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Abstract

This paper describes the design and implementation of the home network system using the home network control protocol (HNCP). The implemented home network system comprises a home server and emulators for networked home appliances (NHAs) such as a TV, a washing machine, an air-conditioner, and a microwave oven. Throughout the implemented home network system, the feasibility of the HNCP is shown.

1. Introduction

Home network is categorized by its application such as a multimedia network, a data network, and a control network. Among three networks, the control network is one of essential solution for controlling and monitoring the networked home appliances (NHAs). The control network in home network is defined as a home control network to differentiate the control network in industrial network in this paper. In a home control network, it requires a light resource overhead and low cost for NHAs operated on an 8-bit microprocessor. In addition, the interoperability bet

limited resources because CEBus has a common language interpreter like a common application language (CAL). Besides, the implementation is not cost-effective due to its structure and message specification [4]. LonTalk [5, 6] has been developed for the control network of the building and home automation. It supports for the OSI seven layers model. Although LonTalk is powerful for the building automation, this protocol had not been widely adopted to the home network due to its high implementation cost and the limitation of static network configuration. ECHONET [7] is one of good solutions for the home network. ECHONET has defined device object classes like messages. However, ECHONET needs large resources because ECHONET has full protocol stack including the communication middleware. EHS [8] is also one of good solutions for the provision of the overall home network. It provides object-based message sets for the home network. However, to implement a device, all of message-object should be considered and large resources are required since each user’s requests are made by the combination of the command messages and thus longer packets may be transmitted. Therefore, it is difficult to implement their message set to each NHAs. LnCP [4] is simple solution for the home control network. However, it is difficult to guarantee the interoperability with other vendor’s NHAs because LnCP has only vendor-specific message sets, and a device-modem interface specification is not specified. It is also difficult to easily extend and upgrade because each layer’s protocol data unit in LnCP is not encapsulated due to its mixed layering architecture.

A home network control protocol (HNCP) is one of good solutions for a low-rate control home network which requires a light resource overhead and low cost for NHAs operated on an 8-bit microprocessor[9, 10]. It has the four-layered protocol stack that provides flexible characteristics for easily upgrading and maintaining. It also provides a user-friendly interface to meet user requirements such as easy-installation, easy-understanding, and easy-
maintenance. For the interoperability between NHAs, the HNCP defines standard device message sets. The multi-master/slave structure in the HNCP is provided for the network maintenance, which enables one of home masters to take a role of the home server when the original one is broken down. This paper describes the design and implementation of the home network system using this HNCP. Throughout the implemented home network system, this paper shows the feasibility of the HNCP.

This paper is organized as follows. In Section 2, the overview of the HNCP is briefly presented. The design and implementation of HNCP and its home network system is presented in Section 3. Finally, a conclusion is given in Section 4.

2. The Overview of HNCP

The key features of HNCP are as follows[9, 10].

- Multi-master architecture
- Standard device message set
- Categorized addressing system
- Standard device-modem interface structure
- Four-layered protocol stack

In this paper, the detailed explanations are omitted.

2.1. Multi-master Architecture

The HNCP provides multi-master architecture. In home environments, several NHAs such as a refrigerator, a TV, a remote controller, and a PC have its own user interface, and they are intelligent system that can control other NHAs. These NHAs are defined as master devices. Among master devices, one master is served as a home server that is charge of the network management (NM) function. DB synchronization problem should be considered to support the multi-master architecture.

2.2. Standard Device Message Set

In HNCP, standard device message sets are specified for the interoperability and the simple implementation. The standard device message set is composed of single command messages, multi command messages, and network management messages. Each device message set has various commands that were used for COTS products. The supported messages can be defined in a device information file that can be downloaded by the internet web cites or the provided diskette. Standard device message sets will be periodically updated for future products.

2.3. Categorized Addressing System

The address of the HNCP network node is categorized with a product code, and a location code or a logical code as shown in Figure 1.

2.4. Standard Device-Modem Interface Structure

In HNCP, a standard device-modem interface is specified as a HNCP interface protocol (HIP) which is an additional protocol of HNCP. The interface between a device and a modem is generally implemented by RS-232C serial communication in low-rate PLC. In HIP, the request/response message with ACK primitives is used, and the HIP message sets for the initialization and the information exchange between the device and the modem are specified.

2.5. Four-Layered Protocol Stack

The HNCP has a four-layered protocol stack that is composed of a physical layer, a data link layer, a network layer, and an application layer. Protocol data units of each protocol layer are encapsulated as shown in Figure 2. To guarantee the flexibility of modem, the physical layer and the data link layer are not specified. The HNCP only specified the guidelines of these layers.

3. Implementation of HNCP and Its Home Network System

3.1. Implementation of HNCP
Figure 3 shows the HNCP structure in the case of D-type modem. As shown in Figure 3, the host and the HNM are connected each other through the RS-232 serial interface. In that case, to guarantee the interoperability between the host and the HNM, the HIP is supported. The HIP has the functions of host-HNM initialization, reliable and transparent communication, and information exchange between the host and the HNM. As shown in Figure 3, there are two processes. One is the HNCP frame related process such as APDU, NPDU, and DPDU. Figure 4 and Figure 5 show the HNCP frame Tx/Rx process in Host. The other is the HIP frame related process in serial interface between the host and the HNM. Figure 6 and Figure 7 show the HIP frame Tx/Rx process.

When a user commands a message, the message and the related arguments are appended into the HNCP Tx frame generation function like Figure 4. After completing the HNCP Tx frame generation process, it is appended into the HIP Tx frame generation function like Figure 6. In Figure 6, after getting the HNCP Tx frame, the packet length, and the packet type (N type or D type), the HIP generates and transmits the HIP Tx frame while it runs the ACK waiting function which is run for the ACK_Time_Out period. In the HIP, only one packet retransmission is allowed.

In the case that the host receives the packet from the HNM, the HIP Rx frame reception function in the host is firstly run. As shown in Figure 7, as soon as the packet is received, the HIP tries to verify whether it follows the HIP frame format checking STX, ETX, CheckSum, and PkLength. If there is an error and the type of the received packet is 'data', it transmits the NAK packet. If there is no error, it is saved into the ACK buffer or the data buffer following the type of the received packet.

In the case that the received packet is saved into the data buffer, it calls the HNCP Rx frame function like Figure 5. In Figure 5, the HNCP Rx frame function checks if the address is its own address. If the address is same to its own address, the packet is disassembled and finally the message and its related arguments are extracted and reflected into the user interface.

3.2. Implementation of Home Network System using HNCP

To prove the feasibility of HNCP, the home network system using the HNCP is implemented. Figure 8 shows the overall structure of the implemented HNCP home network system. It has a multi-master/slave structure including a home server, a TV master and four slave devices(two air-conditioners, a washing-machine and a microwave-oven). The used modems are operated on the base of CSMA/CA (MAC layer) and DSSS (PHY layer).

In Figure 8, the home server configures the network, controls/monitors NHAs, and manages the list and the database(DB) of NHAs. Figure 9 shows the functional block diagram of HNCP home server. The master device like a TV only has the functions of controlling/monitoring the slave devices. So, in the multi-master structure with a home server and a TV, the synchronization of the list and
to the home server and the master device is required.

To configure the network, the home server initially creates a house address (HA) to separate its own PLC home network from the other neighboring network. The creation of HA is achieved by one of auto-configuration and semi-auto configuration. In case of semi-auto configuration, it is assumed that a user already knows that there is no server in the network. So, when a master device with the network management (NM) function is connected to the PLC network, a user commands this master device to be a home server. Then the master device becomes a home server and creates the HA. In case of auto-configuration, when a master device with the NM function is connected to the PLC network, it broadcasts the HA request message. After elapsing some duration, if there is no response on the network, the master device judges that there is no home server. So, it becomes a home server and creates the HA. After completing the auto/semi-auto configuration, when a device is newly added to the network, the home server assigns the HA and the logical/location address to the device and gets the DB information of the newly added device from the diskette or the internet URL. The DB information has the XML format and it is interpreted by the XML parser in the home server. Figure 10 shows an example of XML file of an air-conditioner. After the completion of this process, the device is added in the device list with the home server.

To control and monitor the NHAs, the home server uses three message types such as unicast, multicast, and broadcast. Unicast message is used to control devices and receive the message from slave devices. Multicast message is used to synchronize the database between a home server and master devices, or execute user-convenience functions. For example, in the case of multi-master/slave structure, when a home server updates the device lists, it sends the updated device lists to the master devices using the multicast message. In the case of user convenience, if a user wants to set the temperature of air-conditioners to the same degree, he/she can easily do it using the multicast message. Broadcast message is used to the cases of a search message by a home server and a notification message by a slave device. Figure 11 shows the mainframe of the home server and the device dialog on the home server's mainframe. Figure 12 shows emulators of NHAs which are slave devices.

To manage the list and the DB of NHAs, in a home network system, it is important for a home server to judge if there exists a device on the network. For that, in a HNCP home network system, two methods are used like the following.

- A home server periodically checks the existence of device using the search message. If a device doesn’t reply against the search message till the same periods are expired, the home server judges that the device with no
reply is not in the network and the home server deletes it in the list.

- When a device leaves the network, it broadcasts the leave message and a home server deletes the device in the list and updates the list.

To synchronize the list and the DBs between the home server and the master devices, multicast/notification messages are used. In the case of the synchronization of the list, whenever the list with a home server is updated by device addition or deletion, the home server sends a multicast message to the master devices, and thereby the master devices update the list with them. In the case of the synchronization of the DBs, whenever the status of the slave devices is changed by request messages or some events, the slave devices broadcast a notification message, and the home server and the master devices in the network update the DBs with them.

Figure 13 shows the demonstration of HNCP home network. The black box in right of each emulator is a HNCP modem. Through the implemented HNCP home network system the feasibility of HNCP is shown.

4. Conclusion

HNCP is one of good solutions for a home control network which requires a light resource overhead and low cost for NHAs. In this paper, we showed the feasibility of the HNCP through the implementation of the home control network system which has multi-master/slave structure such as a home server, a TV master, and four slave NHAs (two air-conditioners, a washing machine, and a microwave oven).

To enhance the usefulness of the HNCP as commercial products, two parts should be considered. One is the interconnection between the HNCP network and the heterogeneous networks through the gateway. At present, the development of the gateway between the HNCP and the middleware protocol such as UPnP[11] and OSGi[12] have been implemented. The other is an encryption algorithm for the safety of the home control network system, which will be added and implemented in upgrade versions.

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References

Figure 10: The XML file of air-conditioner

```
<device>
  <deviceType>AC-Conditioner</deviceType>
  <deviceCode>AC123</deviceCode>
  <manufacturer>Household Appliances</manufacturer>
  <name>SDL - AC123 frame</name>
  <GPLR:00:00:00:00:00:00/16 (GPLR)
  <contactID>873-2279/2-contac</contactID>
  <family>AC-Conditioner</family>
  <model>GL-AC123</model>
  <modelNumber>HL-123</modelNumber>
  <description>GL-AC123</description>
  <homeSystem>HL-123</homeSystem>
  <serialNumber>123456</serialNumber>
  <controlMethod>LonTalk</controlMethod>
  <controlType>AC-Conditioner</controlType>
  <valueType>OtherValue</valueType>
  <commandCode>123456</commandCode>
  <commandValue>OtherValue</commandValue>
</device>
```

Figure 11: The mainframe of a home server and device dialogs


