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A Conceptual Approach to Location Management in Wireless Networks

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Abstract

In this paper, in terms of conceptual aspects, we highlight the various common key features and issues involved in the design of the location management scheme for wireless networks. Besides, regardless of supported network types, we briefly review and analyze the main features such as the conceptual basic ideas, key design principles and performance considerations on the existing location management schemes for wireless networks. We expect that the results can provide a comprehensive insight for designing more efficient location management scheme in future wireless networks as well as for fundamentally understanding the various existing location management schemes regardless of supported network types.

Keywords: Location Management, MIPv6, PMIPv6, Wireless Networks

1 Introduction

One of the most important and challenging issues in mobile computing environments is location management. Location management enables the networks to track the location of a mobile user and discover its current point-of-attachment for call delivery or packet delivery[1–3]. A variety of location management schemes for wireless networks (e.g., wireless cellular networks, mobile IP/mobile IPv6 (MIPv6)-based networks and proxy mobile IPv6 (PMIPv6)-based networks, etc.) have been reported over the past decade. Even if these schemes are different in their details, we argue that the underlying fundamental principles and common conceptual techniques of location management schemes are essentially almost the same.

The research for more enhanced and optimized location management is inevitable in order to more efficiently manage a huge population of mobile subscribers and provide them with a range of services in future wireless networks. Therefore, in this paper, we provide a comprehensive overview and classification on various existing location management schemes which have been proposed for wireless cellular networks and MIPv6/PMIPv6-based networks and derive common key conceptual techniques on them. Also, these common conceptual techniques are expected to be easily applied for more efficient mobility and Quality-of-Service (QoS) support in future wireless networks.

2. Conceptual Classification on Location Management Schemes

Generally, the current location management standards[1,2] may not be efficient for supporting a huge user population because they do not consider each mobile user's mobility/traffic characteristics. Besides, unnecessary control traffic and database access load due to such a static and globally applicable location management may cause significant performance degradation throughout the networks.

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Table 1. Functional similarities of wireless mobile networks

Category	Wireless cellular networks	MIPv6-based networks	PMIPv6-based networks
Mobility management type	Network-based mobility management	Host-based mobility management	Network-based mobility management
Location management standards	IS-41/GSM	MIPv6	PMIPv6
Location management operations	Location registration, Call delivery	Binding update, Packet delivery	Proxy Binding update, Packet delivery
Home location database	HLR (home location register)	HA (home agent)	LMA (local mobility anchor)
Local location database	VLR (visitor location register)	AR (access router)	MAG mobile access gateway)
Mobile entity identifier	IMSI (International Mobile Station Identity)	HoA (home address)	MN identifier
Mobile entity locator	MSRN (Mobile Station Roaming Number)	CoA (care-of-address)	HoA

Thus, the previous literatures on location management schemes have been focused on designing more efficient and more optimized per-user location management schemes. However, although the techniques required for each network are somewhat different in their details, we argue that the underlying fundamental principles and common conceptual techniques of their location management schemes are essentially almost the same regardless of supported network types. In this section, from the viewpoint of common key conceptual techniques used for efficient location management, we analyze the previous literatures, providing a brief overview and classification on them. Table 1 and 2 will help the readers to analyze and compare the previous literatures in terms of common conceptual aspects.

Table 2. Basic ideas of location management scheme

Schemes	Basic ideas
Caching-based schemes	Reuse a user's location information that has been acquired during the previous call to that user.
Pointer forwarding-based schemes	Instead of updating the location database such as HLR or HA, which is located far away from the user, just report the location change by simply setting up a forwarding pointer from the old point-of-attachment to the new one.
Anchor-based schemes	Manage a user's location change in a localized manner. In other words, the location information of the user is registered to the local anchor instead of registering it to the location database such as HLR or HA, which is located far away from the user.
Profile-based schemes	Maintain an individual user profile, and take appropriate action for location management according to its profile.
Replication-based schemes	Replicate a user's location information at the selected zones from which it receives the most calls.

2.1 Caching-Based Schemes[4–9]

The basic idea of caching-based scheme is that, in many cases, it may be possible to reuse a user's location information that has been acquired during the previous call to that user. Caching-based scheme can be very effective for the users that receive incoming calls frequently relative to the rate at which they move. Similar to the concept of exploiting locality of file accesses, the caching-based scheme exploits the spatial/temporal locality of calls received by users. In order to locate a user, the cache at the caller's side is queried first. Then, if a user's location is found at the cache, a query process is conducted to the indicated location without contacting the user's home location database. Otherwise, home location database is queried. Note that MIPv6-based schemes as well as MIPv4 with route optimization extensions can be basically considered as adopting caching-based scheme because all CNs should maintain its binding cache for MNs.

2.2 Pointer Forwarding-based Schemes[10–14]

If a user is relatively highly mobile, it might be very unnecessary to update all the location database information whenever it moves. The key concept of pointer

forwarding is that instead of updating the location database located far away from the mobile user, at each move, the reporting in location change can be reduced by simply setting up a forwarding pointer from the old point-of-attachment to the new one. In pointer forwarding-based scheme, routing cost may increase in case of long forwarding pointer chain. Thus, the determination of the optimal forwarding pointer chain length is important. The issues related to the determination of optimal pointer chain threshold have been discussed for wireless cellular networks, MIPv4/HMIPv6 networks, respectively.

2.3 Anchor-based Schemes[5,9,12,15–18]

The key observation of anchor-based scheme is that the network traffic due to location update can be reduced by managing local movements in a localized manner. Anchor-based scheme has been also applied to Mobile IP networks for efficient location management. HMIPv6 is a good example of using a local anchor concept for location management. By using anchor-based scheme, in[5], when an MN changes the subnets within a same localized domain (i.e., mobility anchor point (MAP)), it only sends the binding update message to the MAP. Therefore, HMIPv6 makes the MN's mobility within MAP domain transparent to the HA and the CNs and only when the MN crosses a MAP domain, it sends the binding update message to the MAP, the HA and potentially, the CNs.

2.4 Profile-based Schemes[9,19,20–22]

Generally, most users tend to follow regular routines during some specific periods or on some days of the week. Thus, once these mobility patterns can be recognized in an MN's profile, location management becomes not only easier but also more efficient. Inspired by such an idea, in[19,20], the profile-based strategies were proposed to enhance the performance of location management by improving the intelligence in the user's location lookup procedure. Also, enhanced version of HMIPv6 which exploits an MN's mobility history information was proposed for more efficient and more optimized location management in HMIPv6 networks[22].

2.5 Replication-based Schemes[23-26]

Location databases may become the bottleneck when there are a large number of mobile users in the network. On the other hand, maintaining the location information of specific users at selected sites may also be helpful for faster location lookup of mobile users. Therefore, by replicating user profile in the network, these problems mentioned above can be solved to some extent by a single lookup process on the local database rather than a high latency remote lookup process. However, associated additional cost of replication is the update cost that can be incurred in maintaining consistent replicas every time a user moves. Therefore, a policy to select appropriate replications is also essentially required and its use must be carefully considered.

3. Analytical Summary

In this paper, regardless of supported network types, we have briefly reviewed and analyzed the common features of a variety of existing location management schemes for wireless networks. The basic philosophy behind the various literatures is to devise more efficient and optimized per-user location management schemes using a mobile user's mobility/traffic characteristics. For this purpose, various location management schemes have been reported recently. From the viewpoint of the fundamental design philosophy on them regardless of supported network types, we summarize common design principles and performance issues of location management schemes as shown in Tables 3 and 4, which are expected to provide

Table 3. Common key design principles of location management schemes

Schemes	Common key design principles
Caching-based schemes	- Reducing location lookup (i.e., routing) cost - Reducing the load at remote database such as HLR and HA/LMA.
Pointer forwarding-based schemes	- Reducing location update (i.e., location registration) cost - Reducing the load at remote database such as HLR and HA/LMA
Anchor-based schemes	- Reducing location update cost. - Reducing the load at remote database such as HLR and HA/LMA.
Profile-based schemes	- May be exploited for efficient location lookup, paging, and handover, etc - Preferable for the mobile users that follow their expected behaviors
Replication-based schemes	- Reducing location lookup cost - May provide the load balancing or fault-tolerance

a useful guidance for designing more efficient and optimized location management scheme in future wireless networks.

Several hybrid location management schemes that combine the two or more schemes mentioned above have been also proposed in the literatures[5,9,12,25]. In such cases, they may have all advantages of the combined schemes or may improve some advantage of one scheme while lessening some disadvantage of the other scheme. The common key features on location management schemes that have been derived in this paper can be easily tailored for designing more optimized location/mobility management scheme in future wireless networks.

Table 4. Common major performance issues of location management schemes

Schemes	Common major performance issues
Caching-based schemes	- How to determine an optimal time threshold for maintaining location cache? - At what entity should the location cache be placed?
Pointer forwarding-based schemes	- How to determine an optimal pointer chain length? - Where should the forwarding pointer information be stored?
Anchor-based schemes	- How to select the local anchor for optimal performance gain? - Which type of local anchor (e.g., static or dynamic) should be adopted?
Profile-based schemes	- How to create an individual user's profile? - Pattern learning process for creating and maintaining user profile may be needed.
Replication-based schemes	- Where should the replicas be maintained? - Additional update cost incurred in maintaining consistent replicas may occur.

4 Conclusion

In terms of conceptual aspects, we have briefly reviewed and analyzed the common features of conceptual basic ideas, key design principles and performance considerations on the existing location management schemes for wireless networks. Besides, we have demonstrated that the underlying fundamental principles of location management schemes, regardless of supported network types, are essentially almost the same by exemplifying various location management schemes and their main features and so on. Our future work is to extend our approach to the research on mobility management in mobile computing environments. This topic will include mobility management in any type of wireless network as well as handoff management between heterogeneous networks.

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