Location Management and Mobility Modeling in Wireless Systems

Wenye Wang
North Carolina State University, USA

INTRODUCTION

One of the most salient features of wireless communications is that users can deploy a variety of wireless devices to communicate with others, regardless of their locations. Although mobility support provides flexibility and convenience, it introduces many challenging issues to network design, planning, and performance evaluation. With the increasing demand for multimedia applications, location-aware services, and system capacity, many recognize that modeling and management of location and mobility are becoming critical to locating mobile objects in wireless information networks. *Location management* and *mobility modeling* strongly influence the choice and performance of mobility and resource management algorithms, such as routing, handoff, and call admission control in many types of wireless networks. For these reasons, it is important to understand mobility modeling and location management mechanisms and the manner in which these mechanisms depend on the characteristics of mobile environments. This article is concerned with issues in, and methods for, location management and mobility modeling in wireless data networks.

The most distinguished features of next generation *wireless systems* can be highlighted as reliable *quality of service (QoS)* for various applications and global roaming. Since the intrinsic characteristic of mobile communications is mobility support, wireless systems must be able to locate roaming *mobile terminals (MTs)* at any time to deliver services and to maintain connections, as the MTs move from one service area to another. Location management techniques enable mobile users to move around, even between different systems with dissimilar signaling formats and protocols, while simultaneously offering them incoming calls and maintaining services in progress. Therefore, the objective of mobility modeling is to estimate the current and future locations of a mobile user upon the arrival of a connection request, which involves many parameters, such as moving speed, call duration time, distance between the last known position and destination, and geographical conditions. Location management, however, deals with the problem of how to register or update new location of a mobile user with a wireless system, and how to locate a mobile terminal given the information in system databases.

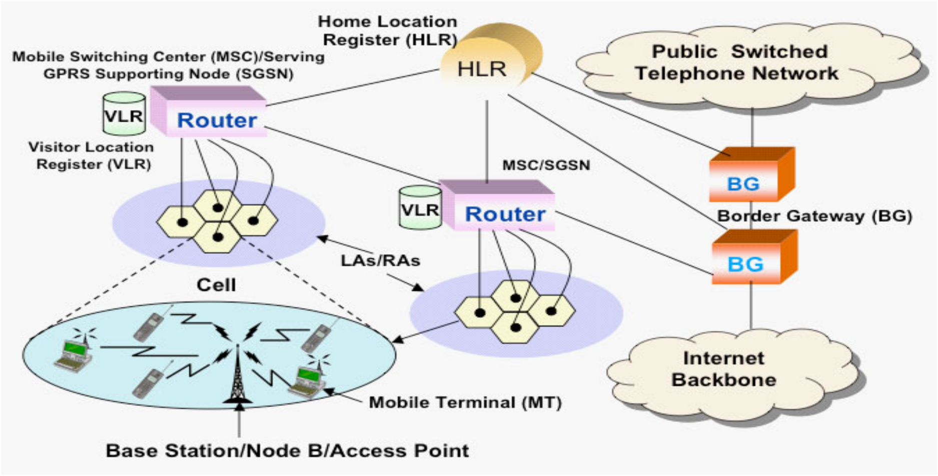
BACKGROUND

System Architecture and Problem Description

In wireless networks, each base station (BS) handles incoming and outgoing connection requests from mobile users residing within its coverage, or radio cell. A cluster of cells can be grouped together, controlled by a mobile switching center (MSC) or a serving GPRS supporting node (SGSN) in *cellular networks* such as *Universal Mobile Telecommunication System (UMTS)*. These MSCs and SGSNs are usually interconnected by wires for high-speed data transmission. The geographic coverage of a group of cells, which is also the area in the control of an MSC, is called a "location area" (LA). In wireless networks, it is very important to maintain the latest location information of each MT in the system so that a connection can be established when an incoming or an outgoing service request is received. However, mobile users change their positions over time. The identity of mobile users and their billing information are stored in a centralized database, a home location register (HLR). When an MT moves into a different region network, it must update or register with a local database, a visitor location register (VLR). In other words, the VLR in a visiting network keeps the most recent location information of a mobile user, and it will communicate with the HLR to renew location information (see Figure 1).

Location management is a technique that updates the location of MTs during the course of their movement and determines the locations of MTs for call delivery. In particular, it includes two phases: location update and *paging*. During location update or location registration, mobile terminals send location update requests to an MSC to establish or refresh their locations information in VLRs. For paging and call delivery, the system needs to search for the called MTs for message delivery. Location update and paging involve algorithms or strategies to send loca-

Figure 1. Network architecture



tion update messages and to find MTs based on known information in network databases; whereas, location registration and call delivery are related to the procedures and signaling messages.

Basic Location Update and Paging Algorithms in Cellular Networks

Location management is a two-stage process that allows wireless systems to discover the current attachment point of a mobile user for call delivery. The first stage is *location update,* or *registration*. In this stage, an MT periodically notifies a network of its new access point, allowing the network to authenticate an MT's identity and revise the user's location profile. The second stage of location management is *paging,* during which the network is queried for the user location profile so that the current position of a called MT can be found (Akyildiz et al., 1999).

The service area of a network is often divided into several LAs so that the MT informs the network when it enters a new LA by monitoring the LA identification (LAI) through public broadcast channels. Usually, MTs send location update requests when they move from one LA to another. With location update/registration, the network is able to keep track of MTs in a specific region constrained by the distance, time, or movement. An LA can be determined by retrieving an MT's record in the HLR; thus, an MT's current residing cell can be found by sending a polling message to all BSs encompassed in an LA. When an incoming call arrives, the MSC, which is associated with the LA of an MT's last registration, sends a paging message via the paging channel to the BSs with the called MT's ID. The serving BS of MT then responds to the network. As a result, the network knows in which cell an MT is residing, and an incoming call can be delivered to the MT.

In current personal communication service (PCS) systems, paging is a fundamental operation for locating an MT. As the demand for wireless services grows rapidly, the signal traffic caused by paging increases accordingly, consuming limited radio resources. In a paging process, a wireless system searches for an MT by sending poll messages to the cells close to the last reported location of the MT at the arrival of an incoming call. Delays and costs are two key factors in the paging issue (Rose & Yates, 1995; Wang Akyilidz, Stüber, & Chung, 2001). Of the two factors, *paging delay* is critical to reducing setup relay of service delivery. *Paging cost*, which is measured in terms of cells to be polled before the called MT is found, is related to the efficiency of bandwidth utilization and should be minimized under delay constraint. Many paging schemes have been proposed to resolve this conflict (Akyildiz, Xie, & Mohanty, 2004).

Mobility Modeling

A variety of mobility models exist that can find applications in different kinds of wireless networks. Because mobility models are designed to mimic the movement of mobile users in real life, many parameters need to be considered. Most of the existing mobility models describe the behaviors of mobile terminals without considering previous records. In this context, we will focus on this type of mobility model and so-called synthetic models, and we will introduce several developments that take traces or profiles into account and combinational models.

Mobility models can be categorized into different groups based on the following criteria (Bai & Helmy, 2004; Camp, Boleng, & Davies, 2002; Hong, Gerla, Pei, & Chiang, 1999; McGuire & Plataniotis, 2003):

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