6 Seamless Networking Technologies

6-1 Overview of Research and Development on Seamless Networking Technologies

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National Institute of Information and Communications Technology of Japan (NICT) completed a project on new-generation mobile communications networks for beyond 3G or 4G in March 2006. This paper presents our vision of new-generation mobile communications networks from networking perspective and their capabilities to be offered: fast and large-capacity handover, cross-network handover, cross-device handover, and interworking between real and cyber worlds. Then, Metro Mobile Ring network technology for the first capability, MIRAI architecture for the second and third capabilities, and other works are presented.

Keywords
Seamless, Handover, Context-aware

1 Introduction

The National Institute of Information and Communications Technology of Japan (NICT) completed its four-year New Generation Mobile Network Project in March 2006. In the course of the project, we investigated the four technical steps listed below, each of which will be required for the realization of new generation mobile communications networks, as we pursued a range of research and development of the related technologies[1](Fig. 1).

(1) Fast, large-capacity handover: Implementation of a wireless Internet environment with fast, large-capacity handover

(2) Cross-network handover: Implementation of seamless communication by cross-network handover across different types of wireless access methods

(3) Service and device cooperation: Implementation of new methods of communication by cooperative operation of communication devices and services (cross-device handover)

(4) Interwork between the real and the virtual worlds: Establishment of a novel space connecting the physical world and the network-based “cyber world”

This article will describe these four steps and present an overview of the specific related research and development.

2 Development of new-generation mobile communications networks

2.1 Fast, large-capacity handover

In the first step toward the realization of new generation mobile communications networks, wide service areas will be established

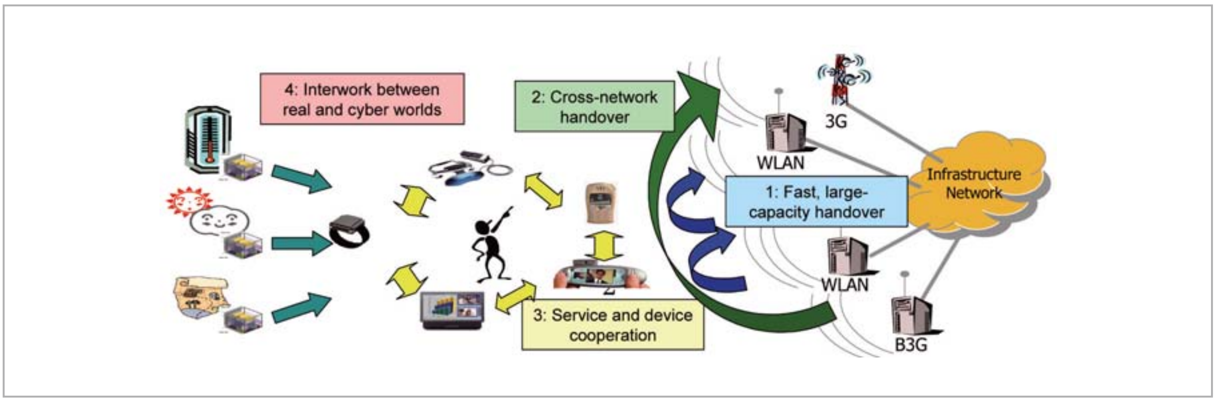

Fig. 1 4 Steps toward new-generation mobile communications networks

based on ubiquitous placement of next-generation wireless LAN base stations. This configuration will allow users to access the Internet using IP-compliant mobile terminals or nodes. Here, the base stations are switched instantly as users move about while using mobile terminals. The system will also enable the smooth operation of real-time Internet applications even when the user is in motion, including VoIP (Voice over IP), video-phone, and radio and video broadcast services. To implement such a system, we must take mobility, poor wireless links, and restrictions on mobile terminals or nodes into consideration as we design a mobile Internet architecture that will provide both autonomous applications and network transparency. At the same time, other technical problems remain to be solved, including rapid (horizontal) handover, roaming support, vertical integration between carriers providing different services, and distributed autonomous frequency allocation.

2.2 Cross-network handover

In this step, two or more wireless networks—for example, cellular networks and wireless LANs—will coexist, and the terminals will feature two or more wireless network interfaces. The user will be able to select the most suitable network according to the situation and seamlessly switch from one to another.

For example, while a terminal may normally communicate via a mobile phone network, when the user enters wireless LAN, Bluetooth, Zigbee, or UWB (Ultra Wide Band) access areas, the terminal will automatically select one of the alternative network services—improving communication speed, reducing costs, and making the most efficient use of frequencies, all from the user's perspective. It will also be possible to distribute traffic to other wireless interfaces when it becomes difficult to continue using one access network due to network congestion. Toward the realization of a seamless network, we must also consider issues such as fast vertical handover, mechanisms for low power consumption, presence services, and software radio.

2.3 Service and device cooperation

Through this step, the user will be surrounded by various devices, from mobile terminals to PCs and home electrical appliances. Our aim is to create new services based on handover among these devices, using PANs (Personal Area Networks).

For example, when a user reaches an office during voice communication over a mobile terminal, he or she could launch a videophone application on the desktop PC at hand and hand over voice communication from the mobile terminal to the videophone on the PC. This sort of service mobility will become possible. As a further example, we may regard the mobile phone as an aggregate of functions such as display, ten-key input, voice input and output, wireless communication, CPU, and memory. By combining these functions with external devices, we could, for example, control the television with a button on the mobile phone or transfer an image from the television to the screen of the mobile phone. “Service and device cooperation” thus refers to the combination of devices and functions around the user according to the user’s request; such cooperation will inevitably lead to a diverse range of creative services. However, it is first essential that we develop technologies for fast service, rapid device detection, device and service description, context management, security, and privacy protection.

2.4 Interwork between the real and virtual worlds

In the future mobile network environment, networks will connect a vast number of nodes that strongly depend on the user’s context (time, place, individual); these nodes may consist of tags, sensors, robots, wearable equipment, and home electrical appliances. From these nodes, the application will acquire and make effective use of information from the real space. It is safe to say that this interwork between the real and the virtual world will lead to the establishment of an entirely novel environment.

If we can combine the real and cyber worlds, we can provide services exclusively for a given place or a particular person; in other words, we will be able to customize the environment according to the time, the place, or the user, in order to provide the most context-sensitive services. For example, it will be possible to structure a printing flow through automatic detection of the nearest printer. It will also be possible to distribute information according to the user’s changing location, estimated using floor-pressure sensors or acceleration sensors built into the mobile terminals or nodes. To realize these services, however, we must first solve a number of challenging problems, such as those related to middleware for the acquisition, description, and management of various contexts, as well as particular issues related to the development of sensor networks.

3 Specific activities

We conducted a range of research and development to work toward implementation of the four steps: fast, large-capacity handover; cross-network handover; service and device cooperation; and the interwork between the real and the virtual worlds.

3.1 Metropolitan area mobile ring network

Metropolitan area mobile ring network technology is a requisite element in implementing the first step—fast, large-capacity handover. Accordingly, we have proposed an All-IP mobile network system that can accommodate approximately one million users in large cities such as Tokyo or Osaka. This system can also easily provide mobile users with various Internet applications, such as VoIP (Vvoice over IP) services. We have also proposed an LMA (Localized Mobility Agent), a network node system that incorporates an All-IP mobile network[2][3]. The key features of this technology consist of a method for mobile terminal routing information management, one that does not lead to deteriorated performance, even with an increase in the number of users; and a fast handover mechanism, which minimizes instantaneous interruption in communications when the access points are switched as the terminal moves. Figure 2 illustrates the concept behind this design.

When a large-scale mobile network is constructed with a conventional hierarchical architecture, this increases the routing information for all the mobile terminals within the network, maintained by the top node of the hierarchy; this in turn increases the routing load of the node and reduces scalability of the network. On the other hand, the proposed method uses a flat network structure (ring and line structures are possible), which provides distributed control of the routing information and increases scalability. The flat structure is also effective in transferring the packets at the wire speed to the adjacent LMAs, enabling fast handover.

Optical metro rings, which connect network nodes through optical fibers in ring structures, are widely used in urban environments. We will be able to implement the proposed network by placing an LMA in each node of the optical metro ring system. The LMA connects 802.11 and 802.16 wireless systems with next-generation cellular base stations. The ring network establishes an IP subnetwork, and mobility is guaranteed with respect to other ring networks and external networks, using the macro-mobility technology such as Mobile IP.

In the first half of the project, we evaluated the basic performance of the LMA functions with a software system installed on a Linux PC[4] per one LMA. In the latter half, we constructed a validation system using LMAs incorporating network processors and then evaluated system performance[5]. We have confirmed that the proposed system is superior in terms of both delay and throughput (relative to a hierarchical network), when each LMA is accommodating approximately 100,000 users. While Mobile IPv4 requires 3 to 6 seconds for handover between LMAs, the proposed method can shorten this time to approximately 1/10 of the time required for Mobile IPv4. Finally, we constructed an experimental network using the indoor and outdoor testbed networks NICT has constructed in the YRP (Yokosuka Research Park) area (Fig. 3). In this case we succeeded in performing a communication verification experiment using a car equipped with a mobile terminal[6].

When the metro mobile ring system is commercialized, we will be able to enjoy a full range of services, including video delivery on the Internet or videophone applications via fast wireless LAN, as we circle on the JR Yamanote Line. The application of this technology will not be restricted to the metropolitan area. Instead it will be applied to many locations, including commercial buildings, amusement facilities, areas along roads or railways, and throughout small and medium-sized municipalities. In this context, we are currently conducting an experiment in commercialization in cooperation with a communications company. (Refer to reference[7] for details.)

3.2 Fast macro-handover

To pursue additional research related to the first step discussed above, we assembled the “SIMPLE” project[8], a collaborative research initiative involving government, industry, and academic organizations—including NICT’s departments related to wireless communication and information & network systems technologies, the Tokyo Institute of Technology, Keio University, the University of Tokyo, and Root Co., Ltd. Under the aus-

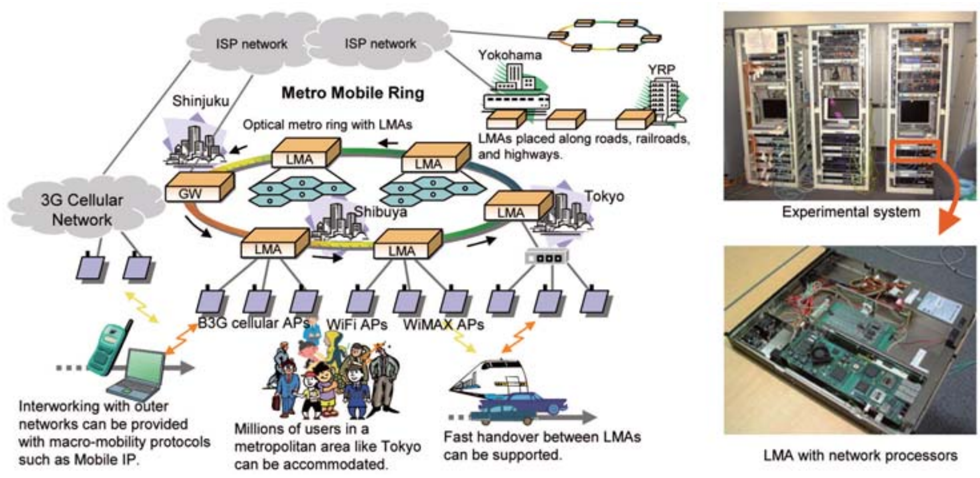

Fig.2 *Development concept of metro mobile ring (left) and experimental system constructed with LMAs (Localized Mobility Agents) implemented with network processors (right)*

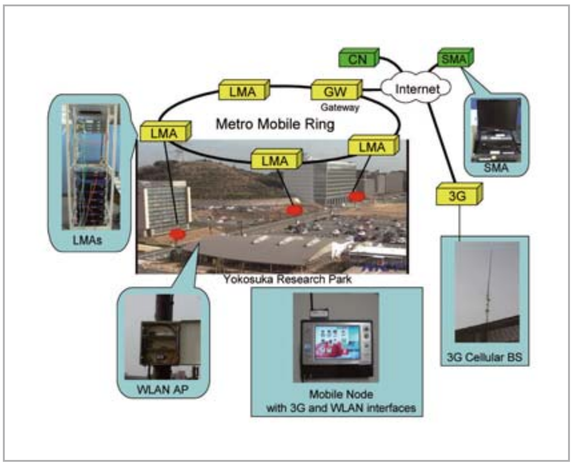

Fig.3 *Configuration of outdoor metro mobile ring experiment*

pices of this project, we conducted a number of verification experiments in fast handover technology. For example, we constructed a fast handover network in YRP (Yokosuka Research Park), utilizing MISP (Mobile Internet Services Protocol) and PDMA (Packet Division Multiple Access) (Fig. 4). We acquired a license to operate the experimental station in the 5-GHz band and used terminal stations and wireless base stations providing physical transmission speeds of 108 Mbps with two IEEE802.11a channels. We confirmed that packet loss did not occur when switching between wireless base stations in an environment of the appropriate wireless signal intensity. We also confirmed that video images did not degenerate even when switching between wireless base stations within a system of transmitting high-definition video (approximately 15 Mbps) from a moving vehicle through wireless base stations for receipt and playback over the network[9][10].

3.3 MIRAI

MIRAI is a technology for implementing the second step, cross-network handover. For this step, we proposed a new communication architecture, which we designated MIRAI (short for "multimedia integrated network by radio access innovation")[11], and conducted research and development related to the implementation and improvement of functions within this architecture. MIRAI's essential

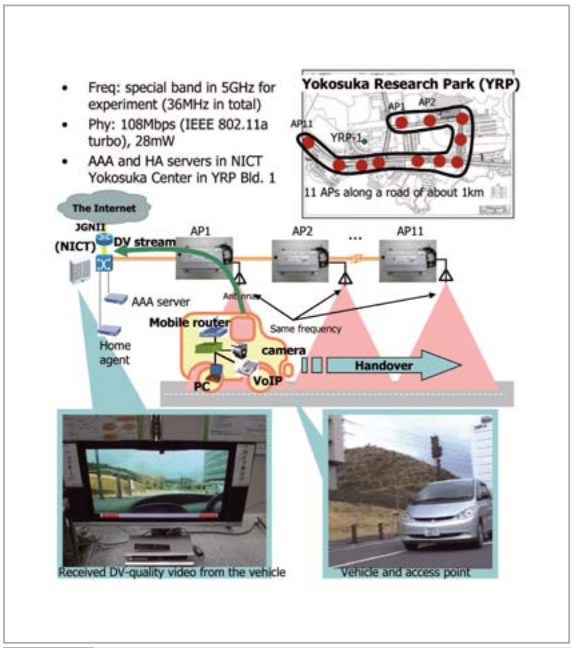

Fig.4 *Fast handover experiment in the SIMPLE project*

characteristic lies in its logical and physical separation of the data path, which transmits the user data, from the control path, which transmits control information such as call initiation and paging, position information, and authentication. These two paths may thus be placed on different wireless networks[12] (Fig. 5).

Using an independent control path to exchange control information between the MIRAI server on the network and the user terminals, MIRAI enables the functions required for mixed wireless environments, including call initiation and paging, position notification, network and terminal authentication before use, and notification of available wireless access networks. As the terminals normally need only to connect to the control network, MIRAI can improve the efficiency of frequency use and reduce terminal power consumption[13].

Our research was based on two approaches: one to implement a control path with a dedicated wireless system[14]-[16], and the other to implement a control path by overlaying it on an existing wireless system[17][18]. Based on the results of this research, we were able to make significant contributions to the "ITU-R Beyond 3G" and the "TTC-ARIB interdisciplinary IP2”[19]. (See reference[20] for details.)

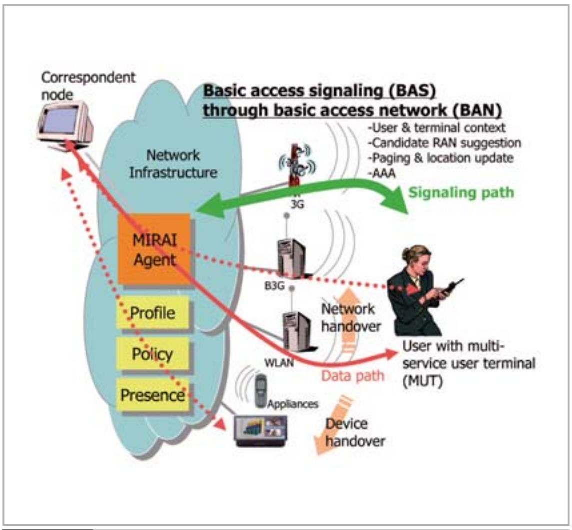

Fig.5 Concept behind MIRAI, involving the separation of control and data paths

3.4 Service mobility

As a technology to support the third step—service and device cooperation—we also conducted research on cross-device handover technology, based on the use of a service mobility proxy[21][22]. This technology enables handover of communications over diverse terminals and devices and supports many communication applications without the need to modify the servers and existing terminals at the receiving end of communications. In addition to PCs, handover is implemented between commercial communications devices (including PDAs and videoconferencing systems), and can also include speakers designed to connect directly to the Internet[23]. It is thus possible to switch among terminals that have different functions—for example, performing seamless handover of voice-only communication to a videoconferencing system with a large monitor.

In the latter half of the project, we completed a prototype of an integrated seamless communications system that combines cross-network handover technology, cross-device handover technology, and position-information platform technology[24] (Fig. 7). The concept behind the system is to place the ubiquitous networking servers responsible for the handover function not on commercial ISP (Internet Service Provider) networks but rather on networks in homes, in companies, and in universities, thus providing diverse mobile functions to the users that form the network system. Such a system functions not only to switch communications according to position information, the status of the network in use, the process capacity of the devices, and the range of available functions, but also allows for control of communication quality and modification of the content of communications.

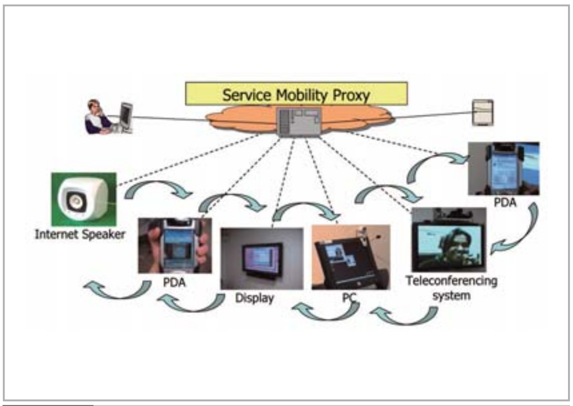

Fig.6 Cross-device handover by service mobility proxy

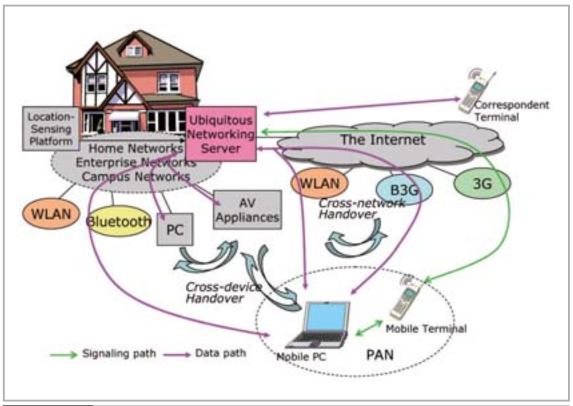

Fig.7 Ubiquitous network server providing all cross-network and cross-device handover functions

3.5 Context-aware mobile services

Context-aware mobile service technology supports the fourth step: interwork between the real and the virtual worlds. Our goal was to implement a network environment capable of handling contextual user information. Accordingly, we constructed a testbed environment equipped with various sensors and service/device detection systems, in our attempt to further the development of context-aware mobile service middleware, context estimation functions, and mechanisms for rapid service and device detection (Fig. 8).

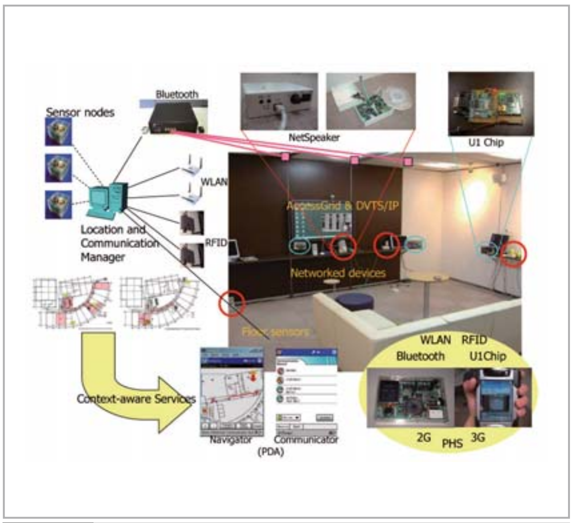

Fig.8 *"Smart space" consisting of various sensors and position estimation systems*

In various places on the second and third floor of the Building No.1 at the YRP (Yokosuka Research Park), we placed active RFID tag readers on the ceilings and walls, weight sensors on the floor, and an indoor positioning system that we developed based on Bluetooth technology[25]. We thus constructed an experimental environment capable of assessing the positions of users through a variety of methods. We also connected diverse devices to the network, including network speakers, videoconferencing systems, displays, and lights. We also installed prototype applications, including one for service switching according to the position and situation of the user and individual navigation, using context-aware service middleware[26]. Further, we also developed the U1 chip[27] indicated in the upper right of Fig. 8, which indicates a wireless communication module that can detect diverse services and devices instantly with low power consumption. This module enables seamless collaboration between terminals in a ubiquitous environment of diverse devices. (Refer to reference[28] for details.)

4 Conclusions

This article presented an overview of research and development of network technologies for the implementation of next-generation mobile communications network systems. In terms of metro-mobile ring technology, we have evaluated basic performance levels, opened prospects for practical applications, and are now examining the details of commercialization. Regarding the research on fast macro-handover, we have confirmed the lossless handover of 15-Mbps high-definition video images. For seamless cross-network handover, we have proposed a new communications network model (the MIRAI architecture), described a seamless communications mechanism based on integrated ubiquitous networking servers (featuring both cross-network and cross-terminal handover), and offered a model for future ubiquitous communication to follow FMC, the current focus of attention. We have also made specific contributions to the ITU-R and other organizations. We have included context-awareness factors in our concept of seamless cross-network handover, based on contextual information relating to the user or the immediate environment, as acquired from various sensors. Finally, we have shown that it is possible to improve user convenience while promoting progress in the communication services.

When we conducted these research activities, we viewed progress in the mobile environment not in terms of system issues but rather based on the human user. We implemented diverse application prototypes on the testbed, mainly taking an approach in which we explored the new generation mobile environment based on feedback from the user experience. Although we cannot say that a "killer application" has clearly emerged for the new generation mobile era, the possibility of an innovative paradigm shift is clear, one that will likely involve the interwork between the real and the virtual worlds. It is important that we continue research and development into a next-generation network that will continue to support this progress, including R&D in sensor networks, context-aware communications, and ubiquitous networking.

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