The Sensor Network based Home Control System: Supporting the Next Generation Home Gateway System for a Ubiquitous Home Environments

Young-Choong Park, Yang-Keun Ahn, Kwang-Soon Choi, Kwang-Mo Jung, and Seong-Dong Kim, *Member, IEEE*

***Abstract* — Fruition for a diverse uIT(Ubiquitous Information Technology) service is currently required through the convergence of what is known as ubiquitous computing technology. In recent years, with the rapid growth of the need for information services, heavier demands have been made upon the supply of high-quality multimedia services that require a high bandwidth. Today, various home network solutions have been proposed to manage these service smoothly and a system able to deal with various types of network traffic without delays. In addition, in established home network environments that mix wired and wireless networks, along with the steady evolution of wireless network technology and the earnest development of ubiquitous computing technology, sensor-based wireless networks have emerged as a core solution for home networks. In this paper, a sensor network-based home control system supporting the next generation home gateway system for ubiquitous home environments is designed and implemented.**

***Index Terms* — Ubiquitous Home System, Wireless Sensor Network, Home gateway, HIES**

I. INTRODUCTION

Various attempts have been made to provide diverse uIT(Ubiquitous Information Technology) services with the convergence of the ubiquitous computing technology in Korea. Examples include ubiquitous solutions such as U-Home, U-City, U-Defense, U-Medicare, and U-Apartment, which extensively serve a wide swath of modern society. Above all, a branch of home network that has completed the research stage and seen profitable projects is mixed ubiquitous technology [7]. This area is beginning to take shape. Its realization will comprise such developments as a multi-function and networks that include information appliances, as well as the convergence of intelligent technology in these areas. It will be realized as an efficient control system of converged and intellectual digital appliances, offering suitable content for an advanced digital appliances and the development of processing technology [5]. In addition, due to the rapid growth of user requirements for information services in recent years, increasing demands are now made on the supply of a high-quality multimedia services that require high bandwidth. Today, various home network solutions have been proposed to manage these services effectively, including high-performance home systems that offer high-quality multimedia service smoothly and a system able to deal with various types of network traffic without delays. In addition, in established home network environments that mix wired and wireless networks, along with the steady evolution of wireless network technology and the earnest development of ubiquitous computing technology, sensor-based wireless networks have emerged as a core solution for home networks [1].

In this paper, HIES(High-performance Interconnection Extendable Subsystem), a platform of a next-generation home network supporting the ubiquitous home network environment is introduced. The design, implementation and testing of this sensor network-based home control system is made using a sensor network that is considered a next-generation wireless network interface.

This paper is organized as follows: in Section II, the requirements and system architecture for the next-generation home platform is discussed through related work. In Section III and VI, the HIES system, the hardware architecture and the operation of the HIES ANIC Sensor Interface Board for the sensor network-based home control are discussed. Section 5 introduces a software module and GUI for this sensor network-based home control, and a virtual ubiquitous house for each instance of module operation verification is established. Finally, the paper concludes with a brief summary and a description of future work in Section 6.

II. RELATED WORK

Sensor network-based home network systems have emerged as a core infrastructure for a ubiquitous network technology with the growth of ubiquitous computing technology. The objective of the ubiquitous network technology it to offer flexible communication to anyone, anywhere, anytime through a wireless network as a sensor network, using wireless LAN, UWB and similar systems. The accommodation of these next-generation wireless network interfaces has emerged as a core network solution of the coming ubiquitous society. Therefore, the de-

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velopment of services forming the basis of this network infrastructure is necessary. On the application system side, flexible control via a wireless network as well as various types of entertainment services that can include the transmission of very large multimedia data streams via wireless networks is required [4]. For this reason, the server required for a ubiquitous society must be able to process a great amount of multimedia data through various types of realistic interfaces (e.g. realistic networks, realistic GUIs) at high speeds.

2.1 Requirements for the Ubiquitous Home System

As shown from the above studies, a great deal of research has been undertaken in areas related to home gateways and servers for multimedia transmissions in heterogeneous home networks. This indicates the development of NGHP in these environments.

NGHP is taking shape as an integration station that combines a set-top gateway and a multi-service gateway. It is becoming a digital convergence media gateway that combines the abilities of the set-top, broadband modem, home networking and IP streaming. It also has the set-top box function of providing services such as HDTV, Content Protection, PVR, Web browsing and Interactive TV, along with the transmission of data, voice and entertainment. In order to have the aforementioned functions, there are several requirements for NGHP:

- Universal networking platform based on open architecture
- NGHP needs data communication between heterogeneous networks and the communication platform for an open architecture supporting many-to-many communications [2].
- Multimedia data switching architecture
  Given that various types of stream sources, such as audio, video, control, data and voice are present in the Internet environment, the switching architecture requires features such as data-capability, real-time switching, delay switching and a mechanism that can switch between channels [3].
- QoS architecture based on next-generation services
  As various types of multimedia data are present in a home, NGHP should classify and process heterogeneous traffic [6].
- Common connectivity standardization
  NGHP requires the modularization of the internal functions of the gateway and network interface as well as common connectivity standardization to be able to connect universally.

The architecture of the NGHP considering the above proposed features is illustrated in Fig. 1.

III. The Proposed HIES System

In this section, a HIES system specified for high-speed data processing using a switching chip and a high-tech wireless network is described.

Fig. 1 shows the HIES system. It consists of a high-speed switching module with six ports and a multimedia of ANICs. As the switching module and HIES ANIC entrain a near-term network interface, it is designed and implemented as a possible scheme for a high-speed and high-quality multimedia service in a ubiquitous home environment. The hardware and switching fabric specifications of the HIES system are illustrated in Fig. 1 [8, 9].

Fig. 1. HIES System

IV. Sensor Network-based Home Control System

Section IV described a HIES system for a high-speed switching. This is a next-generation home gateway for a ubiquitous home environment and a home control system for a sensor network included with the HIES system. This system consists of the following sub-modules: a sensor network-based ANIC module composed of a HIES ANIC Bridge Board and a HIES ANIC Sensor Interface Board, a HIES GUI module as a home control mechanism in a ubiquitous home, a WLAN-based HIES ANIC module for command data processing transmitted to a wireless network in a ubiquitous home, and a sensor network-based home control system including the HIES system for high-speed switching.

4.1 HIES ANIC: Sensor Network-based ANIC Module

A sensor network based HIES ANIC module was created using a StarFabric bridge chipset. Fig. 2 shows a block diagram of the sensor network-based ANIC module and the designed hardware. This module is composed of the following components: a division of a StarFabric Bridge Chip, a division of a LVDS Interface, a division of a CPU using the IXP425 Integrated Chipset, and a division of a PCI Interface. The StarFabric Bridge Chipset makes use of the SG2010 Chip [10]. The StarFabric Bridge Chipset is connected to a PC and an IXP425 network processor, and the LVDS signal is attached to the HIES High-speed switching board through an ERmetZD High-speed Connector.

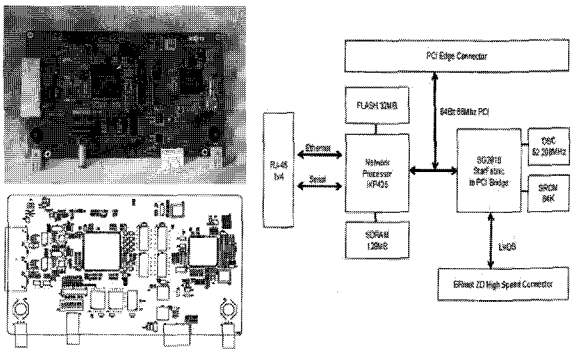

Fig. 2. HIES ANIC Bridge Board

The PCI Interface supports PCI 2.2, and the PCI Bus supports both the 33MHz 32bit mode and the 66MHz 64bit mode.

A HES ANIC Sensor Interface Board is able to connect to a HIES ANIC Bridge Board using a PCI connector to expand its sensor network interface. In this module, as an input/output serial signal is a TTL lever, it is bound to need the chip for convergence to the RS232 Level. Data communication of this module connects externally to the RJ-45 port of an interface card, and direct communication is made to a Bridge Board through a JTAG Pin that does not use PCI signals.

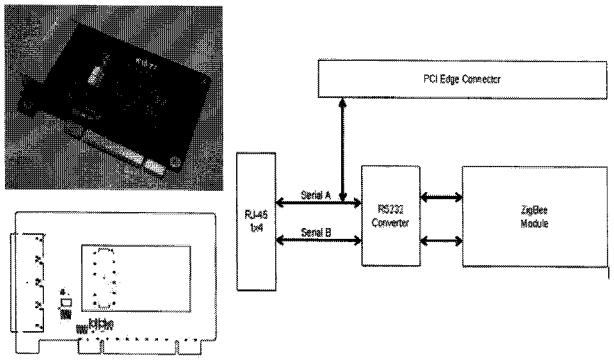

Fig. 3. HIES ANIC Sensor Interface Board

4.2 HIES GUI: Making a Home Control Service for a Ubiquitous Home

Fig. 4 shows a Home Control PAD that information appliances such as a refrigerator, television, gas monitoring system, lamp control system, automatic curtains and door locks can use in a ubiquitous home. Ordinarily, it utilizes a key as a digital album located in a desk or on a shelf; if a user needs to control of appliances, it is designed to control appliances via a home control PAD using an easy button operation.

A HIES GUI for home control is a dialog-based program using eight buttons for the home control system. The main display background is a bitmap at a resolution of 800X480. For this reason, the HIES GUI supports many user-friendly control environments. In addition, it continually displays the On/Off command using a flag on each control button. Fig. 5 shows the HIES GUI Operation Procedure and surveys this step by step.

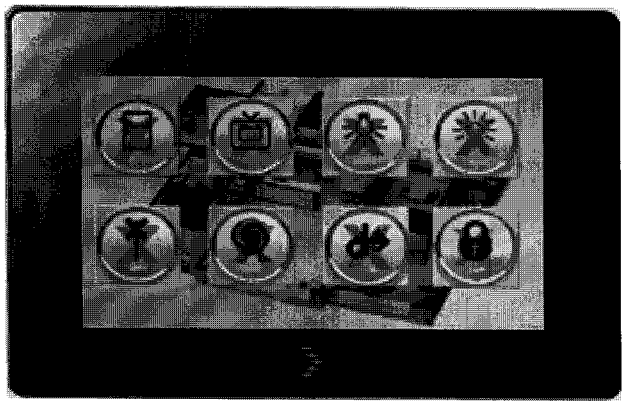

Fig. 4. HIES GUI for Home Control using a Digital Album

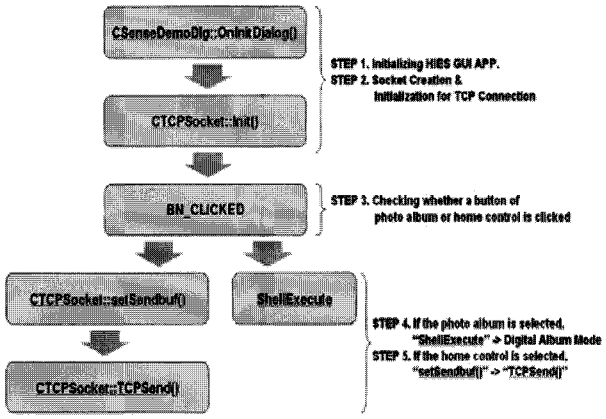

Fig. 5. HIES GUI Operation Procedure

HIES GUI Operation Procedure

STEP 1. Initializing the HIES GUI application
STEP 2. Socket Creation & Initialization for TCP Connection
STEP 3. Verify whether a button of a photo album or A home control is clicked
STEP 4. If the photo album is selected, "ShellExecute" -> Digital Album Mode
STEP 5. If the home control is selected, "setSendbuf()" -> TCPSend(): Transfort On and Off command to HIES System through TCPSend()

4.3 The Sensor Network-based Home Control System

This section describes a sensor network-based home control system in terms of the developed Sensor Network-based HIES ANIC Module and the HIES GUI Module. This system is composed of the following sub-modules: a HIES GUI using a mobile PC and a digital album, a WLAN-based HIES ANIC Module, a HIES System, a Sensor Network-based HIES ANIC Module and a Ubiquitous House constructed as a proxy of a virtual home. A linecard of an internal HIES system and a switching board is attached to a high-speed serial link that has a 5 Gbps line speed. This transmits a multimedia stream. In addition, a home control system as a sensor network-based information appliance control was created using a mobile PC and digital album embedded with a HIES GUI. Windows XP and Embedded Linux are used as the operating systems.

UDP2ZigbeeX: Control Message Transmission Procedure for Appliance Control

STEP 1. UDP Socket Creation & Binding
STEP 2. int_serial: Initialization of a serial port
Loop :
STEP 3. Comparing the received UDP payloads
STEP 4. Selecting the ZigbeeX Command
STEP 5. Data Transmission to Serial Port: write_to_serial()

STEP 6. Message writing: parameter
"TOS_MsgPtr pmsg", "unit8_t length"

The HIES system is loaded with a HIES ANIC embedded with a SG1010 switching chipset and a SG2010 bridge chipset. It also utilizes a StarFabric driver for the HIES ANIC control. It must have a software module, which in this case is a WLAN Driver, as well as TC2UDP, UDP2SF, SF2UDP and UDP2ZigbeX to govern information appliances in the home by transferring control commands to the HIES system using the HIES GUI. Through these software modules, wireless data communication is feasible by controlling the SG2010 and SG1010 chips embedded into the HIES ANIC and HIES System at the driver level. Fig. 6 shows the operation procedure of this system, and describes the UDP2ZigbeX component that controls message transmissions for controlling appliances.

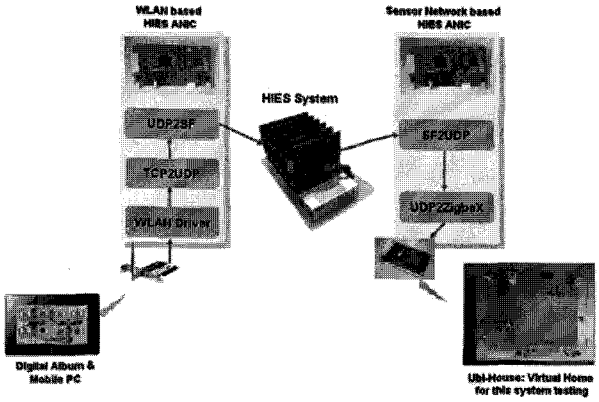

Fig. 6. The Operation Procedure of the Sensor Network-based home control

V. Testing for a Sensor Network Based HIES System

A HES System is a high-speed switching-based home gateway system. Fig. 7 shows the test-bed used for verifying this system.

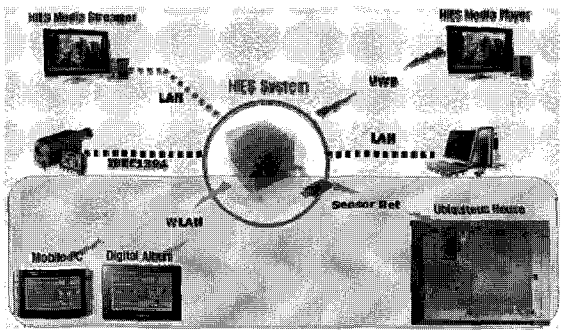

Fig. 7. Home Control Testing and Sensor Network

For an operational inspection of this system, an experiment was conducted that simultaneously tested a media stream transmission using UWB, a real-time digital image transmission using IEEE1394, and a home control using Sensor Network.

First, for the media stream transmission test using UWB, a media streamer and a media player was loaded into the HIES system, and the media stream transmission was run by connecting a UWB module to the HIES system and the PC loaded with a media player processing high-speed wireless data communication. Second, in order to test a real-time digital image transmission, video was created using a camcorder, and an examination was conducted by transferring this video via IEEE1394. Finally, in order to test for a home control using the sensor network, a digital album loaded into the HIES GUI was connected to a WLAN network, home devices of a ubiquitous house including a door lock, refrigerator, and television were controlled via the HIES GUI.

VI. Conclusion and Future Work

In this paper, the HIES system, a next-generation home network platform supporting a ubiquitous home network environment, is introduced. In addition, a sensor network-based home control system was designed and implemented. It uses sensor network technology to support this system.

In the near future, based on the diffusion of ubiquitous computing technology and home-network technologies, users will require the ability to access present appliances ubiquitously from anywhere, anytime. Thus, the end-to-end connectivity between appliances inside the home is possible, in which all information transported will be multimedia data.

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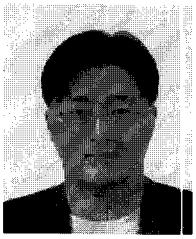

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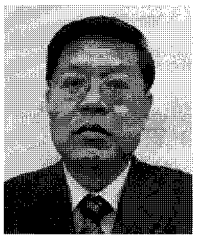

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