6-2 Basic Access Signaling and Context-Aware Seamless Networking

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A variety of wireless access technologies such as cellular system, wireless LAN, Bluetooth, and WiMAX emerged or are emerging. Appliances that can be connected to the network have also been diversified from telephone terminals to consumer electronics and game machines. The presence of such diversified, heterogeneous networks and appliances will be a defining characteristic of the new-generation mobile network era, which will demand advanced telecommunication services and greater usability through optimal selection and switching among networks and appliances. We proposed "MIRAI" architecture where an out-of-band signaling network separated from other networks for data transfer is established and have studied the feasibility and enhancement of the concept. This paper describes the characteristics, deployment scenarios and experimental systems of the MIRAI architecture.

Keywords
Heterogeneous wireless networks, Basic access signaling, Network handover

1 Introduction

To date a variety of wireless access technologies, such as cellular phone systems, wireless LANs, Bluetooth and WiMAX, have emerged or are in the process of emerging. The types of appliances capable of being connected to a network have also been diversified, including telephone terminals, information home appliances, and game machines. The presence of such diversified, heterogeneous networks and appliances will be a defining characteristic of the new-generation mobile network era, which will demand advanced telecommunication services and greater usability through optimal selection and switching among networks and appliances. To meet this demand, we have proposed the "MIRAI" architecture, which is characterized by a Basic Access Signaling (BAS) mechanism for exchanging control information between the user and the network, with studies focusing on overall feasibility and ways of enhancing the underlying concept. This paper describes the characteristics and some deployment scenarios of the MIRAI architecture, together with a discussion of demonstration experiments related to these scenarios.

2 Overview of the MIRAI architecture

2.1 Background of MIRAI

We have proposed our MIRAI communication model for use in a future heterogeneous wireless network environment[1][2]. This model is characterized by its separation of the control path (for transmission of control information) from the data path (for transmission of data). Figure 1 shows a conceptual diagram of the MIRAI structure. The Radio Access Network (RAN) that provides the control path is referred to as the Basic Access Network (BAN). MIRAI exchanges Basic Access Signaling (BAS) between the terminal and the network via the BAN.

This model is based on the concept that the system will permanently connect the user terminal to the core network via the BAN, which transmits all control information—including call initiation and paging—in an environment of multiple available wireless networks. Wireless networks other than the BAN are used only for data transmission. For example, a terminal that has received a videophone request through the BAN would enact a series of steps: selection of a RAN capable of transmitting videophone data and setup a data connection to the network through the RAN.

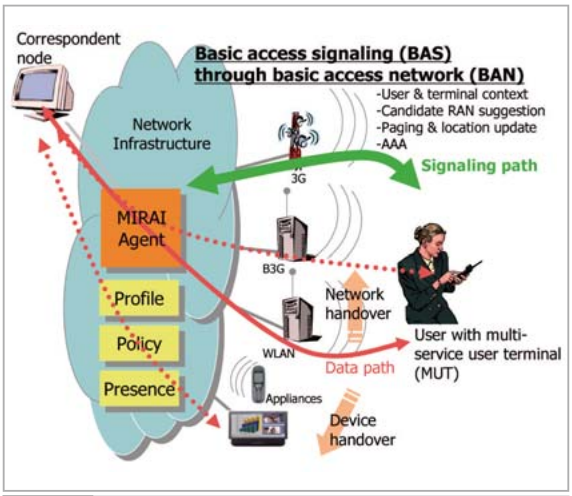

Fig.1 Conceptual diagram of MIRAI

2.2 Characteristics of Basic Access Network (BAN)

The characteristics of the Basic Access Network (BAN) are as follows.

(1) In standby mode, the terminal connects only to the BAN. Power consumption is suppressed by switching off the interfaces of the remaining RANs[3]. Currently, the terminal generally maintains two or more wireless network interfaces on standby to shorten the connection and switching time, which leads to higher power consumption. In the future, software radio technology will make it possible to search for two or more wireless networks for optimal connections. As discussed below, it is possible to limit the search frequencies by transmitting information on the user's position and on the available wireless networks. In this manner, we can expect to see reductions both in power consumption and in search times.

(2) We can improve spectrum efficiency by integrating the individual control channels of the RANs into a single BAN. This generic architecture will also easily accommodate new RANs. Generally speaking, today, we need to specify the wireless methods to be interconnected: for example, we can develop an integration technology after having specified "W-CDMA and Wireless LAN" as the wireless systems to be interconnected. This process could be neither efficient nor extensible.

(3) It is possible to transmit control information unique to a heterogeneous wireless environment together with the information required for mobile communication in general (such as position registration, call initiation, and paging) via the BAN. In other words, it is possible to notify the network of the user's preferences or of the peripheral devices detected by the terminal, to inform the user of the available wireless networks estimated based on the user's position and preferences, to implement pre-authentication in the handover between networks and terminals, and to assist in the handover. These functions will make it possible, for example, to provide the network with contextual information regarding the terminal and the user; to inform the user of the RANs, access points, and peripheral devices that he or she can use next; and to effect authentication (confirming access permission) before switching (handover) of the communication.

2.3 Deployment scenarios for Basic Access Signaling (BAS)

The RAN, which works as a BAN, needs to cover a wide area. Although rapid communication is not necessarily required here, high reliability in the signaling communication is essential. With these concerns in mind, we studied the following three scenarios for the practical deployment of the BAN[2].

(1) The first scenario makes use of a dedicated wireless system newly developed for use with a BAN. This method is ideal and will solve a range of problems in the long run. NTT has also proposed providing a similar wireless network system for future low-performance ubiquitous communications, and for control of a large number of widely distributed devices[4].

(2) The second scenario uses an existing RAN exclusively dedicated to a BAN. A pager system and a second-generation cellular phone system are prospective candidates for use as a BAN, because they satisfy the above-mentioned requirements—wide coverage and high reliability—and because these technologies will be disposed of sooner or later if they are not considered to offer opportunities for reuse. This scenario is considered to be an economically rational one.

(3) The third scenario also uses an existing RAN but superposes a BAS over other communication services within the RAN. This method is referred to as the "overlay" method.

We have compared three implementation methods: (i) the BAS is implemented in a dedicated BAN [corresponding to Scenarios (1) and (2)], (ii) the BAS is overlaid on a RAN [corresponding to Scenario (3)], and (iii) the BAS is not used[5]. In (ii), we considered a cellular phone system and a wireless LAN as forming the RAN. In (iii), we considered a software radio terminal and a terminal having multi radio communication modules as constituting a Multi-service User Terminal (MUT). We took three evaluative criteria into consideration: extent of coverage, power savings (for the entire MUT), and response time from paging to start of data transmission. Table 1 summarizes the results. The evaluation results in terms of costs for both the provider and the user in Tab. 1 are just for reference in this paper because we need careful discussion on them.

If we implement a dedicated BAN, we have the optimum wireless design and high performance, but we incur potentially high costs. If we implement the BAS functions on a RAN, the MUT would ideally transmit and receive control information in all areas accessible to the RAN. Using the infrastructure of an existing cellular phone system, it becomes possible to implement wide area signaling without constructing a new infrastructure. We can also expect notable power savings under this scenario. For implementation method for BAS, it appears possible to construct and use either dedicated hardware or application software. On the other hand, if the BAS is not used in a heterogeneous wireless environment, it will first of all be difficult for the terminal to receive the page. The terminal cannot determine correctly or quickly which wireless services are available at the user's position, and needs to search the wireless networks frequently. In addition, the terminal cannot know from which wireless network the paging request will arrive, so it must keep all network interfaces active. Although software radio terminals can simultaneously connect to two or more wireless networks in principle, the extent of these connections may be limited, due to constraints in implementation. Multi-device terminals pose the problem of high power consumption, as they must maintain two or more active devices. Without BAS, the network is required to incorporate a complicated control system, which will be difficult to operate flexibly in a heterogeneous wireless network environment.

Table 1 *Comparison among implementation methods for Basic Access Signaling (BAS)*

		Extent of coverage	Power savings	Response	Cost	
					Provider	User
BAN (dedicated system)		◎	◎	◎	△	△
BAS on RAN	Cellular phone system	○	○	◎	◎	○
	Wireless LAN	△	×	◎	○	◎
Without BAS	Software radio terminal	◎	○	×	○	△
	Multi-device terminal	◎	△	△	○	△

◎ very good, ○ good, △ may not be good, × not good

3 Scenario 1: Method based on new dedicated wireless network

We investigated a method based on a new wireless system for a BAN[6][7] and constructed a corresponding experimental system[8]. We also developed a new Media Access Control (MAC) protocol for this wireless system. Figure 2 shows a conceptual diagram of the experimental setup. The Common Core Network (CCN) consists of a Resource Manager (RM), a BAN Base Station (BAN-BS), Linux PCs, and other devices. The CCN uses IPv6 and provides a micro-mobility function. We placed all the components of the system in the laboratory on the third floor of the YRP No.1 Building in Yokosuka Research Park. We installed a 5-m antenna on the roof of the building and connected it to the BAN-BS with a coaxial cable. Additionally, poles have been built by NICT along the roads in the Yokosuka Research Park for installing experimental wireless base stations. We installed wireless LAN (IEEE802.11b) and local PHS base stations on these poles. The poles are connected to the terminator in the YRP No.1 Building via fiber-optic cables. We connected the base stations to the experimental system through the terminator.

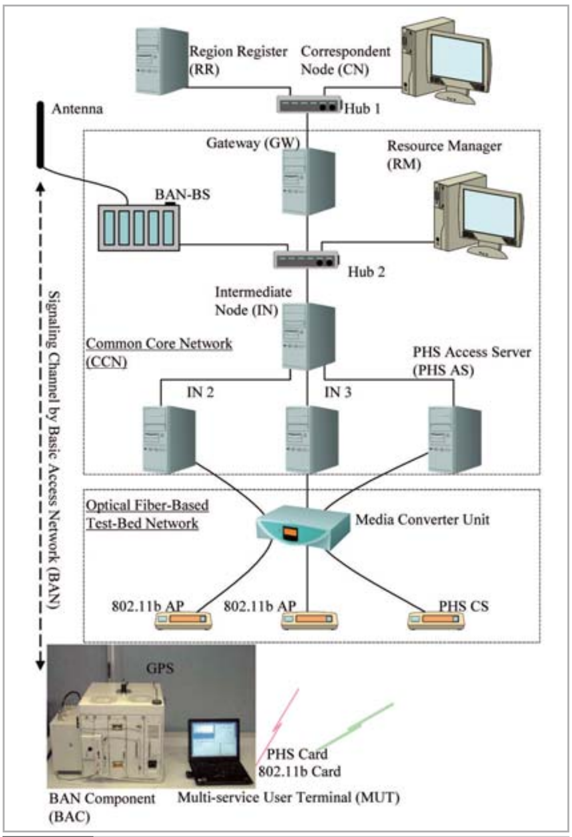

Fig.2 MIRAI system with dedicated wireless system for a Basic Access Network (BAN)

Table 2 Specification of Basic Access Signaling (BAS) dedicated wireless communication

Tx frequencies	BS: 385.3375	BAC: 367.3375 MHz
Tx power	BS: < 1 W	BAC: 200 mW
Ant. gain	BS: 7 dBi	BAC: 2 dBi
Noise figure	10dB	
Modulation	Down: 16QAM	Up: Adaptive QAM(64/16/4) + Bi-orthogonal(32/16/8)
Tx rate	19.2 kilo symbols/sec in a 25 KHz channel	
MAC	Dynamic TDMA / Dynamic TDM	
Multiplex	FDD	

We devised a high-efficiency MAC protocol based on FDD/TDMA for full duplex communication using radio waves near 400 MHz. We combined this protocol with a wireless adaptive modulation unit and developed a two-way wireless communication system[8]. A bandwidth of 25 kHz was used (both for uplink and downlink operations), with a transmission rate of 19.2 kilo-symbols per second. The control packet for transmitting the uplink control information used permanent 4 QAM modulation, to maintain reliability. For uplink data communication, we used adaptive modulation, based on considerations of wide coverage, communication capacity, and power savings within the terminal. The terminal selected one of six modulation modes. On the other hand, the downlink line used only the 16 QAM, for both control information and data. We adopted 1/2 convolutional coding and obtained a coding gain of 5.2 dB at a bit-error rate of 10^{-5}.

When constructing the experimental system, we decided to adopt a two-way paging system that has been in commercial use in the U.S. and Asia, selecting the ReFLEX25 base stations provided by Glenayre. As in the experimental system of Scenario 1, we constructed outdoor wireless areas for the wireless LAN (IEEE802.11b) and the local PHS. For the MUT, a notebook PC was equipped with a wireless LAN card and a PHS card and connected via the serial interface to the ReFLEX25 paging module. We modified the ReFLEX25 downlink frequency from the original 800-MHz band to the 280-MHz band selected for this experiment[9].

The signaling gateway indicated as “Gateway” in Fig. 3 exchanges BAS with the MUT. The base station, BAN-BS, of the two-way paging system exchanges messages with the terminal. The MUT is equipped with software modules for resource management, call control, profile management [Figure 4 shows the Graphical User Interface (GUI) screen], and session management. The resource management module monitors and controls the RAN and the BAS components. The profile management module manages the user profile and preferences. The session management module handles the BAS and the Session Initiation Protocol (SIP) messages between the application on the MUT and the signaling gateway. We improved Linphone, which is a Voice over IP (VoIP) open-source program based on SIP, and installed this as the application.

As in Scenario 1, we installed the base station antenna on the roof of the YRP No. 1 Building and connected it to the base station’s main body within the building. The service area of the BAN was a circle with a diameter of approximately 2 km (Fig. 5). This system was confirmed to operate as follows: the fixed VoIP phone calls the MUT, the MUT receives the call signal via the two-way paging line, selects either the wireless LAN or the PHS, connects the line, and establishes a VoIP session with the fixed VoIP phone. This experimental system could not optimize the downlink line of the two-way paging system due to limitations in the performance of the devices; paging required approximately 10 seconds. More rapid response will become possible through optimization.

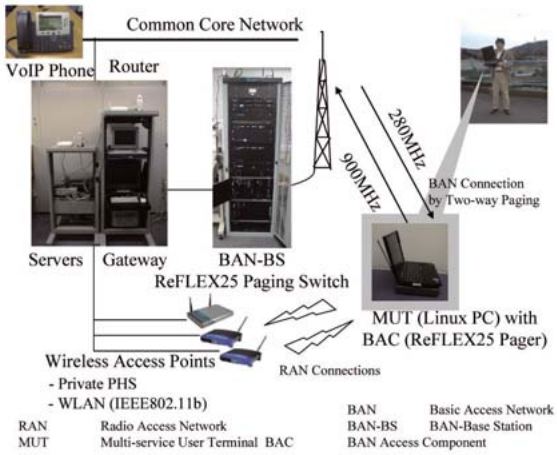

Fig.3 MIRAI system based on wireless paging configuration for Basic Access Network (BAN)

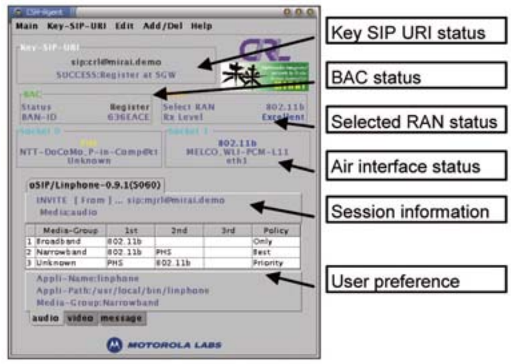

Fig.4 Profile Management GUI

Fig.5 Coverage of Basic Access Network (BAN) in YRP

4 Context-sensitive seamless network

Scenarios 1 and 2 are ideal but require a great deal of time to implement; these are to be viewed as long-term solutions. We addressed the overlay method under the third scenario, as one with relatively high feasibility[10]-[12].

Figure 6 shows the basic concept involved. The BAS is executed between the Ubiquitous Networking Server (UNS) and the terminal. In addition to the functions of conventional network handover, we combined the UNS with the inter-terminal handover function[13] we developed separately[12]. We assumed that one UNS would manage one network domain such as a home network, an enterprise network, or a campus network. The user constructs a personal area network (PAN) of mobile PCs and mobile terminals. The PAN is always connected to the UNS via the BAN. As a defining feature, the user can select an arbitrary RAN as the BAN. The selected RAN is not dedicated to the BAN but can also be used for data communication. The packet for receipt by the user is received by the UNS and is transferred to the PAN via a RAN selected according to the position of the PAN and the user's preferences. As the UNS also performs inter-terminal handover, it can also execute handover to various communication devices, including PCs and AV devices[14].

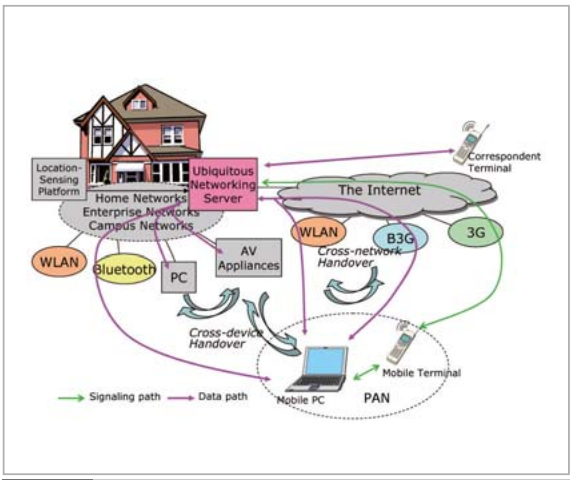

Fig.6 *Overlay MIRAI system*

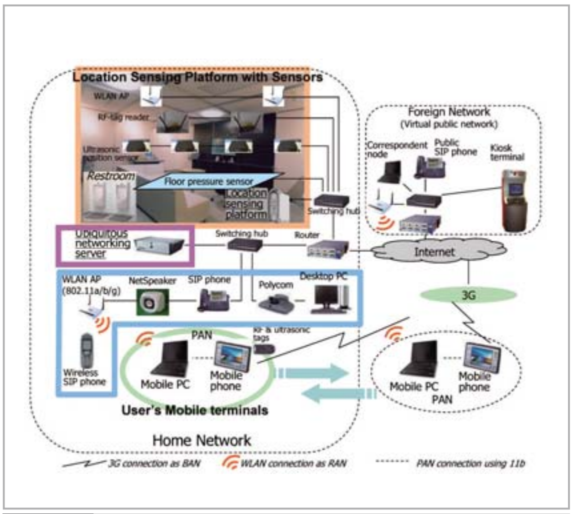

Fig.7 *Configuration of experimental system*

Figure 7 indicates the experimental system we established. The upper part of the home network on the left represents the position information platform, consisting of various sensors[15]. The mobile terminals constituting the PAN are equipped with wireless tags, ultrasonic tags, acceleration sensors, and azimuth sensors. The mobile PCs are equipped with W-CDM and EV-DO card interfaces. We used the ad-hoc mode of the wireless LAN in communications between a mobile terminal and a mobile PC.

This system implements the following elements: (1) integrated operation of network handover and inter-terminal handover, (2) various operations such as network handover, inter-terminal handover, media switching (e.g., switching from a videophone to a voice phone), and QoS optimization (e.g., modifying image quality on a videophone) according to contextual information (e.g., user presence, positions of the user and the peripheral devices, types of network interfaces on the mobile terminal, availability of networks, available network speeds, user-specified priority in selecting the network, and installed functions and processing power of the mobile terminal or peripheral devices), and (3) notification to the communication destination of the user's preferences. For example, the user can inform the caller that the user does not prefer to receive videophone communications. The

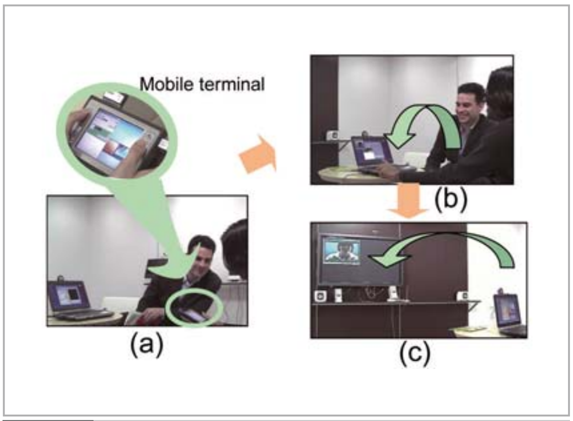

Fig.8 The videophone communication received on a mobile terminal is handed over to a notebook PC, then to a large screen (The communication handover follows steps (a), (b), and (c) in this order)

caller can avoid irritating the user, saving time and trouble by calling via an alternative method such as voice phone.

5 Conclusions

To promote progress in telecommunication services and to improve usability in a future heterogeneous wireless network environment (e.g., through seamless communications) we have proposed our MIRAI architecture based on a Basic Access Network (BAN) structure. In the early stages of the project, we investigated models for implementing the BAN using dedicated wireless systems. In the later stages of the project, we investigated the overlay model, which overlays signals on existing wireless systems, and conducted research with a view toward implementing the most important functions required in a ubiquitous communications environment, such as transmission of contextual user and device information and pre-authentication of the network and devices to which communications are handed over.

In terms of controlling the ubiquitous sensor devices, a major communications carrier has proposed a wide-area control network similar to the BAN proposed in this study. On the other hand, the IEEE802.21 standard (targeting handover independent of wireless media within a multi-device wireless network environment) emphasizes the importance of power savings in terminal operations. As indicated in these examples, it is becoming increasingly likely that future applications will require all of the advantages of the Basic Access Signaling (BAS) investigated in this study.

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