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# Design and performance analysis of hierarchical location management strategies for wireless mobile communication systems

Bong-sue Suh[a,*], Jin-seek Choi[b], Jae-kyoon Kim[a]

[a]*Department of Electrical Engineering, KAIST, Taejon 305-701, South Korea*
[b]*Department of Information and Communications, Kongju National University, Kongju 314-701, South Korea*

**Abstract**

In this paper, we propose three hierarchical location management strategies for wireless mobile communication systems. The first one is home server first (HSF) scheme in which callee's location is queried at callee's home location server first. Next, we propose least-common-ancestor server first (LSF) scheme in which a search starts at the least-common-ancestor server of caller's current location and callee's home server. Finally, we propose distributed LSF in which the location management is made on 2-layered distributed structure. We evaluate the performance of the proposed schemes and compare it with that of another hierarchical scheme proposed by Wang (J.Z. Wang, A fully distributed location registration strategy for universal personal communication systems, IEEE J. Select. Areas Commun., 11(6) (1993) 850–860) and IS-41-based scheme. It is shown that the proposed schemes have reduced location management cost and that the cost is less affected by the increment of communication cost than the compared schemes. 

*Keywords*: Location management; Hierarchical scheme; Wireless mobile systems

## 1. Introduction

In wireless mobile communication systems, the exchange of information with the mobile terminals should be facilitated regardless of their locations. To meet this requirement, the network should have well-defined functions to find out the access points of the mobiles. Thus, the design of an efficient location management strategy is one of the important issues in wireless mobile network [1–3].

Much research on location management has been conducted in two large classes: centralized and distributed strategies. The centralized location management strategies are based on 2-layered structure having the centralized database (Home Location Register, HLR) with the multiple number of the local database (Visitor Location Register, VLR). Examples of the centralized strategies are Electric/Telecommunications Industry Associations (EIA/TIA), Interim Standard 41 (IS-41) [4] and Global Systems for Mobile Communications (GSM) Mobile Application Part (MAP) [5]. The modified versions of these standards such as per-user caching scheme [6], user profile replication scheme [7], pointer forwarding scheme [8] and local anchoring scheme [9] were proposed to reduce the message traffic and the database processing load at the central HLR.

The distributed location management strategies have been proposed to solve the latent problems of IS-41 and GSM MAP standards and their modified versions. Considering the large number of subscribers in future wireless mobile communication systems, the centralized management strategy will become impractical due to the signaling traffic congestion and the high-database processing load at the central database. To solve these latent problems, fully distributed scheme [10] and hierarchically distributed scheme [1] were proposed for personal communication systems. The hierarchical Private Network-to-Network Interface (PNNI)-based location management for wireless Asynchronous Transfer Mode (ATM) networks was proposed and is under discussion in Wireless ATM Forum [11]. In addition, an algorithm to determine the optimal database placement has been proposed in Ref. [12] to reduce the location update and access load on each database on the hierarchical network structure.

The fixed transport networks of mobile communication systems such as cellular, personal communication services (PCS), wireless ATM and international mobile telecommunication 2000 (IMT-2000) networks are structured in a hierarchical way. Hence, the distributed location management based on the hierarchical manner is attractive for the next generation mobile networks.

In this paper, we propose three location management strategies based on hierarchical network structure. The first one is home server first (HSF) scheme, the second

* Corresponding author.

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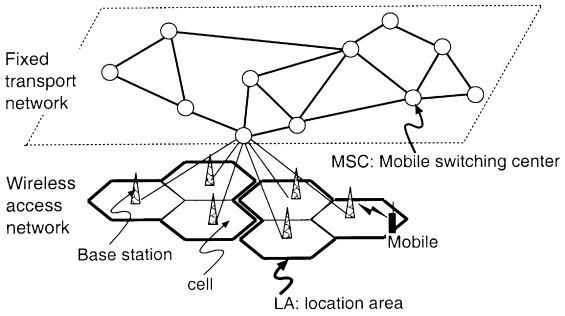


Fig. 1. Wireless mobile communication system structure.

one is least-common-ancestor server first (LSF) scheme and the last one is distributed LSF scheme. We evaluate the expected location registration and call delivery costs with consideration given to the cost of signaling message transmission and database processing. In addition, we compare the location management cost of the proposed strategies with that of a hierarchical scheme proposed in Ref. [1] and an IS-41-based scheme.

## 2. Proposed location management strategies

Wireless mobile communication systems consist of the fixed transport network and the wireless access network as shown in Fig. 1. In order to utilize the limited wireless resources, the service area is divided into a multiple number of unit areas called *cells*. Within a cell, mobiles communicate with the base station through wireless link, and a group of cells constitutes a location area (LA). The mobile switching center (MSC) provides the typical switching functions on the backbone network. An MSC is regarded as a switch in the fixed network in this paper. The location management network on the fixed transport network has functional entities to store information, which enables it to find out under which LA the mobile is located. We call them *location servers* or simply *servers*. When a mobile moves between LAs, the location servers refresh location information, which is generally called *location registration*. When a mobile-terminated call occurs, the network forwards the call to callee in the appropriate manner, which is generally called *call delivery*. Then, the paging signal is broadcast over the whole cells of LA. If the callee replies to paging signal, the connection set-up procedure begins.

Fig. 2 shows hierarchical location management structure with $L$ layers on the fixed transport network. Each LA is composed of a number of cells. The hierarchically distributed servers on layer $k$ ($k = 1, 2, \ldots, L$) have database for keeping information of mobile's location. The mobile enrolls in one of the layer 1 servers. We call this server mobile's *home server*. To the ancestor servers of mobile's home server, the mobile is regarded as *home mobile*. A server regards a mobile as *foreign mobile* which is located under server's coverage but whose home server is outside this server. The mobile identification (ID) is composed of hierarchical *area address* and *terminal number*. The field of area address indicates the location of mobile's home server. It is assigned hierarchically similar to telephone numbers. For $L$-layered structure, thus, the mobile ID has the address form of $A_L A_{L-1} \ldots A_1 + T$. $A_k$ represents the address field of the location on layer $k$ and $T$ is the distinguishable terminal address.

The server on layer 1 has the following location information:

- Home mobile which travels out of server's coverage: address of the parent server on layer 2.
- Mobile which is under server's coverage regardless if it is home or foreign mobile: address of mobile's residing LA.

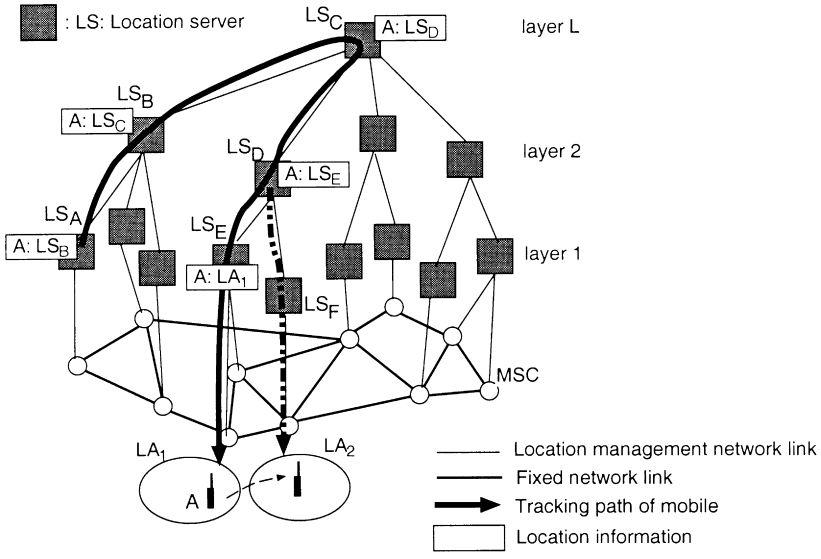


Fig. 2. Hierarchical location management system structure.