. 9. Control ZigBee and The UPnP via Internet

When ZigBee system and communication home electric equipment in which private network is constructed outside internet was controlled through the UPnP internet gateway, time delay was not found because so much data was not needed. However, multi-media communication service with much amount of data showed some delay, which are going to solved.

V. Conclusion

At present, JINI or the UPnP is representative to control home network equipment, and a suggestion to control devices within home network is presented.

To use and control communication equipment within home network constructed with actual private network, their functions should be expanded.

This study prepared ZigBee System and the UPnP internet gateway system by ZigBee and expanding UPnP. For the UPnP gateway system which monitor and control communication home appliances within private home network, Internet users use presentation provided by the corresponding devices, which is the best advantage and users can have the same control environment in Internet network as home.

The present system can only monitor and control home communication devices, but in the future, we need further considerations on support of multi-media contents and on security policy on users' authority for each device which are going to be more important.

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