HOME NETWORKING DIGITAL TV BASED ON LnCP

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ABSTRACT

This paper introduces a new Home Networking Control Protocol, LnCP (Living network Control Protocol) used to connect the digital appliances. LnCP is targeting a convenient and easy-to-use home networking system and basically supports controlling and monitoring the status of connected devices. Then the Home Networking digital TV system with LnCP is presented. The way to configure Home Network and handle other devices through Home Networking TV is explained afterwards.

I. INTRODUCTION

So far the transmission technologies for the home networking have been going their ways without concern of each other. Those include the wireless technologies like IEEE802.11, Bluetooth, HomeRF and the wired technologies such as HomePNA, Ethernet (IEEE802.2/3), Power Line Communication (PLC), and IEEE1394. All of them could be the main technologies that can make the infrastructure of the future Home Network. While they have been competing for the best candidate of the home networking, however, they have never tried to resolve the problems that users could feel when they start to utilize the Home Network. Those issues could be referred to understanding, installation, maintenance and use [1], which means consequently that users want to get some convenience and use their home network easily whatever technologies they use as the lower layer of home network. On top of that, they want to let the legacy appliances connected in their home network rather than the information technology devices. Though Universal Plug and Play (UPnP) [2][3] has been proposed as a middle ware that can connect information technology devices and appliances, it requires a bit heavy hardware specification for appliances and needs an Ethernet or wireless network to be installed to connect devices at home.

Considering all those user's requirements, in this paper, we introduce the new Home Networking Protocol, Living network Control Protocol (LnCP) [4][5]. The LnCP is pursuing a convenient and easy-to-use home networking services at home using PLC. In addition, the Home Networking Digital TV(HNTV) with LnCP is introduced. In LnCP networks, the connected devices like air conditioner and washing machine etc, can be controlled and monitored through HNTV.

The remainder of this paper is organized as follows. The next section presents network architecture for the Home Network and the protocol stack of LnCP. In Sections III, Home Networking digital TV is introduced with system architecture and user interface features. The section IV concludes this paper.

II. HOME NETWORK with LnCP

The architecture of forthcoming home network will support remote access and control via Internet as shown in Fig. 1. For this possible, basically home network should provide a way to connect home appliances and control other devices at a certain device. When controlling and monitoring devices, it's necessary to classify devices into mainly two types: controlling devices and controlled devices. Normally controlling device should be able to get user input and have a user-friendly interface.

Besides since controlling other devices should be performed outside of the home as well, it's also necessary for home network protocol to provide a secure way to control home appliances via Internet and have a bridging function to the another transmission media such as Ethernet, wireless networks, etc.

Seen at Fig.1, home network can be divided into AV network centered by TV, appliance network including white goods and IT network with personal computer. Additionally gateway is needed to connect Home Network to the Internet. All these components compose the environment that users control and check the status of the devices in the home networks remotely. To make all these possible we need a method to connect devices and deliver control command efficiently. Here's LnCP as a solution of them.

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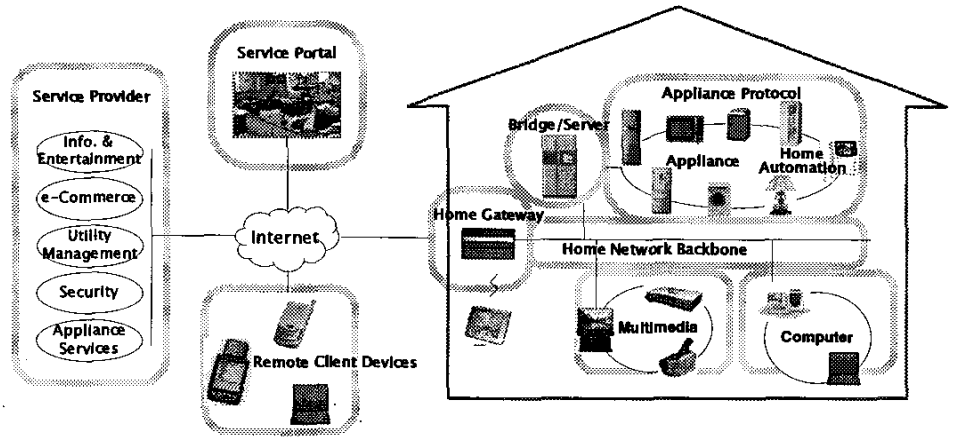

Fig. 1 Home Network Architecture

Firstly LnCP connects all appliances at home and provides controlling and status monitoring over the connected devices and lets all devices know the status of other devices by issuing event notification based on the change of the status of a device.

Even though nearly all kinds of communication media for home networking are possible, Power Line Communication (PLC) is enough to control and monitor devices at home and has some advantages over others. It has low transmission speed at the moment. Nevertheless it reduces user's burden in installing home network at home and does not require users to understand home network well after installing home networking devices at home. And also the fact that low transmission bandwidth is enough for only controlling and monitoring devices can be another advantage of PLC over other technologies.

Another aspect that should be considered while controlling appliances is the maintenance side. Since nearly all of the appliance's lifetime is longer than 5 years, home networking control should be reliable while devices are being used. Supporting this in the home networking protocol requires a simplicity, which means that home networking protocol should be light enough for the device to implement a communication function without disturbing a device's own functions.

Considering these things, LnCP provides a way to let appliances implement communication with low cost and an easy way of controlling appliances and monitoring the status change of devices.

(1) LnCP Features

Devices in LnCP networks are categorized into two types; one is a slave and the other is a master. It's only dependent on device's role in the home network. For example, most people want to control a washing machine watching TV rather than cooking food in front of microwave oven. Therefore, we can call TV as master device in LnCP networks. The main reason to divide LnCP devices is to make the roles of devices in networks simple and light. What slave device should do is to follow the command that is issued by the master device. Thus, master device should know how to control the slave device that user want to control and be able to interpret the command code that is received from the slave devices.

One of the outstanding features of LnCP is that it's based on the event-driven communication. To know the status of other devices, there are roughly two methods. One is questioning other devices periodically and the other is notifying the status changes when the changes happen. LnCP adopts the latter one and enables whole devices to be aware of the status updates of other devices by asynchronous notification.

In addition, LnCP permits slave devices controlled by multi masters as well as single master, which is possible with the combination of pre-mentioned features of LnCP. After controlled by a master device, a slave device notifies the change of the status of itself to the other master devices with event notification method. This allows master devices to control slave devices

consistently.

Another feature of LnCP is Home Code. LnCP looks a home as a close network that is necessary to be private from neighbors. Basically Home Code is generated into random 4 bytes value and is used to prevent neighbor's data from coming over and interfering with.

Lastly LnCP provides variable-length packet structure that is composed of 1-byte command code and input/return arguments. Using this type of message makes it easy to incorporate LnCP into white goods such as air conditioner and microwave oven etc.

The slave devices need to interpret the command codes that only concern them and master devices that want to control slave devices should be able to compose every type of message that has to be interpreted by each slave devices.

(2) Protocol Architecture of LnCP

Fig. 2 shows protocol architecture of LnCP. It consists of four layers. Each of their roles is explained as follows.

1. Application Layer

Message name	Power control	
Command code	0x05	
	Name	Data type
Input arguments	Power value	unsigned char
Return arguments	-	-
Comments	"Power value" is in range of 0 to 255. 0 means "off" and 255 means "on" with full power	

Table 1 Power Control Command Code

Application layer concerns only Command Code set that is directly used to control and monitor the status of other LnCP devices. Main role of application layer is interpreting command codes and performing the proper action according to the command codes. In addition, in case of master device, it has to provide the interface to the user to get an input and display the result of controlling the devices to the user. Table 1 shows a power control command code and explanation.

2. Home Network Layer

This layer takes a role of communicating with other device with LnCP packet. It generates packet as shown in Fig.3. Besides, for reliable communication, it should perform networking functions such as retransmission, error control and flow control etc. Two bytes of packet fields are used for device address system.

3. Data Link Layer

Most common data link layer functions should be done in this layer like other protocols. However at the moment only media access control is defined as *Carrier Sense Multiple Access/Collision Avoidance* (CSMA/CA). The full frame structure and other link control mechanism have to be defined considering the characteristics of PLC. In near future, Home Code will be provided to support the *plug and play* feature and network privacy in LnCP Home Networks.

4. Physical Layer

This layer is concerning the physical media transmission using Modulation/Demodulation method. The specific modulation/demodulation scheme hasn't been decided yet.

(3) Address System

LnCP has a specific address system. As shown in Fig. 3 and Table 2, LnCP has 2-byte long address field. The

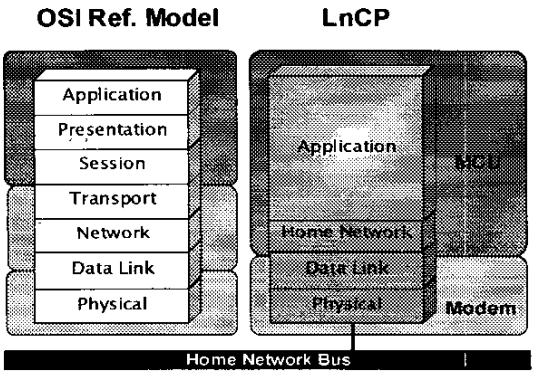

Fig. 2 Protocol Architecture of LnCP

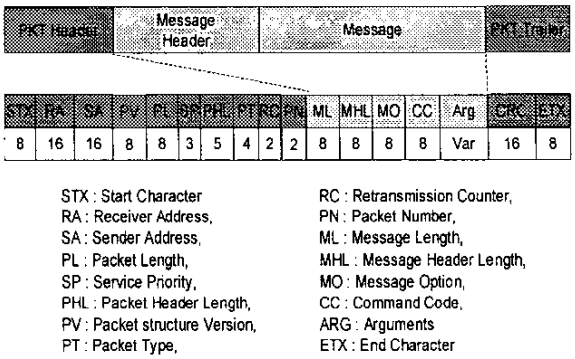

Fig. 3 LnCP Packet Format

first byte in the address field is product code, which is assigned with a unique value identifying the basic function of residential products and has nothing to do with the vender. As shown in Table 3, this product code is predefined. The second byte is the logical address that is used to identify the devices having the same product code. The logical address can be treated as a device address or an area code. Device address is used for addressing the appliances having the same product code. Area code is allocated according to the installed area at home.

Physical address(8bit)	Logical address(8bit)
Product code	Device address
	Area code

Table 2 The structure of address field

Product name	Product code	Address range
Network manager	0x00	-
Refrigerator	0x01	0x0100~0x01FE
Air conditioner	0x02	0x0200~0x02FE
Washing machine	0x03	0x0300~0x03FE
.	.	.
.	.	.
.	.	.
HNTV	0x21	0x2100~0x21FF

Table 3 Product codes

Group address is assigned as all bits in each sub field are set to '1'. For example, 0x01XX indicates the group address of refrigerators, where XX means 'don't care'. 0x3FXX is a group address indicating all appliances that have the same area code. Because the grouping logic in LnCP is oriented to home environment it is useful for home automation.

III. HOME NETWORKING DIGITAL TV

HNTV is implemented on real-time embedded OS with one serial communication interface that can be used in downloading program as well as in communicating with other LnCP devices.

Communication of HNTV is composed of software modules independently from other functions of TV. Therefore there's no other hardware addition except for the external power line modem.

LnCP communication consists of 4 layers as shown before in Fig. 2. In HNTV, external PLC modem takes a role of transceiver that performs physical layer's functions and only CSMA/CA of data link layer. Remaining other functions are carried out in other layers in HNTV

Fig. 4 shows communication system architecture in HNTV. As shown, UART is adopted to connect HNTV with PLC modem. On top of its device driver, basic communication environment are formed.

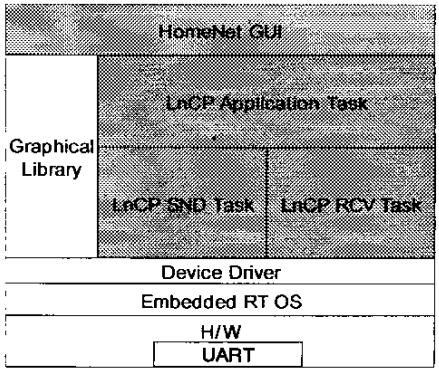

Fig. 4 Communication System of HNTV

In other words, basic home networking infrastructure is provided by LnCP layer performing transmitting and receiving functions as software. Basic functions of LnCP layer are LnCP packet composing, retransmission and traffic control. This layer is responsible for the reliable communication with error control as well. LnCP layer is devised with two tasks in HNTV: LnCP SND Task and LnCP RCV Task. Each of them is taking missions of reliable transmitting and receiving LnCP packets.

LnCP application layer makes messages for controlling other devices. For this purpose, LnCP application task in HNTV prepares a data base for the devices that are to be controlled and updates it when the status of devices has been changed. Items of DB are logical addresses of devices, location information and control functions of devices etc. HNTV makes its DB ready in order to control and monitor other devices when they register to it before they start to be controlled.

These composed messages are delivered through two communication message queues to the lower LnCP layer. Before displayed on the screen of HNTV, these are translated into the understandable information and delivered to the GUI layer through a message queue. The reason that a message queue is used is to support the asynchronous communication interface between human and home networking devices.

GUI layer's main roles are taking user control information well and displaying the status change of the connected devices. GUI is devised with XM graphical library that is used to make GUI for Digital TV in accordance with the main menu of digital TV. HomeNet UI adopts a unfold-menu style to allow the status of connected devices seen at one glance. HomeNet UI

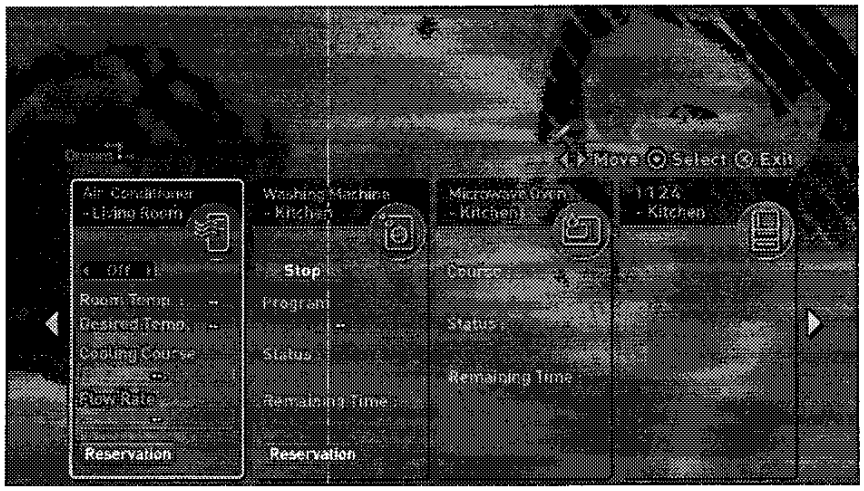

Fig. 5 HomeNet of HNTV

Fig. 6 Event Notification on HNTV

shows controllable functions of devices as well as displays the status of devices with detail items of menu.

HNTV takes mainly master role and partly network manager role in LnCP networks. And it has an ability to register devices when new slave devices are plugged. Another feature of HNTV is an event notification with a popup message on the screen.

Fig. 5 shows HomeNet UI on TV screen. This basic HomeNet UI is called by pressing the Home Net button on TV remote controller. HomeNet UI in HNTV provides four major control panels in one page with which user can see the status and control information. These are about air-conditioner, washing machine, microwave oven and refrigerator. HomeNet UI has the extensibility. Thus, control panels will be expanded as the devices enter the home network. The position of each device is decided according to the status and priority of the connected devices.

The first connected device in Fig. 5, Air-conditioner can be controlled by moving highlighted area with remote controller, which is possible with arrow buttons

in remote controller. On and off states are switched with arrow buttons as well. As shown, desired temperature, cooling course and flow rate can be controlled when they are highlighted. Each device has location information such as living room, laundry and kitchen, which are selected when each of devices is registered. Then it's attached to the HomeNet UI.

Fig.6 explains the alarm function of HNTV, which is utilizing the event-driven feature of LnCP. For example, when cooking is finished with microwave oven, it is automatically notified on HNTV. HNTV supports these notifications with pop-up message windows when it receives specific notification packets.

IV. CONCLUSION

LnCP is the event driven protocol that uses the special message set to control and monitor appliances in Home Network. Furthermore, it is interoperable with any other transmission technologies. Built on all those features of LnCP, Home Networking Digital TV basically has an ability of controlling devices and displaying the status of other devices with a user-friendly interface. Moreover it has an alarm function that can be used to inform users of some actions of home appliances. Though LnCP is using low speed PLC at the moment, it would be possible to develop more informative applications like in an environment of IT network if the speed of transmission media is improved. Currently more works are remained in improving network manager features of HNTV.

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