Internet Home Network Electrical Appliance Control on the Internet with the UPnP Expansion

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Abstract

Electrical appliances of home network 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 UPnP IGD(Internet Gateway Device) DCP(Device Control Protocol) and the UPnP Bridge for control electrical appliance of Internet home network.

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. UPnP Bridge searches for local home network devices by sending control messages. Control Point of 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 via internet through IGD DCP on other home network with control commands of UPnP.

1. 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 wired and wireless home network technologies nowadays. General digital home network is showed by Figure 1. An effective middleware is needed to control the home appliances regardless of any kinds of home network technologies applied, which is like the UPnP (Universal Plug and Play).

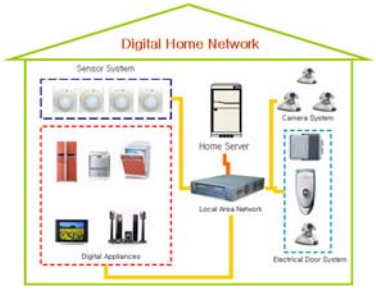

Figure 1. Architecture of general home network

The UPnP is that extends the plug and play concept to the networking based on the standard Internet Protocol.[1] The UPnP is an 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.

In this paper, we propose Internet Gateway that consists of UPnP IGD(Internet Gateway Device) DCP(Device Control Protocol) and UPnP Bridge for control electrical appliance of Internet home network.

UPnP IGD DCP is configurable initiation and sharing of Internet connections, advanced connection-management, management of host configuration, and

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supports transparent Internet access by non-UPnP-certified devices. UPnP Bridge searches for local home network devices by sending control messages. Control Point of 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 via internet through IGD DCP on other home network with control commands of UPnP.

Electrical appliances of home network via the Internet can be controlled with the UPnP expansion like ones in the same home network without modification of existing UPnP.

2. UPnP 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.

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. 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.

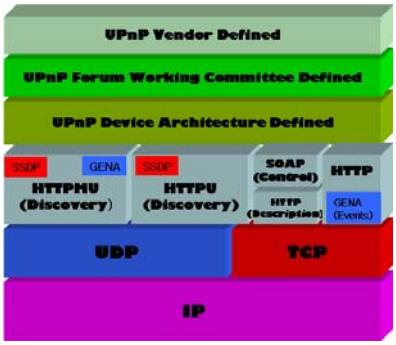


Figure 2. The UPnP Protocol Stack

- 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 also defines the concepts of subscribers and publishers of notifications to enable events.

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.

The subscription must be renewed periodically to continue to receive notifications, and can also be canceled using GENA.

- 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.

UPnP devices listen to the multicast port. Upon receiving a search request, the device examines the search criteria to determine if they match. If a match is found, a unicast SSDP (over HTTPU) response is sent to the control point. Similarly, a device, upon being plugged into the network, will send out multiple SSDP presence announcements advertising the services it supports. Both presence announcements and unicast device response messages contain a pointer to the location of the device description document, which has information on the set of properties and services supported by the device.

In addition to the discovery capabilities provided, SSDP also provides a way for a device and associated service(s) to gracefully leave the network (bye-bye notification) and includes cache timeouts to purge stale information for self healing.

- 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.

Each UPnP control request is a SOAP message that contains the action to invoke along with a set of parameters. The response is a soap message as well and contains the status, return value and any return parameters.

- HTTP/HTTPU/HTTPMU

TCP/IP provides the base protocol stack to provide network connectivity between UPnP devices. HTTP, which is hugely responsible for the success of the Internet, is also a core part of UPnP. All aspects of UPnP build on top of HTTP or its variants.

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.

- 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 Steps to UPnP Networking

The UPnP Device Architecture is a framework that defines the protocols for communication between controllers, or control points, and devices. UPnP functionality involves five processes :

- **Step 1 : Discovery**

When a UPnP device is added to the network, the discovery protocol allows the device to advertise its presence to control points by using the Simple Service Discovery Protocol (SSDP). The information exchanged between the device and the control point is limited to discovery messages that provide basic information about the devices and their services (e.g., their types, identifiers, and pointers to more detailed information).

- **Step 2 : Description**

Using the URL provided in the discovery process, a control point receives XML information about the device, such as manufacturer information like make, model, serial number, and URLs to vendor specific Web sites. In addition, the description process can also include a list of embedded devices, embedded services, and URLs used to access device features.

- **Step 3 : Control**

Given knowledge of a device and its services, control points use URLs provided during the description process to access additional XML information that describes actions to which the UPnP device services respond, along with parameters for each action. Control messages are formatted in XML and use Simple Object Access Protocol (SOAP).

- **Step 4 : Eventing**

When a control point subscribes to a service, the service publishes updates to the control point to announce changes in device status when one or more of the state variables that are event change. Event messages are formatted in XML and use General Event Notification Architecture (GENA) protocol.

- **Step 5 : Presentation**

If UPnP device has an URL for presentation, then the control point can retrieve a page from this URL, load the page into a browser and, depending on the capabilities of the page, allow a user to access interface control features, device, or service information, or any device-specific abilities implemented by the manufacturer.

3. Design of UPnP for Internet connectivity

To provide actual home network service for which communication home electric appliances are connected, services can be provided even when users are outside as well as when they are home. 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. However, control middle wears such as JINI and UPnP suggested to control 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(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 UPnP IGD(Internet Gateway Device) DCP(Device Control Protocol) and UPnP Bridge for control electrical appliance of Internet home network.

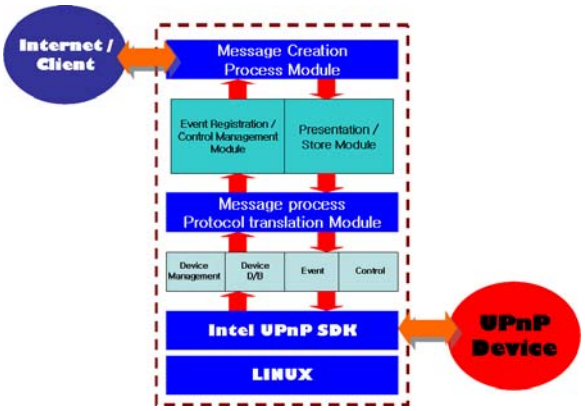


Figure 3. UPnP Internet Gateway System Architecture

3.1 UPnP IGD DCP

IGD DCP(Device Control Protocol) is designed to help internet network and home communication electric appliances to be connected to at 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 specialize functions according to time of information storage. It delivers control order to UPnP Bridge.

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.

3.2 UPnP Bridge

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.

4. UPnP Expansion Realization and The Results of Experiments

UPnP expansion internet gateway system was developed based on Linux(show figure 4). For construction of system and test, sample communication electric appliances that show the same actions as the device of 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 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 IPs. The following Figure 4 shows construction of the system.

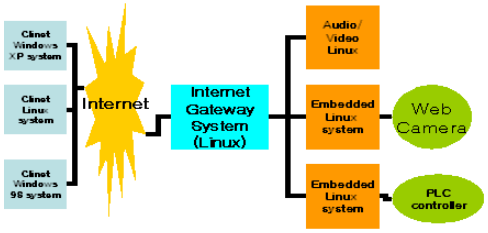


Figure 4. UPnP Internet Gateway System Test Model

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 5 and 6 :

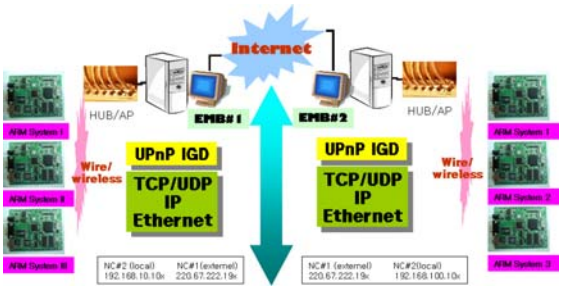
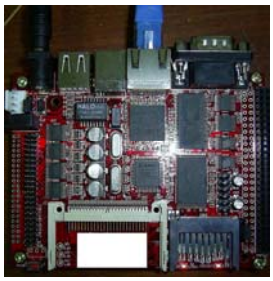
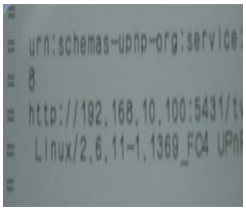


Figure 5. UPnP Expansion Realization Model.

When communication home electric equipment in which private network is constructed outside internet was controlled through 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.

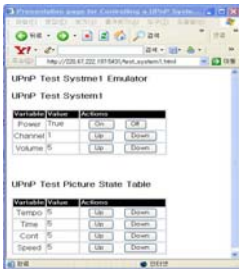


(a) UPnP Test ARM Board



(b) Electrical appliance Connect IP Via Internet Gateway

(c) Connection Via Control Point



(d) UPnP Electrical appliance Control Via Internet

Figure 6. The Results of Experiments

5. Conclusion

At present, JINI or 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 UPnP internet gateway system by 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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