Location Management in Wireless Cellular Networks

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Abstract-- **Cellular networks are spreading rapidly, leading to overloaded systems, unacceptable delays, and increasing computational costs due to inefficient Location Management [LM]. This paper evaluates currently used Static LM technique and shortcomings in LM i.e. presents Dynamic LM technique which is recent theoretical proposals to overcome current flaws.**

Index Terms--**Static Location Management, Location Management Parameters, Dynamic Location Management.**

I. Nomenclature

1) Base Station: A tower or antenna transmitting and receiving radio signals over a cell in a wireless network.

2) Cell: A geographical area serviced by a base station in a wireless network, also used to refer to one or more collocated base stations. Cells are the 'building blocks' of a cellular network, with overlapping cells defining the coverage area of a particular network.

3)Global System for Mobile Communication (GSM): The dominant standard for second generation mobile phone communication, defining the protocols for communication between mobile devices and network cells.

4) Handoff: The process of transferring an in-progress call from one cell or base station to a neighboring cell without interruption.

5) Home Location Register (HLR): The central database in a cellular network, containing information on all subscribers to a particular carrier. This database also contains a record of each user's location, used to route calls to the correct cell.

6) Location Area (LA): A group of neighboring cells combined to form a larger meta-cell. Devices are free to move within this Location Area without performing a Location Update. Location Areas may be fixed, as in current static schemes, or allocated dynamically on a Location Update.

7) Location Management (LM): The maintenance of a record of cell locations for devices in a mobile network. The study of Location Management aims to reduce the net cost involved in maintaining this information.

8) Location Update (LU): Performed by a device in a wireless network to inform the network of the cell in which it resides. This Location Update is usually performed only when leaving the Location Area previously assigned to the device.

9) Paging: Under a Location Area scheme, the network does not know the precise location of a device, only its general area. Paging is performed on an incoming call and involves sending a message to all cells in the Location Area to determine which one contains the destination device.

10) Spectrum: A portion of the electromagnetic spectrum containing a limited frequency range within which a mobile device may communicate. It is vital that multiple signals transmitted on the same frequency do not interfere and hence the allocation of sections of this spectrum is governed by regulatory bodies. A communications provider must purchase a license for a particular frequency band within this spectrum to broadcast cellular data.

11) Subscriber Identity Module (SIM): A small smart card used in mobile phones operating under the GSM standard. This SIM card contains user identification information, as well providing storage space for phone numbers and associated data.

12) Third Generation (3G): A new wireless communication specification replacing second generation technologies such as GSM. Third generation cellular networks provide for high-speed data access in addition to audio communication, with goals of high-quality multimedia and advanced global roaming.

II. Introduction

Cells in a network are grouped into Location Areas (LAs). Users can move within these LAs, updating their location with the network based upon some predefined standard. When a user receives a call, the network must page cells within the LA (polling) to find that user as quickly as possible.

The network can require more frequent Location Updates (LUs), in order to reduce polling costs, but only by incurring increased time and energy expenditures costs from all the updates. Conversely, the network could only require rare LUs, storing less information about users to reduce computational overhead, but at a higher polling cost. Additionally, LAs themselves can be optimized in order to create regions that require less handoff and quicker location of users.

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This paper discusses presently implemented static location management and current progress and theories towards dynamic LM.

III. STATIC LOCATION MANAGEMENT

A. Static Location Update scheme.

In static LM schemes LUs occur on either periodic intervals or upon every cell change. Static LAs incur great costs with the 'ping-pong effect', where users repetitively move between two or more LAs and updates are continuously performed unnecessarily. In static LAs, cells are constant in size and shape and identical for each user. The current static LM standards are IS-41 and GSM MAP. The simple static Location Update schemes exist in static LM.

1) Always-update:

This scheme involves the user updating its location upon every inter-cell movement. This will incur significant energy and computational costs to the network and the user. This may be particularly wasteful, as if a user makes frequent, quick movements within an LA, beginning and ending at the same location, many LUs will occur that might be unnecessary. However, the network will always be able to quickly locate a user upon an incoming call, and extensive paging will not be necessary.

2) Never-update:

In this scheme user won't update its location upon every inter cell movement. But update its location upon on LA changes. In this scheme, resources are saved by constant updates not being required, but paging costs rise substantially. This occurs as every cell within the user's LA must be checked until the user is found which causes excessive overhead for users with an especially high incoming call frequency.

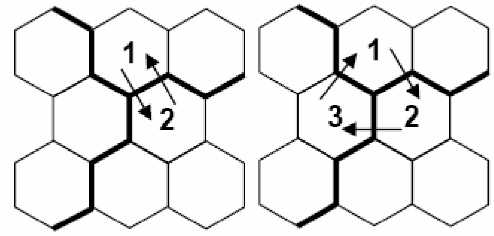
These two schemes are generally unused in real-world systems

3) Static interval-based update:

The final static LM technique discussed requires each user within the network to update at static, uniform intervals. This attempts to provide a balance between the flaws of the previous schemes, as the network will neither be overwhelmed with LUs nor wholly unaware of users' locations. However, users with rapid rates of movement may move into new LAs between updates, causing locating that user to be very difficult. Conversely, an inactive user will not move at all, but will still regularly be sending unneeded LUs.

B. Static Location Area.

Location Areas in static LM are themselves static as well. But their drawback is that they are prone to to the ping-pong effect.



(a) 2-cell configuration

(b) Generalised configuration

Fig 1. Cell ping-pong effect

The ping-ponging effect, illustrated in Figures 1.1(a) and 1.1(b), is the major weakness of static location area scheme. Here a user moves repeatedly between the boundaries of two or more location areas and updates are continuously performed unnecessarily.

The optimal static LA size algorithm, which uses a Fluid Flow mobility model, states that in a network with uniform cell size, cell shape, and user movement speed, the ideal number of cells per LA is,

$$N_{opt} = \sqrt{\frac{vC_{lu}}{\pi R C_{pg}}} \quad (1)$$

Where R is the cell radius, v is the speed of a user, Clu is the LU cost, and Cpg is the paging cost per call.
This equation states that high user speed and LU costs cause a large number of cells per LA to be preferable, while a large cell radius and high paging costs imply that a small number of cells per LA is optimal. Obviously, users are not homogeneous, but with sufficient data collection and analysis of user movement patterns, this is one method to optimize static LAs.

C. Static Location Management Standard

In currently cellular telephone usage, there are two common standards: the Electronic and Telephone Industry Associations (EIA/TIA) Interim Standard IS-41, and the Global System for Mobile Communications (GSM). Both of these are quite similar, having two main tasks of Location Update and Call Delivery. Currently, a two level hierarchical database scheme is used. The Home Location Register (HLR) and Visitor Location Register (VLR). HLR is the central database in a cellular network, containing information of all subscribers to a particular carrier. It also contains a record of each user's location, used to route calls to the correct cell. Visitor Location Registers (VLRs) download data from the HLR concerning current users within their specific service areas. Each LA has one VLR servicing it, and each VLR is designed to only monitor one LA. Additionally, each VLR is connected to multiple Mobile Switching Centers (MSCs), which operate in the transport network in order to aid in handoffs and to locate users more easily. For LUs, IS-41 and GSM both use a form of the always-update method. Inter-cell movements simply cause an update to the VLR, while the HLR does not need any modification, as both the MSC and VLR that the user resides in remains constant. Inter-MSC movements within the same LA cause the VLR to be updated with the new cell address, and also cause an update to the HLR to modify the stored value of the user's MSC. Finally, Inter-VLR movements cause the new VLR to create a record for the user, as well as causing it to send an update to the HLR where both MSC and VLR fields are updated. After this occurs, the old VLR's record for the user is removed. Figure 2 displays a symbolic high-level view of the HLR/VLR architecture.

In Call Delivery the location of user is found by 2 step method. In 1st step HLR is queried to obtain the VLR of the called user. Next, paging is used to poll cells within this region until the

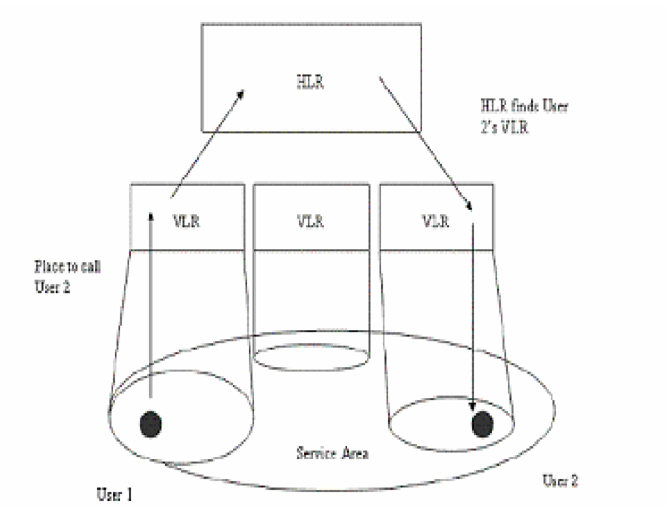


Fig 2. HLR/VLR Architecture Example of call process

IV. LOCATION MANAGEMENT PARAMETERS

To design LAs or determining the best number of LUs user are of highest importance while evaluating the schemes. Paging and user mobility can also be considered. LU costs are generally higher than paging costs. But poor paging procedures and mobility modeling and prediction may lead to either significantly delayed calls or decreased QoS, neither of which are acceptable to a user.

A. Paging:

The most commonly used paging schemes are:

1) Simultaneous Paging:

In this scheme all cells in the users location area are paged simultaneously (at the same time) in order to find the user. This method will find the user quickly; the costs make Simultaneous Paging relatively inefficient. Also it generates excessive amounts of paging traffic. Implementations of simultaneous paging favor networks low user population and call rates.

2) Sequential Paging:

Sequential paging avoids paging every cell within a location area by segmenting it into a number of *paging areas*, to be polled one-by-one. It is found in that the optimal paging mechanism, in terms of network utilization. It is a sequential poll of every cell in the location area individually, in decreasing probability of user residence. The individual delays incurred in this scheme may be unacceptable.

3) Intelligent Paging:

The intelligent paging scheme is a variation of sequential paging, where the paging area to be sequentially polled is calculated by using probability matrix. Intelligent paging aims to poll the correct paging area on the first pass, with a high probability of success. However, this scheme has too much computational overhead incurred through updating and maintaining the matrix, and although perhaps optimal in theory, is effectively impossible to be implemented in commercial cellular networks.

B. User Mobility:

For aid in effectively predicting the user’s next location, user movement patterns are analyzed and mobility models are designed. Many such mobility models exist and can be used by networks in LM.

The user mobility models are :

1) Random walk: This model assumes that the direction of each user-movement is completely random, and hence each neighboring cell may be visited with equal probability. This model is easily implemented as it requires no state information to predict the next cell occupied by a user.

2) Fluid flow: A very general scheme, ignoring individual users but considering the network as a whole, is called ‘fluid-flow’. This method aggregates the movement patterns of users, and consequently can help optimize the network’s utilization and design at a macroscopic level. However, fluid-flow provides no insight on a smaller scale, nor will it give any predictions as to specific user movements at any time.

3) Markovian: Markovian mobility models also exist, where user movements are predicted through past movements. At large computational cost, every inter-cell movement probability is defined for each user. This scheme is based on the assumption that a user moving in a given direction will continue in a similar direction with greater probability than a divergence from course.

4) Activity-based: An extension of the Markovian model, created at perhaps even greater cost, is the activity-based model. In this model, parameters such as time of day, current location, and predicted destination are also stored and evaluated to create movement probabilities.

5) Selective-prediction: Research on all current models shows that none truly does a satisfactory job predicting user movements. Therefore a possible enhancement is Selective-prediction model. , where predictions are only made in regions where movements are easily foreseeable and a random prediction method is used elsewhere.

V. DYNAMIC LOCATION MANAGEMENT

Dynamic Location Management is an advanced form of LM where the parameters of LM can be modified to best fit Individual users and conditions. Unlike static location management strategies, a location update may be performed from any cell in the network, taking into consideration the call arrival and mobility patterns of the user. However many of these proposals are excessively theoretical, and are difficult to implement on a large scale.

A. Dynamic Location Update scheme:

The simple dynamic Location Update schemes exist in dynamic LM are:

Threshold-based: where updates occur each time a parameter goes beyond the set threshold value.
The most common threshold schemes are time-based, movement-based and distance-based.

1) Time-based Update: In this scheme possible threshold is time, where users update at constant time intervals. This saves user computation, but increases overhead significantly if the user does not move. Figure below shows Time Based Update scheme.

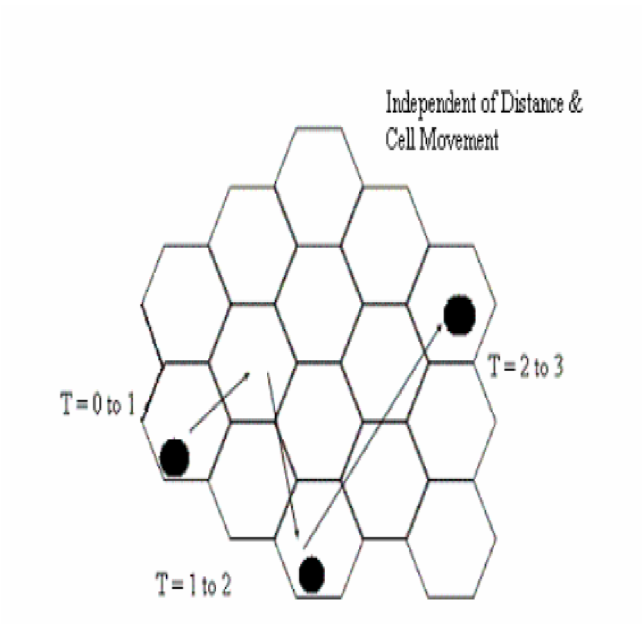


Fig 3: Time based Update scheme

2) Movement-based update: This scheme requires a user update each time they traverse a certain number of cells. The paging area requirement is reduced through this scheme, although unnecessary updates may still be performed as a result of repeated crossings over the same cell boundary. Figure below shows Movement Based Update scheme.

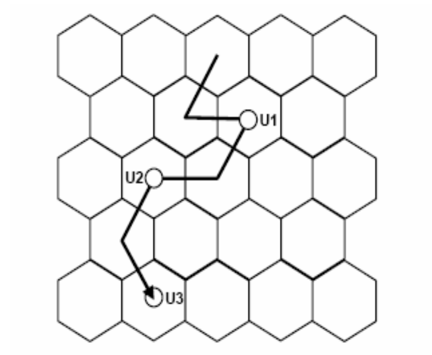


Fig 4: Movement-based update

3) Distance-based Update: In a distance-based scheme the mobile device performs a location update when it has moved a certain distance from the cell where it last updated its location. However, this scheme is not perfect, as it required the cellular device to keep track of such distances, which added much computational complexity. Figure below shows Distancet Based Update scheme

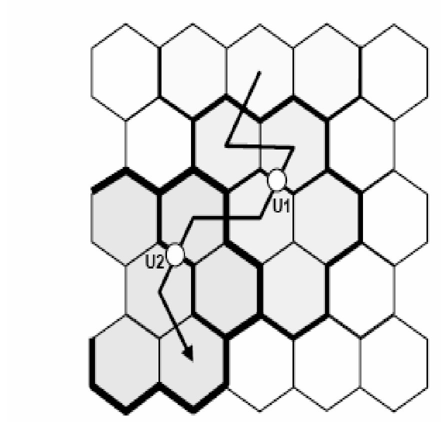


Fig 5: Distance-based update

4) Profile-based scheme: In this scheme a list of the most frequently accessed cells by the user is created, and LU is done only if the user moves outside of these common cells. As would be expected, this scheme is only effective if these predictions can be made accurately and without excessive overhead, but is otherwise inefficient.

5) Adaptive scheme: Adaptive LU schemes can be very flexible and even may differ from each other, as such schemes are designed as to take multiple parameters, such as velocity and mobility patterns, to determine the most efficient LAs. In such an example, having knowledge of a user's past movements combined with the user's current speed and direction allows strong predictive power when determining a possible future location for paging, and consequently LUs may not need to be as frequent, thereby reducing the overall LM costs. However, although these adaptive LM schemes are highly successful in terms of reducing location update costs, they are generally too difficult to implement for large networks, or require excessive computational overhead.

B. Dynamic Location Area

Instead of viewing the network as an aggregation of identical cells, it is now viewed as a directed graph, where nodes represent cells, with physical adjacency shown through graph edges. General movement patterns and probabilities, updated at predetermined intervals, are recorded between these cells based upon handoff information.

Within a dynamic scheme, LAs, instead of being constant and circular, can be diverse and may take different shapes, in order to be optimal for individual user parameters and network characteristics. As well, cells are organized within these LAs based upon frequency of use, with the most frequently visited cells being placed in an ordered array. This array can be used in conjunction with known physical topology to design optimal user LAs, constructed such that the users will need to leave them and make handoffs as infrequently as possible. To further optimize service for the individual user, call interval
times and relative mobility rates are calculated to make low-overhead predictions concerning when LA and cell changes will occur.

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VIII. Biographies

Swati D. Bendale has completed her diploma in computer technology from Bharati Viyapith, Mumbai. And Degree in Information Technology From Godavari Foundation, Jalgaon , a college affiliated to N.M.U. and AICTE approved. Her employment experience includes teaching experience in SVIT, Vasad, a college affiliated to Gujrat university and approved by AICTE.