Advanced Hardware Technologies for Ubiquitous Services

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Abstract

In the coming ubiquitous era, computing, sensing, and communication functions will be present just about everywhere in everyday living space, and novel services that can help make our lives safer, more comfortable, and more convenient are expected. This article describes the current state of research and development in advanced hardware technologies supporting human-centered services and discusses the outlook for services based on these technologies.

1. Trends in ubiquitous services

Passive radio frequency identification (RF-ID) tags and sensors are becoming progressively smaller, cheaper, and better at network interfacing. They are expected to be used in future ubiquitous services giving us safer, more comfortable, and more convenient lives. **Figure 1** shows domestic and overseas trends in ubiquitous services. The vertical axis represents the degree of network usage (i.e., service area coverage) and the horizontal axis represents the types of devices used. First, there are services that target distribution and goods management by attaching compact passive-type RF-ID tags without built-in batteries to goods and combining them with readers connected to the network. In this way, a wide range of such services can be envisioned, from ones that are mainly local in nature [1] to ones that make use of wide-area networks [2]. There are also plans for testing the attachment of ultrasmall tags to admission tickets for event management [3]. In addition to services using RF-ID tags, there are services that use network-con-

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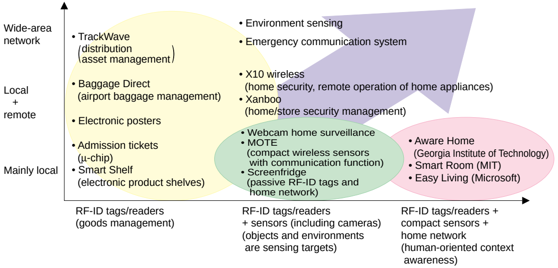

Fig. 1. Trends in ubiquitous services.

nected sensors. These range from wide-area services such as environment sensing, information-collection services in disaster areas, and emergency communication systems to remote services such as home and business security management and home surveillance [4], [5]. Although these services are currently in the development stage, trials of a local service that links RF-ID tags with a home network are under way. Finally, while the targets of sensing in the above two trends are mainly objects and environments, studies have also begun on ways of making life more comfortable and convenient by facilitating interaction between people and appliances or the environment. This will be accomplished by embedding many compact sensors in everyday living spaces such as a home so that the system is aware of people's locations and current circumstances [6], [7].

At present, the services mentioned above are either at the business feasibility study stage or the R&D stage. As sensors equipped with a short-range wireless communication function become smaller, consume less power, and cost less [8], we foresee the formation of flexible sensor networks in individual living spaces that will eventually be linked to form a wide-area sensor network. It should then be possible to provide many diverse services to users regardless of their location.

2. Requirements of basic hardware technologies

Based on these trends in ubiquitous services, we expect to see services expand their focus from goods management to human centric needs. **Figure 2** defines ubiquitous services as human-centered value-added services and summarizes the requirements of basic technologies supporting these services. The idea here is to construct an environment having close-knit interaction between individuals and the living space through the use of densely arranged computing, sensing, and communication functions. In such an environment, the sensor-network system is aware of a user's circumstances including physical condition and of events and phenomena occurring nearby. These capabilities make it possible to provide a user with daily living support.

The key device in this environment is a sensor equipped with a short-range wireless communication function that can even be attached to people. This sensor must have a compact, low-power configuration and an automatic calibration function and be nearly maintenance-free. A user must also be able to use such a sensor by simply attaching it to an object or his/her own body, and there must be almost no maintenance required on the part of the user like changing batteries. The operating system for the CPU (central processing unit) that controls sensors of this

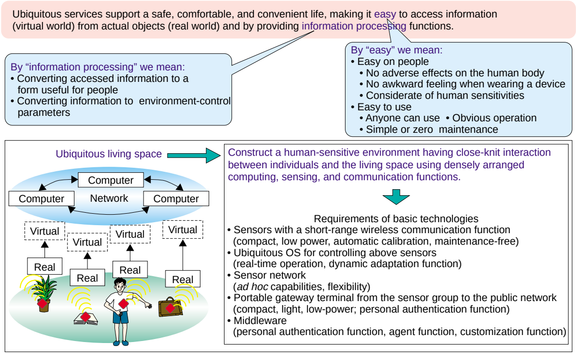

Fig. 2. Definition of ubiquitous services and requirements of basic technologies.

type must be capable of real-time operation and have a dynamic adaptation function.

A group of sensors forms an *ad hoc* sensor network that can pass sensing information to a broadband network via a portable gateway terminal while maintaining flexibility with respect to changing conditions. This portable gateway terminal must have a compact, light, and low-power configuration and a personal authentication function. Furthermore, to simplify the use of this system, the middleware used by the terminal must have an agent function and a customization function.

3. Key hardware technologies

Let us now turn our attention to basic hardware technologies, the key to ubiquitous services. With reference to **Fig. 3**, the main features of the technologies that will be introduced in this special feature are as follows. First, a group of sensors connected to a network by short-range wireless communications is essential for detecting and analyzing the location and state of people and things in everyday living space. In other words, sensors are indispensable devices for providing an individual with sophisticated value-added services.

The second article in this special feature describes a compact wireless sensing device called a stick-on communicator (StiC) that can be attached to all kinds of real-world objects including people, things, and environments. It enables object location and sensing information to be output to a network. The system obtains location information because the StiC has an infrared light-emitter and its light is detected by an infrared camera to extract location. This technique makes it possible to perform high-speed location recognition at a rate of about 50 objects per second including moving objects, which means that the location of about 100 objects within the camera's field of vision can be detected. Furthermore, with the aim of combining this ubiquitous technology with broadband services, the system will incorporate a function for embedding the sensing and location information obtained in this way in real video images and delivering that video to remote locations.

Such a ubiquitous service will also need a device to provide the user with audio and video information based on the data obtained from the sensor group. To this end, we are developing an ultrasmall audio receiving unit called "Voice Ubique" that incorporates an ultrasmall speaker as an actuator (as opposed to a sensor) and uses infrared radiation for short-range wireless communications. This device is so small that it can provide information in the form of audio messages to the user's ear without causing discomfort or any feeling of awkwardness even if it is worn all the time. VoiceUbique also has a built-in RF-ID tag so that value-added audio information specific

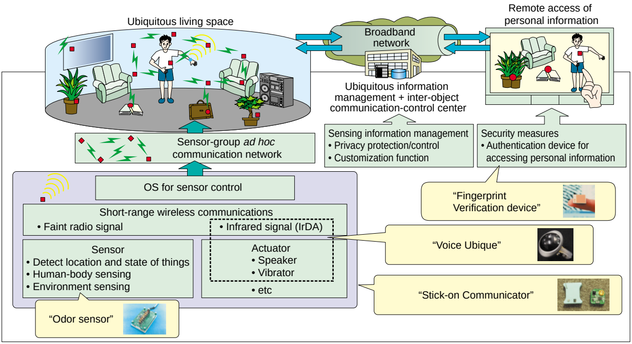

Fig. 3. Hardware technologies supporting ubiquitous services.

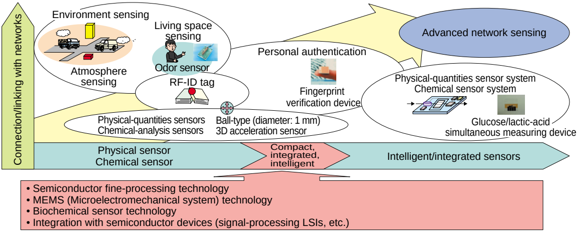

Fig. 4. Trends in sensing technologies.

to wearer can be provided. The third article describes details of the device. To facilitate the creation of value-added services, it will be necessary to obtain and analyze a large volume of information, including personal information, and to provide the user with information timely in any connected environment. Needless to say, it is vital that privacy be protected in such a system. It is therefore essential to incorporate network authentication for accessing personal information and personal authentication for the person using the portable gateway terminal that transfers information from the wearable sensor group to public networks. The fourth article introduces a “fingerprint verification device” for personal authentication that anyone can operate.

The source of information for value-added services is the vital signs of the person living at the place in question and environmental information from that place. The key device for obtaining this information is the sensor. As shown in **Fig. 4**, sensors are becoming smaller, more integrated, and more intelligent through the merger of microelectromechanical system (MEMS) and biochemical sensor technologies based on semiconductor fine-processing technology with analog-signal-processing LSI technology. In addition, if we equip these devices with a wireless communication function and connect and link them with networks, it will be possible to perform advanced real-time sensing while maintaining flexibility with respect to changing circumstances. In other words, a sensor-network system will evolve to become constantly aware of events and phenomena occurring within the targeted living space.

At NTT Microsystem Integration Laboratories, we are researching and developing a number of advanced sensing devices including the fingerprint verification device, a glucose/lactic-acid simultaneous measuring device integrating chemical sensors, and a blood-stream sensor that integrates optical devices. Given the importance to one’s health of living in a comfortable and clean environment, the fifth article describes “odor sensor technology” that can perform highly accurate analysis of trace substances in room air.

4. Outlook for ubiquitous services

Finally, let us discuss the outlook for ubiquitous services and associated issues including the potential for new forms of communication using ubiquitous linking technologies.

The top half of **Fig. 5** shows ubiquitous services focused on managing goods. These types of services are currently being studied for their business potential. In the future, we expect these services to expand into human-centered value-added services and merge with broadband businesses to provide new communication services that “transform the real world into content”, as shown in the bottom half of the figure. For example, we can envision the provision of an image-communication service that enables the user to interact with remote people and things. In the initial stage of commercialization, as passive RF-ID tags become smaller and cheaper, we expect ubiquitous services to target needs like reducing distribution-management costs and improving the traceability of foodstuffs. Developing operations for managing such information at a data center will also facilitate the provision of sophisticated value-added services such as health management and environment control for a more comfortable lifestyle.

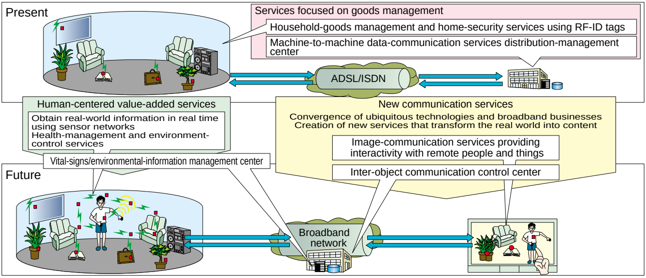

Fig. 5. Outlook for ubiquitous services.

We plan to continue researching and developing advanced hardware technologies with an eye to proposing novel communication services based on the convergence of ubiquitous technologies and broadband enterprises.

References

[1] http://www.y12.doe.gov/orsens/smrtshlf.

[2] http://www.trackwave.com.sg/index.htm

[3] http://www.rhc.renesas.com/business/package_rfid.html

[4] http://www.x10.com/homepage.htm

[5] http://www.xanboo.com/

[6] http://research.microsoft.com/easyliving/

[7] http://www.cc.gatech.edu/fce/ahri/

[8] J. Terada, Y. Satoh, F. Morisawa, S. Mutoh, K. Fujii, and Y. Kado, “A Wireless Sensor-Network System with a Dynamically Programmable Sensor Interface,” Abstracts of IEEE Sensors, pp. 202-203, 2003.

[9] Y. Kado, Y. Matsuya, and T. Tsukahara, “Low-power Circuit Technology toward Ultra-small Network Appliances,” NTT REVIEW, Vol. 14, No. 5, pp. 49-55, 2002.

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He received the M.E. and Ph. D. degrees in electronics from Tohoku University, Sendai, Miyagi in 1983 and 1998, respectively. In 1983, he joined NTT Electrical Communications Laboratories, where he engaged in research on SOI structure formation by heteroepitaxial growth. From 1989 to 1998, he worked on the development of fully-depleted CMOS/SIMOX LSIs and ultralow-power CMOS circuits. From 1999, he engaged in R&D on compact network appliances using ultralow-power CMOS circuit technologies for ubiquitous communications. He has served as a program committee member of the ISSCC (International Solid-State Circuits Conference) since 1999 and a technical committee member of IEEE Computer Elements since 2003. He is a member of IEEE and the Institute of Electronics, Information, and Communication Engineers of Japan.