Issues in Location Management in Mobile Systems *

Nitin H. Vaidya † P. Krishna D. K. Pradhan
Department of Computer Science
Texas A&M University
College Station, TX 77843-3112
E-mail: {vaidya,pkrishna,pradhan}@cs.tamu.edu
Fax: (409) 862-2758
Phone: (409) 862-3411

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Abstract

Integrated voice and data applications will be used by millions of users often moving in a very heavy urban traffic conditions. In order to communicate with an user, one needs to know the user's location. Thus, the network faces a problem of continuously keeping track of the location of each and every user. Location management is one of the most important issues in distributed mobile computing. Location updates will become a major bottleneck in future PCNs, and mechanisms to control the cost of location updates are needed. A trade-off exists between the cost of updates and cost of searches. The goal of a good location management scheme should be to operate at the "*knee point*" of the update and search tradeoff curve. In this paper we are going to present an overview of our work on location management in distributed mobile environments. We classify the space of location management based on different characteristics, and present schemes for each of them. The proposed schemes share a common goal of avoiding unnecessary updates without affecting the search costs.

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†Direct all correspondence to Nitin H. Vaidya.

1 Introduction

Mobile computing is rapidly becoming a major trend in the communications market. Users of portable computers would like to carry their laptops with them whenever they move from one place to another and yet maintain transparent network access through the wireless link. With the availability of wireless interface cards, mobile users are no longer required to remain confined within the fixed network premises to get network access. In order to communicate with an user, one needs to know the user's location. Thus, the network faces a problem of continuously keeping track of the location of each and every user. This problem becomes noticeable when the network sizes are large. In this paper we are going to present an overview of our work on location management in distributed mobile environments.

Location management is one of the most important issues in distributed mobile computing. There are three dimensions to the location management problem :

- Based on where the location information of the mobile hosts is stored, location management can be broadly classified into (i) *centralized*, and (ii) *distributed* schemes.
- Based on whether the location management scheme changes with time, it can be classified as (i) *static*, and (ii) *adaptive.*
- The network architectures can be classified as (i) *fixed network* (comprising of only fixed hosts), (ii) *hybrid network* (comprising of fixed and mobile hosts), and (iii) *mobile network* (comprising of only mobile hosts).

We are interested primarily in networks containing mobile hosts. Therefore, we will be concentrating on only *hybrid* and *mobile* networks. In the first part, we will describe location management in *hybrid* networks. We will first present *static* location management schemes based on *centralized* and *distributed* location servers. We will then present the motivation behind *adaptive* location management schemes. Later we will present an *adaptive* location management scheme. In the second part, we will describe the goal of our ongoing research which involves development of location management schemes in *mobile* networks.

2 Location Management in Hybrid Networks

System Model : We first present a network architecture for a distributed system with mobile hosts. Hybrid networks generally comprise of a fixed backbone network and a wireless network. The fixed network comprises of the fixed hosts and the communication links between them. Some of the fixed hosts, called *mobile support stations* (*MSS*) are augmented with a wireless interface, and, they provide a gateway for communication between the wireless network and the fixed network. Due to the limited range of wireless transreceivers, a mobile host can communicate with a *mobile support station* only within a limited geographical region around it. This region is referred to as a mobile support station's *cell.* Cells are grouped into *registration areas.* There is a location server in each registration area. Each location server maintains information regarding mobile hosts residing in its registration area.

2.1 Centralized Location Management

Each mobile host is assumed to be permanently registered to a particular registration area. The location server of that registration area is called the *home location server* (HLS) for the mobile host. This association of a host with a particular *home location server* is fully replicated across the whole network. The *home location server* is responsible for keeping track of the location information of the mobile host. Location management with home location servers is being used in current personal communication systems standards proposals such as EIA/TIA IS-41[1]. We will briefly describe the scheme for location updates and searches in IS-41. We will then present the drawbacks of these schemes. Later in this section we will present the modified centralized location management scheme using forwarding pointers.

Location updates take place *whenever* the mobile host (mh) enters a new registration area. All location searches go to the HLS of the destination host first, which then returns the current location of the destination host.

Drawbacks : (i) Increase in network traffic when the host crosses registration areas very frequently. As every registration area crossing causes a location update at the host's HLS, this scheme increases the network traffic. (ii) Inefficient location management : Updates on each registration area crossing is useful, if the user is being called frequently, to reduce the search costs (i.e., call set-up time). However, if the user is not being called frequently, regular updates are not necessary. In such scenarios, regular updates lead to inefficient location management.

2.2 Modified Centralized Location Management

In this section we will briefly discuss schemes to avoid the drawbacks of the location management strategy in IS-41. Details can be found in [3]. We use forwarding pointers in addition of HLS to assist in location management. Our main goal is to avoid the increase in network traffic due to location updates at the HLS. We achieve this by not updating the location information after every registration area crossing. Instead, forwarding pointers are maintained at the location servers of the registration areas visited. Location searches include traversing a chain of forwarding pointers. To avoid an increase in the cost of location searches, the length of the chain of forwarding pointers should not be too long. Therefore, the HLS is updated after certain interval of time which is determined based on the following heuristics. (i) Movement-based : HLS update takes place when the number of registration area crossing is M. (ii) Call-based : HLS update takes place whenever a call arrives. Therefore, HLS update will take place whenever a location search takes place.

Performance : The performance of the modified scheme depends on (i) the relative cost of setting and traversing the forwarding pointers (α), and, (ii) call-mobility ratio of the user (r). It was observed from our analysis that forwarding pointers are not beneficial in environments where r is very low and α is very high. The following table gives us a fair idea about when forwarding pointers are beneficial. If they are beneficial, the table shows which heuristic performs the best.

2.3 Distributed Location Management

With the cell size shrinking, the number of calls moving from one cell to the next is increasing. Therefore the amount of signalling traffic is also increasing. The distributed location management approach, is superior to current existing algorithms (centralized) by dramatically reducing the signalling traffic generated by moving hosts. This improvement will be accomplished by storing the location information of a mobile host in various location servers.

[1]The terminology used in IS-41 literature is slightly different. IS-41 uses home location register (HLR) and visitor location register (VLR) databases. However, the information maintained in the HLR is same as what is maintained in HLS, the information maintained in the VLR is maintained in the various location servers.

α \ r	LOW < 0.5	AVG. 0.5	HIGH > 0.5
LOW < 0.5	Call -based	Movement -based	Not Beneficial
AVG. 0.5-1	Movement -based	Call -based	Call -based
HIGH > 1	Movement -based	Call -based	Call -based

Figure 1: Performance Chart

We divide location management strategies into location *updates*, *searches* and *search-updates*. An *update* occurs when a mobile host changes location. A *search* occurs when a host wants to communicate with a mobile host whose location is unknown to the requesting host. A *search-update* occurs after a successful *search*, when the requesting host updates the location information corresponding to the located mobile host. Based on a network architecture comprising of a hierarchy of location servers, we proposed a *search* strategy and various strategies for location *updates* and *search-updates*. We will give a brief overview of the strategies in the following. Details can be found in [1].

Searches : If an incoming call needs to be routed towards a mobile host, it moves up in the network hierarchy until it encounters a location server where location information on the desired mobile host is stored. The information at the location server will be sufficient to route the call to the next location server. At the next location server, more detailed information about the mobile host will be available and so on.

Updates : We proposed three strategies for updating the location information at the location servers and the mobile support stations (MSS), due to the movement of the host. They are (i) Lazy Updates (LU) (update at the MSSs only), (ii) Full Updates (FU) (update at MSSs and location servers), and (iii) Limited Updates (LMU) (update at MSSs and limited number of location servers).

Search-Updates : Location management becomes more efficient if the location updates take place also after a successful search. For example, suppose there is a host h that frequently calls h', and h' is highly mobile. It makes sense to update the location information of h' at h after a successful search, so that in the future if h calls again, the search cost is most likely to reduce. We proposed three strategies to update location information upon a search. They are (i) No Update (NU) (no updates), (ii) Jump Update (JU) (update only at the caller's MSS), and (iii) Path Compression Update (PC) (update at all the location servers and MSSs on the search path).

Performance : The cost metric is the number of messages required for each operation (search, update, and search-update). The performance parameter of interest is the aggregate cost per operation, which is the sum of average update cost upon a move, average search cost, and the average update cost upon a search.

It was noticed that performing search-updates significantly reduced the search and aggregate costs. For the logical network architecture assumed, it was seen that the (combination of Lazy Update and Path Compression) LU-PC strategy performs better than the other strategies for most of the values of C and M. For models with different costs associated with each link, we expect the other proposed strategies to perform well, and sometimes better than the LU-PC strategy for some values of M and C. As shown in Figure 2a, we expect zones in the M-C plane, where one scheme will outperform others for the call frequency and mobility values in the zone. This was evident in our results. As shown in Figure 2b, the M-C plane is divided in two zones, LU-JU and LU-PC. Thus, if the behavior of the mobile hosts (call frequency, mobility) is known a priori, the designer can obtain such an M-C chart and decide which location strategy will best suit the system.

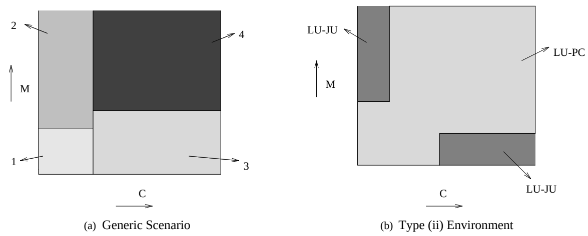

Figure 2: Partitioning of the M-C plane

2.4 Adaptive Location Management

Numerous location management strategies have been proposed in the recent years[1]. These location management strategies are mainly a combination of a *search*, a location *update* strategy, and a *search-update* strategy. The results show that there is not one combination that outperforms others for all values of call frequency (C) and mobility (M). As shown in Figure 2a, we expect zones in the M-C plane, where one scheme will outperform others for the call frequency and mobility values in the zone. Thus, if the behavior of the mobile hosts (call frequency, mobility) is known a priori, the designer can obtain such an M-C chart and decide which location strategy will best suit the system. However, the host behavior (communication frequency, mobility) is not always available to the system designer. Thus, we feel that the location management strategies with the greatest potential benefit are *adaptive* in the sense they react to changes in the host behavior (call frequency, mobility). The basic assumption behind the proposed *adaptive* location management is that the past history of the system will reflect the behavior in the future. Hence, by keeping track of the past history and modifying the management strategy accordingly, one expects to perform well for any call and mobility pattern.

We developed a simple algorithm for *adaptive* location management based on the schemes proposed in distributed location management in the previous section. We performed simulations and compared the results of the *adaptive* algorithm with *LU-PC* and *LU-JU*. It was observed that on the average, *adaptive* performs better than both the schemes [2].

3 Location Management (Routing) in Mobile Networks

Till now, we have been discussing location management schemes for networks which involved interaction with the fixed network infrastructure. We will now investigate the consequence of mobility and disconnections of mobile hosts on the routing overhead in a *mobile* network. We define *mobile* network as a cooperative set of mobile hosts which can communicate with each other over the wireless links (direct or indirect) without any static network interaction [2]. Example of such networks are *ad-hoc* networks [4].

The problem in hand is the complexity of updating the routing information at the hosts in such a dynamic (due to the mobility of the hosts, and host disconnections) network. Topology updates are required for shortest path computation. An inefficient solution is global broadcast. However, it is going to use up the

[2] We assume that a mobile host has the capability to communicate directly with another mobile host. It is also assumed that the mobile hosts have the capability to forward (relay) packets.

already limited wireless bandwidth. Therefore, a tradeoff exists between the topology update overhead and efficient routing. The preferred solution will be to distribute topology updates.

The primary attributes for any routing algorithm are (i) simplicity, (ii) loop-free, (iii) generate shortest path, (iv) quick reconvergence, and (v) low storage overhead. The existing routing algorithms cannot be used for such dynamic networks because

- they were not designed specifically to provide dynamic and self-starting behavior as evident in *ad-hoc* networks,
- Most of them exhibit their least desirable behavior for highly dynamic interconnection topology.
- Existing protocols could place heavy computational burden on mobile computers.
- Convergence characteristics not good enough to suit the needs of *ad-hoc* networks.
- Wireless media – limited and variable range; different from existing wired media.

There has been previous work done in this area [4]. The algorithm described in this paper was a modification of the Bellman-Ford routing algorithm to suit *ad-hoc* environment. It is similar to distance-vector routing. They use sequence number to prevent routing table loops, and, settling-time data for damping out fluctuations in route table updates. The convergence on the average was rapid, however, the worst case convergence was non-optimal. Moreover, their algorithm required frequent broadcasts of the routing table by the mobile hosts. The overhead of the frequent broadcasts goes up as the population of mobile hosts.

At present we are trying to develop routing protocols for *ad-hoc* networks which will have the desired characteristics of rapid convergence and low topology update overhead.

4 Conclusion

This paper presents an overview of the ongoing work at Texas A&M University on location management in distributed mobile environments. We classify the space of location management based on different characteristics, and present schemes for each of them. The goal of our ongoing work is to develop routing schemes in *mobile* networks.

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