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A Study Of Location Management Schemes In Cellular Network With Comparison

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Abstract

A cellular network is made up of cells. The cellular concept was introduced to reuse radio frequency. One of the important issue in cellular network is to find the current location of mobile station (MS) to deliver the services which is called as location management (LM)). It deals with how to track subscribers on the move. Location management in cellular networks has been an important issue for research since few years. This paper presents comprehensive classification of existing major LM schemes, their comparative study and factors influencing their performance.

1. Introduction

In a cellular network, a service coverage area is divided into smaller areas, referred to as cells. Each cell is served by a base station. The base station (BS) is fixed. Each base station is connected to mobile switching center (MSC). Mobile switching center is in charge of a cluster of BSs and it is, in turn, connected to the PSTN. There is a wireless link between BS and MS, so that MSs are able to communicate with wire line phones in the PSTN.BSs and MSs are equipped with a transceiver. Figure 1 illustrates a typical cellular network. A base station is marked with a triangle.

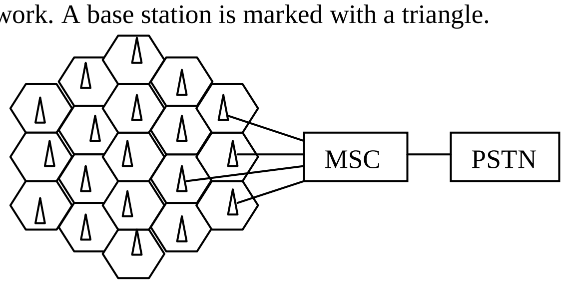

Figure 1. A typical cellular network

The frequency spectrum allocated to wireless communications is very limited. The cellular concept has been introduced to reuse the frequency. Each cell is assigned a certain number of channels. To avoid radio interference, the channels assigned to one cell must be different from the channels assigned to its neighboring cells. However, the same channels can be reused by two cells, which are far apart such that the radio interference between them is tolerable. By reducing the size of cells, the cellular network is able to increase its capacity, and therefore to serve more subscribers. For the channels assigned to a cell, some are forward (or downlink) channels which are used to carry traffic from the base station to mobile stations, and the other are reverse (or uplink) channels which are used to carry traffic from mobile stations to the base station. Both forward and reverse channels are further divided into control and voice (or data) channels. The voice channels are for actual conversations while the control channels are used to help set up conversations. A mobile station communicates with another station, either mobile or land, via a base station. A mobile station cannot communicate with another mobile station directly. To make a call from a mobile station, the mobile station first needs to make a request using a reverse control channel of the current cell. If the request is granted by MSC, a pair of voice channels will be assigned for the call. To route a call to a mobile station is more complicated. The network first needs to know the MSC and the cell in which the mobile station is currently located. How to find out the current residing cell of a mobile station is an issue of location management. Once the MSC knows the cell of the mobile station, the MSC can assign a pair of voice channels in that cell for the call. If a call is in progress when the mobile station moves into a neighboring cell, the mobile station needs to get a new pair of voice channels in the neighboring cell from the MSC so the call can continue. This process is called handoff (or handover). The MSC usually adopts a channel assignment strategy, which prioritize handoff calls over new calls.

2. Location update and paging

LM deals with how to keep track of an active mobile station within the cellular network. In the first approach, MS reports its current location to network, this function is called as location update (LU). A location update is used to inform the network of a mobile device's location. This requires the device to register its new location with the current base station, to allow the forwarding of incoming calls. Each location update is a costly exercise, involving the use of cellular network bandwidth and core network communication; including the modification of location databases. A wide variety of schemes have hence been proposed to reduce the number of location update messages required by a device in a cellular network. Location update schemes are often partitioned into the categories of static and dynamic.

A location update scheme is static if there is a predetermined set of cells at which location updates must be generated by a mobile station regardless of it mobility. A scheme is dynamic if a location update can be generated by a mobile station in any cell depending on its mobility. Static schemes offer a lower level of cost reduction but reduced computational complexity. Dynamic schemes adjust location update frequency per user and are hence able to achieve better results, while requiring a higher degree of computational overhead.

In second approach, the paging operation is performed by the cellular network. When incoming call arrives for mobile station, the cellular network will page the MS in all possible cells to find out the cell in which the MS is located so incoming call can be routed to the corresponding base station. This process is called as a paging

3. Location update schemes

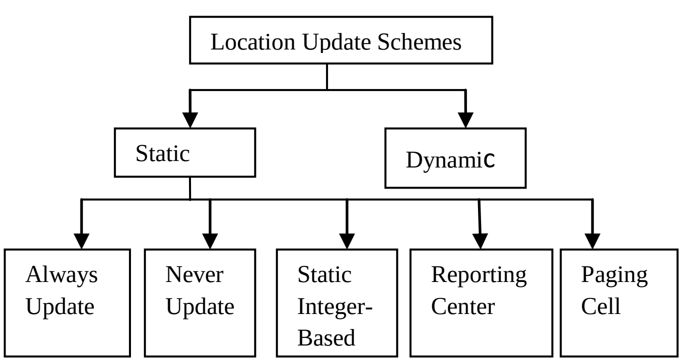

Figure 2. Static location update scheme

Location update schemes can broadly be classified into static and dynamic as shown in figure 2 and figure 3.

3.1. Static LU schemes

Static LU schemes can be classified as Always-update, Never-update, Static-interval Based, Reporting Center and paging cell. In always –update, MS update its location upon every inter cell movement this will incur significant energy and computational cost to both the network and the user, especially to the most mobile users.

This may be particularly wasteful as if a user makes a frequent, quick movements within an LA, beginning and ending at the same location, many LU will occurs that might be unnecessary, especially if few or no calls are incoming. However, the network will always be able to quickly locate a user upon an incoming call and extensive paging will not be necessary.

The converse method would be to never require the user to inform the network of intercell movements, only updating on location area changes and named never-update. In this scheme, resources are saved as constants updates are not required, but paging costs rises substantially. This occurs as every cell within user's LA may need to be checked during paging due to the lack of information, which causes excessive overhead for users with a high incoming call frequency.

The static-inverse based schemes required MS to update its location after every predefined uniform time period that provides a balance between the extremes of previous two schemes. Locating highly mobile users becomes difficult under this scheme. Inversely a stationary user regularly enforces unwanted LUs.

In reporting center scheme, subset of cells have been selected and those selected cells are called as reporting cells.MS will update its location (i.e. ID) whenever it moves into a new reporting cell .When incoming call arrives for mobile station, the cellular system will page all cells within the vicinity of the reporting cell which was last reported by the MS.

In paging–cell (PC) schemes groups the cells into the paging areas, all cells within that paging area are paged simultaneously and each paging area can be paged sequentially until the target MS is located by the network upon the arrival of a call, however long delay may occur in locating the MS. Table 1 illustrate the comparison between all the static LU schemes.

LU Schemes	Update cost	Paging cost	Advantage	Disadvantage
Always update	High	Low	Network will always be able to quickly locate a user upon an incoming call.	Incur energy and computational cost to user and network.
Never update	Low	High	Never required the user to inform the network of intercell movements.	Every cell within user's LA need to be paged.
Static interval	Constant	High	Provides balance between extremes of previous two schemes.	Locating highly mobile users become difficult.
Reporting Center	Low	High	Need to update location only when MS moves to other reporting cell.	High computational overhead.
Paging cell	Low	High	Several calls locate accurately.	Long delay may occur in locating the MS in large network.

Table 1. Comparison between static LU schemes

3.2 Dynamic LU schemes

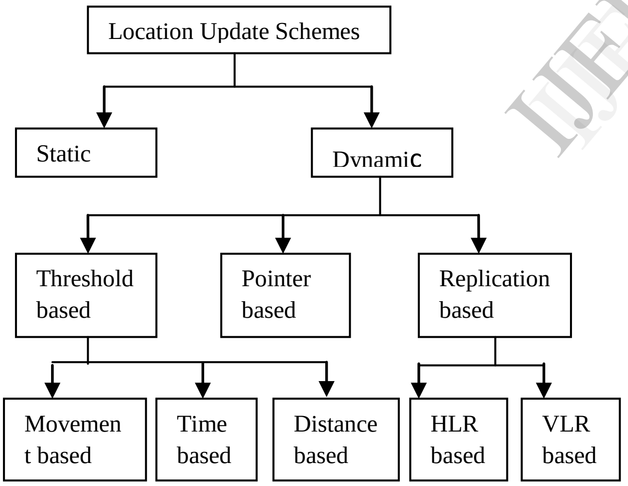

Figure 3. Dynamic location update scheme

Many dynamic LU schemes exist, in order to improve upon excessively simple & wasteful static LU schemes. Dynamic LU schemes can be classified as shown in figure 3.Under threshold based schemes; LU occurs each time a parameter (time, distance, movement) goes beyond a threshold value, which can be modified as per basis.

In time based scheme, MS updates its location every T unit of time, which saves computation but incurs needless LUs when MS does not move. This time-based scheme is very similar to the common static LU scheme, with the important difference of the time value being modifiable.

In movement based schemes, each MS keeps a counter. Whenever it crosses the boundary of cell it increases counter by one when the counter reaches a predefined threshold, say M. MS update its location. It works better than time based scheme, unless the MS is highly mobile. In such a case, this method becomes quite similar to the static always-update scheme, where many unnecessary updates might occur.

In distance based scheme, each MS keeps track of the distance between the current cell and last reported cell. When distance reaches a predefined threshold say D. MS updates its location.

In HLR based replication scheme, the LM messages which to be routed to current (nearest) HLR rather than the master HLR but it imposes extra load on current HLR, thus reducing its performance. In VLR based replication scheme, location information of MS is replicated among VLR so that the mobility information is more readily available to the network.

The problem in replicated based scheme is to keep these replicas updated whenever the user profile is updated. In pointer-forwarding schemes, some updates to the HLR are avoided by setting up a forwarding pointer from previous VLR to the new VLR and penalty is time delay for tracking current location of MS. Table 2 illustrate comparison between dynamic LU schemes.

LU Schemes	Update cost	Paging cost	Advantage	Disadvantage
Time based	Low	High	Simplicity.	Worst overall performance compare to other dynamic LU strategies
Movement based	Low	High	Simplicity.	It may suffer from ping pong effect.
Distance based	Low	High	This strategy performs significantly better than time based and movement based strategies in both memory less and markovian movement pattern.	It is hard to compute distance between two cells and requires lot of storage.
HLR level replication	Low	High	Messages directly routed to current HLR	Extra burden on current HLR Call establishment delay
VLR level replication	Low	High	Mobility information is more readily available to network.	Overhead of regularly updating distributed mobility information.
Pointer based	Low	High	Forwarding pointer used Burden on HLR is reduced.	Increased call establishment delay.

Table 2. Comparison between dynamic LU schemes

4. Paging

While mobile devices perform updates according to their location update scheme, the network needs to be able to precisely determine the current cell location of a user to be able to route an incoming call. This requires the network to send a paging query to all cells where the mobile device may be located, to inform it of the incoming transmission. It is desirable to minimize the size of this paging area, to reduce the cost incurred on the network with each successive paging message. Ideally the paging area will be restricted to a known group of cells, such as with the currently implemented location area scheme. An optimum paging area size calculation involves a trade-off between location update cost and paging cost. This technique is used in many location management schemes to reduce the location management costs incurred. The most commonly used paging schemes are summarized below. These have seen extensive use in real-world telecommunications networks.

4.1 Simultaneous Paging

The simultaneous paging scheme, also known as blanket paging, is the mechanism used in current GSM network implementations. Here all cells in the users' location area are paged simultaneously, to determine the location of the mobile device. This requires no additional knowledge of user location but may generate excessive amounts of paging traffic. Implementations of simultaneous paging favor networks with large cells and low user population and call rates. This scheme does not scale well to large networks with high numbers of users, necessitating the development of more advanced paging techniques.

4.2 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, 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 however, and hence it is suggested that paging areas are formed from a larger number of cells. The number of cells per paging area is a factor which needs to be optimized and may lead to excessive call delays, particularly in large networks. The order by which each area is paged is central to the performance of the sequential paging scheme. Suggests several methods to determine the ordering of paging areas in a sequential scheme. The simplest ordering constraint is a purely random assignment, where each paging area is polled in a random order. While this reduces the total number of polling messages over a blanket scheme, it is far from optimal. Schemes favouring paging areas located geographically closer to the previously updated location are found to further reduce the total number of paging messages required. These schemes necessitate knowledge of the geographical structure of the network however, and may perform poorly for high movement rates.

4.3 Intelligent Paging

The intelligent paging scheme is a variation of sequential paging, where the paging order is calculated probabilistically based on pre-established probability metrics. Intelligent paging aims to poll the correct paging area on the first pass, with a high probability of success. This efficient ordering of paging areas requires a comprehensive knowledge of user residence probabilities. Discusses that the success of an intelligent paging scheme hinges on the ability of an algorithm to calculate the probability of a user residing in each cell of the current location area. An algorithm to calculate the paging area ordering based on a probability transition matrix is presented in [8], claiming to result in the optimal poll ordering. The computational overhead involved in this scheme is quite high however, requiring the computation of an n×n matrix for a system with n cells, and hence is infeasible for a large cellular network.

5. Conclusion

Development of efficient location management technique is an important step in determination of optimal solution to the problem of managing mobility. Cell size in cellular network is irregular in nature, the behavior of mobile movement changes from cell to cell and from user to user. Thus, the need for designing an adaptive location management schemes for tracking roaming mobile becomes imperative.

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