Home Network Control Protocol for Networked Home Appliances and Its Application

Jae-Min Lee, Kwan-Joo Myoung, Dong-Sung Kim, Wook-Hyun Kwon •
CISL, School of Electrical Engr. and Computer Sci. Seoul National University, Seoul, 151-742, Korea
Beom Seog Ko • Digital Appliance Research Lab., LG Electronics Inc., Korea
Young-Man Kim • Digital Appliance Network Business, Samsung Electronics Co., Ltd., Korea
Yo Hee Kim • PLC Team, Korea Electric Research Institute, Korea

ABSTRACT

This paper describes design and implementation of home network control protocol for networked home appliances. The proposed network protocol has four-layered protocol structure and device-modem interface structure for the flexibility of modems based on power line communication. The standard message set is specified to guarantee the interoperability between various home appliances. The proposed protocol can be easily implemented because it has minimum network overhead.

Keywords : Home Network Control Protocol, Networked Home Appliance, and Power Line Communication

Ⅰ. INTRODUCTION

The home automation system is one of killer applications in home network. Power lines have been considered as a convenient carrier for the home automation system. To implement the home automation system using power line communication (PLC), the interoperability between networked home appliances (NHAs) should be guaranteed. In addition, the implementation cost should be low, even though it cannot guarantee high reliability. It also should have minimum network overhead, due to the limit of micro-controller in NHAs. The standardization of network protocol in the home automation system using PLC has played the important role in satisfying these requirements.

There is standardization for network protocol in the home automation system. For example, the X10 [1], LonTalk [2,3], CEBus [4], ECHONET [5], and LnCP (Living network Control Protocol) [6-8] standards define the network protocols and interface standards. Although the X10 has been used since the 1970' s it is typically suited for simple on/off control. It cannot meet the requirements of NHAs. CEBus have been developed with the purpose of control network in the home automation. CEBus has common language interpreter like Common Application Language (CAL). However, the implementation cost is non-economic by its structure and message specification [6]. LonTalk was also designed for control network. LonTalk supports OSI seven layers model. Even though, LonTalk is powerful for the home automation system, this protocol had not been widely adopted due to high cost, less flexibility, and other barriers [3].

LnCP is simple solution for the home automation. However, LnCP has mixed layer, and it is difficult to maintain and upgrade. It does not define the device-modem interface, for the external modem. In addition, LnCP cannot guarantee the interoperability because LnCP is designed for specific appliances.

Therefore, a new protocol has been required for interoperability and economic implementation in the home automation system based on PLC.

This paper proposes design of a new network protocol, Home Network Control Protocol (HNCP) for NHAs [9, 10]. HNCP mainly targets on low-speed control network based on PLC. HNCP has four-layered protocol architecture. Each layer' s protocol data unit is encapsulated to guarantee the maintainability. To guarantee the interoperability, the standard device-modem interface and standard message set are specified in HNCP. HNCP also specified the network management and simple flow control and error control to enhance the network reliability. A home server program and an appliance emulator are shown as implementation results.

This paper is organized as follows. In the following Section, user requirements of HNCP are presented. Key features of HNCP are presented in Section 3. Then, a home server program and an appliance emulator based on HNCP are presented as implementation results in Section 4, Finally, the conclusions are shown in Section 5.

Ⅱ. USER REQUIREMENTS OF NETWORK PROTOCOL

In this Section, the user requirements of network protocol in the home automation system are listed as follows;

- Guarantee the interoperability
- Low implementation Cost
- Minimum network overhead.
- Guarantee the transmission of emergency data
- User convenience
- Maintainability

First, the main object of network protocol in the home automation is to guarantee the interoperability between various home appliances and vendors. If NHA has different capability of network, the connected modem should meet the requirement of the NHA. For example, a master device that has powerful microprocessor want to control the home automation system, this NHA should contain the network layer of network protocol, while if a slave device just respond the master's request, the slave device only have the application layer. Therefore, the flexibility of modem should be guaranteed for interoperability.

Seconds, the implementation cost of network protocol should be low. There is no need to use high cost network such as industrial network in home environment.

Third, the network overhead in home appliances should be minimal because the performance of microprocessor of home appliances is low.

Fourth, the successful transmission of the emergency data in home security system or home care system should be guaranteed. Network protocol for the home automation does not require high network reliability and real-time property that are needed in fieldbus or industrial network. However, emergency data should be transmitted reliably.

Finally, because ordinary people use the home automation system, the network protocol should guarantee the user convenience and maintainability. User wants to easily control and monitor NHAs with powerful user interface devices. Based on the above user requirements, HNCP is designed and implemented.

Ⅲ. KEY FEATURES OF HNCP

In this Section, the characteristics of HNCP are discussed. The key features of HNCP are as follows;

- Multi-master architecture
- Four-layered protocol structure
- Categorized address system
- The standard message set
- Simple network management
- The standard device-modem interfaces structure
- Simple flow control and error control

1. Multi-Master Architecture

HNCP has multi master architecture. In home environment, several home appliances, such as refrigerator, TV, remote controller, and PC have its own user interface, and they are very intelligent system that can control other devices, while, washing machine or micro-oven just respond the master's request. To guarantee the compatibility of the controlling and monitoring, only one control cycle is allowed in slave device. Figure 1 shows the multi master architecture of HNCP. TV, PC, refrigerator is master device, and the others are slave device. User can control

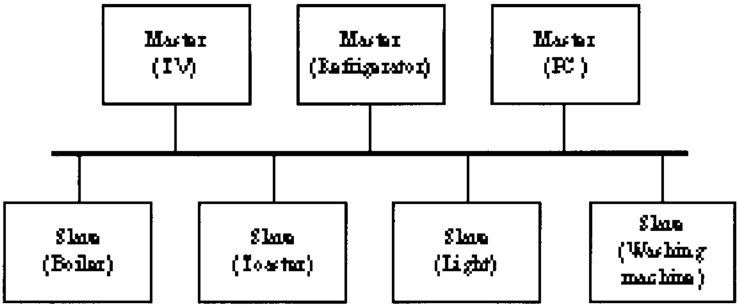

Figure 1. Multi-Mater architecture of HNCP

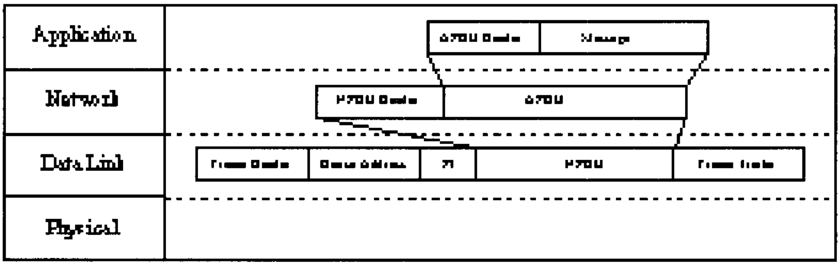

Figure 2. The protocol architecture of HNCP

toaster through master device, such as TV or refrigerator.

2. Four-Layered Protocol Architecture

HNCP is four-layer protocol, physical layer, data link layer, network layer, and application layer. However, to guarantee the flexibility of modem, physical layer and data link layer are not specified. HNCP only specified guidelines of these layers. And service data units of each protocol layer are encapsulated to guarantee interoperability. Figure 2 shows the protocol architecture of HNCP.

1) Data link layer

Data link layer of HNCP is not detailed specification. Only some guidelines are specified as follows;

- Because HNCP is multi master structure and immediate transmission is required, MAC sublayer should be Carrier Sense Multiple Access (CSMA).
- In MAC, Frame Check Sequence (FCS) should be added for frame error checking.
- Service data unit (SDU) of MAC contains House Address (HA), Packet Information (PI) and Network layer protocol data unit (NPDU).

Frame Header	HA	PI	NPDU	Frame Trailer

Figure 3. The SDU in MAC sublayer of HNCP

HA is 4 bytes address and is generated by network management. HA can differentiate own network and neighboring networks. If the HA of the received frame is not correct, this frame is discarded in MAC sublayer. This scheme can prevent the interference by the adjacent networks if no blocking filter is used. HNCP supports the recovery scheme of the HA collision with adjacent networks. It also can reduce the processing overhead of upper layers. PI is used for Initialization of the home automation system. Using PI, The Plug and Play (PnP) function will be implemented. Figure 3 shows the SDU in MAC.

2) Network layer

In network layer, three functions, such as address control, priority control, and error control, are provided as follows;

- Address control: The individual address and group address of this own node is memorized in network layer. The source address of the received frame is stored in slave device. This information is used when the response frame is sent back.
- Priority control: Priorities of frames are handled in network layer. In HNCP, four priorities are provided. The higher priority frame has, the faster and more reliable transmission is guaranteed.
- Error control: If the response frame of the transmitted frame is not received within a specific time interval, this frame is retransmitted. The number of retransmission time is limited within three.

By the bit operation of address field, three transmission services are provided as follows;

- Broadcasting service
- Multicasting service
- Unicasting

Four packet types are specified as follows;

- Request packet
- Successful Response packet
- Failed Response packet
- Notification packet

If packet type is request packet, the source address of the received frame is memorized to prepare the response packet. If packet type notification packet, the source address is not memorized, and no response packet is transmitted. The Network layer Protocol Data Unit (NPDU) is shown in Figure 4.

The components of NPDU are classified as

DA	SA	PL	NOpt	APDU

Figure 4. The NPDU of network layer in HNCP

follows;

1. DA/SA: Destination address and Source address that are memorized in network layer. Address flag and product code are included in first byte. Second byte is address from 0 to 255.
2. PL: The packet length of NPDU. Maximum packet length is 111 bytes.
3. Nopt: Network option is made as follows;
   - SP: Service Priority
   - NHL: NPDU Header Length
   - PV: Protocol Version
   - NPT: Network layer Packet Type
   - RC: Retransmission Counter is limited three.
   - PN: Packet Number of transmitting packet
4. APDU: Application layer Protocol Data Unit is explained the following Subsection.

3) Application Layer

Application layer provide message format. Through application layer, the application program in home appliances can control and monitor other home appliances. Response packet is added ACK/NAK field. If the packet is successful response packet, return arguments may be added, while error code is added in failed response packet. The message format of request packet and notification packet is composed of service code, command code, and input arguments. The standard message set of HNCP is presented in Subsection 3.4. Figure 5 shows the APDU format of HNCP

The components of ADPU are specified as follows;

- AL: The APDU length. Maximum packet length is 103 bytes.
- AHL : The APDU Header length for upgrade.
- AOpt : The APDU option is used for message set version and etc.
- SC : The Service code is used for describing the type of service that is served by application layer. Due to service code, the variable in command code field will be written with the following argument value, or read and responded to the master.
- CC : The command code is variable in the device.
- ACK/NAK : ACK or NAK will be added when the slave will be sent the response packet.
- Arg1: Arguments may be added if

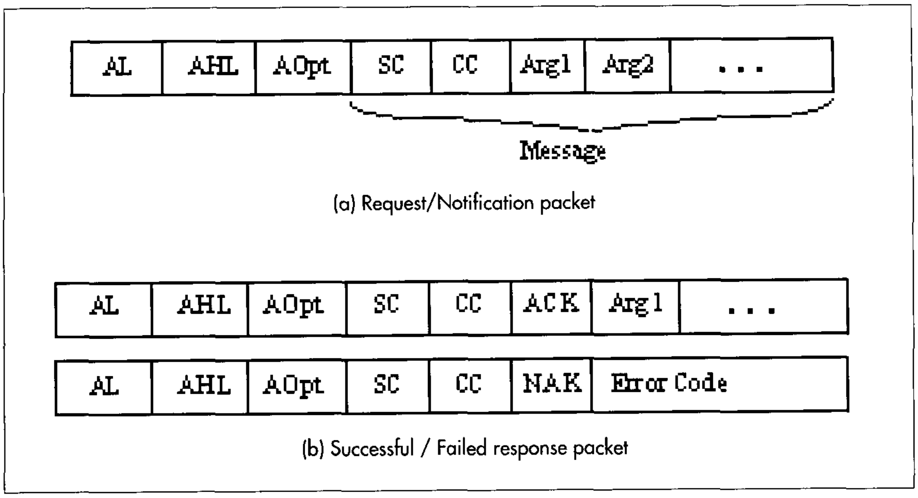

Figure 5. APDU format of Application layer in HNCP

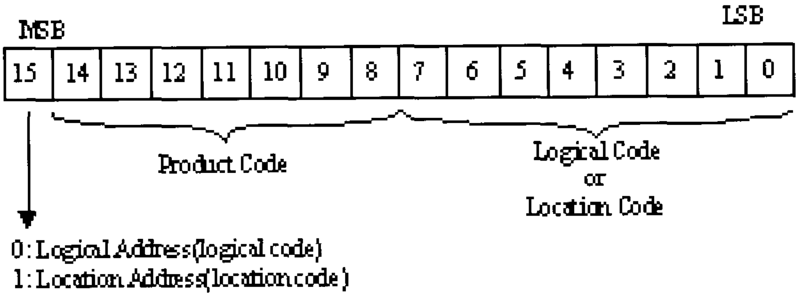

Figure 6. Categorized address system

necessary.

- Error Code : If the request packet is not received successfully or the device is unable to execute the command, the corresponding error code is responded.

3. Categorized Address System

The address of network node is categorized with product code, and location code or logical code that is defined by flag. Master can make group addresses by simple bit operation. Besides, product code is used to decide the type of message set. Figure 6 shows the structure of address field.

4. The Standard Message Set

Each message is composed of message code, input arguments, and return arguments. Message code represents command of action in home appliances. The received device may response with return augments if the request packet is executed successfully.

While, if the request packet may not be executed, the failed response packet is transmitted. Three message sets are classified in HNCP, general message set, device-specific message set, and network configuration message set. The common message codes used in mostly home appliances are formed a group as general message set. The common message codes of the specific devices are formed as device-specific message set. Network configuration message set is used for setting and maintaining their home network. Table 1 shows the part of the message set for air-conditioner

Table 1. The part of air-conditioner message set

CC	DATA	Description
0x00	0/1	Reserve
0x01	0/1	Power On/Power Off
0x02	0/1	Start / Stop
0x03	0-4	Operation Mode
0x04	10-40	Room Temperature
0x05	10-40	Target Temperature
0x06	0-4	Wind Velocity
0x07	0/1	Wind Direction Up/Down
0x08	0/1	Wind Direction Left/Right
0x09	0-7	Subscription Mode

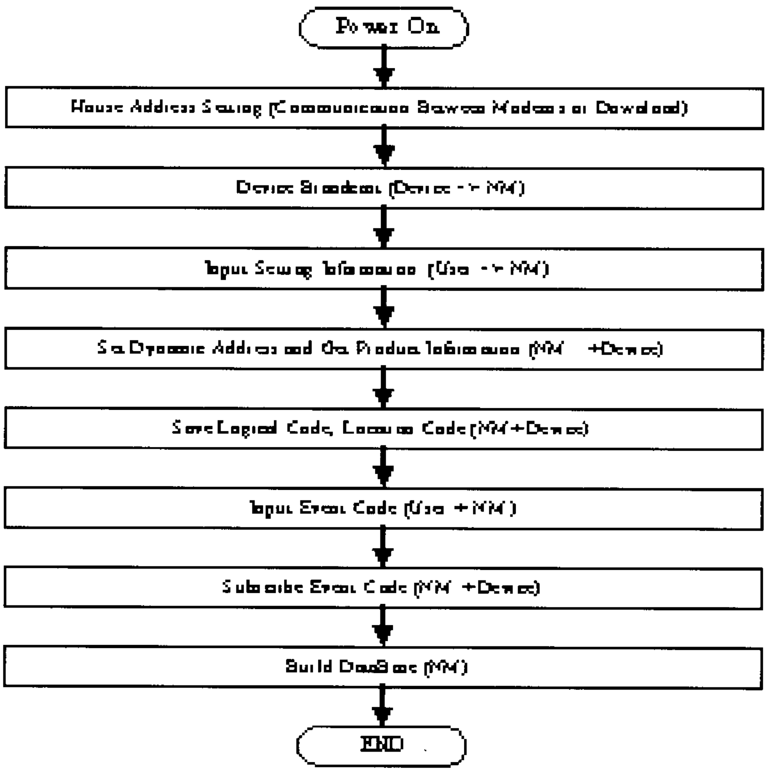

Figure 7. The flow chart of network configuration

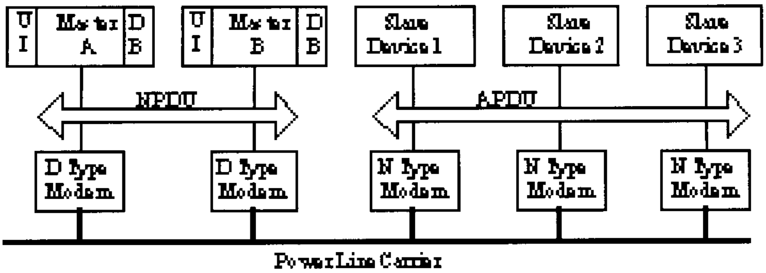

Figure 8. The example of the home automation system

5. The Network Management

Network management in HNCP is composed of initialization management, configuration management, and error management. For realization HNCP, configuration management is mainly focused in this paper. Configuration management and error management is operated by notification packets from NHAs

Figure 7 show the flow chart of the network configuration procedure that is executed before first initialization. At least one network management of master devices is activated and operated this procedure.

6. The Standard Device-Modem Interfaces Structure

In HNCP, standard device-modem interfaces are specified. Many NHAs have different ability. Master devices want to control and monitoring other devices. On the contrary, slave devices just react the master' s request. Simple devices like a light or a sensor do not have micro-controller, so the application S/W should be ported in modem and devices are just connected via digital I/O.

Thus, different modems can be used in one control network. To solve this problem, standard interface structure is specified in HNCP. The interface between device and modem is implemented by RS-232C serial communication.

The data format in the interface is APDU or NPDU through the types of modem. Before starting normal communication, the information of device and modem should shared each other.

In HNCP, N type and D type modems are classified to meet different home appliance' s ability. N type modem offers below network layer. D type modem offers data link layer and physical layer. Figure 8 shows the example of the home automation system implemented with HNCP, and Figure 9 show the data format of device-modem interface.

The components of interface data format are specified as follows;

- STX/ETX: The start and end of interface

STX	IPL	IPT	IPN	APDU or NPDU	CRC	ETX

(a) The interface data format

STX	IPL	IPT	IPN	CRC	ETX

(b) The ACK or NAK of interface data

Figure 9. The data format of device-modem interface

data are added

- IPL: The interface data length
- IPT: The type of interface data packet is specified in IPT field. ACK/NAK and initialization data packet types are specified.
- IPN: The interface data packet number is specified to identify the ACK/NAK packet.
- CRC: 1 byte checksum is used to check the error of device -modem interface

Ⅳ. IMPLEMENTATION OF HNCP

To prove the availability of HNCP, We implement a home server program and an appliance emulator based on HNCP. An air-conditioner is emulated. The home server program and the air-conditioner emulator are operated in PC. Figure 10 shows the mainframe of the HNCP home server. When a user wants to control and monitor a NHA, the corresponding device window is used. Figure 11 shows the device window in home server when an air-condition emulator is connected.

In the appliance emulator as shown in Figure 12, the received request packet is executed and the response packet is sent back to the home server.

Due to the home server and air-conditioner emulator, HNCP is proved its availability in the home automation system.

Ⅴ. CONCLUSIONS

In this paper, a HNCP is designed and implemented. It is based on user requirements of the home automation system based on PLC. The home server program and an appliance emulator based on HNCP are presented as implementation results.

HNCP guarantee the interoperability between various NHAs. Because HNCP is also very simple solution, the implementation cost is low, and the network overhead is

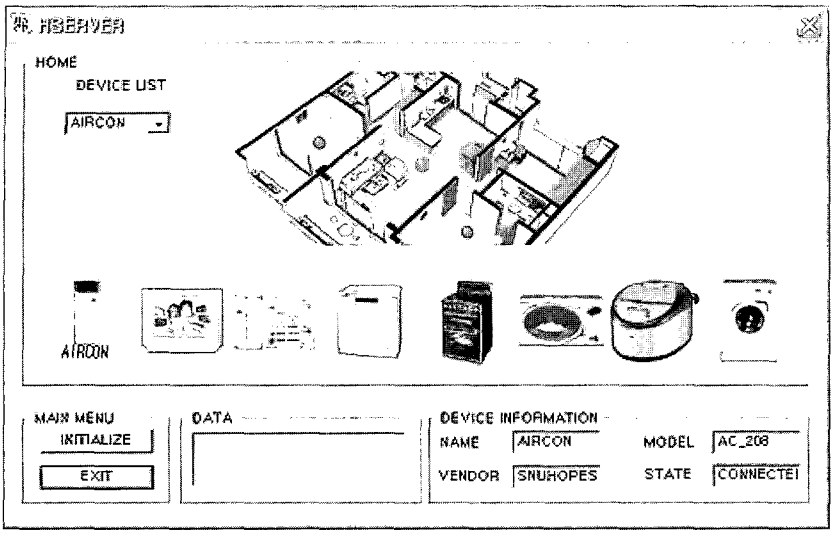

Figure 10. The mainframe of home server using HNCP

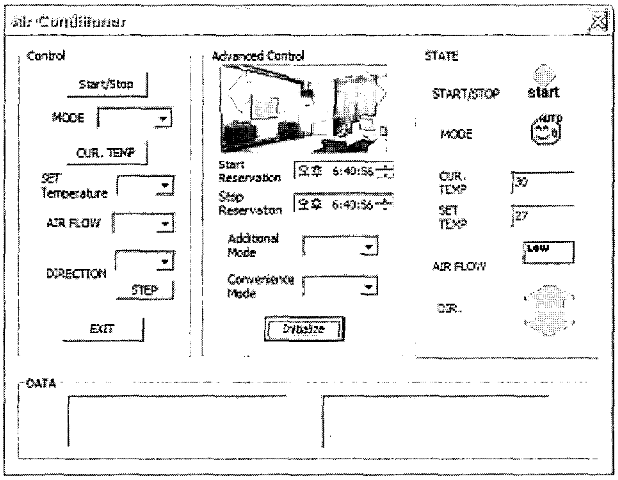

Figure 11. The device window in the home server

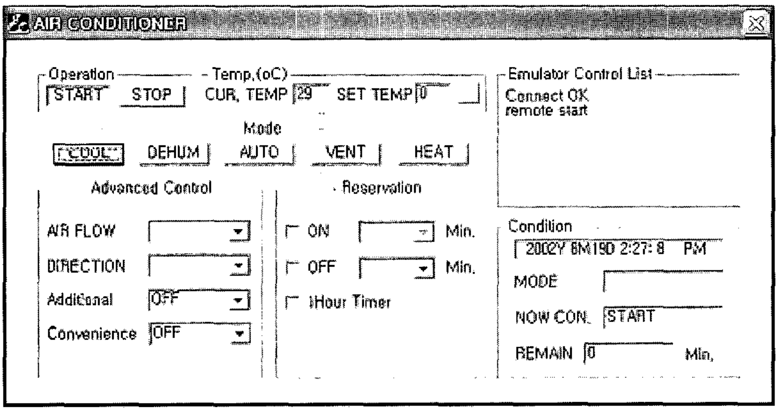

Figure 12. The mainframe of air-conditioner emulator

small. The results of this paper show the availability of HNCP in the home automation system.

In the near future, HNCP will be applied to commercialized NHAs. The overall home automation system using HNCP will be implemented.

To enhance the usefulness of HNCP, it is necessary to develop the bridge between HNCP and Internet protocol such as UPnP middleware. Encryption algorithm will be necessary to guarantee the safety of the home automation system.

Ⅵ. ACKNOWLEGMENT

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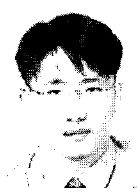
저자 소개



Jae-Min Lee was born in Korea on 1971. He received the B.S. and M.S. degrees in Electronics from Kyungpook National University, Daegu, Korea, in 1997 and 1999, respectively.

Since 1999, he pursues the Ph.D. degree from Seoul National University, Seoul, Korea. His main research interests are currently home network system and industrial networks.

Kwan Joo Myoung was born in Korea on 1972. He received the B.S. degree in electrical engineering from Hanyang University, Seoul, Korea, in 1995. From 1995 to 1999, he worked as a researcher at Daewoo Heavy Industries LTD.

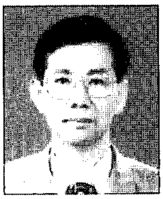
He received the M.S. degree in electrical engineering & computer science from Seoul National University, Seoul, Korea, in 2001. Since 2001, he pursues the Ph.D. degree from Seoul National University. His main research interests are currently the design and implementation of home network system.

Dong-Sung Kim was born in Korea, on 1969. He received B.S. and M.S. degrees in the Department of Electronic engineering from Hanyang University, Korea, in 1992 and 1994, respectively.

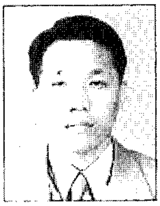
From 1994 to 1998, he worked as a full-time researcher in Engineering Research Center for Advanced Control Instrumentation at Seoul National University. Since 1998, he has been pursued a Ph.D. degree at EECS, Seoul National University, Korea. From 2000 to 2001, he was a part-time lecturer at Dongguk University, Seoul, Korea. His main research interests are currently the design of a protocol for network systems, scheduling of real-time communication, and networked control systems. He has been an IEEE/ACM member since 1998.

Wook Hyun Kwon was born in Korea on 1943. He received the B.S. and M.S. degrees in electrical engineering from Seoul National University, Seoul, Korea, in 1966 and 1972, respectively.

He received the Ph.D. degree from Brown University, Providence, RI, in 1975. From 1976 to 1977, he was an adjunct assistant professor at University of Iowa, Iowa City. Since 1977, he has been with the School of Electrical Engineering, Seoul National University. From 1981 to 1982, he was a visiting assistant professor at Stanford University, Stanford, CA. Since 1991, he has been the Director of the Engineering Research Center for Advanced Control and Instrumentation. His main research interests are currently multivariable robust and predictive controls, statistical signal processing, discrete event systems, and industrial networks.



Beom Seog Ko was born in Korea on 1958. He received the B.S. degrees in Mechanical Design from Seoul University, Seoul, Korea, in 1977 and 1981, and M. S. degrees in Automatic Design from KAIST, Seoul, Korea, in 1982 and 1984, respectively. Since 1984, he is Chief research engineer in LG Electronics Digital Appliance Research Lab. His main research interests are home network system and Building Management System.



Young-Man Kim was born in Korea on 1958. He received the B.S. degree in Electronics from Myongji University, Seoul, Korea, in 1977 and 1983. Since 1983, he is Principal Engineer in Air Conditioner R&D Group, SAMSUNG Electronics Co., Ltd. His main research interests are home network system.

Yohee Kim was born in Korea on April 16, 1944. He received M.S. degrees in electrical engineering from Yonsei University and the Ph.D. degree from Kyunghee University, Seoul, Korea in 1992 and was with KEPCO (Korea Electric Power Corporation) 15 years. He has been with KERI (Korea Electro-technology Research Institute) Changwon , Korea, from 1981 to 2001. Now he is executive director of KERI, Seoul, Korea, and Chairman of the PLC-forum Korea, from 2000 to 2001. His main research interests are currently optical communication and optical fiber system

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