A Novel Mobility Management Framework for Future Generation Integrated Wireless Networks

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Abstract
The concept of using a separate network to carry signaling packets related to some basic mobility management functions in heterogeneous wireless network environment is presented in MIRAI (Multimedia Integrated network by Radio Access Innovation) architecture, proposed in [1]. In MIRAI architecture, a dedicated network takes care of the mobility functionalities of the participant wireless access networks. The dedicated network, called Basic Access Network (BAN), is primarily used for paging whenever a call arrives for the mobile user for any of the wireless interfaces of the user’s multi-service terminal, and for wireless system discovery when the user wants to initiate a call/session. In this paper we present the operation of the BAN in concert with the rest of the IP-based network, to realize a common signaling framework for heterogeneous mobility.

Keywords

1. INTRODUCTION

With the backdrop of phenomenal success of iMode and fairly rapid adoption of IMT-2000 in Japan, researchers in both academia and industry have begun to show more and more interest in new-generation wireless communication networks where the concept of heterogeneity in networks as well as in access technologies will play a pivotal role. To exploit the full potential of internet technologies, Japanese government adopted so called “e-Japan Strategy” in early 2001 [2], including an explicit goal for wireless communications: to create an IPv6-based high-speed wireless Internet access environment and to enable seamless mobile communication services. MIRAI (Japanese for “future,” and an acronym of “Multimedia Integrated network by Radio Access Innovation”), a project we at the Communications Research Laboratory are working on, is one of the Japanese national projects of the e-Japan Program for the seamless integration of heterogeneous wireless systems [1].

With the goal to design a flexible and open architecture suitable for a variety of different wireless access technologies, as well as for applications with different QoS requirements and different protocols, the MIRAI project focuses on the research and development of a common tool, a common platform and a common access. The solution is based on a Multi-service User Terminal (MUT), an IPv6-based wireless supporting Common Core Network (CCN), and a Basic Access Network (BAN). A later section briefly describes the MIRAI architecture.

One of the major questions of mobility management is how to page a dormant terminal in a power-efficient way, while keeping the network traffic minimum. Most of the solutions offered so far take IP based paging approach [3]-[4], assuming only one air interface in the terminal. This poses two problems. First, many systems consumes a lot of power even just to listen to paging signals. Secondly, for a multi-service terminal, there is ambiguity as to which of the air interfaces to use while paging the terminal. MIRAI takes a unique approach of using a separate air interface for paging. This dedicated network, namely, Basic Access Network, is discussed in this paper.

The rest of the paper is presented as follows. Section 2 gives a brief overview of MIRAI architecture to layout the background of the mobility related signaling here. In section 3, we discuss BAN - its responsibilities and functionalities, and user terminal with BAN air interface. The mobility management model of MIRAI is presented in section 4. One implementation example of BAN is given in section 5. Finally, section 6 concludes the paper with some outline of future research and experiment. Table 1 lists the acronyms used in this paper.

Table 1: List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>BAN</td>
<td>Basic Access Network</td>
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<tr>
<td>BAC</td>
<td>Basic Access Component</td>
</tr>
<tr>
<td>BS</td>
<td>Base Station</td>
</tr>
<tr>
<td>CCN</td>
<td>Common Core Network</td>
</tr>
<tr>
<td>CN</td>
<td>Correspondent Node</td>
</tr>
<tr>
<td>CoA</td>
<td>Care-of-Address</td>
</tr>
<tr>
<td>GR</td>
<td>Gateway Router</td>
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<tr>
<td>HA</td>
<td>Home Agent</td>
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<tr>
<td>MUT</td>
<td>Multi-service User Terminal</td>
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<tr>
<td>RAN</td>
<td>Radio Access Network</td>
</tr>
<tr>
<td>RM</td>
<td>Resource Manager</td>
</tr>
<tr>
<td>SA</td>
<td>Signaling Agent</td>
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<tr>
<td>SG</td>
<td>Signaling Gateway</td>
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2. MOBILITY IN FUTURE GENERATION WIRELESS NETWORKS

2.1 Background

Unlike voice-oriented cellular systems where the question of mobility management is confined within the administrative domain of a particular carrier, future generation systems will bear a much broader sense of
mobility. Coupled with IP-based transport of multimedia services, various forms for access technologies and terminal equipments will give a multi-facet meaning of mobility. With the growing popularity of personal digital assistants (PDA) with various wireless access components (e.g. WiFi, Bluetooth, or Compact Flash interface cards for PDC or PHS), we can easily assume that a future user terminal will in general have multiple air interfaces belonging to possibly different carriers or providers. With IP being prime transport for packets and the contents residing mostly in public Internet, this will give rise to a scenario where user of such multi-module multi-service devices will demand for mobility support across access technologies as well as carriers or service providers. This is in addition to the obvious demand for mobility support within a particular carrier’s coverage area or a provider’s service domain.

Mobility management, broadly speaking, has to accommodate two techniques – location management and handoff (or handover) management. Location management basically deals with finding the real location of a terminal and/or its nearest point of attachment to the network, and routing calls to the terminal. Cellular systems maintain location registers (HLR/VLR) and paging mechanism for this purpose. In case of internet, Mobile IP [5]-[6] and similar solutions are proposed for supporting mobility. Network entities like Home Agent (HA) and Foreign Agent (FA) are used along with terminals with ‘Mobile IP’- supporting TCP/IP stack. Handoff management deals with efficient, reliable and quick handoff while maintaining and enrouting of ongoing sessions when the terminal moves from the coverage area of one network access point (e.g. Base Station, WLAN access point, etc.) to another. Handover is a common concept in cellular systems, if not in internet. However, both location management and handoff management are, so far, dealt within the administrative domain of the operators. With the rollout of diverse 3G and 4G systems with a wide range of target coverage, from low rate, high-tier, large coverage to high rate, low-tier, hot-spot coverage, efficient mobility management will require a streamlined network architecture which exploit the best of both cellular and internet world. Location management should be able to track and page both active and dormant terminals. Handover mechanism should support both horizontal (intra-system) handover and vertical (inter-system) handover [7].

2.2 The MIRAI Architecture

MIRAI architecture consists of three major entities.

Common Core Network (CCN): This can be a managed IPv6 network providing a common platform through which all MUTs will communicate with correspondent nodes in the Internet. In principal all access points of radio access networks (RAN) are connected to this network. The network provides QoS-guaranteed routing and seamless handover among RANs. This enables natural integration of various heterogeneous networks. It has a common database for managing users’ profiles through entries such as authentication, location, preferred access system, billing, policy, users’ terminal capabilities, etc.

Basic Access Network (BAN): It provides a common control/signaling channel to enable all MUTs to access the common platform. The network is basically used to enable paging and support wireless system discovery.

Multi-service User Terminal (MUT): The MUT is equipped with a multi-radio system. All terminals have a Basic Access Component (BAC) to communicate with the BAN base stations.

The MIRAI architecture provides seamless communication between mobile hosts and correspondent nodes in the Internet. Fig. 1 illustrates the network configuration of the architecture. The network is assumed to be based on IPv6. Various wireless access points are connected to CNN directly. CCNs are connected to the greater Internet via gateway routers. In general, the RANs may overlap, and a mobile host can have access to several RANs in one location.

Mobile IPv6 [6] is the envisioned protocol for connecting CCNs and providing global (macro) mobility management. In a CCN-managed area, fast handover between base stations often belonging to different RANs with high-speed wireless access requires local (micro) mobility management. Inside a CCN, mobile hosts are identified by their Care-of-Address (CoA). Cellular IPv6-like [8] micro mobility protocol will route packets within a CCN.

The concept of a CCN and a separate BAN offers providers of wireless services the possibility to setup an infrastructure without a huge investment of resources. New providers can easily connect to the core network, provided that they use a correct interface. They do not need to have their own infrastructure before they can start their business, but
instead can use the infrastructure provided by the CCN and BAN.

3. BACIS ACCESS NETWORK (BAN)

3.1. Functionalities of BAN

Here we innumerate some major functionalities and usage of BAN.

- BAN is mainly used to support heterogeneous paging. In a mobile environment, systems must be energy-efficient since terminals rely on batteries to operate. We expect that wireless IP communicators will be “reachable” continuously (i.e., “always on”), although not be necessarily communicating most of the time. In essence, mobile hosts will be in an idle state, but passively connected to the network infrastructure. It is then extremely inefficient to have to scan all RANs, and wait for a paging message. Moreover, since wireless networks are optimized for special services, they may not be very efficient for paging messages. A wireless network that is optimized for this kind of traffic is more efficient.

- BAN can provide wireless system discovery. The BAN enables common access; every mobile host can use this BAN. The network provides the terminal with information about currently available wireless networks, so that the terminal does not have to scan all possible RANs.

- BAN is used as a signaling network especially to enable vertical handoffs. Such a dedicated network can provide this service efficiently and securely.

- BAN can provide an infrastructure to allow mobile hosts to determine their location. This information can, in turn, be used by BAN to provide a mobile host with information about available services in its region. Location management becomes further important for roaming and paging.

- BAN is used as a medium for most signaling and control messages. This simplifies the design of new wireless access services, since signaling is performed by another entity (BAC).

- Since we have a heterogeneous architecture in which multiple RANs can be used (semi) simultaneously, we need to have a network access synchronization mechanism so that a terminal could know when to tune the SDR to another access network. The BAN can provide such a service straightforwardly.

- Finally, BAN can also be used as a wireless access service when a user uses a BAC in standalone. It is, however, primarily suitable for very low bandwidth messaging services such as short messages.

3.2. Basic Access Component in Multi-service User Terminal

As shown in Fig. 2, a multi-service user terminal will contain a BAC with a locator and SDR-based network interfaces. The BAC is used as a primary component to communicate with the BAN and it has an embedded positioning capability offered by the locator component (e.g., a GPS receiver). The BAC sends out location update data to enable paging when the mobile host moves across the paging boundary, and for system discovery when the mobile host initializes a call.

In a multi-service User Terminal, besides BAC, there will be one or more subsystems for accessing (communicating with) subscribed service systems or RANs. These are indicated as Subsystem A, ..., Subsystem N, in Fig. 2. Mobile hosts include all standard transport protocols and wireless specific control services.

3.3. Operation of Basic Access Component

While kept powered, the BAC will continue to be tuned to the base station transmitter to receive the broadcast channel and to be able to transmit when necessary. The BAC will be involved in active sessions of communication with the base station in the following defined events.

(i) Location Update (Soft Binding): The BAC will send its physical location information to the network to facilitate location management and service/resource optimization. This will also enable the network to deliver calls (page) to the mobile terminal when the latter is not actively attached to any RAN. Location update is performed whenever the terminal is (a) first turned on (i.e. BAC is powered), (2) enters into the coverage of a new BAN base station, (3) responds a page, and (4) initiate a service access.

(ii) Access Initiation (Wireless System Discovery): When the user initiates access to a service network, BAC will send a packet to BAN, requesting a list of available wireless systems in its current location. This packet will contain location information, authentication information and other data necessary for resource optimization. In return, BAC will receive a list of RANs available around the terminal and, a security key to access the IP domain of
these RANs. BAC will pass this information to Central Processor of the mobile terminal.

(iii) Call Receive (Paging): It is through BAC that the mobile terminal will be informed about an incoming call/packet. If the user decides to receive a call, BAC will initiate RAN access as described in (ii).

(iv) Vertical Handover: When a forced (out of service area) or solicited (preferred service) handover is about to occur, BAN can play an important role to facilitate smooth transition between services.

4. MOBILITY MANAGEMENT MODEL OF MIRAI

In this section we describe the proposed mobility management model of MIRAI. This model is based on the implementation of two-level IP mobility, namely, macro mobility over micro mobility, in concert with signaling (soft binding and paging) by BAN. Mobile IPv6 is to be implemented for IP mobility between different CCNs or different domains. With a CCN domain, a micro mobility protocol (e.g. Cellular IPv6 [8] or HAWAII [9]) will route packets.

4.1. Elements of the Mobility Architecture

Fig. 3 shows the major elements of the mobility architecture using BAN. Besides the air interface related components, e.g. BSs, the network includes a Signaling Gateway (SG), Signaling Agent (SA), and Gateway Router (GR).

- **Signaling Gateway** manages one or more BAN base stations under it, and acts as the gateway between BAN specific network (not necessarily IP based) and the rest of the IP based network.
- **Signaling Agent** is the key element in the proposed structure. It works as the mobility agent for the signaling network, i.e. BAN. It also performs resource management in a CCN for the visiting terminals. For this purpose, it maintains two databases, namely, Location Database (LDB) and Resource Database (RDB). Geographical data e.g. latitude, longitude, altitude, etc. of the terminals belonging to the home network (but may be presently visiting a different network) are stored in LDB. This database is updated with the location update of the terminal. RDB keeps resource information of the deployed RANs in the corresponding CCN. Resource information include map of the base station/access points, feature matrix of the RANs, etc. Another important responsibility of SA is to operate as an AAA server. Each local SA constitutes the entry point of the trust chain for the user. It maintains security association with RANs in a CCN and GR/SA of other CCNs. It should also have trust relationship with SG of BAN.
- **Gateway Router** is the designated IP router of a CCN. The Home Agent (HA) for macro mobility of IP is implemented in GR. It also acts as the root router of the domain for micro mobility of IP within a CCN.

4.2. Signaling Mechanism in MIRAI using BAN

In the Fig. 4, the overall signaling BAN-based mechanism is shown.

When the MUT initiates a call or session, it requests for a list of available wireless services from the network using

![Figure 3: Elements of Signaling Architecture.](image1)

![Figure 4: Signaling mechanism for incoming and outgoing calls.](image2)
going through security and IP mobility signaling using the connected RAN, the finally connects to the desired corresponding node (CN). On the other hand, when a CN wants to connect to the MUT, the packet arrives at the signaling agent of the current domain (CCN) of the MUT, if it is not attached to the network. SA performs paging through base stations of BAN. In response, the MUT registers itself and obtains a list of available RANs in the current location. Then as is done for access initiation, MUT connects itself to the IP network and starts communication with the CN.

5. IMPLEMENTATION OF BAN

As stated earlier, the main objective of BAN is to provide a common channel for all the participant terminals while a user initiates an access to any network or when a call arrives targeted for the user. Since BAN will be used mostly at the time of establishing new service connections a relatively low bit rate two-way data communication channel between the mobile terminal and the network would suffice. However, the channel should be highly reliable, given the fact that without the establishment of this channel, the user would not be able to access any RAN service. Moreover, initial authentication data will be carried by this channel. Therefore reliability is the single most important criteria while developing BAN. Similarly, since access to any RAN service is dependent on the access to BAN, wide coverage (deployment penetration) of BAN is key to the implementation of the integrated wireless networks. However, BAC, which will probably be embedded in the mobile terminal, will obviously be a tiny component with limited power and computational capacity. To embed such a component in every mobile terminal of future generation, it should be optimized for simplicity and low cost. Implementation issues of BAN are detailed in [10].

We developed a BAN prototype system in the frequency band of 400 MHz. The system is designed for FDD/TDM/TDMA operation with a pair of downlink and uplink channels each with 25 kHz bandwidth. Transceivers for both the base station and mobile station are developed according to a newly developed air-interface. Table 2 shows the main system parameters. To meet the contrasting requirements of wider coverage and higher system throughput using minimal power, adaptive modulation is implemented.

Using the procedure illustrated in [10], we calculated the throughput improvement factor when the above modulation methods are used incrementally. Fig 1 shows the result for various standard deviation of log-normal shadowing. In the lower 3 lines, an SNR margin of 15 dB is used to take the Rayleigh fading into account.

5. IMPLEMENTATION OF BAN

Table 2: System Parameters of Ban Implementation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BS: 385.3375 MHz</th>
<th>BAC: 367.3375MHz</th>
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</thead>
<tbody>
<tr>
<td>Tx frequencies</td>
<td>&lt; 1W</td>
<td>&lt; 1W</td>
</tr>
<tr>
<td>Tx power</td>
<td>16QAM</td>
<td>8IQBi-Orth,</td>
</tr>
<tr>
<td>Modulation</td>
<td>16QAM</td>
<td>4QAM, 16QAM, 4QAM</td>
</tr>
<tr>
<td>Trans. Rate</td>
<td>19.2 ksym/s in a 25KHz channel</td>
<td></td>
</tr>
<tr>
<td>MAC</td>
<td>Dynamic TDMA</td>
<td></td>
</tr>
<tr>
<td>Duplex/Multiplex</td>
<td>FDD/TDM</td>
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REFERENCES