日本財団 The Nippon Foundation 助成

IIPS

Institute for
International Policy Studies
・Tokyo・

IIPS International Conference

"The IT Revolution and the Transformation of Society"

Tokyo

November 5-6, 2003

"A Prospect of Ubiquitous Computing Environment: New applications and Issues"

By
Prof. Hideyuki Tokuda

Chairperson/Professor,
Graduate School of Media and Governance
Faculty of Environmental Information
Keio University

A Prospect of Ubiquitous Computing Environment: New applications and Issues

Hideyuki Tokuda

[1] Graduate School of Media and Governance
[2] Faculty of Environmental Information, Keio University
hxt@sfc.keio.ac.jp

Abstract. The evolution of the Internet in 90's gave us a new dimension of social information infrastructure. Extended use of the Web technology with high speed broadband networks created a new life style in the cyberspace era.
Advances in mobile wireless communications and pervasive devices such as Internet-ready cell phones, WiFi-ready PDAs, handheld devices, sensor devices, RFID tags are accelerating the further evolution of our life style in the ubiquitous networking era. In the ubiquitous networking era, every daily objects will be connected to various networks and we will be able to access and control any objects and services at anytime and from anywhere.
In this paper, we discuss a prospect of ubiquitous computing environment. In particular, potential application domains are described and some of early prototype examples are shown. The possible issues are also discussed from social as well as technical point of views. We then summarize the strong and weak points of the future of the ubiquitous network society.

1 Introduction

In the early 80's in Japan, we had a very small three-node experimental computer network which uses a telephone line for communications. Even setting a dedicated telephone line for a UNIX machine was a very difficult task in Japanese universities. In the mid 80's, Japanese research community was able to join the TCP/IP community with great help from US researchers such as Dr. Dave Farber and Dr. Larry Landweber who were creating the CSNET[1] at that time. This was the beginning of the Internet era.

The evolution of the Internet in 90's gave us a new dimension of social information infrastructure. Extended use of the Web technology with high speed broadband networks created a new life style in the cyberspace era[2]. Popularity of Internet-ready cellular phones, such as i-mode phones, also accelerates the further growth of the cyberspace. Using a small device such as an i-mode phone, we could enjoy various kinds of information and services such as news, digital cinema, entertainment, e-ticketing, e-billing, and e-banking at anytime and from anywhere.

Advances in mobile wireless communications and pervasive devices such as Internet-ready cell phones, WiFi-ready PDAs, handheld devices, sensor devices, IC tags are accelerating the further evolution of our life style in the ubiquitous networking era[3–5]. In the ubiquitous networking era, every daily objects will be connected to various types

of networks. We will be able to access and control any objects and get various services at anytime and from anywhere.

In this paper, we discuss a prospect of ubiquitous computing environment. In the remainder of the paper, potential application domains and some of early prototype examples are discussed in Section 2. Section 3 describes the possible issues from social as well as technical point of view. Sectoin 4 summarizes the strong and weak points of the future of the ubiquitous network society.

2 Ubiquitous Application Domains

This section first describes the gap between Mark Weiser's vision of the ubiquitous computing environment and the current technology, then presents the smart space and smart furniture projects we are involved. Finally we describe ubiquitous applications we have developed using the Smart Space and Smart Furniture.

2.1 Mark Weiser's Vision and its Gap

Mark Weiser once stated the Silicon-based information technology is far behind in terms of supporting our everyday activities in a natural way[4]. By comparing old technology like writing with a pen, our PC-based word processor solution did not give us calm interface at all. We must know so many things before an ordinary person can start to write a letter with a PC.

The gap between Silicon-based information technology and calm technology was not reduced dramatically, however the computer scientists made some progress such as use of pointing devices, a WSIWYG frame work, real world oriented interface, voice controlled interface technology.

The current progress of wireless mobile networks and pervasive devices will narrowing the gap between Mark Weiser's vision and the Silicon-based information technology. Among new information technology many researchers are working on, in particular, the following key technology would contribute the progress towards the ubiquitous network society.

- 3G and 4G mobile wireless phones
- passive, active, and smart tags
- GPS and indoor-location systems
- sensor networks and smart dusts
- mobile ad hoc networks
- HCI technologies
- personalization technologies
- context-aware applications
- location-aware applications
- p2p technologies

By having these technology ready, new application domains could appear in our society. First, we may see new ubiquitous platforms, appliances, and networks. We

will then expect new applications in new life style, health care and nursing, education, employment, environment, participation in society, consumption domains. We will be able to enjoy new types of services, commerce and contents in each domain. As we summarized in the ubiquitous networking forum[6], these new domains are shown in Figure1.

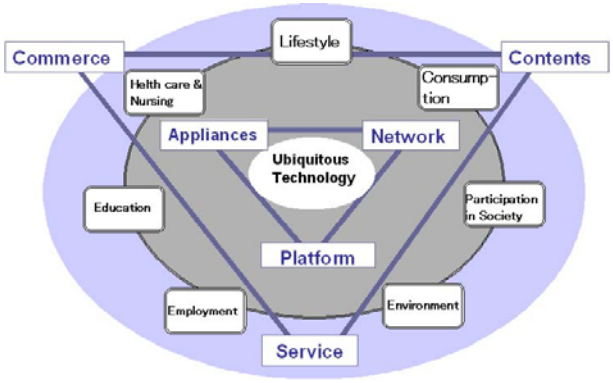

Fig. 1. Ubiquitous Application Domains

Web technology give us yet another active work space, namely a cyberspace. The ubiquitous technology will narrow the gap between the cyberspace and real physical space we are living on. In the following subsections, we will describe some of our experimental results towards creating such ubiquitous applications.

2.2 Smart Space

The goal of the Smart Space project is to create a smart environment where many appliances, embedded devices and sensors are seamlessly connected for supporting human-to-human, human-to-device, device-to-device collaboration[7, 8]. In such smart environment, "computational intelligence" is embedded into surrounding environment and wearable devices of human could communicate in an ad hoc manner. In order to utilize real-time environmental information for various types of collaboration, we need to develop a real-time sensor/device networks, integrated sensor processing module, efficient wireless networking, wearable networking, dynamic e-directory services, and new software framework.

We have built "Box-in-the-Box" shown in Figure2 as a testbed for performing experimental tasks in the Smart Space project. It is designed as a cage constructed inside the room of the building without any additional supporting materials. We have created artificial walls where we could embed various types of sensors, devices and embedded servers.

The space in the Box-in-the-Box is divided into five regions, each of which is a basic unit of the control domain in Smart Space. Regions are used not only as the different

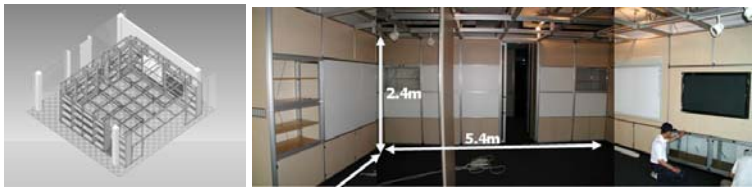

Fig. 2. Structure of the Box-in-the-Box

location in the Smart Space, but as those in the assumed distance field. A PC and a factory control computer, called DUONUS are configured in each region to manage local sensors and appliances.

Various kinds of sensors, audio/visual equipments, and lighting equipments shown in Figure 3 are connected to each network system, and all systems are connected with each other through the backbone, 100Base-TX Ethernet. The location sensors using RFID, called E-code spider recognizes the position of a person or a device on the magnitude of the region.

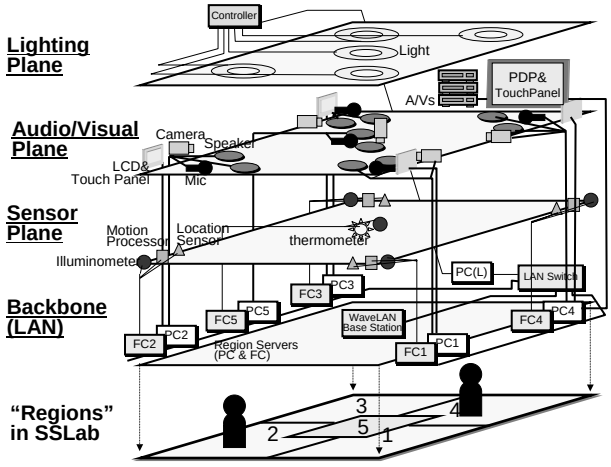

Fig. 3. Embedded Sensors, Appliances, and Networks in B-in-B

2.3 Smart Furniture

The Smart Furniture project aims to extend non-smart space to have smart functionality by simply putting Smart Furniture in a public or private space[9]. Smart Furniture contains computing units, communication units, sensor units and actuation units. Users

can use Smart Furniture as a gateway to the cyberspace, 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. By the smart hot-spot service means that it can provide not only the gateway to the cyberspace, but also various services in the real space. In smart hot-spot environment, services have several aspects such as personalization, context awareness or device coordination. The combination of the Smart Furniture's physical structure, hardware devices, and its software technology can transform the legacy space into a smart space instantaneously

We have designed and developed four types of Smart Furniture, namely a pole type, message board type, lamp type, and mirror type.

Fig. 4. Lamp, Mirror, and message board type Smart Furniture

2.4 Experiments

To demonstrate many features of the Smart Space Lab. and Smart Furniture, we have developed several prototype systems including Virtual Network Appliances and a Zero-Stop Authentication System.

Virtual Network Appliances

Virtual Networked Appliance (VNA)[10] is an adaptive middleware architecture we have tested in the Smart Space Lab. Its goal is the realization of "virtual" networked appliances based on dynamic integration of distributed functional components of networked appliances. Unlike other networks of appliances, VNA allow us to create a

network of functional components of the appliances. A user then creates a virtual appliances based on the existing appliances. It is called the *bottom-up* integration. The *top-down* integration, on the other hand, constructs the requested virtual appliance by dynamically binding the compatible function components for the user. The VNA may reconstruct the appliances whenever availability of required function components has changed. Figure 5 depicts VNA architecture.

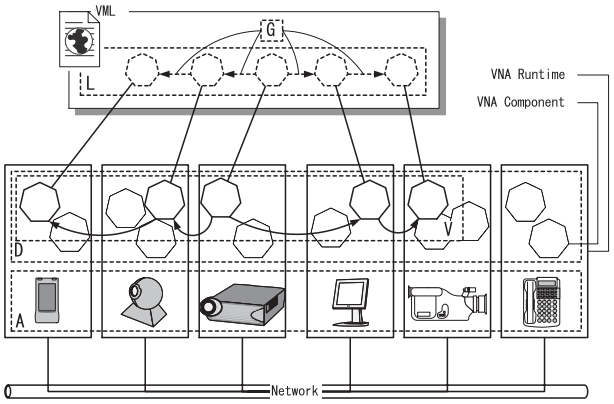

Fig. 5. Virtual Networked Appliance Architecture

The VNA's template is defined with an XML-based markup language (VNA Markup Language, VML). To make VNAs portable among various physical appliances, we introduced a new mechanism called *Virtual Plug&Play*[11]. The key advantage in our architecture is a property of a server-less distributed configuration.

Zero-Stop Authentication System

Existing authentication systems require users to input their names and passwords or show their identification cards to access computers and software. Let us assume, for example, that a user borrows books, and checks out of a library. In the library, the user needs to show an identification card to a librarian, and the librarian checks whether the user is valid. After authenticating the user, the librarian checks books to lend. In this process, both the user and the librarian need certain time for the authentication.

The key challenge is to eliminate users' waiting time for authentication with security levels of authentication kept. This system realizes a sensor-based automatic authentication: zero-stop authentication, which diminishes user-computer or user-software interaction mentioned above, providing "zero-stop" property[12]. We define "zero-stop" property as a property of an authentication system not to make moving users pause during authentication process. To achieve this property, a system needs to meet the following four functionalities:

– Correctly detecting users and objects.
– Providing active authentication that requires no input from users.
– Providing real time response.
– Presenting feedback of authentication results.

Two types of sensors are equipped with the gate server, and they are RF-based sensor devices; a wireless LAN device to detect users and an RFID tag sensor to detect objects. Hardware composition is explained in Figure 6 with its specification in Table 1 and Table 2.

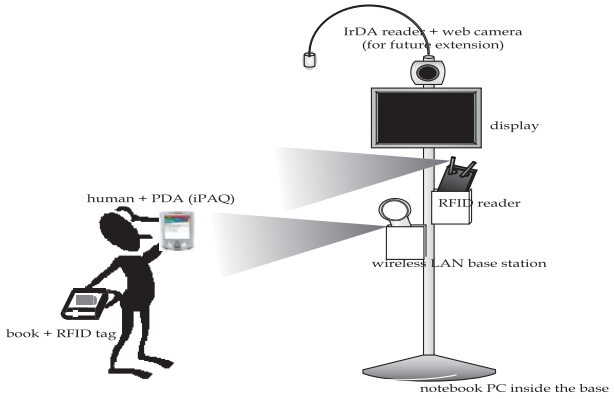

Fig. 6. Hardware Configuration of the Prototype System

Table 1. Computing Devices Used in the Prototype System

item	**iPAQ**	**ThinkPAD**
Type	User Terminal (PDA)	Gate Server (notebook PC)
CPU	StrongARM 206MHz	Intel PentiumIII 850MHz
Memory	64MB	256MB
OS	Familiar Linux v0.5.1	FreeBSD 5.0 CURRENT
Network Interface	802.11b	802.11b (IBSS-Mode)
Others	TFT Display	

Table 2. Sensor Devices Used in the Prototype System

item	**Wireless LAN**	**RFID Sensor**
Type	User Terminal (Wireless LAN)	Gate Server (RFID Reader)
Detection Range	160m(outside),50m(indoor)	15m(indoor)
Read Rate		75 tags / second
Operating Frequency	2412-2484 MHz	303.8 MHz
Others		

3 Social Concerns and Technical Issues

We may face many social concerns and technical problems in evolving to the ubiquitous computing environment. Pervasive nature of cell phones have been changing a life style of young folks already[13]. The social implication of such cell phones are not well analyzed yet, but we need to foresee potential issues[14]. It is not a trivial task to forcast various social concerns and technical issues, but we will attempt to enumerate some of these.

The digital divide problem is still the well-known social concern when everyone was willing to use the Internet and PC technology in the world. In the ubiquitous network society where many wireless mobile communications, pervasive devices, and tags are in daily use, people are more concerned about the privacy and security in our community.

Let us enumerate the following questions. It is still not clear to produce a common answer to these questions yet. It may depend upon how we govern the use of technology in our community.

- Who can access who's private information and why?
- Who has a right to control IC tags and its information?
- How to reduce the anti-social activities and vandalism in the network?
- How to establish the trust and credibility in our community?
- How to bootstrap ubiquitous services?
- What kind of society we would like to design when the use of these technology becomes natural.

For instance, a surveillance camera network is one of the sensor network systems becoming popular in many cities. Some communities are willing to install to increase the safety of their community. However, if we have too many camera network systems, it is not clear whether we can increase the safety or not. The potential risk of abusing such camera networks may increase, then we must minimize the privacy risk of the community. Use of IC tags technology may face the similar concerns. The increased traceability and tracking ability of ordinary objects in our society may increase the potential abuse of the technology. We need to produce a better solution to reducing everyone's privacy risk and increasing the social safety.

The ubiquitous computing technology is still in early stage of its development. We need to develop better solutions to following issues.

- Safety and reliability of embedded software

– Energy performance of many sensor systems and tags
– Reliablity and security of authentication systems
– Robustness and Safety of the networks
– Software architecture for context-aware applications
– Service finding, binding, and rebinding
– Natural and Calm Service Interface
– Interoperability of various services

Even now, it is a serious problem to cope with computer viruses and distributed denial service (DDOS) attacks to the Internet. The large number of spam mails are also reducing the usability of the network. We need to solve these issues from the both side of social aspects as well as the information technology aspects.

4 summary

In 90's, the evolution of the Internet gave us a new dimension of an information infrastructure in the cyberspace era. The pervasive nature of the ubiquitous computing technology may give us yet another impacts on our life style. The calm nature of the technology will empower a person's, group's, and community's capabilities dramatically over the next few years.

New applications which we can expect in the ubiquitous computing are very wide including health care and nursing, education, employment, environment, participation in society, and consumption domains. Every daily objects will be connected to various types of networks seamlessly, we will be able to get various services at anytime and from anywhere. Any information or services users need will be dynamically adjusted in a context-aware (situation-dependent) and a personalized fashion.

The increase use of the ubiquitous computing technology such as wireless mobile communications, pervasive devices, and IC tags may introduce new social concerns. It is, however, our responsibility to understand the essential problems and foresee the potential side effects in our society. We need to produce a better solution to reducing everyone's privacy risk and increasing the social safety in the ubiquitous network era.

Acknowledgement

We thank all members of the Tokuda Lab. and Uchida Yoko Corporation for their collaborating work on "Smart Furniture".

References

1. Douglas Comer, "The computer science research network csnet: a history and status report", *Communications of the ACM*, vol. 26, no. 10, pp. 747–753, 1983.
2. Mary B. Williamson, Andrew Glassner, Margaret McLaughlin, Cheryl Chase, and Marc Smith, "Constructing community in cyberspace", in *CHI 98 conference summary on Human factors in computing systems*, 1998, pp. 84–85.

3. Deborah Estrin, Ramesh Govindan, and John Heidemann, "Embedding the internet: introduction", *Communications of the ACM*, vol. 43, no. 5, pp. 38–41, 2000.
4. Mark Weiser, "The Computer for the 21st century", *Scientific American*, vol. 265, no. 3, pp. 66–75, Sept. 1991.
5. Mark Weiser, "Some Computer Science Problems in Ubiquitous Computing", *Comm. ACM*, vol. 36, no. 7, pp. 74–83, July 1993.
6. Ubiquitous Networking Forum, "UNF", http://www.ubiquitous-forum.jp/.
7. H. Tokuda el al., "Reliable, Real-Time and Reconfigurable System (R3-System) Project", in *IEEE Workshop on Networked Appliances*, Nov. 1998.
8. T. Okoshi, S. Wakayama, Y. Sugita, S. Aoki, T. Iwamoto, J. Nakazawa, T. Nagata, D. Furusaka, M. Iwai, A. Kusumoto, N. Harashima, J. Yura, N. Nishio, Y. Tobe, Y. Ikeda, and H. Tokuda, "Smart space laboratory project: Toward the next generation computing environment", in *International Workshop on Networked Appliances*, 2001.
9. Masaki Ito, Akiko Iwaya, Masato Saito, Kenichi Nakanishi, Kenta Matsumiya, Jin Nakazawa, Nobuhiko Nishio, Kazunori Takashio, and Hideyuki Tokuda, "Smart furniture: Improvising ubiquitous hot-spot environment", in *International Workshop on Smart Appliances and Wearable Computing (IWSAWC2003)*, May 2003.
10. Jin Nakazawa, Tadashi Okoshi, Masahiro Mochizuki, Yos hito Tobe, and Hideyuki Tokuda, "VNA: An Object Model for Virtual Network Appliances", in *IEEE 2000 International Conference on Consumer Electronics*. IEEE Consumer Electronics Society, June 2000, pp. 364–365.
11. Jin Nakazawa and Hideyuki Tokuda, "A pluggable service-to-service communication mechanism for home multimedia networks", in *Proceedings of the tenth ACM international conference on Multimedia*, 2002, pp. 621–630.
12. Kenta Matsumiya, Soko Aoki, Masana Murase, and Hideyuki Tokuda, "Zero-stop authentication: Sensor-based real-time authentication system", in *International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2003)*, Feb. 2003.
13. Howard Rheingold, *Smart Mobs: The Next Social Revolution*, Perseus Publishing, 2002.
14. James E. Katz and Mark Aakhus (Ed.), *Perpetual Contact: Mobile Communication, Private Talk, Public Performance*, Cambridge University Press, 2002.