Different-Type Network Connection for Dynamic Collaboration

By Akira KATO,* Masanobu ARAI* and Ryuhei FUJIWARA†

ABSTRACT This paper discusses two research and development items that present good examples of how new forms of convenience can be created when different types of networks interwork while taking advantage of one another’s strong points. One is the prototype of a mobile phone equipped with a terrestrial digital TV receiver, which can serve as an interactive portable TV terminal targeted at individual users. Sharing resources with the existing third-generation cellular telephony service, the prototype is almost the same in size as the mobile phones currently on the market and is suitable for practical use. The other is an ad-hoc system aimed at collecting sensor data. We have developed a wireless sensor terminal that can operate on a tiny solar cell the size of a business card, as well as an ad-hoc multi-hop sensor network system whereby sensor terminals are located in a mesh topology, with each several hundred meters apart, thus autonomously establishing a network of multi-hop transmission routes. We believe that having these networks of different types interwork closely with the Internet will create new business in the coming years.

KEYWORDS **Terrestrial digital TV, ISDB-T, OFDM, Third-generation cellular phone, Wireless sensor terminal, Solar cell, Ad-hoc multi-hop radio sensor network**

1. INTRODUCTION

As the use of portable terminals, such as notebook PCs, PDAs, and mobile phones, has grown, technological advances in these devices have improved their data processing capability. Also, in addition to wired connector-based connection to fixed Ethernet networks, many other different forms of communications infrastructures have been put into practical use. Examples include wireless connection approaches where users gain LAN access using wireless LAN links or connect to the Internet via cellular radio systems. Under these circumstances, terminals and access nodes that are capable of switching access networks or simultaneously accessing different networks have potential for new markets.

Described below is the status of the work that the Network Development Laboratories is conducting to develop technologies for connection between networks of different types. The topics discussed are a mobile phone terminal equipped with terrestrial digital TV capability integrating broadcasting and communication, and an ad-hoc system that uses remote terminals as relay stations to collect sensor data. Neither system is technologically innovative. However, they present good examples of how new forms of convenience can be created when different types of networks interwork while taking advantage of one another’s strong points, as compared to when those networks operate independently.

*System Platforms Research Laboratories
†Ubiquitous Platform Development Division

· Development of an integrated communication/broadcasting terminal (3G cellular phone terminal with terrestrial digital TV capability)

In Japan, full-fledged terrestrial digital TV broadcasting started in December 2003. The signaling system of this broadcasting service has a broadcasting slot intended for mobile terminals. In addition to the high definition television broadcasting service for residential TV receivers (fixed reception service), another service aimed at mobile receivers such as cell phones (mobile reception service) is slated to be launched in 2005. Integrating a broadcasting receiver with a mobile phone allows individual users to participate in broadcast programs in real time and to enjoy on-demand services. Furthermore, users will be viewing programs at different times for different lengths of time at different locations from when they watch TV in their homes. These and other changes have potential for overturning the conventional TV business model whose primary revenue source is advertisement fees. Also, it will become possible for users to view the content, received with their home TV sets or PCs, on their mobile terminals by using some sort of memory device as a carrying medium. Also likely is the deployment of DRM (Digital Rights Management) technology that links the usage of

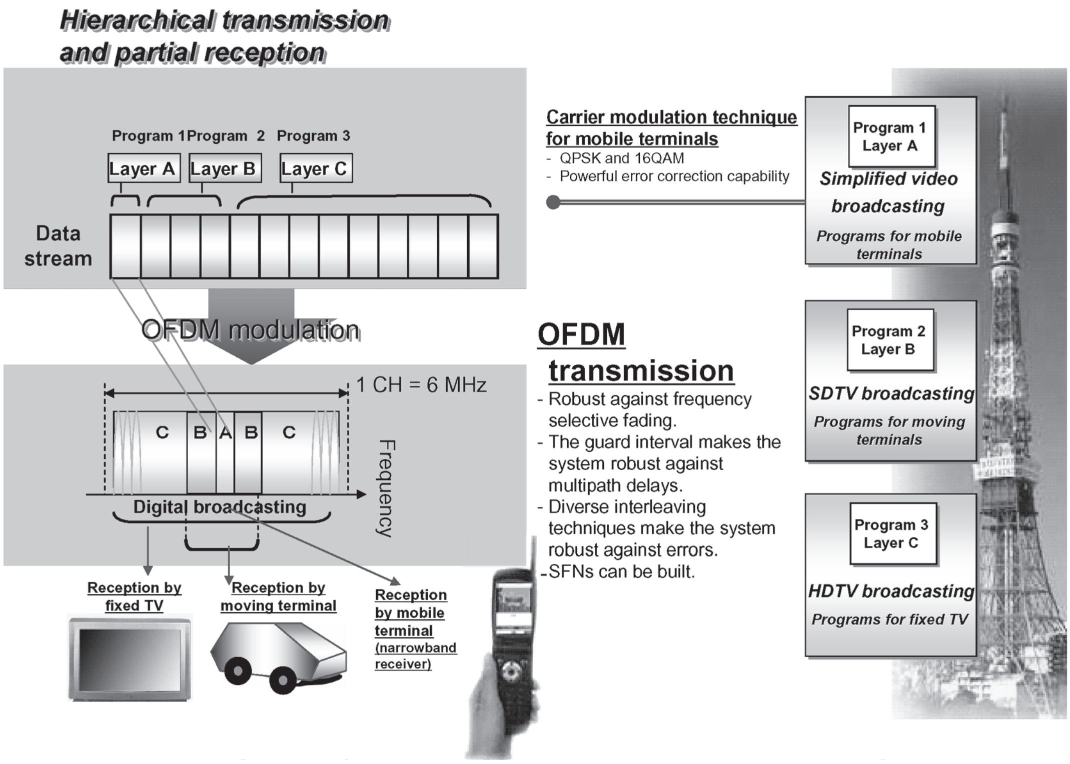

Fig. 1 Outline of Japan's terrestrial digital TV broadcasting system.

content to charging activity via communication. Our prototype of the mobile terminal is described in detail below.

Figure 1 illustrates the characteristics of Japan's terrestrial digital TV broadcasting system (ISDB-T). ISDB-T employs OFDM as the digital modulation technique, making the system robust against multipath fading and Doppler shift. Also, the system deploys several measures aimed at mobile reception, such as making it possible to select the parameters of carrier modulation technique and error correction geared to program reception by mobile terminals. Furthermore, ISDB-T adopts a method whereby a single channel is divided into 13 frequency blocks (segments) and these segments are grouped into up to three hierarchical layers, permitting different broadcasting parameters to be set for each layer independently (hierarchical transmission method). This mechanism allows a dedicated frequency block within a single channel to be secured for broadcasting to mobile terminals (one segment of layer A in Fig. 1).

Photo 1 shows the appearance of the prototype that we developed in cooperation with the Mobile Terminals Division and released in September 2003. **Figure 2** gives the function block diagram of this prototype. The upper part of the terminal that folds in two contains a TV receiver, and the lower part is equipped with a 3G cellular radio set.

Photo 1 Appearance of the prototype.

This prototype, which is built on the basis of a 3G mobile phone model, features an additional function to receive on a dedicated frequency for mobile receivers of terrestrial digital broadcasting. As hardware

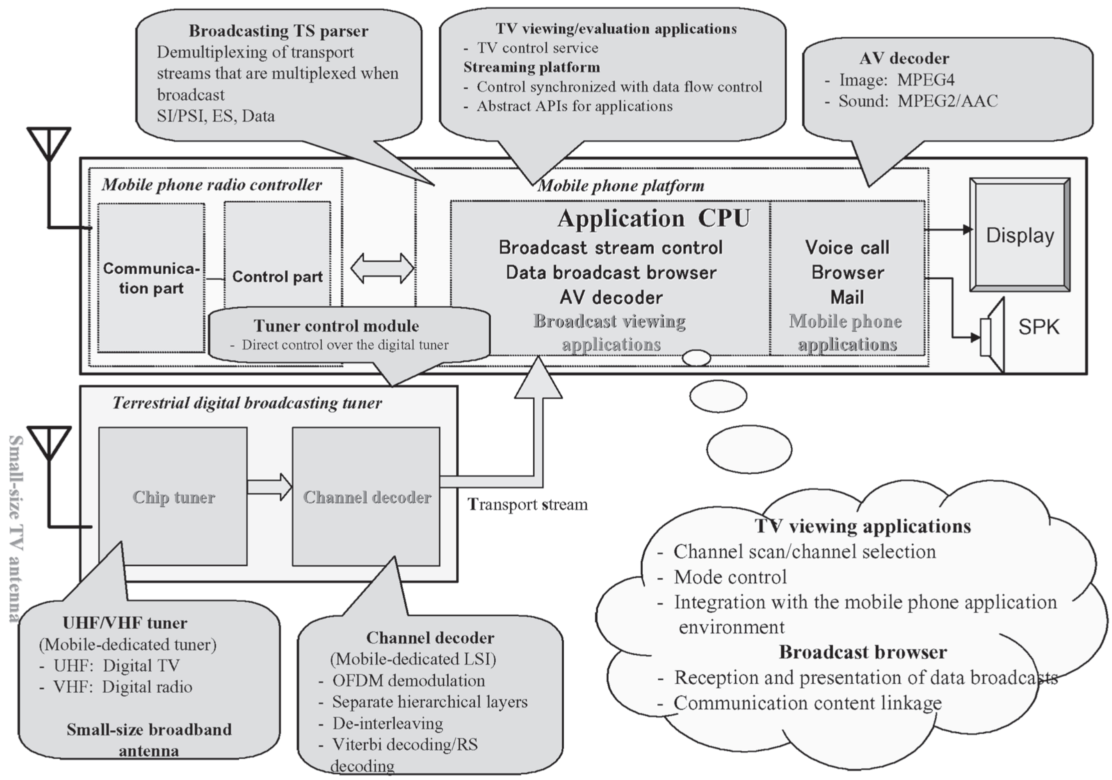

Fig. 2 Function block diagram of the prototype.

components to be added to the prototype, we developed a small-size TV antenna, a UHF tuner, and a system LSI chip for OFDM demodulation. Also, as built-in software for the mobile phone, we created TV reception control software that exerts control over these hardware components so as to enable the selection of the desired TV channel, and software that processes received broadcast streams (MPEG2 transport streams) to reproduce images and sound. Of particular note is that the digital stream decoding capability necessary for image and sound reproduction was realized in the form of firmware on the DSP built in the mobile phone, keeping the amount of additionally required resources to a minimum. This has enabled us to complete the prototype, which is virtually the same size as mobile phones currently on the market, ahead of competitors around the world. In fiscal 2004, we will need to add functionality for data broadcasting reception that has yet to be standardized, while no substantial change is likely to be necessary. The development of this terminal has made it possible for individuals to use video, audio, and data broadcasting services offered by the terrestrial digital TV broadcasting system anywhere anytime, while at the same time enjoying the interactive Internet communication capability of the 3G mobile phone in real time.

2. DEVELOPMENT OF AN AD-HOC MULTI-HOP SENSOR NETWORK SYSTEM

Today, the Internet is spreading to every corner of the globe. However, there are instances where return on investment in installing wired Internet infrastructure over a wide area cannot be expected due to an insufficient amount of information or where physical limitations make such Internet infrastructure difficult to implement. We have devised two innovations to counter these situations. One is a “power-saving wireless sensor terminal (hereinafter referred to as a sensor terminal).” A group of sensor terminals, each equipped with a standalone power source that requires no external power supply or maintenance by human personnel, autonomously form a network and relay environmental data, collected by their sensors, from one terminal to another to a remote location.

The other is an "ad-hoc multi-hop sensor network system," which allows elaborate wide-area environmental monitoring by having sensor terminals located several hundred meters apart in a mesh topology. With this system, sensor terminals can be installed in various locations such as forests, rivers, and mountains, where it has previously been difficult to install such devices. The characteristics of the system are described below.

1) Ad-hoc multi-hop communication

A group of newly developed sensor terminals arranged in a mesh topology communicate with adjacent terminals via radio links, thus implementing a power-saving network. The ad-hoc multi-hop communication technology enables the autonomous setup of multi-hop transmission routes and maintenance and management of the network. Use of this technology allows sensor terminals, located several hundred meters apart in a mesh topology, to form a network autonomously and to relay collected environmental data from one terminal to another to the monitoring center at a remote location over radio (the specified low-power radio frequency of 429MHz is used). Also, as shown in the configuration diagram of **Fig. 3**, if a sensor terminal fails, an alternative route is automatically found, enabling the reconfiguration of the network to ensure an optimum networking environment. Thanks to this feature, a highly reliable wide-area monitoring system can be established.

2) Development of a "power-saving wireless sensor terminal" equipped with ultra-low power consumption technology

By exploiting a unique intermittent reception technique and circuit technology that reduce power consumption substantially while the terminal is not engaged in communication, the sensor terminal operates on a very small amount of power, about 3mW a day on average (assuming that there are 30 nodes and that 30 measurements are made every day), as illustrated in **Fig. 4**. This permits the sensor terminal to operate solely on a tiny solar cell the size of a business card, like the one shown in **Photo 2**, while making it possible to use the sensor terminal even in a sunless place or during the nighttime and rainy season. **Table I** shows the specifications of this newly developed terminal. We intend to make the terminal more compact and to reduce power consumption further.

3) Elaborate wide-area environmental monitoring catering to diverse needs

Several different types of sensors can be mounted

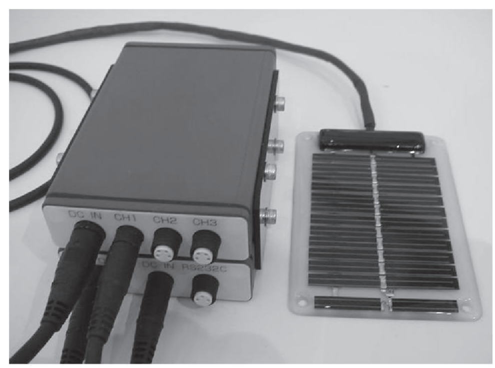

Photo 2 Tiny solar cell's size of a business card.

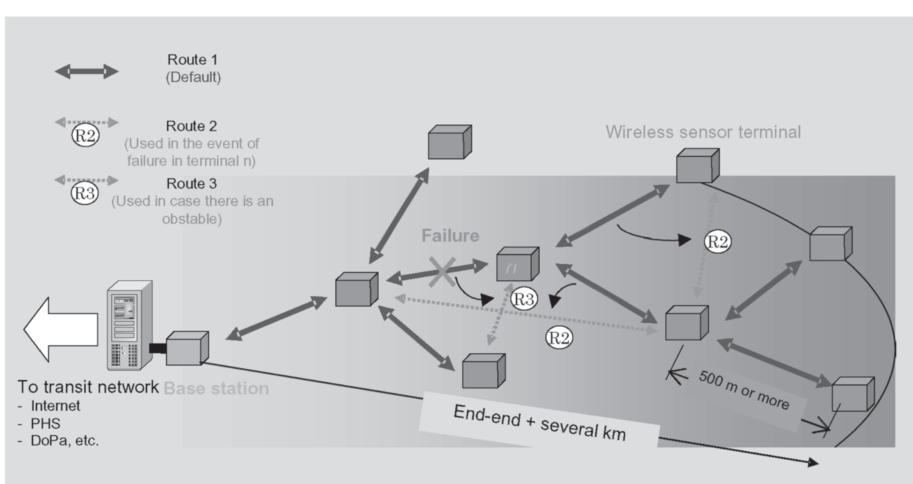

Fig. 3 Configuration diagram of ad-hoc multi-hop communication.

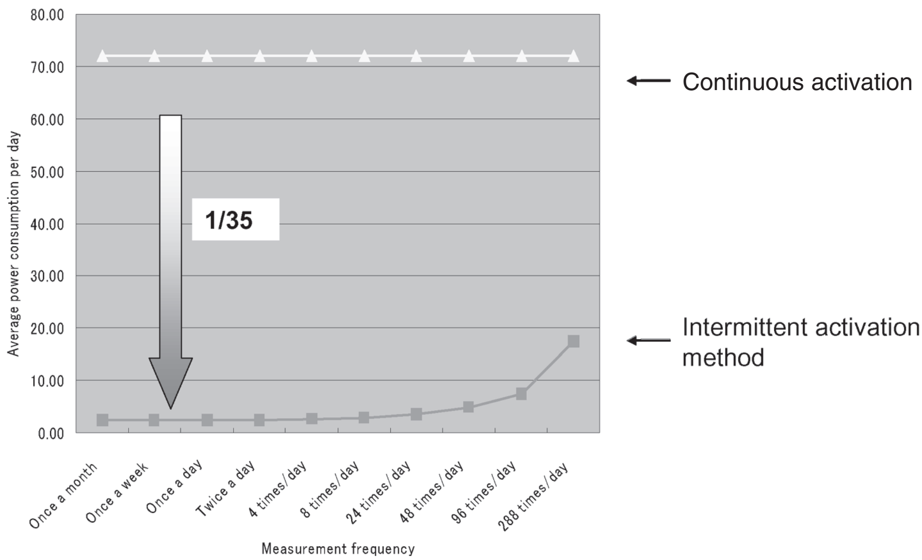

Fig. 4 Average power consumption with respect to measurement frequency (assuming 30 nodes).

Table I Specifications of the newly developed terminal.

Item	Specifications
Size	10(W) × 6.5(D) × 2(H) cm (main unit) 10(W) × 6.5(D) × 2(H) cm (battery)
Operating temperature	–10°C – 60°C
Radio system	ARIB STD-T67 specified low-power radio - 429MHz
Driving system	
Command	The base station issues two types of command to drive the terminal. (A) Ad-hoc multi-hop route setup, (B) Specified node measurement + data collection
Activation method	ID node specification by intermittent reception; and Intermittent activation by a built-in clock (time-specified)
Sensor interface	Serial interface, or interrupt + RS-232C data
Reliability enhancement measures	Retransmission in the event of a timeout or bit error Ad-hoc reconfiguration triggered by data acquisition failure
Data encryption	To be supported.
Waterproof standard	JIS IP64

on a sensor terminal as appropriate for the intended purposes such as measurements of temperature, humidity, and sunlight. Terminals can communicate with one another over distances of up to 1km or so. Installing sensor terminals several hundred meters apart in a mesh topology realizes elaborate wide-area environmental monitoring.

The “sensor terminal” can easily be installed by a layman without expertise in networking technology. By taking advantage of this feature of the sensor terminal, we intend to develop solutions that allow people to obtain a more detailed and scientific understanding of natural or urban environments with which they are familiar. In this way, we shall endeavor to create new areas of business while always taking into consideration symbiosis with nature and preservation of the environment.

Figure 5 illustrates an example of the application of this concept. In this example, a network comprising elementary schools in the basin of a lake is

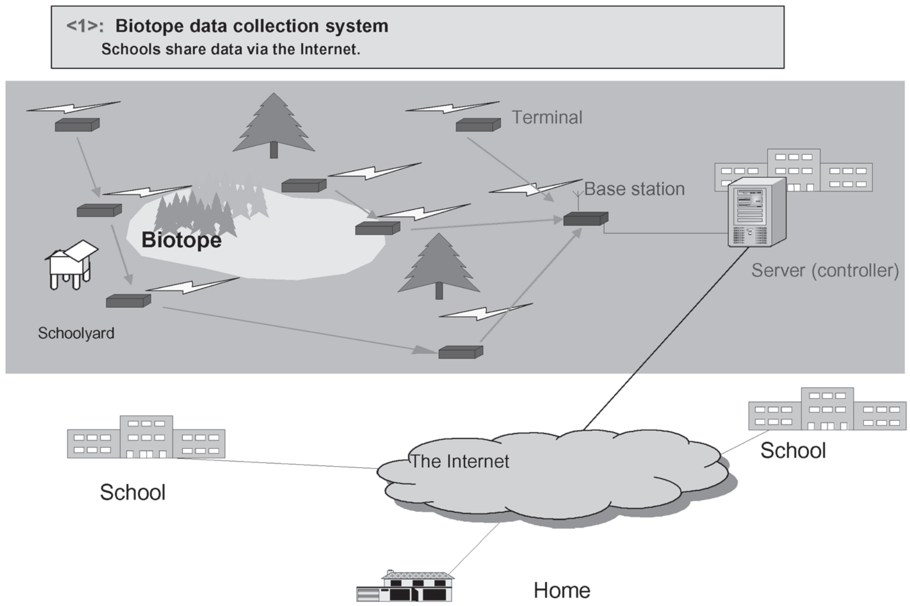

Fig. 5 Example of the application.

established for wide-area monitoring with the aim of restoring the natural environment of the lake. The project is slated to start in November 2003, with sensor terminals installed around biotopes of three elementary schools near the Kasumigaura Lake in Ibaraki Prefecture, Japan. Students of these elementary schools will collect data about the environment in and around their schools and keep records on observations of the wildlife in their respective areas, such as water plants, frogs and dragonflies. The elementary schools will share collected data with one another and use it for their environment education programs. We plan to promote the introduction of this system to all other schools in the Kasumigaura region, and to schools across the country, as part of environment preservation efforts and environment education activities. By encouraging the building of communities aimed at realizing an eco-friendly society not only in this and other regions of the country but also in other nations, we aim to achieve the restoration of the environment.

By working together with companies in various fields of business as well as with NPOs, NEC will make aggressive efforts to develop wide-area environmental monitoring solutions that are best suited to the specific needs of individual customers, including the following:

① Environmental monitoring for ecosystem management
② Environmental monitoring for city planning
③ Environmental monitoring for disaster prevention
④ Environmental monitoring for educational purposes
⑤ Environmental monitoring for building construction
⑥ Environmental monitoring for agriculture

3. CONCLUSION

In this paper, we have discussed two research and development items, which present good examples of how new forms of convenience can be created when different types of networks interwork while taking advantage of one another's strong points. When the purpose of a terminal is to implement multiple means of communication, it is important that the terminal should not only support physical implementations of those means but also feature middleware that guarantees service continuity and integrity without users being aware of differences in the means of communication. Such middleware establishes a communication path best suited to the service being requested, according to the security policy of the network to which the terminal has moved, while using the terminal-stored data about the individual in a secure manner. Although details are omitted here due to limitations of space, we have continuously been extending and improving this type of middleware as our core technology. It is featured in both of the systems described in this paper.

In addition to the two items discussed herein, the Network Development Laboratories is conducting R&D work on different-type network connection with respect to such items as interworking between wireless LAN and cellular wireless system and interworking between non-contact IC card and cellular wireless system. We are considering presenting the results of these R&D efforts on future occasions. Our understanding is that the full-fledged embodiment and commercialization of the "new forms of convenience" stemming from these inter-network connection technologies should be promoted as we develop more ways to use them based on feedback from the market. We will appreciate requests and advice from any division concerned.

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Akira KATO received his B.S. degree from Saitama University in 1975. He joined NEC Corporation in 1975. He is engaged in the development of application platform for mobile terminal. He is now Senior Manager of System Platforms Research Laboratories.

Masanobu ARAI received his B.S. degree from Tokyo University in 1979, and his M.S. degree in 1981. He joined NEC Corporation in 1981. He was engaged in the development of digital switching systems and their interface key devices such as BORSCHT and ISDN, and is recently engaged in optical switching and ubiquitous sensor network system. He is now an Executive Manager at NEC System Platforms Research Laboratories.

Mr. Arai is a member of the Institute of Electronics, Information and Communication Engineers of Japan.

Ryuhei FUJIWARA received his B.S. degree from Tokyo Denki University in 1975. He joined NEC Corporation in 1975. He is engaged in the development of ubiquitous network services platform. He is now a Chief Manager at NEC Ubiquitous Platform Development Division.

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