Home Station, Novel Architecture of Home Gateway and its implementations
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Abstract: - Although a number of home networking solutions such as wired and wireless technologies, middleware technologies, and home gateway technologies have been emerging, none of them dominates the home networking market with satisfying users’ demand on higher quality services. Especially in the home networking environments where diverse technologies coexist, the digital convergence is the important functionality that a home gateway should support. In this paper, Home Station, a novel architecture of home gateway, that can solve this problem and serve various functions including process of multimedia data, control and monitor of devices, discovery of devices, and management of home network, is proposed.

Key-Words: - Home Station, Common Protocol, Home Gateway, Residential Gateway, and Home Network

1. Introduction
As Internet that only particular group had used became popular among many unspecified persons, the demand of the users and the market came to increase dramatically. From simple improvement of the connection speed to development of wireless connection, it is not too much to say that a lot of effort has been put into developing technologies for users’ conveniences. Recently, the desire for more convenient life such as communicating, controlling and monitoring home electronic devices from other electronic devices located anywhere is growing more than PC-oriented Internet services. While current home network technologies have been developed for their own specific services respectively such as controlling services, A/V streaming services, data exchange services, and so on, which caused a home gateway to support a variety of technologies and to have higher processing power, the future home network technology will open an era of digital convergence when newly developed technologies will be compatible with the existing technologies. Till now, however, home gateway has been developed focusing on PC, digital settop box, and IP-based home gateway platforms. Existing home gateway is a system that goes through complicated process such as protocol conversion by using software and is developed only for certain services. In this paper, the problems of current home networking technologies are considered. And then, Home Station System, a new home gateway that has various functions to satisfy the demands of users and requirements mentioned in [1] is proposed.

2. Problems of Home Networking Technologies
Though various wired and wireless technologies have been developed or in the process, none of these has been chosen as an international standard of home networking until now. Most of home networking technologies including home gateway technologies are becoming de facto standards rather than international standards by the linkages of the companies and their governments in the common interests. Moreover, each home gateway technology is developed aimed at only a certain service application such as A/V streaming service between IEEE1394 and IEEE802.11b[2], simple interconnection of home network and the public access network[2], packet processing algorithm in a home gateway[3], energy management[4], and device controlling service. Thus, there is no powerful technology that is able to satisfy user-oriented high-quality services. In other words, it is the biggest problem in the current home networking market that killer application cannot emerge due to the emergence of too many technologies and the subsequent difficulty
in making an international standard among them. For several years from now on, in the area of wired and wireless home networking and home gateway technologies, it is expected that some of them that have substantial effects technically and economically in the market will be de facto standards and be used reciprocally. When we take into account the market hereafter and the demand of users, however, it will have only short-term effect to make de facto standards by integrating some specific technologies and using them. For the long-term effect, a new technology standard that can accommodate all of those technologies will be needed. Therefore, it is urgent to make technical standards of new middleware and gateway for home networking that can combine all existing technologies with maximizing their strong advantages and making use of them reciprocally.

3. Home Station

As mentioned above, a new technology, which is able to guarantee compatibility and connectivity among heterogeneous networks and devices in them, has not emerged yet. Also high-speed hardware platform that is able to accommodate high-speed multimedia service oriented to home entertainment, which is considered important to households, has not been developed, either. Current home gateway systems in the market have been developed on PC-based or STB-based platforms and support only a specific protocol such as IP. However, while the processing speed of CPU has almost reached to the point of saturation, transmission speed of upcoming networking technologies are expected to catch up with the processing speed of CPU by experts, which brings the need of development of new architecture of home gateway system rather than PC- or STB-based home gateway system.

Home Station is a new home gateway system that guarantees compatibility and interconnectivity among various existing home network technologies as well as upcoming home network technologies, and has the capacity to process high-speed multimedia data.

3.1 Approaching method for structure design

Home Station is one of home gateways that can be set up in households and offices. It accommodates various wired and wireless interfaces thoroughly with its connectivity and compatibility, and supports functions of controlling and monitoring devices as well as A/V streaming services. It is also able to perform entertainment functions essential to the next generation home networking services. For this, Table 1 shows service functions required in the home network, which are the most important points for designing architecture of Home Station, and implementing methods.

Table 1. Approaching method for designing Home Station architecture

<table>
<thead>
<tr>
<th>Service Function</th>
<th>Realizing method</th>
</tr>
</thead>
<tbody>
<tr>
<td>connectivity compatibility</td>
<td>Insertion of Universal Home Control Protocol</td>
</tr>
<tr>
<td>controlling and monitoring of devices</td>
<td>Design of Universal Home Control Protocol</td>
</tr>
<tr>
<td>Real-time multimedia service</td>
<td>High-speed switch or bus system Bandwidth management QoS function</td>
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<tr>
<td>Internet service</td>
<td>Management of IP address resources</td>
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<tr>
<td>PnP</td>
<td>Common Protocol signaling related to device registration</td>
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<tr>
<td>Home network management</td>
<td>Common Protocol signaling related to home network management</td>
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<tr>
<td>Security function</td>
<td>Realizing user authentication and security function</td>
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</table>

3.2 Architecture of Home Station

Fig.1 shows overall architecture of Home Station and protocol stacks that are placed into each functional block of Home Station. First, Common Protocol layer has inserted at the bottom of application layer to support compatibility and interconnectivity among various protocols. Application program is to send data of application layer to Common Protocol layer through API that Common Protocol provides. Other functions that are provided by Common Protocol are lower layer interface function that interfaces between Common Protocol layer and lower protocol layers, traffic management function, home network management function, resource management function, and Common Protocol addressing function. Though other devices use different network addresses, by using Common Protocol address in the application layer, a device connected to Home Station is aware of their existence and is able to locate them and to communicate with them without difficulty.
When it comes to the structure, Home Station consists of several interface card modules for accommodating network physical interfaces and Home Station Internal Processing (HSIP) module for switching data, controlling devices, and overall management. All these card and HSIP modules have linkages with one another through a Common Bus[5] on a backplane. One card module can be divided into Gateway Interface (GI) block and HSIP interface block. GI block supports protocol layers of a specific network protocol and processes an incoming packet from physical to network layer. And then, it extracts Common Protocol packet and delivers it to HSIP interface block. HSIP interface block notifies Common Bus Controller that a packet has arrived and waits until permission signals for Common Bus usage is activated. After receiving bus grant signal from Common bus Controller, HSIP interface block can send the Common Protocol packet to the HSIP module.

In HSIP module, address conversion block extracts a destination Common Protocol address and searches a real physical or network address of a destination device corresponding to the destination Common Protocol address. Traffic management block stores an incoming packet to one of three class buffers according to the packet priority and sends packets to the Common Bus controller one by one according to the QoS algorithm. Finally, Common Bus controller forwards an input packet to a destination card module and also notifies the physical or network address of a destination device. In the destination card module, after being processed in the GI block, Common Protocol packet forwarded by Common Bus controller can be sent to a destination device through physical layer by using a physical or a network address of a destination device. Fig.2 depicts these packet delivery procedures between two devices in heterogeneous networks.

### 3.3 Interface Card Module

Fig.3 and Fig.4 show detail structure of interface card module and Streaming Gateway Interface(SGI) card module for MPEG stream service. An FPGA chip of card module is internally composed of SPR for checking status and setting of Common Bus interface and card module, Common Bus interface for signalling with Common Bus controller in HSIP, and control signal generator that generates various control signals. In SGI, FPGA block is built additionally which converts inputted LVDS MPEG signals to MPEG TS packet of 188 bytes.
3.4 HSIP Module

As Fig. 5 shows, HSIP has four FPGA modules, and consists of Common Bus controller that generates signals related to Common Bus, traffic controller for rate-limiting of input traffic, SPR for checking and setting HSIP status, and address table controller for changing a Common Protocol address in a Common Protocol packet into a physical or network address of a destination device. CPU block gets interrupt signals generated in SPR and processes management packets for PnP, home network management, and device control.

3.5 Home Station System

Fig. 6 represents an experimental prototype of Home Station system. Maximum seven interface card modules and one HSIP module can be connected to Common Bus through connectors on a backplane. Common bus is designed as 100MHz 32-bit parallel bus and theoretically supports 3.2Gbps throughput. Each interface card module that wants to make use of Common Bus observes IDLE signal which represents the status of bus usage. When common bus is not used, it activates /REQn (n : the number of interface card modules) signal. In Fig. 7, the Common Bus arbitrator in Common Bus controller calculates priority of each card module and activates only one of /GNTn signals. During bus transaction, Common Bus controller updates the priority of each card module and prepares next bus transaction. Basically, Common Bus arbitrator is designed to guarantee fairness arbitration.
4. Experiment of Home Station

As shown in Fig.8, For conducting an experiment of Home Station, four different traffic sources are generated simultaneously and sent to Home Station. Firstly, we played two DVD movies from two DVD players in two PCs respectively then linked one source to one PC that is connected to IP network and the other one to two PDAs that are connected to wireless LAN network by using broadcasting method supported by Home Station. Secondly, we tested two VoIP Phones connected to different interface card modules. Lastly, we also sent video streaming of a camcorder connected to IEEE1394 network and displayed it on a PC connected to other interface card module. As a result, we checked that all the video and audio traffic reached to the destination without packet loss and played in real time, and that various additional functions of Common Protocol and Common Bus worked properly.

5. Conclusion

In this paper, we proposed Home Station as a home gateway with new architecture, which guarantees connectivity and compatibility among heterogeneous networks in the home. Home Station offers multimedia service focused on home entertainment, user-oriented functions of controlling and monitoring home electronic devices, and functions of managing home network. Structurally, card modules in Home Station are scalable and expandable, which can interconnect all network interfaces regardless of wired and wireless interfaces. We also confirmed the suggested architecture of Home Station and Common Protocol installed in it worked properly through implementations and experiments. Currently, we are designing interface card modules that are able to support more various kinds of network protocols as well as low-cost switching chip supporting high-speed full-mesh switching method in order to replace 32-bit parallel bus in backplane.

References: