지능형 디지탈홈을 위한 콤퍼짓 센서제어네트워크 및 테스트베드의 연구

이 규 호*

A Study of a Composite Sensor and Control Network and Its Test-bed for the Intelligent and Digital Home

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요 약

네트워크 기술이나 반도체 집적기술, 그리고 임베디드 시스템 기술의 발달로 넓은 범위의 영역에서 센서네트워크 활용이 가능해졌다. 따라서 센서네트워크는 그것이 적용되는 응용분야에 따라서 여러 가지 형태와 차별화된 특성으로 다양화되고 있다. 지능형 디지털 홈은 고유한 특성의 센서네트워크를 구성할 수 있는 한 분야이다. 본 논문에서는 컴퍼짓 센서 및 제어 네트워크를 제안하고, 이의 차세대 지능형홈네트워크 적용에 대해 논의한다. 또한 제안된 네트워크의 개발결과와 이를 기반으로 한 지능형홈서비스, 그리고 가상시험환경인 테스트베드의 개발결과를 제시한다.

ABSTRACT

Advances in technologies of networking, chip integration, and embedded system have enabled sensor networks applicable to a wide range of areas. Sharing some common characteristics, sensor networks are thus diversified in features depending on their applications. An intelligent and digital home can be one area to establish a particular feature of sensor network. This paper proposes a composite sensor and control network, and discusses its applying to the next generation intelligent and digital home. Development results of the network and a test-bed as a virtual test environment are also presented. The proposed network can not only be efficiently applying to achieve new home intelligences but also provide a sound solution to maintenance and operations of home network or devices.

키워드

Sensor Network, Intelligent Home Network, Context Awareness, Node, Platform, Test-bed

Ⅰ. Introduction

Advances in such technologies as networking, chip integration, and embedded processors have enabled sensor networks applicable to a wide range of areas. Sharing some common characteristics, sensor networks are thus diversified in features depending on applications. An intelligent and digital home can be one domain to establish a sensor network featured particularly[1][2].

An intelligent and digital home network is a typical

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digital convergence which combines home devices for providing emerging new services: home education & entertainment, home office, home automation & control, information access, etc[3][4]. In order to implant intelligence to the home, all devices placing at the living home area have to be connected anyways to a central control point. Such a connection can be considered as a sensor network; each node becomes sensing points and a user gathers sensed data to be aware of home situations.

A typical wireless sensor network consists of a large, sometimes huge, number of nodes which are capable of taking environmental measurement such as temperature, light, humidity, etc. These nodes transmit wirelessly their sensed data to a running application that makes decisions based on these data. One node included in a sensor network is charging with a gateway which extends a communication path to the IP core network. These aspects of the wireless sensor network bring such challenging issues as management of limited power and storage[5][6], routing path establishment and topology management[7], etc.

Intelligent and digital homes, however, are in different features from the typical wireless sensor network. Sensing is required mostly inside of home devices, and the devices communicate with outside service networks as well as with each other through home networks. One home device thus normally contains one networking node which a not large number of sensors directly connect to, while one gateway and a large number of sensing nodes constitute a typical sensor network. In addition, the home network usually requires an opposite communication path, as a control channel, which transfer user requests to the devices.

This paper proposes a composite sensor and control network applicable to the next generation intelligent and digital home, and discusses to develop not only functional entities which can effectively constitute the network but also a test-bed which can serve a virtual test environment.

The paper is organized as following: Section 2 discusses a concept of the composite sensor and control network. In Section 3 and 4, development of the network that is applying to the intelligent digital home and the test-bed that is used for testing the developed network elements are presented respectively. This paper is concluded in Section 5.

Ⅱ. Composite Sensor and Control Network

Figure 1 shows a typical wireless sensor network which consists of one gateway and a number of sensing nodes.

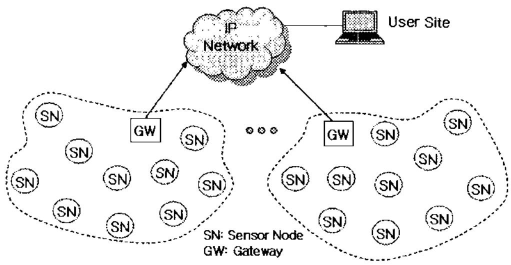

Fig. 1. Wireless Sensor Network

Every node in this network must not only be able to measure an environmental state but also facilitate a common computing platform to perform such essential tasks as routing, reliable transmission, energy management, and so on.

A composite sensor and control network proposed in this paper, as shown in Figure 2, is much different. A regional node in the network consists of one networking platform and a number of environmental sensors all of which are directly interfaced to the platform. The regional nodes can communicate with each other over any sort of wire or wireless network like Ethernet and wireless LAN. This network is also inter-networking with the IP-based core network by means of a gateway.

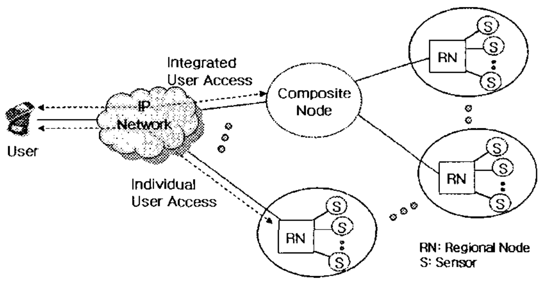

Fig. 2. Composite Sensor and Control Network

The gateway can functionally implicate a composite node. The composite node that is connected anyhow to the network aggregates regional node information and mediates functionally between user requests and node circumstances. Accessing the composite node, a user can monitor node situations and give controls to the nodes. Opposite communication paths, in addition, are required for giving controls, which transfer user requests to the nodes.

In case of existing regional nodes independently of the composite node, the gateway can reside separately from the composite node in the same network. A user directly accesses the regional nodes in this case. Thus the regional node not-depending on the composite node has to facilitate user access environment, which can provide the user with both monitoring node situations and giving controls to the node.

Ⅲ. Development of Network

3.1 Applying to Home Network

Nodes implicated in the composite sensor and control network are networking in various sort of wire or wireless ways. Especially for the home network, there are such typical means as Ethernet, PLC (Power Line Communication), Wireless LAN, ZigBee, etc[4].

Sensors are concentrated to the regional node, and the node is interfaced with the network. In addition, if required, the node has an output interface for providing control information. These interfaces depend on the sort of network or sensors, while the node is commonly applicable to various service domains. The node is usually based on a computing platform in order to provide not only such interfaces but also execution environment of software program.

Building a home network as a composite sensor and control network, the node has to facilitate commonly-specified interfaces so that it can be independent of types of home network or devices. Owing to a wide and rapid progress in the home network, a variety of technologies and products co-exists in home networking, devices, and services. This has resulted that developers or users face to be complicated to develop new solutions or facilitate intelligent home services. Therefore it demands to develop a node control platform, included in the regional node, which is commonly applicable to various digital home devices. This can not only be essential for developing efficiently new home devices or application services but also provide a sound platform for maintenance and operations of home network or devices. In addition, commonly- specified interfaces can be convenient for connecting home devices to the network.

3.2 Operational Organization Model

Figure 3 shows an operational organization model of the proposed home network, which is based on the composite sensor and control network. The model consists of a node control platform as a foundation of the regional node, a composite node and a user operator. The node control platform includes three commonly-specified functionalities for connecting with home network and home devices.

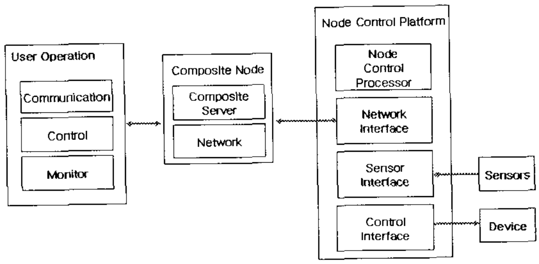

Fig. 3. Operational Organization Model of the Developed Network

Through interfaces to home devices, the node not only accepts measurement from sensors placing in home devices but also provides sensing points with control information. The control information comes from doing context awareness with respect to measurement and user-given references.

The result of doing the context awareness is also displayed on the user terminal so that users can proceed to the next step. Users can remotely establish or create new references as well as aware situations of the home devices by the user terminal connected to Internet. The user operation is independent of its location.

3.3 Node Control Platform

Four such typical wire and wireless home networks as Ethernet, PLC, Wireless LAN, ZigBee is considered for developing a commonly-specified network interface of the node control platform. SPI (Serial Peripheral Interface) becomes one common specification of interfacing the platform to such home networks. The PHY and MAC layers depend on the networking medium. A physical separation between MAC and Network layers can make the main body of the platform common for any sort of networks and the network interface module of the platform optional according to the sort of network. The SPI can be a unified interface between them.

There exist a number of sensors in home devices, which measure situation values usually for temperature, humidity, optics, electricity, gas, etc. Even the same sort of sensors can have so different characteristics that they produce different ranges and units of output. The platform supports both analog and digital ports for connecting sensors.

Figure 4 shows definition of device situation states. The sensing range has three limit ranges: system, user, and user definition. For the user definition value, user upper and lower limit values decide if the system needs to control. A system endurance range shows limitations on the system, which it bears without any fatal disorder.

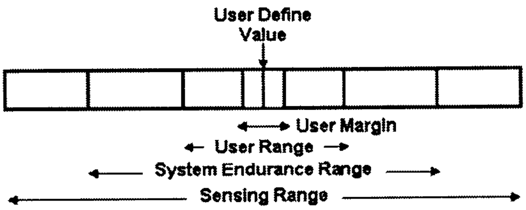

Fig. 4. Definition of Device Situation States

The control interface included in the node control platform transfers control information to the home devices. The platform continuously collects measurement from sensors placed in home devices. Context awareness is done in either the composite node or the regional node in order to decide intelligently device situations.

If the measurement is out of the permission range and the result of awareness shows that a home device needs to control, the platform put a control packet formatted in 32-bit data on the control interface. Taking such a 32-bit control packet, an actuator which may be included in the home devices executes a designated control procedure according to contents of the packet.

The 32-bit control packet format consists of three operation modes: sense, control and context awareness. Depending on what the device is able to be facilitated with, one of these modes is initiated.

3.4 Developed Hardware and Software

The developed hardware of the regional node consists of three separate functional units: a main body of processing, a network interface unit, and a sensor interface unit. The main body is a processing platform based on a micro-controller and memory devices.

The network interface unit contains integrated circuit devices for PHY and MAC layer functionalities. Depending on sort of network medium, the appropriate network interface unit is used for building a regional node. The unit supporting any sort of network medium is connected to the main body by means of the SPI interface.

The developed software consists of a web-server, a TCP/IP protocol to communicate, firmware and a boot loader. The TCP/IP protocol coincides with such home networks as PLC, Wireless LAN, ZigBee, etc. A web-server includes units for sense input, sense processing, control processing, sense output, and a graphical user interface.

The composite node, as a functional mediator between user requests and node circumstances, assembles nodes information and provides environment of user monitor and control access.

Ⅳ. Development of Test-bed

4.1 Requirements

Co-existing a variety of technologies and products in network, devices, or services has also resulted in facing complicated to test, verify, and apply new technologies or services. A simulated virtual machine is helpful for such a situation[8].

Test environment consists of an actual functional unit and a virtual simulated unit. The virtual simulated unit presented in this paper is placing instead of a real home device, which may be hard to be facilitated, containing multiple sensors, while the actual functional unit includes the implemented node and its operational service software.

In order to connect with the test-bed, the node has not to require any additional functionality. This means that the node has to interface with the virtual simulated unit physically the same as an actual home device. In addition, the test-bed needs to configure characteristics of sensors without modifying the main routine of the simulation program in order to create various testifying situations. It also demands to activate multiple sensors at the same time, which is to simulate a home device providing a number of sensing values concurrently.

A graphic user interface can facilitate a test-bed user to generate conveniently various test operations. The user not only establishes characteristics of various sensors but also provide virtually various environmental situations with the nodes. To do this, the user requires to choose arbitrary any cases and execute them through the graphic user interface

4.2 Implementation

The test-bed for testing the developed regional nodes, as shown in Figure 5, consists of three such units as a graphic user interface, a simulator of sensor characteristics, and a normalization unit of signals. The graphic user interface can facilitate a test-bed user to configure conveniently various test operations. The simulator of sensor characteristics generates sensed output values with respect to conditions of the sensors chosen in the graphic user interface. In general sensors produce outputs with different ranges as well as different units of values with respect to given environmental circumstances. The developed regional node, like other control platform, has interfaces for a TTL voltage range of analog and typical I2C digital sensor inputs. Normalization of signals adjusts the chasm between the range of sensor output and the node acceptance range.

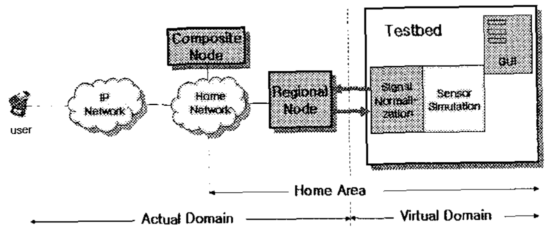

Fig. 5. Architecture of Testing Environment

Figure 6 and 7 shows an implemented graphical user interface and an operation sequence flow of testing nodes with the test-bed, respectively. On the left side of the graphical user interface, a user first chooses sort of sensors, and then preset an environmental value on each selected sensor. Executing for the given sensor values, the simulator produces outputs in a digital format which are resulted from calculation of the sensor characteristic functions. The outputs expressed in digital are transferred to the normalization unit through a communication path.

Receiving these data, the normalization unit stores them into a memory space and executes a given algorithm to generate normalized values of them. If the node uses an analog sensor input port to connect with the test-bed, the normalization unit creates actual signals with respect to the normalized values. The normalization unit directly provides digital data established in the typical I2C format if it connects to the node via a digital sensor input port.

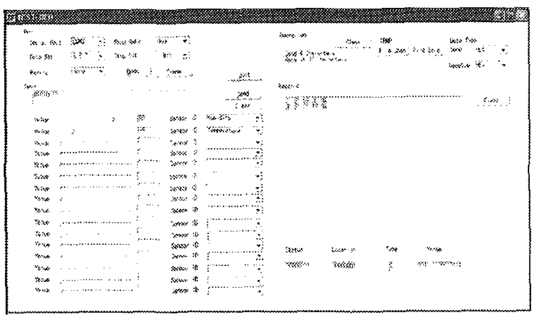

Fig. 6. Graphical User Interface for Test-bed

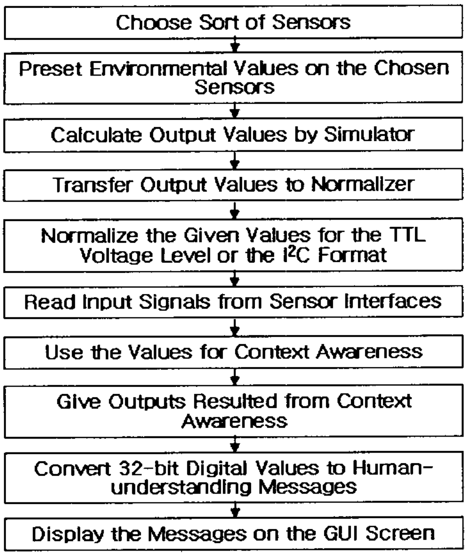

Fig. 7. Operation Sequence Flow of Test-bed

Taking the sensed data from those sensor input ports, the node uses them to make a decision of a certain situation. A context awareness algorithm is applied for such a decision. Decision results are ready for showing to users anyways, and accordingly the control data comes out to the control output port of the node in order to send to actuators if needed.

During testing procedures the test-bed instead of actuators fetches the control data, which are fixed in a 32-bit format, from the control output port of the node, and then converts them into human- understanding messages. These messages are finally displayed on the right side of the graphical user interface so that the user can compare these results with its initially established circumstances.

Ⅴ. Conclusion

A composite sensor and control network is proposed in this paper, which is applicable to the next generation intelligent and digital home. The network is considered as one particular feature of sensor network. It consists of a composite node as a mediator functionally between user requests and node circumstances, and multiple regional nodes each of which is able to measure an environmental state and facilitate a common computing platform to perform task programs. This paper also presents development results of the network that is applying to the intelligent home.

Owing to verification importance of development, especially for the case that it is hard or expensive to build a real test environment which users can configure arbitrarily situations on it, a test-bed for testing the developed node is also presented. A combination of the actual functional unit and a virtual simulated unit establishes the test environment. The virtual simulated unit is placing instead of a real home device, which may hard to be facilitated, containing multiple sensors, while the actual functional unit includes the implemented node and its operational service software.

The proposed network can not only be efficiently applying to achieve new home intelligences but also provide a sound solution to maintenance and operations of home network or devices.

References

[1] H. J. Lee, et, al, “Technologies for Ubiquitous Home Networking (in Korean),” The Magazine of Korea Information and Communications Society (KICS), Vol.21, No.3, pp54-65, March 2004

[2] H. Schulzrinne. X Wa. And S.Sidirolou, “Ubiquitous computing in home networks,” The IEEE Communications Magazine, Vol.41, No.11, pp.128-135, November 2003

[3] H. R. Lee, “Trends for Home Network Standards (in Korean),” Korea Radio Station Management Agency Periodical, January 2006

[4] Korea Home Network Industries Association (HNA), Survey and Future Progress Strategy for Home Network Industries (In Korean), May 2007

[5] A. Kansal and M. Srivastava, "Energy-Harvesting-Aware Power Management," Wireless Sensor Network (Chapter 9), Artech House, Inc., 2005

[6] D. Ganesan and B. Greenstein, "Storage Issues in Sensor Networks," Wireless Sensor Network (Chapter 13),

Artech House, Inc., 2005

[7] H. Karl and A. Willig, Protocols and Architectures for Wireless Sensor Network (Part II: Communication Protocols), John Wiley & Sons, Ltd, 2005

[8] H. J. Kim, et, al, "Design and Implementation of Home Network Test-bed (in Korean)," Proceedings of the Korea Multimedia Society Spring Conference, Vol.7, No.1, p479-p482, 2004

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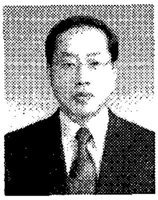

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