WIRELESS COMMUNICATIONS AND MOBILE COMPUTING
Wirel. Commun. Mob. Comput. 2007; **7**:937–950
Published online 16 May 2007 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/wcm.508

Network and access technologies for new generation mobile communications–overview of National R&D Project in NICT

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Summary

R&D on new generation mobile network has attracted a growing interest over the world on the background of rapid market growth for 2nd and 3rd generation cellular networks and wireless LANs/MANs. The National Institute of Information and Communications Technology (NICT) started the New Generation Mobile Network Project in April 2002, and has developed fundamental technologies to enable seamless and secure integration of various wireless access networks such as existing cellular networks, wireless LANs, home networks, intelligent transport systems (ITS), the Beyond-3G (B3G) cellular and other wireless access systems. This paper overviews the achievements of the project focusing on network and access technologies. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: MIRAI architecture; seamless communications; media handover; metro mobile ring network; security platform; Mobile Ethernet; OF/TDMA; SDR

1. Introduction

The market for 2nd and 3rd—generation cellular networks and wireless LANs (WiFi) has grown rapidly in last several years. The cellular phone has become one of our inevitable items and almost all laptop PCs have been equipped with wireless LAN devices. Other than those networks, we are expected to have 'System Beyond the Third Generation (B3G)' cellular network and high-speed wireless LAN, metropolitan area network (MAN) and wide area network (WAN) in the near future. The official term was identified as 'IMT-Advanced' in ITU in 2005. Moreover, digital broadcasting service is also expected to become popular soon. Various types of wireless network coexist in our life; however, it is not always convenient for users. User needs to have many access terminals to access those networks and needs to have many login IDs or numbers for those networks. User needs to login network or dial again with a different terminal each time when the user moves from one network coverage to the other to keep connected.

Security is also an issue for wireless networks. Wireless is basically open to anyone else; however,

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if information could be easily leaked to outsiders or attacked from others, wireless network will never be a reliable infrastructure in our life.

In order to mitigate the above problems, a paradigm of design concept should be shifted from system-centric to human-centric. From the human-centric point of view, the improvement in 'quality' is also required in addition to radio transmission speed. This motivates the project to research and develop fundamental technologies to facilitate seamless and secure integration of heterogeneous networks, including existing networks and future networks.

The New Generation Mobile Network Project started in National Institute of Information and Communications Technology (NICT) in April 2002. In the project, we proposed a basic architecture 'Multimedia Integrated networks by Radio Access Innovation (MIRAI)', which provides the seamless and secure integration of various heterogeneous wireless networks, such as 3G and B3G cellular networks, the IEEE 802.11-compliant high speed wireless access systems, advanced home networks, ITS networks, and digital broadcasting networks [1–3]. Based on this architecture, the project has focused on three research topics: (1) wireless access technology including broadband transmission over 100 Mbps in mobile environment and software-defined radio, (2) media handover technology including seamless mobile networking and ubiquitous networking, and (3) security platform technology including authentication and fast handover capabilities between heterogeneous networks. In order to demonstrate and evaluate these technologies, a field testbed was constructed in Yokosuka Research Park (YRP).

This paper overviews our 4-year project, its technical achievements and a field test bed for the integrated evaluation of our developed technologies.

2. MIRAI Architecture

The MIRAI architecture employs a specialised connection to exchange control messages for establishment of communication session and cross-network handover [1–3]. We call this connection as Basic Access Network (BAN) [4,5]. BAN is an always-on connection between a mobile terminal and a mobility manager. Since it exchanges small signalling messages, it does not require high data rate, but should have wide coverage and should be low cost.

The BAN exchanges various controlling information, such as wireless resource information, on/off request for each air interface, handover requests, authentication, SIP signalling, terminal context information such as available networks, available application settings, and presence information of the user [6,7]. The BAN in the MIRAI architecture is shown in Figure 1. The MIRAI server as a mobility manager includes functionalities for wireless resource discovery, authentication to select wireless networks, handover management, the home agent and the SIP server.

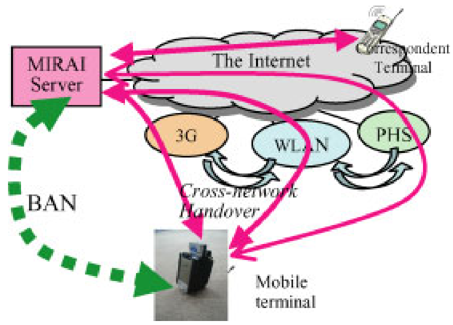

Fig. 1. BAN and MIRAI server in MIRAI architecture.

There are several requirements for BAN. First, the coverage area should be wide, since the BAN and MIRAI server manages any mobility issues and should be available anywhere. Second, the BAN should be of low power consumption and low cost per connecting time, because the BAN is assumed as always connected. On the other hand, since data amount is small, the BAN does not need to have high speed data rate. Third, the BAN needs to be secure for authentication and exchange of user privacy information such as location data.

There are various advantages on using the BAN. The first advantage is the low power consumption, because power is not required for BAN connection. The BAN connection should only be always on. Other interfaces for high-speed data sessions may be switched off until communication session such as VoIP and videophone is requested. The second one is that the user can select optimum connection according to network and device contexts, such as transmission speed and availability of networks and protocols. The quality of service (QoS) can be changed according to available network bandwidth to achieve service adaptation. BAN gives smooth handover even on a handover between different networks whose transmission data rates are much different (Figure 1).

3. Core Technologies

Interconnection between the networks may be established by switch processing in layer two (L2)

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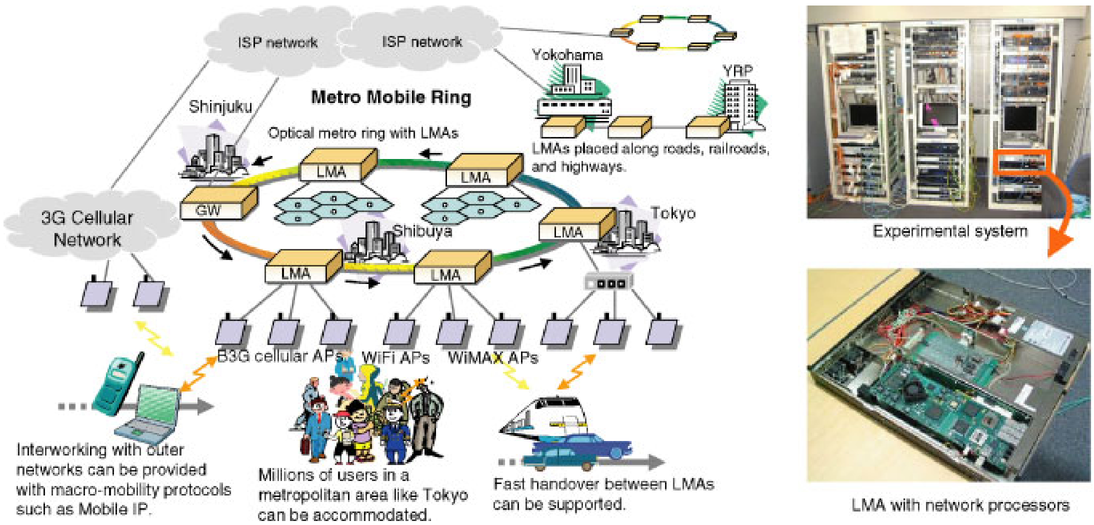

Fig. 2. Metro mobile ring for metropolitan-area large-scale mobility-support network.

or layer three (L3) and the mobile IP technology. The heterogeneous networks are interconnected over a high-speed ring network, which covers, for example, a metropolitan area. In the user terminal, software defined radio (SDR) technology allows the user to switch communication systems by changing only the software. The terminal ensures seamless handover while the user moves across heterogeneous network coverage. This concept also includes mobile personal area network (mobile PAN), in which different type of terminals are connected to each other and handover between the terminals is supported.

The project focused on the following six core technologies to achieve the MIRAI architecture: (1) metro mobile ring technology for large-scale micro mobility, (2) cross-network and cross-device handover technology, (3) mobile Ethernet—L2-based real-time network handover technology, (4) wireless security platform technology, (5) Dynamic parameter controlled OF-TDMA—high-speed wireless access technology, and (6) software defined radio (SDR) technology. The details of these technologies are described in the following sections.

3.1. Metro Mobile Ring Technology for Large-Scale Micro Mobility

The new-generation mobile network would need to accommodate millions of users and to provide them with any services available on the Internet while they move around. We have proposed a novel concept called 'metro mobile ring network' to support IP-based high-speed handover between access points of a mobile network that would be deployed in densely-populated areas like Tokyo [8]. The metro mobile ring provides mobility for data services by scalable location management and fast handover capabilities. Figure 2 shows the concept of the metro mobile ring network.

Micro-mobility management is an effective way to reduce the number of mobile IP registrations with a home agent and to shorten the round-trip time for it while a mobile node moves locally. Existing approaches, however, adopt a hierarchical topology and location information concentrates on the mobility agent rooted at the hierarchy. The proposed architecture connects multiple localised mobility agents (LMA) on a flat-ring network to distribute the location information of visiting mobile nodes, thereby avoiding load concentration.

The location of a mobile node (MN) is registered with an LMA, which has a fast packet-forwarding function over the ring and a packet delivery function for registered MNs. The LMA maintains location information of the MNs that are in the coverage of access networks under the LMA. At least one LMA acts as a gateway (GW) to an outer network. Packets are transferred in one direction in the ring and when an LMA receives a packet from the adjacent LMA, it forwards the packet to the next so that the packet goes exactly one round. After forwarding it, the LMA checks whether the destination IP address of the packet, which has been copied, is registered. If matched, it delivers the packet towards the MN in the access network. Each LMA refers to its own binding list only and the GW does not have to resolve the MAC address of the destination MN. This is a major difference from

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a Token Ring or RPR (Resilient Packet Ring), which are L2 ring networks.

Optical ring networks for fixed communications have already been widely used in metropolitan areas. Putting the function of LMA into every network node is one promising way of easily deploying the metro mobile ring. WiMAX and its family, next-generation WiFi, and B3G cellular are considered to be possible access networks for the metro mobile ring.

We have implemented and tested the proposed ring network with network processors [9]. For example, when 100 000 MNs were registered with each LMA (four LMA in total), the metro mobile ring obtained better performance in throughput and latency compared to the network with a hierarchical topology. Although 3–6 s was observed for handover between different LMAs with standard Mobile IP, the latency was decreased by about one tenth with the proposed network (Figure 2).

3.2. Cross-Network and Cross-Device Handover Technology

'Media handover', in our definition, includes not only cross-network handover but also cross-device and other handovers to provide a variety of services to users using various networks and devices in an efficient, flexible and human-centric way at a low cost.

In order to create networking technologies that allow users to access the network without being aware of individual networks and devices, we developed three separate technologies: cross-network handovers [4], cross-device handovers [10] and a location-sensing platform [11].

Cross-network handover is enabled with the MIRAI architecture (Figure 3) in which an out-of-band Basic Access Signaling (BAS) protocol enables a mobile terminal to communicate with a MIRAI agent in a fixed network through any radio access network (RAN) chosen by the user as the Basic Access Network (BAN). The MIRAI agent exchanges signalling information such as location update, paging and handover with mobile terminals. It uses information on the location of mobile terminals and on the availability of RANs to decide which RAN to use, taking the user's preferences into account. The separation of signalling path from data paths saves energy [12] and facilitates handover between RANs.

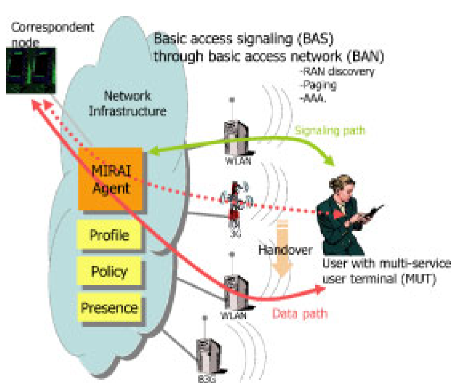

Fig. 3. Cross-network handover in the MIRAI architecture.

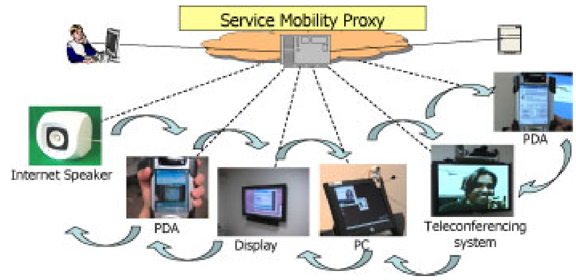

Fig. 4. Service mobility proxy (SMP) for cross-device handover.

Cross-device handover is provided by a service mobility proxy (SMP) [10], which switches a connection from one device to another (Figure 4). Not only forwarding packets to a specified device but also transcoding and media adaptation of on-going application are performed.

Location-sensing platform [11] supports various contextual sensing technologies such as RFID, floor sensors and WiFi that are installed in YRP Building No.1 (Figure 5). RFID and WiFi AP detect user ID but accuracy of position is not high. Floor sensor, on the other hand, achieves higher accuracy but cannot detect

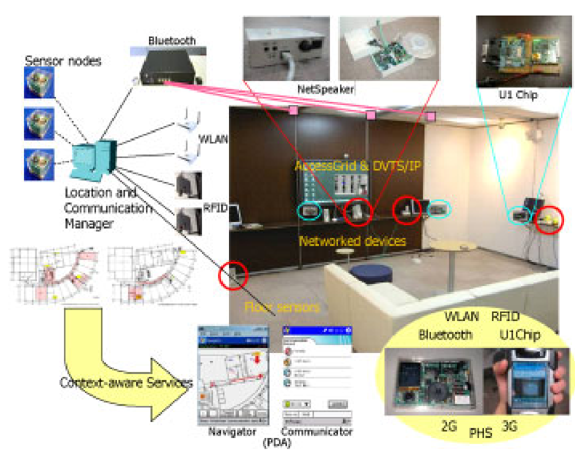

Fig. 5. Location-sensing platform in Smart Space.

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user ID. In order to obtain high resolution as well as to recognise individual users, we have designed some fusion algorithms to combine the results of the sensors.

3.3. Mobile Ethernet–L2-Based Real-Time Network Handover Technology

The network handover technology described in Section 3.2 is based on L3 switch architecture. It is applicable to general networks without modifications to them. However, the latency for handover is not small enough to achieve real-time handover.

The Mobile Ethernet is a metropolitan area Layer 2 based network that accommodates different types of radio systems satisfying a common interface for both data and signalling [13]. The Mobile Ethernet can extend a support area using other technologies, such as Provider Bridge [14] and also connect to the Internet via a router as shown in Figure 6.

In the Mobile Ethernet, every message is virtually broadcasted on the core network shared with proper MAC addresses and allows to plug-in various radio systems, such as 3G, WLAN, wireless MANs and 4G, following a common MAC interface. To achieve scalability, L2 switches with path-learning caches are deployed in the network. A path to a destination MAC address is learned at all switches on the path and unnecessary broadcast is suppressed, once the path is learned [15,16].

The Mobile Ethernet provides a real-time handover mechanism based on L2 switch architecture and a prediction mechanism of seamless handover for real-time applications. It also provides a signalling mechanism to update path-learning caches on the switches dynamically, and needs suppressing broadcast signalling traffic.

The Mobile Ethernet consists of L2 switches, the Common Signaling Server (CSS) and Buffering Server. There are three types of L2 switches called the Gateway Switch (GSW), the Branch Switch (BSW) and the Edge Switch (ESW). The GSW has the basic mobility functions, such as MAC address learning with exchanging L2 mobility management frames and IPv6 multicast traffic control without flooding, and interfaces for MAC address replacement and MAC address table setup to the Common Signaling Server. A BSW is the intermediate switch between a GSW and an ESW and has the basic mobility functions in it. An ESW manages MAC frame transfers, such as relaying common radio signalling messages between a mobile device and the CSS besides the basic functions.

The CSS manages messages to control mobile devices and radio systems. The server informs to a mobile device adjacent APs list for the network access point detection and mobility management instruction such as a handover request [17]. The mobile device, on the other hand, informs various common radio signalling messages, such as the Location Area Update message for mobility management in dormant mode [18] and measured received-signal strength information used for triggering in network initiated handover [19]. The Buffering Server keeps user data frames for paging mobile devices. The components and interfaces are shown in Figure 7.

The Mobile Ethernet architecture defines all the components and specifications. Our experimental Mobile Ethernet system [20] consisting of different types of radio systems, W-CDMA(3G) and IEEE802.11b, verifies the common MAC interface and components for lossless and real-time handover.

The future Mobile Ethernet expects a Mobile Ethernet switch which is used as a GSW, a BSW, or an ESW and a CSS/Buffering server integrated somewhere in the network, once the specification and interface of each component is verified and standardised. The network also expects any access points at any location and provides wireless access to

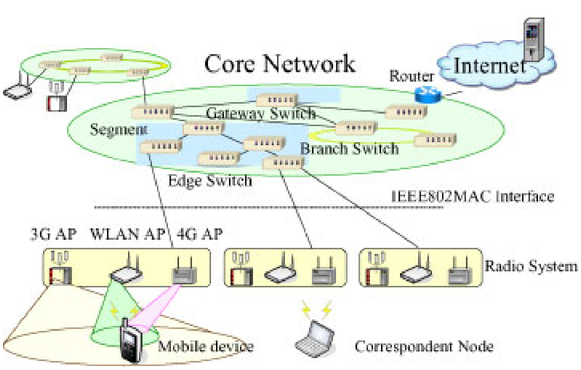

Fig. 6. Mobile Ethernet.

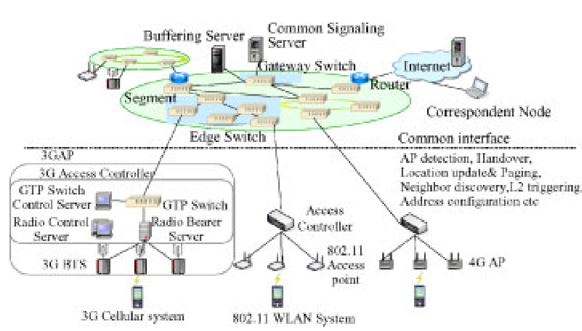

Fig. 7. Components and interfaces.

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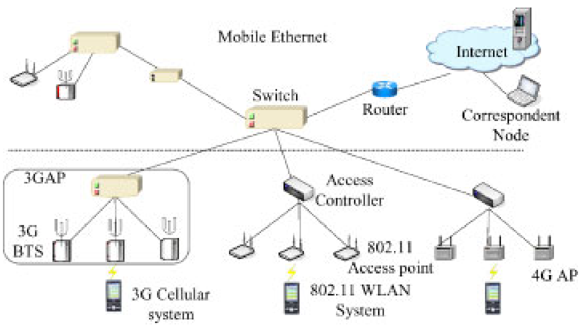

Fig. 8. Future Mobile Ethernet.

users anytime. The future Mobile Ethernet is expected to provide a ubiquitous wireless network independent of radio systems showed in Figure 8. In near future, a mobile device can configure its radio adjusting to available radio systems and services at a user location. The mobile device changes its radio from one to the other seamlessly and expects a unique address, such as IP address for efficient service continuity. The Mobile Ethernet has the feature not to change an IP address to access any radio systems.

3.4. Wireless Security Platform Technology

Network access authentication is an important issue, which is consistently used with application level authentication, because users expect service continuation with no interruption even in the case of real-time applications.

We proposed the security framework for the Mobile Ethernet consisting of application level authentication, network access authentication, and the security link between the two authentications [21]. The framework expects that a user device is divided into two components, a personal identity card (PIC) securely storing any kind of certificates, such as wireless access/ISP certificates, and a mobile device holding the delegated certificates used for network access/application level authentications. It defines mutual authentication between the PIC and the mobile device with certificate activation in the PIC using biometrics or another method.

The application level authentication is mutual authentication between a mobile device having the delegated certificate and service providers, such as ISP. The network access authentication is also mutual authentication between the mobile device and wireless networks. The device authenticates a wireless network when it connects to it. The network also checks whether the device has the right to access it. Figure 9 shows the

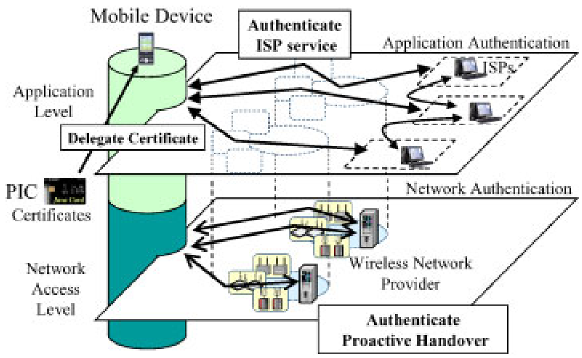

Fig. 9. Application and network authentication framework.

framework to accommodate both application level and network access authentications.

When a mobile device moves to a different radio system in the same segment (intra-segment handover), the device sends an Update Entry Request (UER) to the AP and goes up the hierarchy until the UER reaches the AAA server shown in Figure 10. The network access authentication is done by a two-way handshake between the device and the AAA server. When the mobile device moves to a radio system in another segment, it goes up to the AAA server in the hierarchy.

In the case of handover, a real-time application expects authentication on the fly. The Mobile Ethernet expects proactive authentication taking advantage of the network initiated handover. The network knows which radio system is to be used when a mobile device moves out of current communication area. The network transfers the security context from the ESW where the mobile device in located to the new ESW and authenticate beforehand without sending a request in the future.

The authentication framework assumes many service providers, such as application and wireless

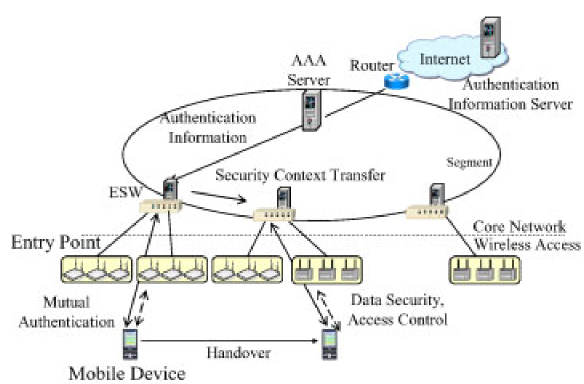

Fig. 10. Proactive network access authentication.

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access, and many users. In such system, if users authenticate by sharing a secret every time they move, it requires heavy computation for users to do beforehand. It is preferable to employ a ticket-granting service and register each provider with each AAA server in a segment. The ticket-granting authentication is applied to ubiquitous environment assuming a PIC for each user for any services (Figure 10).

There are two discussions in wireless security. One is to have a common mechanism to keep confidentiality among radio systems. The other is to provide functions to maintain availability.

The Mobile Ethernet expects to integrate various radio systems. Each radio system has its own authentication mechanism on it and some mechanisms are not consistent with others. We introduced a security key management utilising location information of a mobile device [22] that is independent of radio systems. We also proposed the functions to protect the wireless interface of the Mobile Ethernet from Denial of Server (DoS) attacks.

In the mobile environment, location information is a candidate for authentication. The authentication uses the list of location of a mobile device as a shared context between a mobile device and the AP. The location of a mobile device changes in accordance with the user movement. The location is shared between the device and the AP when the user starts communication [23–25]. The list of location information, which is a kind of trail of the mobile device, is considered as a shared context between the two entities.

An AP of the network, whereas, computes the location of a mobile device by the signal strength [26] from the device. These locations are shared by transmitting between the device and the AP. Although it is coarser than that of the Global Positioning System (GPS), a unique ID of an AP at which the device is connecting is also seemed to be location of the mobile device. The location information shared between a mobile device and a network is utilised as a seed to generate a symmetric key between the mobile device and the AP that performs mutual authentication.

A track is a list of location information of a mobile device. The location information, for instance, is the ID of a radio system. Once a track is created, the list is updated separately on the mobile device and network, and kept consistent. The latest location, then, is inserted at the top of the list and the oldest one at the bottom is removed to keep the length required.

The track is used as a shared context for mutual authentication between a mobile device and the AP to solve the following issues: (a) Eavesdropping and Prediction, (b) Compromise and (c) Confliction.

3.4.1. Eavesdropping and prediction

If there is an eavesdropper who sniffs any traffic of a mobile device at any place, an attacker can have the location information of the device. The attacker, however, hardly predicts the entire track of the device from the location information which the eavesdropper has. If the strong enough key variation is 2^{128}, the estimated minimum length of the track is greater than 40 and looks practical computation when implementing on a mobile device.

3.4.2. Compromise

The compromise of the track caused by its long-term use never happens because it is frequently changed along with the move of a mobile device. It is assumed that the mobile device is so robust that the track will not be disclosed by any physical attacks.

3.4.3. Confliction

There is a confliction in tracks such that a track of a mobile device is equivalent to that of the other devices. The network avoids by detecting the likelihood of the confliction. It enables that, for instance, a user carries two mobile devices whose tracks do not conflict.

Wireless security is treated as the extension to the wired network security and focuses on access control and confidentiality, but the core feature of wireless network is availability. We expect security threats in its wireless part of the Mobile Ethernet that come from the openness of Ethernet frames in air. Contents in air are protected by the established cryptography, but contexts including headers are open in air. A malicious person can trace the MAC address of a mobile device and attack it. Untraceability of a mobile device becomes an important requirement for Denial of Service attacks, besides wireless jamming, wireless session hijacking, and wireless association flooding.

We have proposed the Transient MAC Address (TMAC) scheme which allows a mobile device to dynamically change its MAC addresses to escape from the tracing [27,28]. Only a mobile device and the AP to which the device is connecting can remember the transition of the MAC address, as the TMAC is updated by means of a one-way keyed hash function. An attacker, who does not acquire the TMAC key, cannot predict the next TMAC from the current TMAC.

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3.5. Dynamic Parameter Controlled OF-TDMA–High-Speed Wireless Access Technology

The high-data-rate transmission technique aims at over 100 Mbps in B3G cellular network in high-speed mobility environment and around one Gbps in hot spot environment. The protocol requires (1) easy accessibility under changes in frequency, bandwidth and communication system, (2) robustness against transmission delay due to lengthy cables, as APs may be located on various spots via optical fiber cables, and (3) simple enough to link with multiple MS and easy to be introduced. This ultra high-speed radio access protocol has been studied in wireless LAN [29], ITS using millimetre-wave [30], etc. None of the past studies, however, have never taken (1)–(3) into consideration in developing a prototype to make precise evaluations of its throughput. In order to achieve 100 Mbps carrier bit rate under high mobility environment and can access IP network easily, we proposed a new multiple access scheme that is based on 'dynamic parameter controlled orthogonal frequency and time division multiple access (DPC-OF/TDMA)' [31]. In this scheme, users share 'slots' that use certain number of subcarriers and a certain number of OFDM symbols. To access the slots, mobile stations use a packet-reservation-based protocol: packet reservation dynamic time-slotted multiple access (PR-DSMA) [32]. In addition, to avoid co-channel interference from adjacent cells and increase frequency utilisation efficiency, we use an adaptive modulation scheme that is based on an interference detection algorithm.

DPC-OF/TDMA is based on OFDM transmission. As shown in Figure 11, the subcarriers in OFDM symbols are divided into subchannels that have a certain number of subcarriers. Correspondingly, time domain is divided into sub-blocks that have a certain number of OFDM symbols. The area with a certain number of subcarriers and a certain number of OFDM symbols calls as 'slots'. Users share the slots. When MSs communicate with AP, first, each MS registers itself to AP. Then, AP allocates slots to the MS. The information of the allocation is included into frame control message slot (FCMS) of the downlink and AP transmits the slot with a certain cycle as shown in Figure 1. We call the area between two FCMSs a TDMA frame. Each subchannel has at least an FCMS. Each MS does not have to access all subchannels. As shown in Figure 12, each MS can decide the number of subchannels that the MS assigns by taking the scale of MS, power consumption, and fare into account. Moreover, if MSs can access all of subchannles, the MSs can change the number of subchannles by changing parameters and the modulation scheme used in the slots can be changed by changing parameters. That is why the proposed scheme is named as 'DPC-OF/TDMA'. However, in order to know which subchannel is not in use, all MSs had better receive all of subchannels.

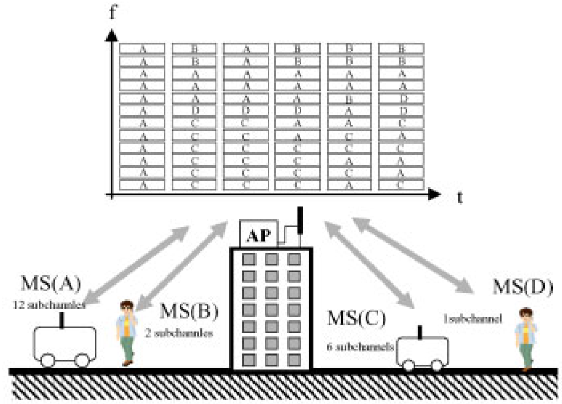

Fig. 12. Application image of DPC-OF/TDMA.

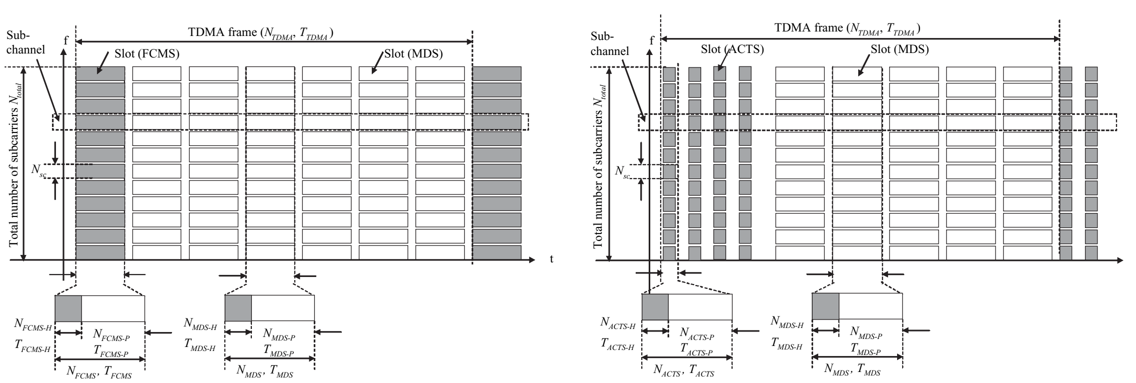

Fig. 11. Frame construction of DPC-OF/TDMA (left: downlink, right: uplink).

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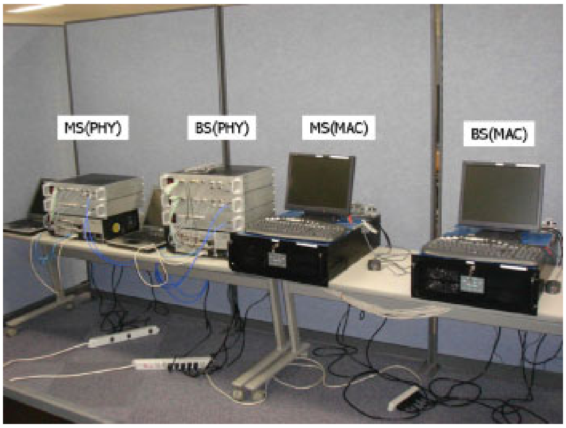

Fig. 13. Prototype of DPC-OF/TDMA system.

In the proposed scheme, each cellular zone has a common frequency band. In this case, the avoidance of co-channel interference is one of the big problems. To solve the problem, we use a delay profile estimation method and an information method of the estimated delay profile from MSs to AP and adaptive modulation scheme (AMS) and mutlti-level transmit power control (MTPC) as described in [33]. Moreover we change the coding gain by changing parameters in order to realise multi-rate transmission. MIMO-OFDM technique is also employed to get higher transmission rate in multipath environment.

We have developed the prototype of the proposed scheme (Figure 13) and evaluated its fundamental performance. As a result, RF transmission rate as 1.6 Gbps has been achieved within the bandwidth of 100 MHz.

3.6. Software Defined Radio (SDR) Technology

The new generation mobile communication system will functionally integrate mobile communication systems including cellular and high-speed mobile wireless access systems, non-wireless systems, and broadcasting systems to enhance inter-system compatibility. A user needs to have only one terminal to achieve multiple communication systems. The most promising technology to achieve such terminals is SDR technology, which allows users to switch communication and broadcasting systems by changing software alone [3,34]. A user therefore will carry only one terminal for various kinds of wireless services of user's choice.

NICT has developed an SDR platform that consists of FPGA board, CPU boards, and RF boards, as shown in Figures 14 and 15 [3,35,36]. The specifications are listed in Table I. The size is 20 cm wide, 20 cm deep, and 8 cm high. For the SDR platform, users firstly install their favourite software that can realise communication systems by using compact flash card. Then the software

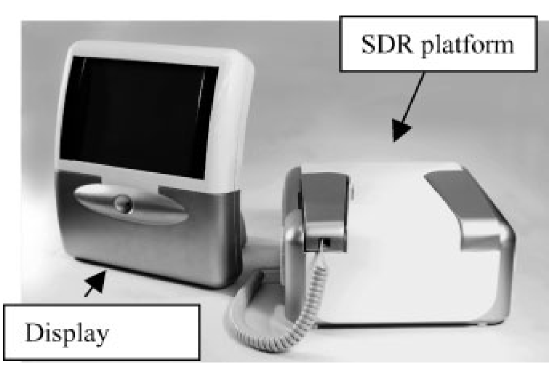

Fig. 14. SDR platform prototype.

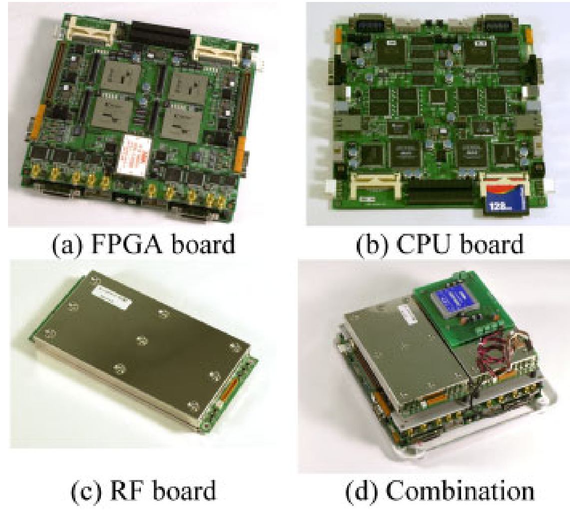

Fig. 15. Components of SDR platform. (a) FPGA board; (b) CPU board; (c) RF board; (d) Combination.

Table I. Specifications of SDR platform.

FPGA board	
ADC	2 ch/170 Msps/12 bit/0 dBm input
DAC	2 ch/500 Msps/12 bit/0 dBm output
FPGA	Xilinx XC2V4000,6000,8000 (selectable)
IF to RF board	Analog in (2 ch)/Analog out (3 ch)/Cont (5 bit)
External clk I/F	Input 5M-66 MHz, 0 dBm 2, 4, 8, 16 times clk generate automatically
External output	CPU-IF (Max 80 Mbyte/s) External output(Max 600 Mbyte/s)
CPU board	
CPU	430 MIPS (240 MHz) × 2
OS	μ-ITRON (PrKERNEL v4)
I/O	Compact flash, RS232C, USB, Ethernet/JTAG
RF boards	5 GHz band + 2 GHz band + VUHF boards

DOI: 10.1002/wcm

is stored to the memory in the platform. After that, users can customise a menu that shows users' priority for the communication systems installed in the memory. On the platform, software packages for W-CDMA, IEEE802.11a/b and digital terrestrial broadcasting have been developed, because these communication and broadcasting systems currently exist as the systems that need high-speed signal processing. Each software package consists of physical layer part (for communication and broadcasting systems) and MAC/DLC layer part, IP layer part, and application part (for communication system). In the platform, 150–800 MHz (receipt), 1.9–2.4 GHz and 5–5.3 GHz bands (transmission and receipt) are available.

On the platform, software packages for W-CDMA, IEEE802.11a/b and digital terrestrial broadcasting (13 segments Japanese terrestrial HDTV, 64QAM-OFDM, information rates 21.47 Mbps) have been developed, where required capacity in FPGAs to realise each of the wireless systems is obtained. As for W-CDMA physical layer, 43577 and 28691 slices are needed for FPGA 1 and FPGA2, respectively. As for IEEE802.11a/b physical layer, 655/10146 and 21966/2421 slices are needed for FPGA1 and 2, respectively. 15996 and 23798 slices are needed for two FPGAs to realise digital terrestrial TV (13 segment HDTV). For example, in the case of Xilinx Virtex2 series FPGA, the number of slices in a XC2V6000 that has 600 million system gates is 33792. From these results, it is found that we need only two FPGAs that are two XC2V6000 to realise all communication and broadcasting systems that need high-signal-processing-power.

By using the developed SDR terminal, two types of scenarios can be demonstrated. One is system 'selection' demonstration. First of all, SDR terminal connects with a W-CDMA BTS simulator (Base station) and communicates with the other people in a wired network. Then, by changing the volume, the input signal level from BTS to SDR terminal decreases and the input signal level from wireless LAN access point increases. In this case, the SDR terminal automatically installs wireless LAN software and continues to communicate with the people in a wired network. The other is system 'multiplexing' demonstration. First of all, SDR terminal connects with W-CDMA BTS simulator (Base station) and communicate with the other people in a wired network. Then, by changing the volume, the input signal level from wireless LAN access point increases. In this case, the SDR terminal receives both W-CDMA and wireless LAN signals.

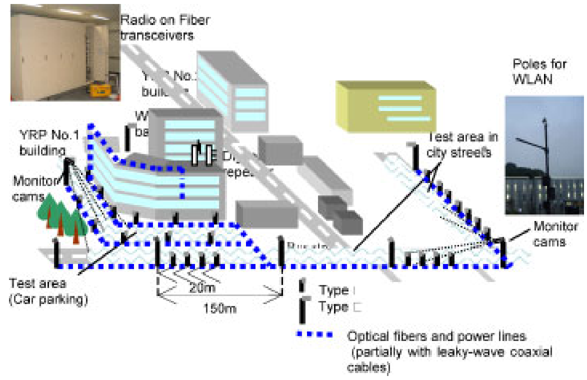

Fig. 16. YRP test bed.

4. Test Bed for Integrated Demonstration of Prototypes

A test bed was constructed in Yokosuka Research Park (YRP) to evaluate newly developed core technologies described in Section 4. Figure 16 shows the overview of the test bed. The facilities include optical- and Ethernet-based network infrastructure, LAN switches, routers, poles with access points for wireless LAN, cellular base station, leaky wave coaxial cables along the street, etc. Digital TV repeater in UHF band is also available to test SDR terminal that switches between the digital TV receiver and other wireless network terminal such as PHS and wireless LAN. This area provides a good radio environment to test various wireless systems, thanks to geographical isolation from populated areas. The YRP test bed has optical fiber cables and power cables along with its streets and in a car parking. We installed wireless LAN access points on the light poles connecting to the fiber and power cables. Experimental W-CDMA base station was located on the top of YRP No. 1 building that covers the streets and the car parking in YRP.

On 28–29 March 2006, an integrated demonstration of prototypes took place successfully in this test bed. The demonstration included seamless and secure network handover between 3G cellular phone and IEEE802.11 wireless access system in a running car on a street, seamless device handover between different displays, speakers, and information terminals, and a compact and smart SDR terminal.

5. Standardisation Activities

One of the targets of the project is to promote the international standardisation. NICT contributed

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to create a new group IEEE802.21 in the IEEE standardisation activities in 2005, to establish a standard on media-independent handover interoperability among 802-base systems and between 802-based and non-802-based systems [14]. The mobile Ethernet with a high-level security would be a basic platform for this purpose. The group is expected to finalise the specification until the end of 2006. Some other contributions also have been made on SDR technology to ITU-R WP8F and SDR Forum.

6. Conclusion

This paper has summarised the R&D activities of the New Generation Mobile Network Project that has been conducted in NICT during a 4-year period from April 2002 to March 2006. The new concept 'MIRAI' and core technologies to realise in the new generation mobile network based on the MIRAI concept are overviewed. The core technologies are metro mobile ring network, seamless media handover, mobile Ethernet, security platform, OF/TDMA wireless access and SDR. An integrated demonstration test including all of the developed core technologies was successfully carried out in the YRP test bed.

Further studies on the core technologies mentioned in this paper are expected to achieve cognitive radio by integrating those technologies in future. In the cognitive radio, system senses, or is aware of, its operational environment and can dynamically and autonomously adjust its radio operating parameters accordingly by collaborating wireless and wired networks. Cognitive radio would have radio equipment with multi-purpose, multi-band, and multi-service on the frequency band from VHF/UHF to 6 GHz.

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DOI: 10.1002/wcm

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DOI: 10.1002/wcm

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DOI: 10.1002/wcm