Smart Furniture: Improvising Ubiquitous Hot-spot Environment

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Abstract

We developed Smart Furniture, which extemporaneously converts the legacy non-smart space into a Smart Hot-spot which consists of computational services. Since the Smart Furniture is equipped with networked computers, sensors and various I/O devices, it can provide various services by alone or by coordinating with other devices. In this paper, the physical structure and middlewares for the Smart Furniture are described. The prototype systems to realize Smart Hot-spot such as a Crossing Window System, an Active Authentication System for Library, a Mobile TV-phone System, and an Environmental Information Monitor System are also introduced.

1 Introduction

This paper presents the Smart Furniture project which aims to realize improvised ubiquitous hot-spot computing environment. The goals of the project are (1) creating a physical structure called Smart Furniture which is composed of hardwares such as computers, sensors, and appliances, and (2) developing software technologies for realizing smart hot-spot services. We have designed and implemented the Smart Furniture to acquire extendibility and reconfigurability for future development.

With the growth of computing technology especially in networking and mobility, the idea of ubiquitous computing[1] became hot topic in the computer engineering. Ubiquitous computing originally assumed computers embedded into objects and environment, and assist our life without consciousness.

To realize ubiquitous computing environment, various researches are introduced. In almost every these researches, special rooms equipped with sensors, devices and computers are used to detect human activity and provide services. In our previous work, we build Smart Space Laboratory (SSLab)[2] as a laboratory of ubiquitous computing, which is equipped with sensors, embedded devices and computers. To coordinate these devices, four layered networks were build. However, the cost and time for building such a room is a barrier to the deployment of the ubiquitous computing environment.

The Smart Furniture project, instead, aims to extend non-smart space to have smart functionality by simply putting Smart Furniture in place. Smart Furniture contains computers, sensors, and appliances. Users can use Smart Furniture as a gateway to the cyber world, as a service operator, or as a service receiver. We have also designed and implemented middleware and application software required for smart hot-spot services. The combination of the Smart Furniture's physical structure, hardware devices, and its software technology can transform the legacy space into smart space.

In the remainder of this paper, we present the the definition of smart hot-spot in Section 2. Section 3 describes the design of the Smart Furniture. Section 4 describes the architecture of the Smart Furniture. Section 5 describes the prototype systems running on the Smart Furniture. Section 6 concludes the paper and mentions future work.

2 Improvised Smart Space

This section first describes existing smart spaces, then defines smart hot-spot and argues improvised smart space.

2.1 Exsisting Smart Space

There are many researchers working on ubiquitous computing environment. Active Badge system[3] is an early fruit on this research area. In this research, they used IR ray sensors to detect users' locations. They also developed telephone calling routing system using users' location. Active Bat system[4], EasyLiving project at Microsoft Research[5]

and Aware Home project at Georgia Tech[6] also aim at realizing ubiquitous computing environment.

In these researches, special rooms equipped with various sensors and devices are built. Middlewares to deal with sensors and devices and support applications are also developed and running on computers in these spaces. We call these spaces "Smart Space". Smart Spaces are characterized by following features; (1) identification and detection of activity of users (2) sensing users' and devices' location and (3) control and coordination of devices.

2.2 Smart Hot-spot

We define the word "Smart Hot-spot" as an extended hotspot where features of the Smart Space are provided. Within the Smart Hot-spot, various services are provided to users and devices. These services enable context awareness, device coordination and personalization. The Smart Hot-spot does not just provide low level functionalities such as accessibility to a network. The Smart Hot-spot provides functions independant of services.

2.3 Smart Furniture

Smart Furniture is a platform for systems to realize Smart Hot-spot. By simply placing the Smart Furniture, we can turn legacy spaces into Smart Hot-spots. Smart Furniture is needed to be equipped with networked computer, I/O devices and sensors. Coordination with existing network infrastructure or user's devices are also required.

3 Design

3.1 Goals

The following items are detailed functions and characteristics required for the Smart Furniture to realize Smart Hotspot. Figure 1 shows an early design image of the Smart Furniture.

- **Improvisational Setting**: Since the main goal of the Smart Furniture is to improvise the smart hot-spot, the system itself must be small and light enough to carry around. The installation procedure should also be simple. Middlewares running on a Smart Furniture are required to support transparency of devices and location.
- **User Friendliness**:

  User Friendliness must be accomplished in two aspects, the appearance of furniture and the interface of services. Smart Furniture should be placed especially in place where we usually spend, not in a data center or computer specific room. Therefore its appearance must fit to our surroundings.

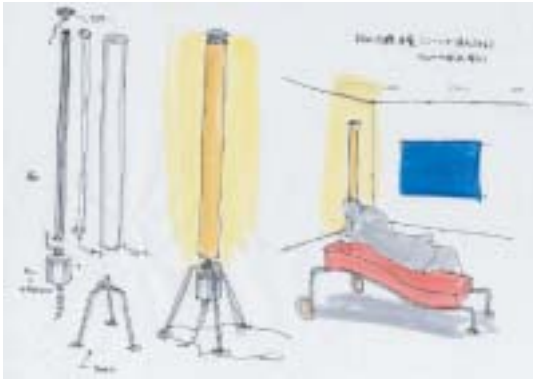

Figure 1. Design Image of Smart Furniture

Users of Smart Furniture may not be highly skilled PC users. Therefore, input and output interfaces should be intuitive. We assume that the input devices of Smart Furniture should not be mice nor keyboards but touch sensors or voice input systems. The output devices would be a display, a speaker, or a light.

- **Extendibility and Reconfigurability**: Smart Furniture is a platform of various smart hot-spot services. Therefore it must provide hardware level and software level extendibility and reconfigurability to run various applications. By acquiring these characteristics, it is easy to re-use and update the Smart Furniture and is also convenient for future development.

3.2 Scenarios

The following scenarios show using Smart Furniture in our daily life. Various services are provided by the Smart Furniture placed on private and public spaces.

Smart Hot-spot in Private Space

Ken bought Smart Furniture equipped with lamp and display for his home use. He placed it in his living room, which fitted to his room.

He had already had several home appliances such as TV and VCR with network connectivity. But he needed to control them separately even for simply watching TV. After having placed Smart Furniture in his room, an integrated user interface of applinaces appeared in the touch screen on the Smart Furniture. The middleware in the Smart Furniture coordinated home appliances.

Sensors equipped with the Smart Furniture detect Ken's presence and room's temperature. After controlling air conditioner several times, it learned his preference and automatically controlled when he entered the room.

Smart Hot-spot in Public Space

Acco was going to participate in a meeting. Before leaving home, she checked the Smart Furniture showing weather forecast as colors of lamp. She decided to bring an umbrella. When she arrived at the station, she found public Smart Furniture showing train schedule. She learned that the train was delayed, and she called to a participant of the meeting that she was going to be late with her cell phone. She used a display and a camera on the Smart Furniture to communicate on TV-phone.

When she arrived at the station near the meeting place, she began to check the map with her PDA. Since its screen was too small, she used the display on the Smart Furniture as an output device of the PDA.

When she was going back home, she checked her room's temperature using Smart Furniture at the bus stop. Since she has her ID card, public Smart Furniture recognized her and coordinated with her private Smart Furniture in her home automatically. She controlled the air conditioner to maitain comforable temperature through the public Smart Furniture.

4 Architecture

This section describes the architecture of the Smart Furniture which is comprised of two parts: physical structure and middlewares. Figure 2 shows an overview of the architecture of the Smart Furniture. As a physical structure, we developed devices which are equipped with computers, sensors and I/O devices. As middlewares, we developed Virtual Networked Appliances Framework and Wapplet Framework, which support networking, device coordination and service roaming.

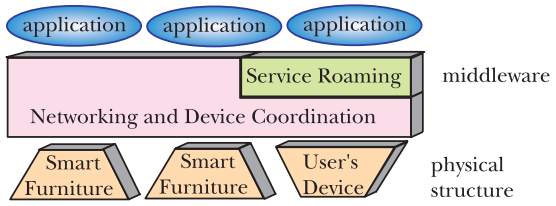

Figure 2. Smart Furniture Architecture

4.1 Physical Structure

We have designed and developed the physical structure of Smart Furniture with Uchida Yoko Corporation, an office and IT equipment manufacturer. We have considered three different situations, thus we have designed three types of Smart Furniture which are pole type, lamp type and mirror type.

Pole Type Smart Furniture

At the first stage of Smart Furniture project, we developed Pole Type Smart Furniture. Pole type is mainly focused on the use in public space, such as train stations, bus stop or campuses. In such places, smart furniture provides unspecific service to unspecific person with unspecific devices. Therefore, Pole Type Smart Furniture was designed as an extendable pole, to which various devices and sensors are attached.

Pole type Smart Furniture is composed of mainly three parts; base, pole, and case. The photos of each part are shown in Figure 3. To maintain the extendibility and reconfigurability of Smart Furniture, each part is designed with a reusable modular material, and we can decompose each part to acquire adaptability for various services.

In the pole type Smart Furniture, we have attached and installed four pluggable devices. On top of the Smart Furniture, there is an IrDA reader for user detection. On the pole, from the above, there is a LCD display with touch panel, an RFID reader, and a speaker.

Figure 3. Pole Type Smart Furniture

Lamp Type Smart Furniture

Lamp type Smart Furniture shown in Figure 4 is designed for home use. Even in home, there are various information acquired by sensors or devices. This design is considered as a user friendly indicator of such information.

The lamp type Smart Furniture is cylindrical lamp which consist of 6 color light in serial. Each color light contains red, green and blue LED and we can assign its color from

PC through RS-232C so that we can set each color. The height of lamp type Smart Furniture is 1450 mm and diameter of the lamp is 70 mm. The length of each color lamp is 200 mm so that 1200 mm of lamp are used to show information.

Networked computer in the Lamp coordinates sensors and devices around the Smart Furniture and encode their information to 6 colors.

Figure 4. Lamp Type Smart Furniture

Mirror Type Smart Furniture

Mirror type Smart Furniture shown in Figure 5 was designed to coordinate with other Smart Furniture. Mirror type Smart Furniture has iPAQ installed inside. We can see LCD and use stylus through a half mirror. When LCD is turned off, the Smart Furniture looks just like a mirror. Linux is installed in the iPAQ and it has wireless LAN (IEEE 802.11b) connection.

4.2 Middlewares

For the Smart Furniture, we developed middlewares to support networking, device coordination and service roaming. To support networking and device coordination, we developed Virtual Networked Appliance Framework. To support service roaming, we developed Wapplet Framework.

Virtual Networked Appliances Framework

To improvise Smart Hot-spot, network between infrastructure and Smart Furniture, Smart Furniture and Smart Furniture, and Smart Furniture and devices are required. In addition, mechanism for coordinating devices is needed. For this purpose, we utilized Virtual Networked Appliance (VNA) framework[7].

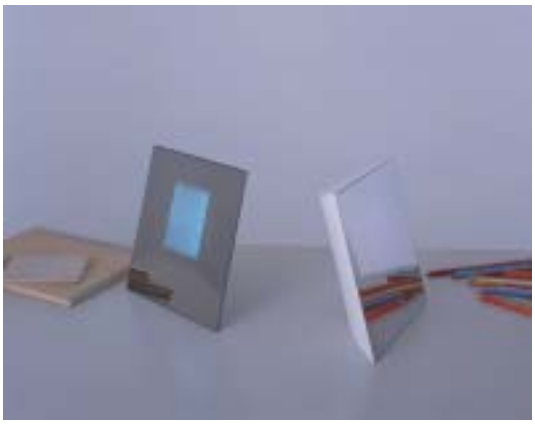

Figure 5. Mirror Type Smart Furniture

VNA framework is a middleware that federates appliances' functions. Users can virtually combine different appliances' functions and create a new virtual networked appliance. Figure 6 depicts VNA framework architecture.

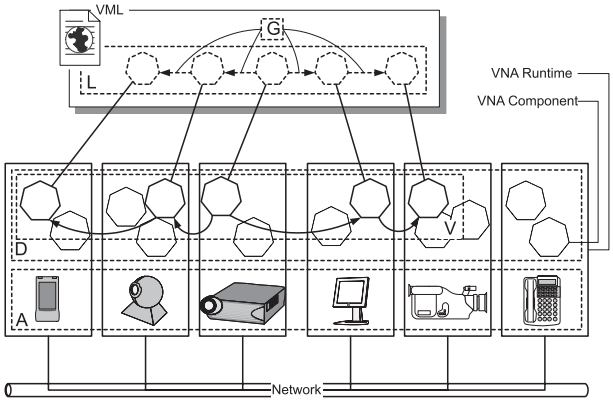

Figure 6. Virtual Netoworked Appliance Framework Architecutre

Wapplet Framework

For extending the functionalities of mobile devices using Smart Furniture, services running on personal devices are required to move to the Smart Furniture. For this feature, we utilized a Wapplet framework.

A Wapplet framework[8] shown in Figure 7 is a distributed application framework for service roaming. It provides application programmers with device coordination

and device switching. To realize device coordination functionality, location transparent method invocation (LTMI) protocol was developed. LTMI never forces application programmers to manage the locations of mobile objects unlike conventional device coordination protocols such as Java RMI and SunRPC. Furthermore, in this framework, device switching is realized by transporting mobile objects.

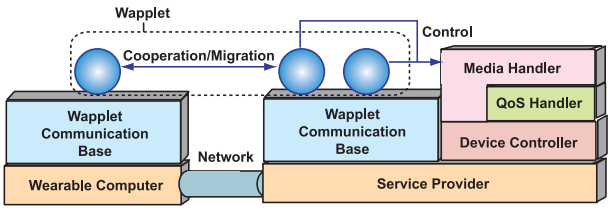

Figure 7. Wapplet Framework System Architecutre

5 Prototype Systems

To demonstrate Smart Hot-spot environment, we developed five prototype systems using Smart Furniture; a Crossing Window System, an Active Authentication System for Library, a Mobile TV-phone System, an Environmental Information Monitor System and Smart Furniture Configurator.

A Crossing Window System

As a coordination of the Smart Furniture in public and private space, we developed a Crossing Window System. A Crossing Window System is a prototype system that provides users in public space with interfaces to control home appliances. Unlike remote controllers for TVs or videos, Crossing Window provides users with feedback of control results using displays or speakers. Therefore, users can recognize whether their control command is successfully executed. We use VNA Framework to coordinate public and private Smart Furniture, and federate various home appliances around private Smart Furniture.

An Active Authentication System for Library

We have developed an active authentication system for library using Active Authentication System[9], and installed it into the Smart Furniture as showin in Figure 8. Each user has a client device with wireless LAN and books with RFID tags. When the user pass through in front of the Smart Furniture, it detects MAC address of user's client device and books' RFID tags and automatically authenticate them.

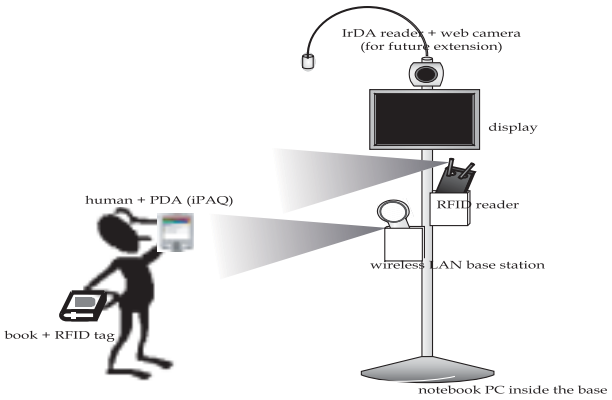

Figure 8. Active Authentication for Library

A Mobile TV-phone System

We developed a mobile TV-phone system as a prototype system of service roaming in Smart Hot-spot using Waplet framework. Figure 9 shows the architecture of the system. We assumed that a user had a cell phone without a camera. In legacy environment, a user can talk by cell phone with a voice. Software modules for visual connection are also in the cell phone, which don't work. When he or she enter to the hot-spot environment, the modules move to the Smart Furniture and establish establish TV-phone connection using a camera and a display on the Smart Furniture.

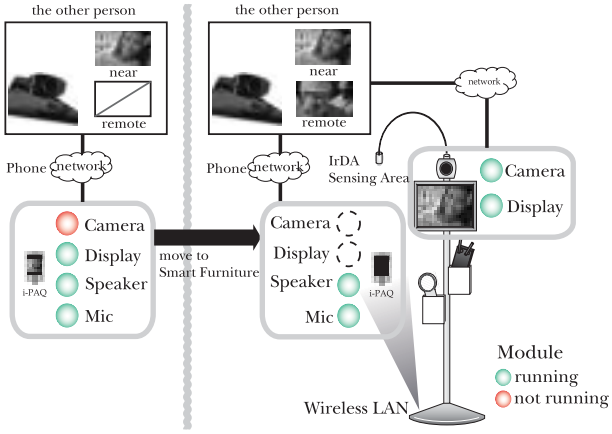

Figure 9. Mobile TV-phone

An Environmental Information Monitor System

Using Light type Smart Furniture, we developed environmental information monitor. We implemented crowd monitor, weather monitor and network traffic monitor. We coordinated sensors in the Smart Furniture and devices using

VNA framework to acquire environmental information. In conventional user interfaces, environmental information are generally shown using numbers, but displaying these information as colors of light helps users recognize such information intuitively.

A Smart Furniture Configurator

We developed smart furniture configurator on mirror type Smart Furniture as an example of coordination of several Smart Furniture. When setting mirror type Smart Furniture near another Smart Furniture, we can get its status and configure it on mirror screen using styluses. For instance, we can set the type of information displayed on the lamp type Smart Furniture, and learn which information is displayed when mirror type Smart Furniture are set near the lamp.

We developed prototype systems of the Smart Hot-spot and demonstrated these systems in several places. Through this experience, we verified improvisational setting of the Smart Hot-spot. We could install various systems to the Smart Furniture because of the support of middlewares and flexibility of the physical structures which allow attachment of various devices and sensors. However, their appearances are needed to be improved for user friendliness. Devices and computers in the Smart Furniture should be smaller and lighter to be widely deployed.

Middlewares currently used support device federation and service roaming. We need middlewares to integrate sensors and generate advanced world model. Current Smart Furniture constructs primitive world model using proximity. This model only works for recognition of users around the Smart Furniture. Currently we are working on the development of World Modeling System using multiple Smart Furniture.

6 Summary

In this paper, we have described the design and implementation of Smart Furniture, which is a platform of Smart Hot-spot, and aims to realize improvised ubiquitous hot-spot computing environment. The Smart Furniture is composed of two parts; physical structure and middlewares. By utilizing the Smart Furniture, we can furnish the legacy non-smart space with the Smart Hot-spot services extemporaneously.

We are planning to continue creating new versions of Smart Furniture. We are currently designing a table type, which will include advanced functions such as personalization and access control. The added functions are especially important when Smart Furniture are used in public spaces. They need to allow users to temporarily use Smart Furniture as personal terminal, and switch back to public mode discarding any personal information, thus keeping the user's privacy.

Acknowledgement

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