MOBILITY MANAGEMENT IN WIRELESS SYSTEMS

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Contents

Summary

First and second generation of wireless networks are based on non-IP based infrastructure. On the other hand, next-generation wireless systems are envisioned to have an IP-based infrastructure with the support of heterogeneous access technologies. Efficient mobility management techniques are critical to the success of both current (i.e., first and second generation wireless networks) and next-generation wireless systems. Mobility management enables mobile wireless networks to locate roaming terminals for

wireless services and to maintain connections as the terminal moves into a new service area. It contains two components: location management and handoff management. In this article, different aspects of mobility management are discussed. Location management and handoff management in non-IP-based and IP-based wireless networks are described in detail and state-of-the-art technologies for efficient mobility management are presented.

1. Introduction

First and second generation of wireless networks are based on circuit switched infrastructure. These networks support voice and low data rate services such as short message service (SMS). However, the air interface technologies of such networks are inadequate to support high data rate services such as multimedia, streaming services, file transfer, and gaming. Next-generation wireless systems are designed to support these high data rate services. These networks are envisioned to have an IP-based infrastructure with the support of heterogeneous access technologies. IP-based wireless networks are better suited for supporting the rapidly growing mobile data and multimedia services, since they can bring the successful Internet service paradigm to mobile providers and users. In addition, IP-based wireless networks can integrate seamlessly with the Internet to allow mobile users to access the information, applications, and services available over the Internet. Moreover, IP technologies provide a better solution to integrate different radio technologies transparently in such a way that users perceive them as one communication network. Currently, several IP-based architectures are proposed for integrating heterogeneous wireless networks to provide ubiquitous communications [1].

One of the research challenges for next-generation wireless systems is the design of intelligent mobility management techniques that take advantages of IP-based technologies to achieve global roaming among various wireless networks. Mobility management enables mobile wireless networks to locate roaming terminals for call delivery and to maintain connections as the terminal is moving into a new service area. Thus, mobility management supports mobile terminals (MTs), allowing users to roam while simultaneously offering them incoming calls and supporting calls in progress [2].

Mobility management contains two components: location management and handoff management. Location management enables the system to track the attachment points of MTs between consecutive communications. Handoff (or handover) management enables the network to maintain a user's connection as the MT continues to move and change its access point to the network. Moreover, when a user is in the coverage area of multiple wireless networks, for example, in heterogeneous wireless environments, handoff management provides *always best connectivity* [27] to the user by connecting the user to the best available network [26]. In next-generation wireless systems, there are two types of mobility for MTs: *intra-system* (intra-domain) and *inter-system* (inter-domain) mobility. Intra-system mobility refers to mobility between different cells of the same system. Intra-system mobility management techniques are based on similar network interfaces and protocols. Inter-system mobility refers to mobility between different backbones, protocols, technologies, or service providers. Based on intra- and inter-system mobility, the corresponding location management and handoff management can be further classified into intra- and inter-system location management and handoff management.

Efficient mobility management techniques are critical to the success of next-generation wireless systems. Efficient location management design implies minimized signaling overhead for location update and paging as well as minimized update and paging delay. Similarly, efficient handoff management support implies minimum latency and packet loss during handoff. In particular, handoff latency is critical for real-time applications such as voice, real-time video, and streaming services and packet loss during handoff is important for both real-time and non real-time applications. Hence, handoff management has become more critical in fourth generation (4G) wireless networks which support multi-media services. For instance, services such as FTP require zero packet loss during handoff. Similarly, Internet-based gaming services require very low handoff latency. Therefore, efficient handoff management design implies minimized handoff failure rate, packet dropping rate, and handoff latency. In addition, Quality-of-Service (QoS) requirements, scalability, and robustness are also important.

2. Importance of Mobility Management

Mobility in wireless networks can take different forms [2], such as:

- *Terminal mobility*: the ability for a user terminal to continue to access the network when the terminal moves;
- *User mobility*: the ability for a user to continue to access network services from different terminals under the same user identity when the user moves;
- *Service mobility*: the ability for a user to access the same services regardless of where the user is.

In addition, a terminal or a user may be considered by a network to have “moved” even if the terminal or the user has not changed its physical location. This may occur when the terminal switched its connection from one type of wireless network to another, e.g., from a wireless local area network to a cellular network.

Mobility management is the fundamental technology to enable the seamless access to next-generation wireless networks and mobile services. Future IP-based wireless networks support all types of multimedia services including real-time services such as voice and video streaming as well as non-real-time services such as email, web-browsing, and FTP. Basic requirements of mobility management in next-generation wireless networks should include: first, the support of all forms of mobility; second, the support of mobility for both real-time and non-real-time applications; third, the support of users seamlessly moving across heterogeneous wireless networks in the same or different administrative domains; fourth, the support of an on-going user application session to continue without significant interruptions as the user moves. This session continuity should be maintained when a user changes its network attachment points or moves from one type of wireless network to another; and last, the support of global roaming, i.e., the ability for a user to move into and use different operators’ networks. Finally, location management in next-generation wireless networks is critical to provide location based services.

In order to satisfy the above requirements, next-generation wireless systems with mobility management should have two basic functional capabilities:

- Location management: a process that enables the system to determine a mobile device's current location, i.e., the current network attachment point where the mobile device can receive traffic from the system.
- Handoff management: a process that enables a mobile device to change its network attachment point while keeping its on-going traffic uninterrupted. If the network attachment point change involves the roaming into another network with a different operator, then network access control is also involved in the handoff process. Network access control includes authentication (verify the identity of a user), authorization (determine whether a user should use the network service), and accounting (collect information on the resources used by a user).

In the following sections, technical details of location management and handoff management are explained. Research challenges and the current research work on mobility management are also introduced.

3. Location Management

Location management enables the system to track the attachment points of MTs between consecutive communications [3]. It includes two major tasks. The first is *location registration* or *location update*, where the MT periodically informs the system to update relevant location databases with its up-to-date location information. The second is *call delivery*, where the system determines the current location of the MT based on the information available at the system location databases when a communication for the MT is initiated. Two major steps are involved in call delivery: determining the serving database of the called MT and locating the visiting cell/subnet of the called MT. The latter is also called *paging*, where polling messages are sent to all the cells/subnets within the residing registration area of the called MT.

3.1. Location Management in Stand-Alone Cellular Networks

There are two standards for location management in stand-alone cellular networks: Electronic / Telecommunications Industry Associations (EIA/TIA) Interim Standard 41 (IS-41) and the Global System for Mobile Communications (GSM) mobile application part (MAP). The IS-41 standard is adopted in North America, while the GSM MAP is commonly used in Europe. Both standards are based on a centralized two-level management hierarchy. Two types of location databases, home location register (HLR) and visitor location register (VLR), are used to store the location information of MTs. Each user is permanently associated with an HLR in his/her subscribed network. A user profile which includes the subscribed services, billing information, and location information is stored at the HLR for each user. Each VLR stores a copy of a user profile (downloaded from the HLR) for the MT visiting its associated area.

Cells in cellular networks are partitioned into *registration areas* (RAs) in IS-41 (*location area* in GSM). All the base station controllers (BSCs) in an RA are connected to a mobile switching center (MSC), as shown in Figure 1, which provides switching functions and coordinates location registration and call delivery. Each MSC has a co-located VLR for location tracking. All the MSCs are connected through the backbone wireline network. An RA is usually under the control of one MSC. When an MT moves from one RA to another, it performs a location update by sending a registration message to the new VLR through the new base station (step 1 and 2 in Figure 1). The new VLR sends a location registration message to the HLR (step 3). The HLR performs the required authentication procedures and records the ID of the new serving VLR of the MT. The HLR then sends a registration acknowledgment message to the new VLR together with a copy of the user profile of the MT (step 4). The HLR also sends a registration cancellation message to the old VLR serving the old RA (step 5). The old VLR removes the record of the MT and returns a cancellation acknowledgment message to the HLR (step 6).

When initiating a call in cellular networks, the calling MT first sends a call initiation signal to the serving MSC through a nearby base station (step 1 in Figure 2). The MSC sends a location request message to the HLR of the called MT (step 2). The HLR determines the serving VLR of the called MT and sends a route request message to the VLR (step 3). The MSC serving the called MT allocates a temporary identifier called temporary local directory number (TLDN) to the MT and sends a reply to the HLR together with the TLDN (step 4). The HLR forwards the TLDN to the MSC of the calling MT (step 5). The network then set up a connection from the serving MSC of the calling MT to the serving MSC of the called MT (step 6). After receiving the call, the serving MSC of the called MT broadcasts polling signals to all cells within the associated RA. The called MT sends a reply to the polling signal which allows the MSC to determine its current residing cell. This procedure is called *paging*.

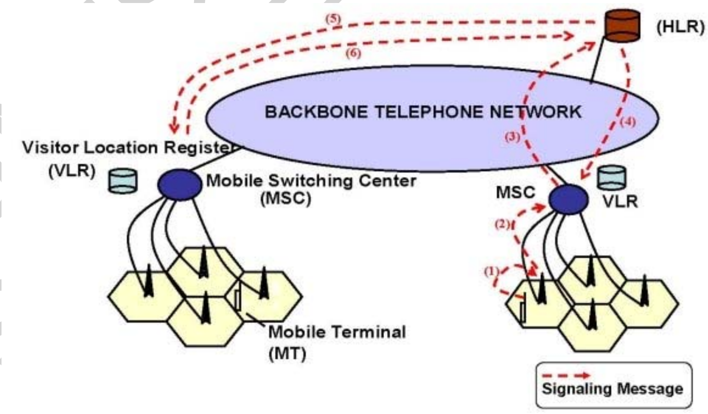

Figure 1: Location registration in stand-alone cellular networks

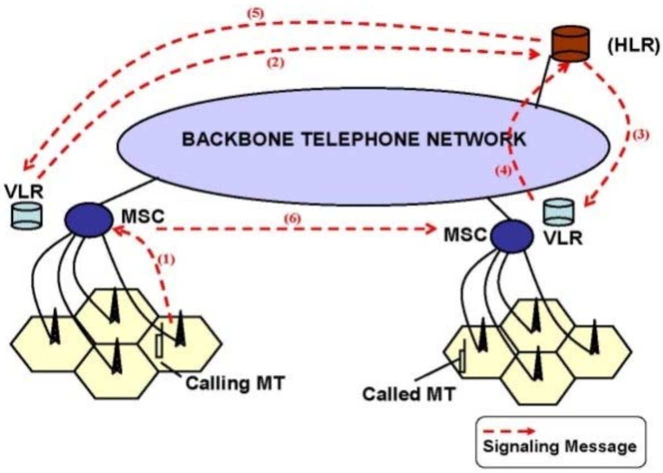

Figure 2: Call delivery in stand-alone cellular networks

3.2. Location Management in Non-IP-Based Heterogeneous Cellular Networks

When multiple heterogeneous cellular networks are co-located, it is suggested that the interworking/interoperating (I&I) function should be provided to accommodate roaming between dissimilar networks [9]. Intra-system roaming can be handled by the legacy location management mechanisms from stand-alone cellular networks. However, additional gateways are needed to handle the interworking and interoperating issues when roaming among heterogeneous cellular networks. For existing practical systems, several solutions are proposed for some specific pairs of interworking systems. Under the proposed solutions, the I&I function is implemented in either some additional interworking unit with the help of dual-mode handsets or a dual-mode HLR to take care of the transformation of signaling formats, authentication, and retrieval of user profiles.

Research activities are conducted to design general location management mechanisms for inter-system roaming of heterogeneous networks. The research activities can be grouped into two categories: location management for adjacent dissimilar systems with partially overlapping coverage at the boundaries and location management in multitier systems where service areas of heterogeneous networks are fully overlapped. All these solutions propose additional entities that take care of interworking issues between different wireless access networks.

A Boundary Location Register (BLR) is proposed in [10] to facilitate location management for inter-system roaming between two adjacent wireless systems with partially overlapping area, as shown in Figure 3. The BLR is located inside the boundary area of the two systems and maintains the roaming information of MTs crossing the boundary. A dynamic inter-system location update policy is developed. An MT reports its location when its distance from the boundary is less than an *update distance*. The update distance is variable over time depending on the network load and the mobility patterns of each MT.

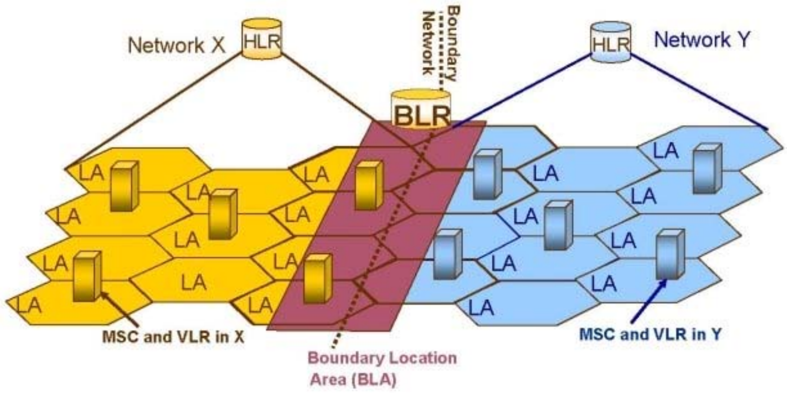

Figure 3: Boundary location register proposed for inter-system roaming

When the service areas of heterogeneous cellular networks are fully overlapped, an MT is reachable via multiple networks. Multitier wireless systems are recognized as an efficient way to improve the capacity and quality of mobile services. The objective is to integrate the higher- and lower-tier systems into a single system to provide the advantages of all tiers in an integrated manner. The multitier HLR (MHLR) approach is introduced in [11]. Inside the MHLR, a tier manager connects all heterogeneous HLRs. Based on this MHLR approach, two location registration strategies are proposed, single registration (SR) and multiple registration (MR). Under the SR method, an MT is allowed to register with the MHLR on only one tier, the lowest, at any given time. The MT always receives services from the lowest tier because of low cost and high bandwidth. Under the MR method, an MT is allowed to register with the MHLR on multiple tiers concurrently at any given time. The individual tiers perform their own roaming management as if they are not integrated. The tier manager of the MHLR keeps track of the currently visited high-tier and low-tier VLRs of an MT.

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