LTRACK
A novel location management method

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In this paper we propose a new location management algorithm for mobility networks. Our algorithm is called LTRACK, it stands for “location tracking”. The signaling load that LTRACK puts on the network can be significally less than that of conventional location management algorithm.

Over the past few years there has been extreme growth in wireless communications. The mobile networks of today use cellular architecture. In a wireless network service access points are usually called base stations. Mobile nodes are connected to the networks via base stations, each of the base stations covers one cell. There are wireless links between the base stations and the mobile equipments. Base stations are interconnected with routers to form a network. This network usually uses fixed links. As the mobile node is moving around, it changes its connection point to the network from time to time. The event when the mobile equipment moves to a new service access point is called handover or handoff.

Any mobility protocol has to solve two separate problems: location management (sometimes called reachability) and session continuity. Location management means keeping track of the positions of the mobile nodes in the mobile network, session continuity means to make it possible for the mobile node to continue its sessions (e.g. phone calls) when the mobile node moves to another cell and changes its service access point. Several solutions exist to both problems [2,4,5,6]. This paper addresses the problem of location management.

Location management has to answer the following questions [1]:

- When should the mobile terminal update its location to the network?
- When a call arrives, how should the exact location of the called mobile equipment be determined?
- How should user location information be stored and disseminated throughout the network?

Of course these questions are not independent, and should be answered together.

Because of the growth of mobile communications and the limitations of resources (especially frequency), more and more efficient algorithms are needed for routing, call management and location management.

This paper is structured as follows: An overview of location management schemes of today’s mobile networks is given in Section 1. Then LTRACK is introduced in Section 2. After explaining the LTRACK network architecture and handover mechanisms, various qualities of LTRACK are examined in detail. In Section 3 LTRACK is compared to other location management schemes. In Section 4 we draw the conclusions.

1. Location management schemes

When an incoming call arrives to a mobile node, its exact location has to be determined. This requires location management. Today’s mobile networks (e.g. GSM) use location area (LA) based location management scheme[1,9]. It means that the cells are grouped into location areas. The network always knows which location area the mobile node is currently staying in, but does not have information about which cell it is in. At the time of the incoming call the network determines the exact location of the mobile equipment within the LA. This is called paging, see [1,9].

This introduces hierarchy into the network, which is an important property of modern mobile networks. For example IP micro mobility protocols use similar hierarchy in the IP based network [2,7,8].

1.1. GSM

In a GSM network (Global System for Mobile communications, the European cellular phone standard) the Home Location Register (HLR) stores the positions of the mobile nodes. If the mobile node does not have open sessions, and it is in idle mode, the HLR does not store the exact position just the Location Area Identifier that the mobile node is staying in. When a call arrives all the base stations within that specific location area broadcast a paging message through their broadcast channel. The mobile node must reply to the paging message, so the exact location can be determined. It is obvious that the mobile node has to update its location information, whenever it crosses a location area boundary. One drawback of this scheme is that when a mobile node moves back and forth between two neighbouring cells that belong to different location areas, a lot of location update messages have to be sent.

1.2. MobileIP

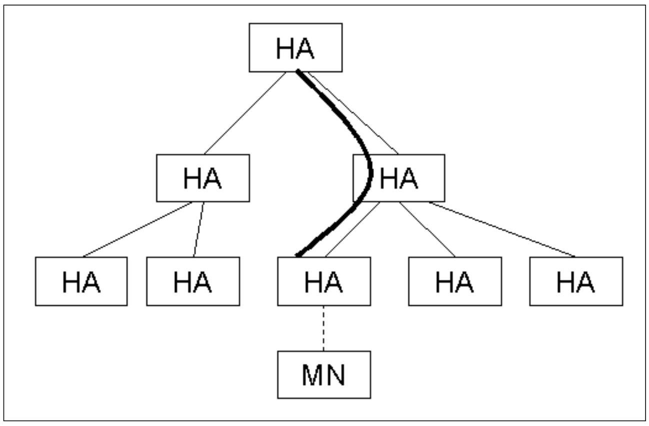
Not only the Internet is based on IP (Internet Protocol), various telecommunication networks can use an IP backbone. There is an increasing need for mobility within the IP world. MobileIP, the IP mobility solution is an extension of IPv4, the current IP version, but it is an integral part of IPv6.

In the MobileIP mobility scheme, a router called home agent (HA) keeps track of the actual position of the mobile node. All incoming calls arrive to the HA of the mobile node, so finding the mobile node is no problem, the HA has always up to date location information. The drawback is that the mobile node has to update its location every time it changes access points. It is a serious problem, because the goal of MobileIP is to provide global mobility within a large-scale IP network (e.g. the Internet). If the mobile node is far from its HA, MobileIP may generate a huge amount of signaling traffic on the network.

1.3. HMIP

HMIP (Hierarchical Mobile IP) uses the same approach as MobileIP, but instead of having one single HA for every mobile node, it uses a hierarchy of HAs [3,4]. Each HA of a given hierarchy level knows which HA of the next lower hierarchy level has location information about the mobile nodes in its subnetwork. One of the HAs at the lowest level knows the exact location, see *Fig. 1.* The mobile node still has to notify the HAs whenever it changes its access point, the advantage of HMIP over MobileIP is that it puts much less signaling load on the network.

Fig. 1.
HMIP Location Management Hierarchy

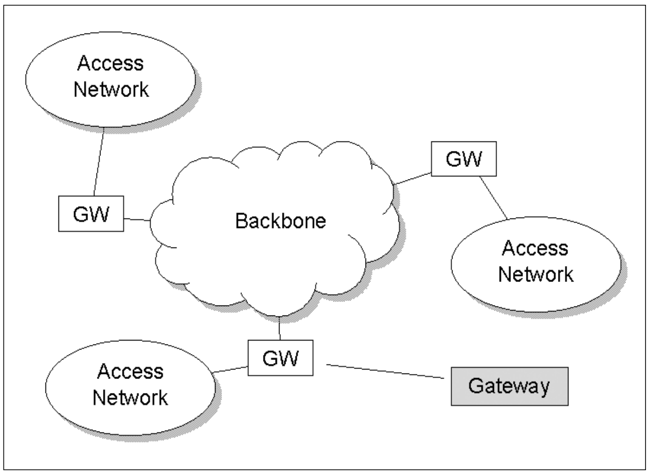


1.4. IP micro mobility

IP mobility protocols also introduce some kind of hierarchy into the mobile network, see [7,8] for examples. They usually interoperate with Mobie IP, Mobile IP is called macro mobility protocol in this environment. The network is partitioned into access networks (micro mobility networks), see *Fig. 2.*

The HA is notified only when the mobile node moves from one access network to another. This is different from the GSM scheme because the exact location of the mobile node within the access network is also stored in a (possibly shared) database. The gateway of the access network (that connects it to the core network) is responsible for finding the mobile node within the access network when an incoming packet arrives, the mobile node is not paged in this scheme, although some micro mobility protocols also allow paging areas (similar to location areas).

Fig. 2.
Micro Mobility architecture



2. LTRACK

2.1. Network architecture

LTRACK (Location Tracking) is a completely new approach for location management in mobile networks. An LTRACK network is built up from LTRACK nodes. A mobile node is connected to one of the LTRACK nodes in the network, and it can change its point of connection.

Every mobile node has an entry in a home LTRACK register (HLR). The basic idea behind LTRACK is to find a compromise between the Mobile IP scheme (where the HA has exact location information) and the GSM scheme (where only the LA and no further information is known). The HLR of LTRACK does not have exact location information, but when an incoming packet arrives, the exact location of the mobile node can be determined.

2.2. Locating the mobile node

In LTRACK each mobile node has a unique identifier similar to IP addresses or phone numbers. This unique identifier is connected to its home address. It is similar to the home address of the Mobile IP scheme.

For each of the mobile nodes, the HLR stores the last address where it received location update message from. It is a “next-hop” towards the node. The mobile node is either connected to that LTRACK node, or that LTRACK node knows a “next-hop” LTRACK node towards the mobile.

Once an incoming call arrives, there is a series of LTRACK nodes pointing from the HLR to the mobile node, see *Fig. 3.*

LTRACK nodes has to be able to find routes to each other. This can be easily solved by using LTRACK over an IP network, thus letting IP routing do the job.

2.3. Handover

When the mobile node moves from one LTRACK node to another, handover takes place. The LTRACK node that the mobile moves away from is called the old LTRACK node, the one it moves to is called the new LTRACK node.

There are two different kinds of handover in LTRACK: "normal handover" and "tracking handover". In a normal handover the mobile equipment updates its entry in the HLR. It sends the address of the new LTRACK node to the HLR. In case of a tracking handover the mobile sends the address of the new LTRACK node to the old LTRACK node.

Incoming calls always arrive to the home address of the mobile nodes, the HLR handles them. So the HLR has to locate the mobile node. It sends a request to the LTRACK node where it received the last normal handover message from. That LTRACK node either still has the mobile node connected to it, or knows a next hop LTRACK node towards the mobile node where it forwards the request. Thus, a normal handover can be followed by some tracking handovers before another normal handover takes place.

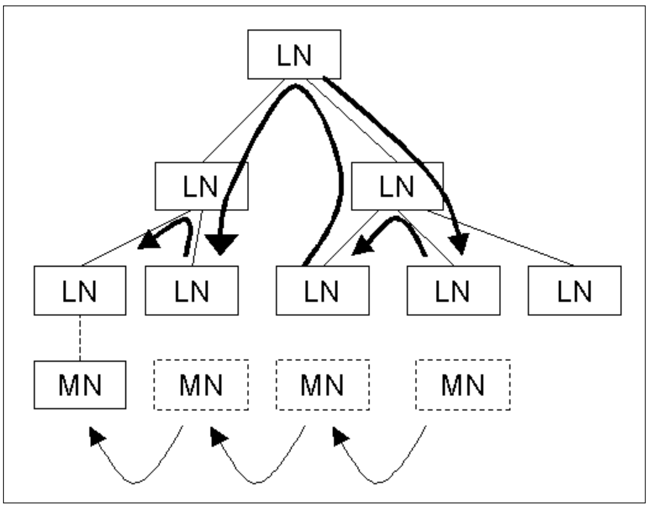
2.4. Advantages

If only normal handovers are used, the location management scheme becomes very similar to the Mobile IP scheme. The HLR always has exact location information about the mobile equipment.

The disadvantage of normal handovers is that they generate much more signaling traffic on the network than tracking handovers. The old and new LTRACK nodes are usually "close" to each other, the HLR can be further away, so this can be an important point.

Another advantage of tracking handovers is the following. Consider a series of tracking handovers between two normal handovers as the mobile node is wandering around in the LTRACK network. If it connects to the same LTRACK node two times on its path (i.e. it moves away from it and returns later) thus generating a loop, the locating request message coming form the HLR will not loop. The LTRACK node will directly forward the request to the LTRACK node towards which the mobile node left the last time it left. So if the mobile node moves back and forth between two LTRACK nodes, it would require a lot of signaling with normal handovers (Mobile IP scheme), but it is no problem with tracking handovers.

Fig. 3.
LTRACK locating of the MN



Who decides when should normal and tracking handovers be used? It may depend on our design goals. Either the mobile node can decide or the network can force a handover type. It is important that a normal handover can always be used, but there are some limitations on the use of tracking handovers. Handovers are usually initiated by the mobile equipment based on power or bit error rate measurements. A tracking handover can only be carried out successfully if communication between the mobile node and the old LTRACK node is also possible, not just between the mobile and the new LTRACK node. This means that tracking handover is a soft type handover. With a small workaround, a hard variant of tracking handovers can be defined that can be used even if the mobile can only communicate to the new LTRACK node. The old LTRACK node can be notified indirectly by sending the notification message to the new LTRACK node which forwards it the old one.

So by using tracking handovers we can minimize signaling traffic on the network. Why should normal handovers be used at all then? Obviously, if a lot of tracking handovers are used consecutively, the path from the HLR to the mobile node may get very long. It means that it will take several hops, and thus a long time for the HLR to locate the mobile node. As this should be avoided, normal handovers should also be used too. It is important to see, that this is not always the case. If the mobile visits only 5 LTRACK nodes on its path, but moves back and forth between them several times, locating the mobile node will no way need more than 5 hops.

What should decisions be based on?

It is possible to limit the number of tracking handovers allowed between two normal handovers. If no more than *n* tracking handovers are allowed between two normal handovers, locating the mobile node should not need more than *n* hops. It can take less as we have seen, but not more.

Another approach can be to limit the time allowed between normal handovers.

It is also possible to cluster the network to LTRACK areas (LTAs). A normal handover is required when the mobile node moves from one LTA to another one. While roaming around within the same LTA, tracking handovers are used. Locating the mobile node should not take more hops than the number of LTRACK nodes in the LTA. This scheme has the same drawback as the GSM scheme. If the mobile node moves back and forth between two neighboring cells that belong to different LAs, normal handovers will be used which results in generating a lot of signaling traffic.

These methods can also be combined. The network can be partitioned to LTAs, a normal handover is required when moving from one LTA to another, but the number of tracking handovers between normal handovers can also be limited within one LTA, so can the maximum time between normal handovers.

2.5. Functionality

LTRACK nodes can be routers in the real world. How are base stations connected the network of LTRACK nodes? There are three different approaches:

- Base stations are LTRACK nodes too.
- Base stations are connected to LTRACK nodes.
- Hierarchical approach.

The naive solution is to define base stations as LTRACK nodes too. When the mobile equipment moves from one base station to another, it moves from one LTRACK node to another. In this scheme the routing functionality and the base station functionality get mixed up, which is usually undesired.

An approach that uses a more structured network is to connect base stations to LTRACK nodes. In this scheme LTRACK nodes are similar to GSM Base Station Controllers. An LTRACK node can serve several base stations. When a mobile equipment moves from a base station to another one, and both base stations are served by the same LTRACK node, the old and new LTRACK nodes are the same. That is the only LTRACK node that has to be notified. When the old and new base stations are served by different LTRACK nodes, an LTRACK handover takes place. This solution decreases the number of required LTRACK handovers for the same number of handovers. Thus, a smaller number of hops will be needed when trying to find the mobile node.

The hierarchical approach is to define LTRACK nodes as small networks. The networks at the lower hierarchy level can be any kind of mobility networks, they can even be LTRACK networks. Thus a two or more level LTRACK network can be built.

3. Qualitative Analysis

Unlike the previously mentioned location management schemes, LTRACK allows different and dynamically controlled parameters for different users. This means that the actual LTAs do not have to be the same for all of the mobile nodes. Different mobile nodes can have different limits on time or on the number of consecutive tracking handovers. Moreover all these parameters can change in time. The system can be automatically fine tuned “on the fly” based on various measurements (e.g. traffic, delay or signaling load).

4. Quantitative Analysis

We have run some simulations using MATLAB. The purpose of the simulation was to compare the signaling load of different mobility schemes.

The simulated network consisted of 36 base stations arranged in a 6x6 grid and 14 routers interconnected to form a tree. Hierarchical Mobile IP is based upon a tree topology network, that is why we used this topology for comparisons.

We examined one mobile node making a random walk with the length of 100 handovers.

The network topology and the path of the mobile equipment were exactly the same in all cases.

Four protocols were examined:

- Mobile IP
- Hierarchical Mobile IP
- LTRACK (*t* = 3)
- LTRACK (*t* =10)

Variable *t* denotes the maximum number of tracking handovers allowed between two normal handovers.

Signaling load was measured in hops. *Fig. 4.* shows the results of the simulations.

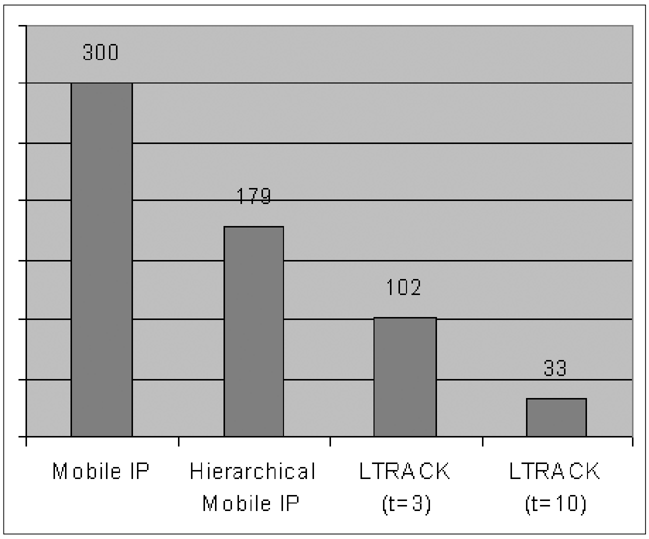


Fig. 4. Signaling requirements of various protocols

Fig. 4. shows clearly that Hierarchical Mobile IP puts much less signaling load on the network than standard Mobile IP, but LTRACK does much better than them even with a small *t* value.

How can LTRACK be made efficient. LTRACK generates less traffic if:

– It is run over a more optimal topology than the tree.
– There are more than one normal handovers between two incoming calls.
– An LTRACK node serves more than one base stations.
– The mobile node visits some LTRACK nodes more than once on its path.

5. Conclusions

After defining location management and giving a brief overview of location management schemes we have introduced LTRACK, a new location management method. Its network structure and various handover mechanisms were explained in detail. After qualitative and quantitative considerations LTRACK was compared to MIP and HMIP location management.

Future works should include examination of various network topologies, how they suit LTRACK, and more simulations.

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