A Novel Home Network Protocol for the Controlling and Monitoring Services through Internet

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Abstract. This paper proposes the communication architecture for the Home Networking services and introduces a new Home Networking Control Protocol, Living network Control Protocol (LnCP) to connect the devices at home to communicate each other. LnCP is targeting a convenient and easy-to-use home networking system and basically provides controlling and monitoring the status of connected devices. The real products capable of Home Networking like Internet Gateway, Digital Set Top Box and Digital TV are introduced in this paper. The way to configure Home Network and handle other devices in LnCP networks is explained as well.

1 Introduction

Home Network can be defined on basis of the purposes and services. Generally it can be defined as follows: A Home Network interconnects remote electronic products and systems, enabling remote access to and control of those products and systems, and any available content such as music, video or data. In other words, the services of Home Network can be referred to the remote controlling and monitoring through Internet basically providing the connectivity and communication among the electronic products at home. In addition, the current multimedia services prevailing in Internet are going to be implemented with A/V devices in Home Networks.

To accomplish a Home Network mentioned above, we need a transmission method to connect devices at home. 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[1]. All of them could be the main technologies that can make the infrastructure of the future Home Network. And especially the protocols that can be used for remote controlling electronic appliances based on PLC are Lonworks, CEBus and Konnex [2]. Moreover, there is a middle ware solution like Open Service Gateway initiative (OSGi) and Universal Plug and Play (UPnP) [3][4]. Especially they're manifesting itself as a gateway solution for Smart Home. However it’s hard for those technologies to come...
closer to the normal users because nearly all of those are not considering the user’s expectation to the Home Network. Those issues could be referred to understanding, installation, maintenance and use [1]. Beside, the cost effect and the resource efficiency should be taken in consideration before adopting those technologies in the legacy appliances and Home Networks.

This paper introduces the communication architecture for the remote controlling and monitoring services of Home Network and a new communication protocol for those services in Home Network. In addition, the important devices for Home Networking services such as Internet Gateway (LnGate), Home Networking Digital Set Top Box (HNSTB) and Digital TV (HNTV) are introduced.

2 Home Network Architecture

In this section, the Home Network architecture that can provide the remote controlling and monitoring services over the devices at home is introduced. On the basis of the architecture, a new Home Network control protocol, LnCP, is introduced. With this protocol, all devices in Home Network understand each other with the capability of controlling and monitoring each other.

First of all, the network architecture for the controlling and monitoring services through Internet is shown in Fig. 1. As shown in the figure, 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 make the environment that users control and check the status of the devices in the Home Networks remotely. When the Home Network has been connected to Internet through residential gateway, the remote controlling and monitoring services of the devices at home are provided by the portal server. This indirect service through Internet portal server can prevent normal

![Fig. 1 Home Network Architecture](image-url)
Internet users from accessing the Home Network directly and has an advantage to provide the Home Network users with the program upgradeability through the service portal and the useful information to users like Internet recipe for micro wave oven cooking.

Another alternative for composing Home Network can be using home server or intelligent gateway rather than simple one that just understand Home Network control protocol and Internet protocol. In that situation, home server has to have as much power as the specific service portal in perspective of gathering information for its Home Network devices and presenting the Home Network to the remote users. Therefore, it could be a defect in the sense that each home needs a more powerful and expensive home server to build a Home Network.

As mentioned earlier, there are lots of transmission methods that can be used as Home Network infrastructure at home. However, most users want Home Network to be installed easily without additional lines. Viewing in that aspect, wireless solution and PLC could be the best candidates at the moment. But while thinking of the controlling and monitoring services in Home Networks at low cost, PLC would be better. Even though the PLC has now low speed in transmitting data, it is more suitable to the electronic appliances because it can use the existing power outlet of the house and most of appliances need electricity. Consequently PLC was selected as a transmission media for connecting electronic appliances in the proposed Home Network architecture.

3 Home Network Protocol - LnCP

This chapter introduces a new Home Network control protocol that can control and monitor the state of the device in the Home Network, which is called as Living network Control Protocol (LnCP). Basically it’s independent of the transmission media and has characteristics of being simple and light enough to be implemented with 8-bit MCU.

3.1 LnCP Features

As a Home Network protocol, LnCP has following features.

   Master and Slave Communications: 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 sent from the slave devices. And also LnCP supports multiple masters, which means that a master controls slave
devices and the other masters can detect the status of the slave device and the information of all devices in Home Networks is going to be synchronized.

**Event Driven Communications:** In order 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. To support this, three types of packets are defined in LnCP: Request Packet, Response Packet and Event Packet. Those packets are identified with the Packet Type field in the packet header.

**Command Code for Controlling and Monitoring:** LnCP provides variable-length packet structure that is composed of 1-byte command code and input/return arguments as shown in Fig. 2. 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.

![LnCP Packet Format](image)

**Address Code by product:** LnCP has a specific address system. As shown in Fig. 2, LnCP has 2-byte long address field. The 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 vendor. This product codes are predefined. The second byte of the address field 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. With the combination of these two fields, devices in LnCP networks are identified and able to communicate with each other.

Table 1 shows the product codes and address range of LnCP products.

**Home Code:** Whether using PLC or Wireless Solutions, it’s unavoidable to get interfered with the signal from neighbors. Although PLC recommends using Blocking Filter and Wireless Solutions recommend using channel shifting to protect a Home
Network from others, LnCP defines Home Code to make a Home Network to be independent from others in packet level communication. 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.

Table 1 Product Codes

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Product Code</th>
<th>Address Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Manager</td>
<td>0x00</td>
<td>-</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>0x01</td>
<td>0x0100–0x01FE</td>
</tr>
<tr>
<td>Air Conditioner</td>
<td>0x02</td>
<td>0x0200–0x02FE</td>
</tr>
<tr>
<td>Washing Machine</td>
<td>0x03</td>
<td>0x0300–0x03FE</td>
</tr>
<tr>
<td>TV</td>
<td>0x21</td>
<td>0x2100–0x21FE</td>
</tr>
<tr>
<td>STB</td>
<td>0x22</td>
<td>0x2200–0x22FE</td>
</tr>
</tbody>
</table>

3.2 LnCP Protocol Architecture

LnCP pursues the total Home Networking services even though it’s based on the low speed transmission like PLC. That implies that LnCP is not only the protocol for the controlling and monitoring services among electronic appliances but also the one to provide the services as in Internet. As shown in Fig. 3, LnCP protocol architecture has 4 layered structures to deliver the messages according to the service. The left part of the architecture means the controlling and monitoring services in Home Network. Through this part, all devices in Home Network can communicate and perform the controlling and monitoring. The explanations of each layer follows.

Physical Layer: This layer is concerning the physical media transmission using Modulation/Demodulation method. LnCP doesn’t care the transmission method. As
result LnCP is independent of the transmission technologies.

**Home Network Layer:** In major, this layer concerns the data transfer between devices in Home Network. Therefore, in this layer the multiple access control is performed with *Carrier Sense Multiple Access/Collision Avoidance* (CSMA/CA). And the *plug and play* feature and network privacy are supported with home code. And also this layer takes a role of communicating with other device using LnCP packet. It generates packet as shown in Fig.2. 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.

**HomNet Message & Application Layer:** HomNet Message layer concerns only command code set that is directly used to control and monitor the status of other LnCP devices. Main role of this 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, which is mostly performed in application layer.

### 4 Home Networking Systems

In this section, some systems are introduced, which are all implemented based on the Home Network architecture mentioned previously. Those are gateway interconnecting Home Network and Internet, Home Networking Digital TV and Home Networking Digital Set Top Box. Of course all other slave devices like air conditioner, washing machine and microwave oven etc, have been implemented with Home Networking features. Those are intended to be controlled through masters in LnCP networks and Internet service portal.

#### 4.1 LnCP/Internet Gateway

The basic role of the gateway program called LnGate, is to interconnect Internet and the Home Network. It sends all devices information in Home Network to the portal server via TCP/IP socket. And also it can control and monitor the devices in Home Networks with LnCP packet communication. Thus it enables users to control and monitor the Home Networks through Internet and even mobile phone since the portal server has the mobile interface.

Fig. 4 shows the LnGate. This program can be installed in PC and gateway with network interface and PLC interface to be a network manager for the proper Home Network control. As shown, all the devices connected in Home Network are described in two ways: Blue one means that the device is now turned on and the dark gray one means that the device is now turned off and the light gray means that the device is not connected in the network. Controlling and monitoring the specific functions of the devices can be done in the right side blue window after selecting the device in the left
Fig. 4 LnGate

4.2 HNTV/HNSTB

HNTV/HNSTB is implemented on the real-time embedded system with one serial communication interface that can be used in downloading program as well as in communicating with other LnCP devices. Fig. 5 shows communication system architecture in HNTV/HNSTB.

As shown, UART is adopted to connect HNTV with PLC modem. On top of its device driver, basic communication environment are formed. The basic

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communication with LnCP packet is performed by mainly two tasks: LnCP SND Task and LnCP RCV Task. Each of them is taking missions of reliable transmitting and receiving LnCP packets respectively. HomeNet message layer makes messages to control other devices. For this purpose, LnCP application task in HNTV/HNSTB 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/HNSTB makes its DB ready in order to control and monitor other devices when they register to it before they start to be controlled. Lastly, GUI layer’s main roles are taking user control information 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 an unfold-menu style to allow the status of connected devices seen at one glance as shown in Fig. 6. HomeNet UI shows controllable functions of devices as well as displays the status of devices with detail items of menu.

HNTV/HNSTB takes mainly master role and partly network manager role in LnCP networks. And those have an ability to register devices when new slave devices are plugged. Another feature of HNTV and HNSTB is an event notification with a popup message on the screen. For an instance, when the cooking is completed in micro wave oven or gas oven, a message pops up to show the cooking’s done, which is described in Fig. 6.

Fig. 6 HomeNet feature on HNTV/HNSTB

5 Conclusions

The ubiquitous network services need various networks interconnected. Those would be Mobile Network, Wireless Data Network, BISDN and Home Network. Among those, Home Network would be the smallest and most private one. But to
A Novel Home Network Protocol for the Controlling

To accomplish the ultimate ubiquitous network services, it is the time to think over how the Home Network should be organized. Having those in mind, this paper has introduced the Home Network Protocol, LnCP and the network architecture for the Home Networking services.

The network architecture provides indirect access to the Home Network through portal server, which makes easy for normal users to manage and maintain their Home Networks. On the basis of the proposed architecture, the remote controlling and monitoring via Internet and mobile phone have been implemented with LnCP. To support those services, the LnGate has been devised to interconnect Home Network and Internet. LnCP has been proposed to connect appliances at home. Basically it is targeting the controlling and monitoring services in Home Network at the moment. But in the future it would be possible to expand the service areas and develop more informative applications like in an environment of IT network as the speed of transmission media is improved.

As a future work, the network security and encryption method should be researched to ensure Home Network safe.

Acknowledgement

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References