

# Approaches to User-Centric Computing System for Ubiquitous Solutions

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The ubiquitous computing system has become a key component in the growth of broadband networks. This paper describes the features of a ubiquitous computing system that consists of a broadband core network and an IP-based LAN and non-IP based ad-hoc networks. It also describes our approaches to user-centric systems for realizing ubiquitous solutions.

## 1. Introduction

The Internet and cellular networks have become important facilities in recent years, and the utilization of information services in daily life is becoming more popular. Also, demands for easy-to-use information services that are optimized for individual users are getting stronger. Considering this situation, we can soon expect the emergence of the “ubiquitous communications society,” in which everyone can access information and services at any time and any place by using ubiquitous computer terminals that are connected to society’s network.

**Figure 1** shows an image of the ubiquitous society. There are three ubiquitous features of this society:

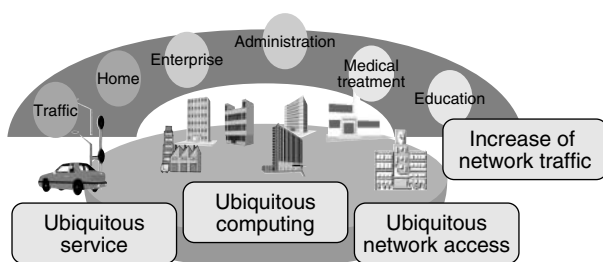


Figure 1  
Image of the ubiquitous society.

- 1) Ubiquitous accessibility to networks,
- 2) ubiquitous computing, and
- 3) ubiquitous services.

To handle the enormous amount of traffic associated with this level of ubiquity, the ubiquitous society will require a huge broadband network capability.

Wireless LAN (Local Area Network) technology is driving the progress in network accessibility. Standardization activities at the IEEE802.11 committee and interoperability tests performed by the WiFi Alliance have made it possible to provide high-performance, low-price products such as mobile terminals and wireless-embedded PCs (Personal Computers) that can be used in the office or home. Moreover, wireless LAN services in public places such as stations hotels, and fast-food restaurants are expanding and an increasing number of people are enjoying ubiquitous network services.

For instance, business people can use a wireless terminal to obtain information from a company’s information system through a public wireless LAN access point. We expect that companies will use this accessibility to speed up their business.

One important requirement for developing the ubiquitous society is the ability to instantaneously optimize services for individual users without the need for them to perform annoying operations. To do this, a system must automatically recognize the users' situations and environmental information. In other words, what is required is real-time acquisition and utilization of information about a person or product in the real world so users can enjoy the services they need anytime and anywhere. A key concept in systems with this capability is "user-centric computing."

RFID (Radio Frequency Identification), which uses identification tags containing IC chips with a wireless communication interface, is suitable for real-time acquisition of information about commercial products into information systems. RFID tags have more advanced features than simple barcodes; for example, they can store IDs and other information, are rewriteable, and exchange data without physical contact. We expect that RFID tags will enable more advanced applications than conventional barcodes. Attaching RFID tags to all commercial products will enable the creation of logistics systems that are significantly different from conventional ones. Also, RFID tags will bring new business opportunities, because they enable consumer information to be directly relayed to producers via a network as shown in **Figure 2**.

To achieve a profitable RFID service, inven-

tory management, POS (Point of Sales) management, and production management will have to collaborate with each other to form a total logistics system. XML (Extensible Markup Language)/Web service technology is growing on the Internet and makes it possible to achieve this collaboration and build a framework in which different computer systems can work together to provide services.

We believe that ubiquity achieved through network access, computers, and services will become a valuable commodity in the future. Next, we will describe a ubiquitous system architecture for realizing the above-mentioned services and also introduce our approach to a user-centric computing system for ubiquitous solutions.

## 2. Ubiquitous system architecture

Ubiquitous systems for realizing ubiquitous computing consist of heterogeneous network systems that are quite different from the homogeneous IP-based systems found in a corporate network environment.

Because there is now a variety of communication protocols for consumer electronics, sensors, and RFIDs that use their own networks and systems, most likely there will be multiple communication protocols coexisting in harmony, with standardization of these communication protocols proceeding on a continuous basis.

In addition, the user scenario may vary depending on whether the user is at home, in the office, or in a mobile environment. The home environment will be more complex than the office environment in terms of managing consumer electrical appliances and conventional computers, because the devices sometimes have their own proprietary or legacy network interfaces. Because consumer electrical appliances and information devices communicate with each other in the home and mobile environments, PANs (Personal Area Networks) will also grow. In this scenario, operations management systems will differ from

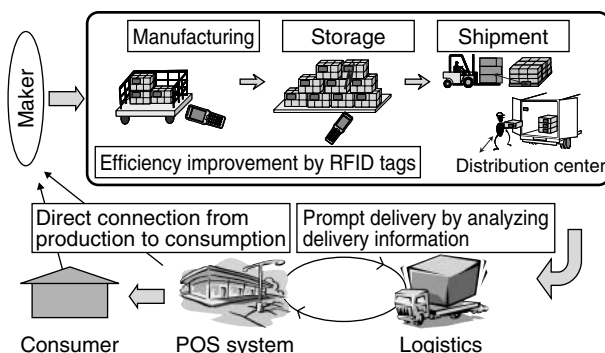


Figure 2  
Logistics system using RFID tags.

existing office network management systems.

Dissimilar networks will be connected using an IP-based LAN, so information terminals can communicate peer-to-peer and information services can work with each other via broadband network interconnections.

**Figure 3** shows a ubiquitous system architecture. The core network is a broadband network to cope with a rapidly increasing traffic load. This network connects with an IP-based LAN in an

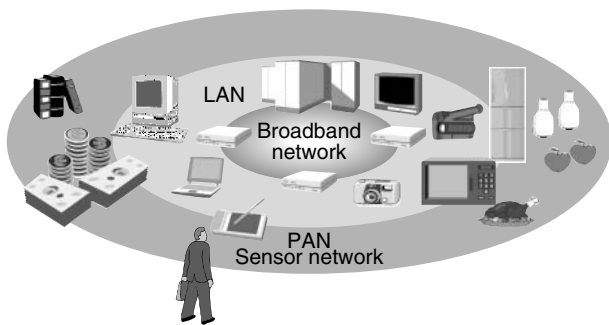


Figure 3  
Image of ubiquitous system architecture.

office, home, or mobile environment and finally reaches non-IP-based ad-hoc networks.

In such an architecture, there will be a huge amount of consumer electronics, sensors, and other equipment connected to the non-IP network, and this equipment will generate a continuous stream of traffic far bigger in volume than the traffic generated by individuals accessing services with their terminals. To cope with the massive demand for data transfer, the broadband capability of networks will have to be significantly enhanced.

Applications in a ubiquitous system cover many domains, for example, mobile computing, consumer electronic appliances, ITS (Intelligent Transport Systems), e-Japan, manufacturing, and logistics. Fujitsu has an advantage here because we have expertise in semiconductors, network infrastructures, servers, clients, system integration, and many other areas. We will use this advantage to become a leading company in ubiquitous computing (**Figure 4**).

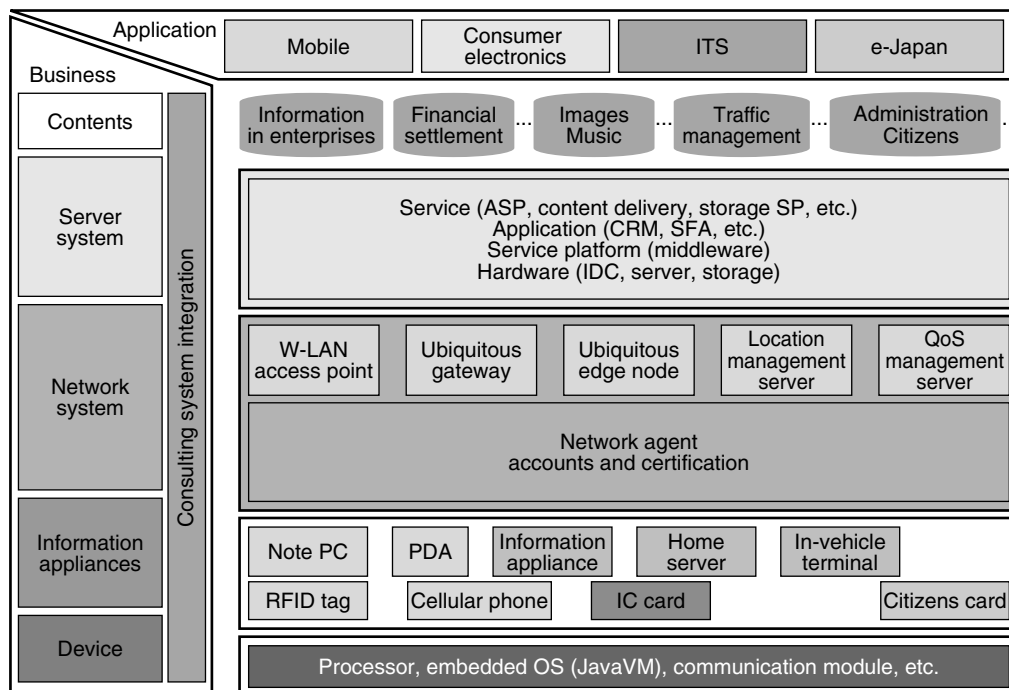


Figure 4  
Fujitsu's approach for ubiquitous society.

The terminals in a ubiquitous network system need a function for connecting to a different system. We have therefore developed a terminal that allows a user to easily connect to a ubiquitous network. This terminal can act as a gateway between non-IP-based RFIDs and IP-based information services and has seamless roaming capability between home and mobile environments. The following section explains how it works.

### 3. Key elements of user-centric computing system for ubiquitous solutions

The user-centric computing system is a ubiquitous system consisting of information and devices that users can access anytime and anywhere. In this system, the RFID systems, home networks, personal mobile terminals, and other gateways to the users' real-world environment will become key elements for ubiquitous solutions.

#### 3.1 Gateway to RFID

As described above, RFIDs and contactless IC cards are new identification devices that are used in commercial products and by individuals in a ubiquitous system.

If products carry their own RFID tags, people can identify the products in real time in a market by receiving identification information via the Internet. Also, if a mobile terminal (e.g., a cellular phone or PDA [Personal Digital Assistant]) has built-in RFID capability, it could be used to access services that automatically communicate with the terminal and nearby RFID tags and then instantaneously optimize themselves to suit the user's individual needs.

Contactless IC cards having the same short-range wireless communication technology as RFID tags could be used to identify individuals. They can also contain accounting and billing information for authentication and encryption so that people can make transactions easily and safely.

It is important to develop new gateway ser-

Table 1  
Gateway function with contactless communication.

Item	Requirements
Communication with RFIDs	Multiple protocols such as ISO14443/15693 and FeliCa
Communication with IP network	Correspondence with IPv6 and use of XML/Web service
Gathering/transferring	Virtualized expression of the tag/sensor information
Security	Protection of private data

vices, for example, to connect an RFID network to the Internet. One of our ideas for a new gateway service is shown in **Table 1**. We call this concept the "ubiquitous gateway." In this concept, ubiquitous gateway functionality is installed in various devices, for example, portable terminals such as PCs, PDAs, and cellular phones, and also in home gateways and sensor devices.

We are advancing the development of a common ubiquitous-gateway functionality for these devices, and we have built this functionality into a prototype terminal for ubiquitous computing. We describe this terminal in more detail in Subsection 3.3.2.

#### 3.2 Gateway to homes

A home gateway could be placed in each home to access to and from the home securely.

Fujitsu started shipping a first-stage product called the FNS (Family Network Station) in November 2002. The main specifications and a photograph of the FNS are shown in **Table 2** and **Figure 5**, respectively.

The home gateway has two important functions in the ubiquitous system: 1) to facilitate equipment interoperability in a home environment and 2) prevent unauthorized accesses to the users' information from outside the home. These two functions are discussed below.

The setting up of equipment and networks was not a big problem in corporate systems because it was done by network specialists. However, problems such as how to ensure plug & play capability have recently become important,

Table 2  
Main specification of FNS.

Item	Specification
Function	Wireless LAN router (802.11b)
	Storage server
	Remote access
	TV recording
CPU	GeodeGX1 233 MHz/333 MHz
HDD	40 GB/80 GB
OS	Linux

because more and more home users want to connect AV (Audio Visual) equipment and PCs to their home networks. For example, plug & play equipment must be able to obtain a network address and set other parameters automatically. Furthermore, equipment should make its services and/or connection information available so it can be used by other equipment.

To protect privacy, when accessing from or to, for example, a content provider or a friend's equipment, the home gateway should offer only the information that is required.

To meet this need, we have developed Home2Home technologies, which are basic technologies for transferring digital contents between homes using direct access through secure connections.

Home2Home technologies have the following features for connecting home gateways easily and safely and expanding an inter-home network service:

- 1) Easy execution of security policies and utilization of attribute information about home equipment.
- 2) Auto-configuration of home backbone network to accommodate equipment and network conditions.
- 3) Infrastructure for connecting homes via a reliable third party.
- 4) Grouping based on home equipment attributes and security policy provided by a reliable third party.



Figure 5  
FNS (Family Network Station).  
Photograph: FMFNS-102 (standard model)/  
FMFNS-202 (TV model)

- 5) Secure content delivery to home gateways within the same group.

The first trial version of Home2Home technologies has been installed in an FNS-based system as an additional function, and we have started to evaluate its performance and operability.

### 3.3 Gateway to individuals

This section describes the development of a terminal for ubiquitous computing that has gateway functionality in a ubiquitous network.

#### 3.3.1 Terminal systems for ubiquitous computing

We expect that terminal devices and mobile terminals will evolve from traditional mobile computing (MC) devices in the coming ubiquitous computing (UC) era.

One of the evolutionary stages between MC and UC might be nomadic computing (NC), which is a type of UC in which users carry their own terminals. This is a transitional stage toward a UC style in which users do not carry their own terminals but access services by using devices in



the environment and computing resources in interconnected networks.

In the NC user scenario, the following functions are required: 1) advanced presentation capability to users, 2) acquisition of information about users and their environment so services appropriate for the user, location, and situation can be provided, 3) accessibility to a ubiquitous network.

- 1) Regarding advanced presentation to users, it is important to display only what the users need to use the services. Of course, to display all the needed information on the small displays found on portable devices, it is also necessary to improve the performance and quality of those displays.
- 2) Regarding the acquisition of information about users and their environment, the computing system must be able to recognize a user and detect the user's location and surrounding situation without user operations. In the NC system, this information is collected by sensors in the terminals or is delivered by sensor networks.
- 3) Regarding accessibility to a ubiquitous network, it will be necessary to support various high-speed packet networks such as W-CDMA (Wideband-Code Division Multiple Access), Hot Spot Wireless LAN, and Bluetooth. Another requirement is seamless switching between mobile networks and home networks.

### 3.3.2 Prototype development

Based on the above-mentioned requirements, we have developed a handheld prototype for NC that has a high-resolution display, sensors for identifying a user or environment, and a network interface for connecting with a ubiquitous network (**Figure 6**).

This prototype has a four-inch LCD (Liquid Crystal Display), which is the same size used by handheld PDAs. However, to improve the prototype's usability, we used a color, 254 ppi (pixels

per inch) field-sequential-color (FSC) LCD that meets the SVGA (Super Video Graphics Array) standard. This is the world's first handheld terminal to achieve this level of resolution.

To identify a user, the prototype uses Fujitsu's MBF300 sweep-type fingerprint sensor. Also, to identify a product, it has a multi-protocol (ISO14443 Type B,<sup>1)-4)</sup> ISO15693,<sup>5)-8)</sup> and Felica<sup>9)</sup>) RFID reader-writer.

The prototype also has the following interfaces: 802.11b wireless LAN, Bluetooth, CF (CompactFlash) slot, and SD (Secure Digital) slot. A variety of cellular cards such as a PHS (Personal Handyphone System) data card can be inserted into a slot to connect with public networks.

The prototype's specifications are summarized in **Table 3**.

We chose the Intel XScale processor, because it has the high performance and low power consumption required to browse the Web and access Web services. Also, we chose Microsoft's CE.NET, because it has the security functions (e.g., encryption and SSL [Secure Socket Layer]) and Web technologies (e.g., XML/XSL [Extensible Stylesheet Language]) required for ubiquitous computing.

We decided that the prototype's UI (User In-



- (a) Rear of prototype device. A CMOS camera for capturing and an LED light are mounted.
- (b) Front of prototype device. A 4-inch, landscape view SVGA LCD is mounted. Buttons and jog dial are located on the left for single-hand operation. A CMOS camera for capturing the user and a microphone and speaker are mounted for communication.

Figure 6  
Prototype device.

terface) should enable the user to browse, access, and edit with the minimum of operations under all situations. We therefore used a jog dial so the prototype could be operated with just one hand (**Figure 7**). The buttons and jog dial are located in optimal positions, as on PDAs and smart phones. Also, a touch panel on the LCD makes it easy to select icons and menu items and make handwritten inputs. The prototype has different modes that enable the user to quickly and easily

Table 3  
Specifications of prototype Nomadic Computing device.

Item		Specification
CPU		Intel® PXA255 (400 MHz)
Memory		RAM: 128 MB, FLASH ROM: 64 MB
Display		4.0-inch FSC-LCD, SVGA
Network		Wireless LAN (802.11b), Bluetooth, IrDA (SIR)
Audio		Monaural speaker & monaural microphone
Camera		350 000 pixel camera × 2
Sensor		Fingerprint sensor
External slot		SD card, CF card (Type-2)
External connectors		USB 1.1, cradle (USB/RS232c), 2.5 mm diameter stereo headset, DC-In
User IF		Touch screen, jog dial, buttons, etc.
Power	Battery	3.7 V, 1035 mAh
	AC adapter	AC 100 to 240 V, 50 to 60 Hz/DC 5 V, 2.4 A
Size (W × D × H)		Approx. 141 × 27.6 × 83 mm
Weight		Approx. 275 g
OS		Windows CE.NET 4.2



Figure 7  
Input system.

select items from a menu in a ubiquitous computing environment. The modes are Camera mode, Personal Information Manager (PIM) mode, Remote Desktop Protocol (RDP) mode, and Voice over IP (VoIP) mode. There is also a dial switch on the top of the body (**Figure 8**).

This prototype can run any Windows CE application, for example, a Web browser, viewer, or RDP client software. **Figure 9** shows the prototype displaying an SVGA-resolution Web page that is designed to be browsed using a PC. We think that, because most Internet contents are designed for browsing with a PC, handheld terminals should have the same resolution as PCs. The combination of the FSC-LCD and jog dial provides good visibility and operability without the need to perform extra vertical scrolling.

The prototype also has two cameras: one at the front for capturing the user's face for teleconferencing and another at the back for capturing other people and surrounding scenes.

### 3.4 Next-step terminal technologies for user-centric computing

#### 3.4.1 Zoom-view user interface

One of our ideas for next-step technologies in a terminal is the zoom-view user interface, which makes it easy to change the size of still images. Terminals for ubiquitous computing will most likely become smaller as device technologies improve, and we are investigating ways to improve the user-interface software for presentations and

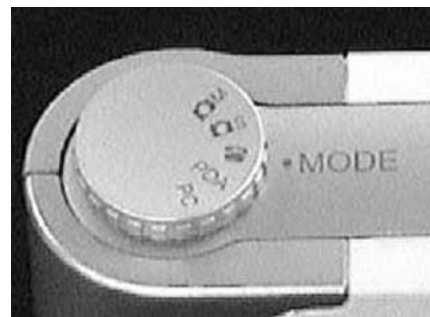


Figure 8  
Dial switch for mode selection.

also improve hardware such as the FSC-LCD, as we discussed in an earlier section.

The decision to display contents in thumbnail view or detail view depends on the display's capabilities and will usually be more critical in a handheld terminal. Showing more items with their own images in a single view makes it possible to display more information but at a lower visibility due to their smallness. Displaying information in hierarchies may make searching easier, but it may also make the information harder to recognize. Therefore, software for zoom viewing would facilitate presentations of images on a small terminal screen (**Figure 10**).

A zoom-view user interface allows easy



Figure 9  
Display of Web page.

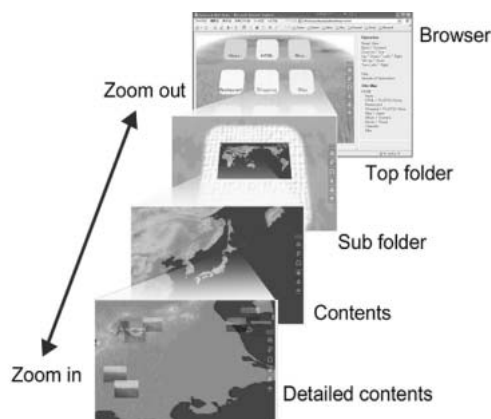


Figure 10  
Screen samples of Omnizoom.

browsing of thousands of images arranged in a hierarchy. Also, interpolating views using animation during zooming makes it easier to navigate the display.

We have developed the “Omnizoom” application based on the zoom-view user interface technology used in Windows and are transferring this to the Windows CE platform so the same zoom-view capability can run on our terminal.

### 3.4.2 Seamless information environment

As described in Section 3.3, the UC style will shift from users carrying terminals to users utilizing their environments. After the shift, people will be able to use the terminals they find in their environment as if they were their own. In the advanced stage, a user could continue a session after switching to another terminal, or a session could be carried out on multiple terminals with dissimilar human interfaces, for example, displays with different sizes and resolutions.

To realize these functionalities, technologies to do the following will be required: manage the users' environments and status, certify users and display information about their environments on their terminals, protect users' privacy, and determine how to correctly display information on each device being used by referencing a shared database.

Even more advanced functions could be used to determine the user's intentions without specific instructions from the user. This could be achieved, for example, by identifying location information and other clues from the user and the user's environment. We are currently developing advanced functionalities by using short-range wireless technology.

In a future scenario, a user might receive an email on a small terminal and then walk up to a public terminal and wirelessly display the email on the public terminal's large screen for everybody to see. The equipment needed to do this will need to be able to detect the user's approach using radio and authenticate the user's information with



the user's profile. Establishing a relationship between terminals would enable safe information sharing using short-range radio links. Of course, other wireless technologies, for example, a wireless network infrastructure, would also be needed. Therefore, a technology for making data exchangeable between dissimilar terminals could reduce the traditional limitation of closed services and make them open to a wide variety of terminals.

## 4. Summary

In this paper, we described the features of a ubiquitous computing system and the system gateway functions we have developed for RFID, home networks, and personal mobile terminals as key elements for user-centric ubiquitous solutions. Our prototype terminal realizes ubiquitous services through nomadic computing, and our Home2Home technology enables a home network to connect to a ubiquitous network.

## References

- 1) ISO/IEC 14443-1:2000 Identification cards -- Contactless integrated circuit(s) cards -- Proximity cards -- Part 1: Physical characteristics.
- 2) ISO/IEC 14443-2:2001 Identification cards -- Contactless integrated circuit(s) cards -- Proximity cards -- Part 2: Radio frequency power and signal interface.
- 3) ISO/IEC 14443-3:2001 Identification cards -- Contactless integrated circuit(s) cards -- Proximity cards -- Part 3: Initialization and anticollision.
- 4) ISO/IEC 14443-4:2001 Identification cards -- Contactless integrated circuit(s) cards -- Proximity cards -- Part 4: Transmission protocol.
- 5) ISO/IEC 15693-1:2000 Identification cards -- Contactless integrated circuit(s) cards -- Vicinity cards -- Part 1: Physical characteristics.
- 6) ISO/IEC 15693-2:2000 Identification cards -- Contactless integrated circuit(s) cards -- Vicinity cards -- Part 2: Air interface and initialization.
- 7) ISO/IEC 15693-2:2000/Cor 1:2001.
- 8) ISO/IEC 15693-3:2001 Identification cards -- Contactless integrated circuit(s) cards -- Vicinity cards -- Part 3: Anticollision and transmission protocol.
- 9) <http://www.sony.co.jp/Products/felica/>



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