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Mobile User's Location Management using Bloom Filter

Pragyan Acharya[#1], Sudhansu Sekhar Singh[*2]

[#]*School of Electronics Engineering, KIIT University*
Bhubaneswar, India

[*]*School of Electronics Engineering, KIIT University*
Bhubaneswar, India

***Abstract*— Cellular networks have become so pervasive that they resulted in some undesired consequences like increase in computational cost, delays and system overloading. Various Location Management (LM) schemes such as static LM and dynamic LM have been adopted for cost reduction. Basing upon the cellular network's geographic layout, location update is done in static LM. Dynamic location update schemes are based on the status and state of the mobile. Although dynamic LM is efficient in cost reduction, its effectiveness is limited because most of the theories are in the infancy stage and fail to suit the reality of life. Hence most wireless systems employ static LM. This paper proposes a method for the use of a paging mechanism which has used the technique of Bloom filtering in the Never Update strategy of static location management to select cells to be paged and thereby helps to reduce the polling cost to a greater extent. Numerical results show that the use of bloom filter improves the never-update strategy of static location management scheme.**

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***Keywords*— Mobile Computing, Static Location Management, Never Update strategy, Always update strategy, Bloom Filter.**

I. INTRODUCTION

Ability of providing mobility is the most important characteristic property of cellular system. The total number of worldwide mobile telephone subscribers is predicted to pass five billion by 2011 constituting about 72% of the total population. This increases the complexity of the system needed to manage all the users. Unlike a wired connection where the signals have been passed through guided medium to the correct destination, wireless system doesn't enjoy the luxury of knowing the location of the user. Hence it has to incorporate ways to trace out the user and subsequently to send the data into the system and thereby to enable a mobile system access the services of the system it is connected to. The process of keeping track of the present or last known location of the mobile is called as Location management (LM). Cells are grouped into Location Areas (LA). LA can be of same size or different size due to geographical constraints. The users move inside these areas based on some pre-defined standards [1]. When a user receives a call the network pages the cells of a LA to locate the user. Frequent Location Updates reduce polling costs, but with consumption of time and energy from all the updates. Less frequent Location Updates will store less information about user's location. It has the advantage of reducing computational overhead no doubt but has the disadvantage of higher paging cost. Hence a trade off has to be made between all these important considerations [2][3].

Location management system has been divided into two parts- static LM and dynamic LM. In static LM scheme the cellular network's geographic layout determines when the location updating needs to be done. Dynamic location update schemes are based on the status and state of the mobile. Although dynamic LM is efficient in cost reduction, its effectiveness is limited because most of the theories are in the infancy stage and fail to suit the reality of life. Static Location management incurs greater cost, but most cellular networks use this scheme. This paper proposes the use of Bloom Filter for local prediction of the cell in a Location Area where the user resides. Prediction of the exact cell location where the user is present makes the system page only that cell instead of all the cells in a Location area. This paging strategy supports Mobile Computing and Communications.

II. BASIC CONCEPT

A group of cells constitute a single Location Area. These cells are assigned a location area identification value. Each base station in the LA broadcasts its identification (ID) number in a periodic fashion over a control channel. The Mobile Stations (MS) that are attached to the Base Station (BS) within the LA are required to listen to the control channel for the LA ID. If the LA ID changes, the MS has to send a location update message to the new base station. The VLR database will receive the updated information forwarded by the base station [4][5]. All the cells in the new LA will be paged whenever there is an incoming message. This forms the basis of static Location Management. It is of two types such as always-update and never-update strategy [6].

A. Always Update

Every time the user moves into a new cell the always-update strategy performs a location update. Paging is not required to locate the user when an incoming call arrives.

B. *Never Update*

The never-update scheme never requires the mobile device to update its location with the network.

C. *Local Prediction Mechanism Using Bloom Filter*

An n-bit Bloom Filter Identity Vector (BFID) is assigned to every Mobile Unit (MU) which is sent periodically to the local cell for location updation. Base Station receives superimposition of pulses from all the MUs in the local cell and stores it as Cell Vector. Whenever there is a call terminated to any MU, the BFID of this MU is compared in a bitwise manner with each cell vectors of the most recent LU cycle. A pulse is sent when the corresponding bit is "1". If the base station detects one or more pulses in the *i*th bit interval, it infers that at least one MU in the cell contains a "1" in the *i*th bit else it concludes that all MUs inside the cell have BFIDs that are zeros at the *i*th bit. The zero in the *i*th bit in the cell vector conveys that a MU with an ID of "1" in the *i*th bit is not in the cell.

Consider a system consisting of three cells and six MUs as depicted below. During the most recent LU cycle, the cell vectors of cell 1 to cell 3 are 10011, 11101, and 01100, respectively. Suppose a call is terminated to MU 6. We compare the BFID of MU 6 with the cell vectors. Since the third and the last bit ofMU6 are one, we should send a paging message to the cell only if the corresponding bits of the cell vectors are also "1." It turns out that only cell 2 should receive the paging message.

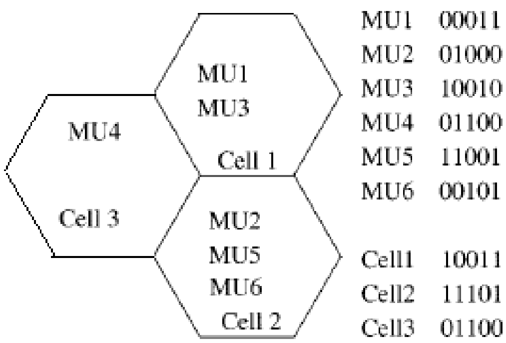

Fig. 1 Illustration of paging mechanism using Bloom Filter

Mathematically, let l_i where $i \in [1,M]$, be denoted as the cell vector obtained in the most recent LU cycle in cell i from a system of M cells. When a call arrives for the MU with ID BFID, cell j is paged if

$$BFID \otimes l_j = BFID \quad (1)$$

where $\otimes$ denotes bit by bit multiplication. This operation is called Bloom filtering[7].

III. SYSTEM MODEL

An attempt is made in this paper to develop a strategy with the intention of finding out a possibility for reducing paging cost. The objective is sought to be fulfilled by using Bloom Filter. The strategy is built up in the line of Gauss-Markov Mobility Model. That the use of Bloom Filter can reduce cost is explained by the following example.

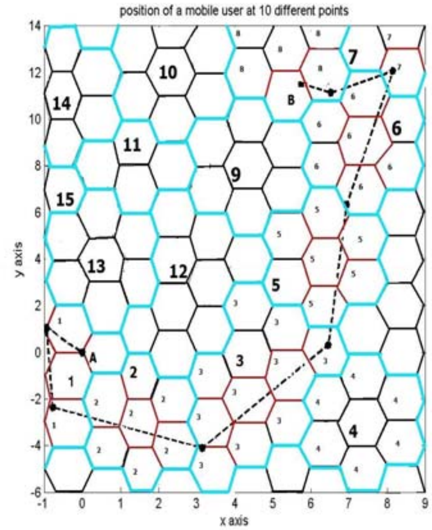

Fig. 2 Example depicting the Location Areas a User crosses

Suppose a user starts its journey starting from point A and reaches its destination B following a mobility pattern similar to what is defined in Gauss Markov Model. The whole area has been divided into hexagonal cells and grouped into LAs. Taking into consideration the various physical or geographical constraints like buildings, hills etc, the number of cells in LA are not kept constant. The User which is assigned with a BFID sends it periodically to the base station and the base station stores it as cellvector. Whenever there is a call terminated to the mobile of this user, the BFID of the MU is compared with all the cell vectors of the LA. The cell vectors are obtained from the most recent LU cycle. That cell is paged where equation 1 is satisfied. The red coloured cells indicate the cells the user crosses. Location areas are coloured blue for ease of identification. Cost has been calculated for always- update and never-update strategy using this Model. The cost incurred in the never update strategy has been reduced by locally predicting the cell by the use of a Bloom Filter. The graph has been taken to scale with 1cm = 1km. The distance travelled by the user and time taken to cross each cell is taken to be 1 unit.

IV. COST ANALYSIS

At each LA, a user updates its location to the base station. It is assumed that the user updates immediately upon entering another location area and any subsequent call will page the user only in that area. The cost of paging will be different for different LAs depending on the number of cells and the cost of paging each cell. It is assumed that the update costs are the determining factors for all such transitions. Number of messages exchanged, consumption of CPU cycles, etc. estimate the cost when a user does a location update after crossing an LA boundary. Those LA transitions which involve inter-MSC update will be much more expensive [8].

Call arrival for a user follows Poisson distribution with mean rate λ. The inter-arrival time between calls are exponentially distributed with this rate. But paging is not triggered for all the calls, especially when the user is in the middle of a call because the system is aware of the user's position. Hence there is no paging. Call waiting tone, busy tone or forwarding to mailbox are some of the different ways where such type of call arrivals are dealt with. The total cost of LM is equal to the LU cost added to the paging cost. The paging cost is defined as the product of call arrival rate λ, number of cells in the paging area (N) and a constant representing the cost per paging message. Overall paging cost can be reduced by reducing any of these parameters. LU cost calculation is more complicated. It can be defined as the cost per LU (which is dependent on number of CPU cycles, number of messages sent etc.) divided by the dwelling time within the current LA, T_{LA}.

Total Cost = Location Update cost + Paging cost

$$= C_{lu}/T_{la} + N^* \lambda^* C_p \text{ [9]} \quad (2)$$

Where

C_{lu} = Cost of location update

T_{la} = Dwell time in each location Area

N = No of cell in each location Area

λ = call arrival rate

C_p = Paging cost

Location update cost (C_{lu}) and paging cost (C_p) are taken as unity. Cost has been calculated using the above equation for both the always-update and never-update strategies. Lastly Bloom filtering technique is used in the never-update strategy and its result is compared with the previous two techniques.

V. RELATED WORK

In this section numerical analysis of always-update and never-update is carried out. We evaluated these strategies in terms of location update cost and paging cost.

A. Always Update Strategy

From the system model we find that the user crosses 23 cells. Since each cell is considered to be a Location Area, the user crosses 23 location areas thereby updating 23 times. Figure 3 exhibits a direct and positive relation between cost and distance. With the covering of more and more distance, both the number of location area boundary crossing and thus the number of location update goes up. This makes the cost incurred to move in an upward trend.

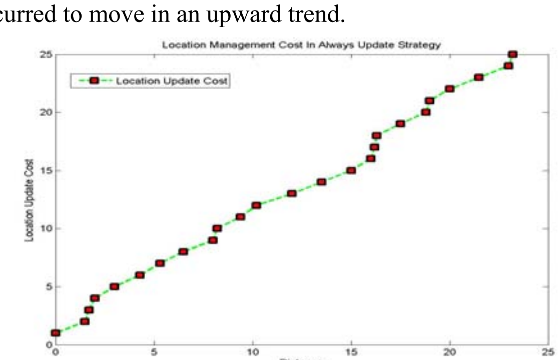

Fig. 3 Location Update cost in Always-Update strategy

Analysis:

1) *Location Update Cost*
Location update cost increases but it performs well for users with a low mobility rate or high call arrival rate but performs poorly for users with high mobility requiring many location updates and excessive use of resources.

2) *Paging Cost*
Since every cell crossing results in location update, the base station is well aware of the mobile unit's location. Hence paging cost is zero.

B. Never Update Strategy

Inspection of the system model shows that the user crosses a total number of 8 location areas while moving from point A to point B. Each location Area comprises of a group of cells. Every time the user crosses a location area it gets updated. When a call arrives the network pages all the cells of the location area the user resides. Figure 4 depicts the cost incurred due to paging and updation in each location area. Graph has been plotted for various call arrival rate (λ) equal to 3, 5, 8 calls/hr. The number of cells for each location Area is determined from the system model developed.

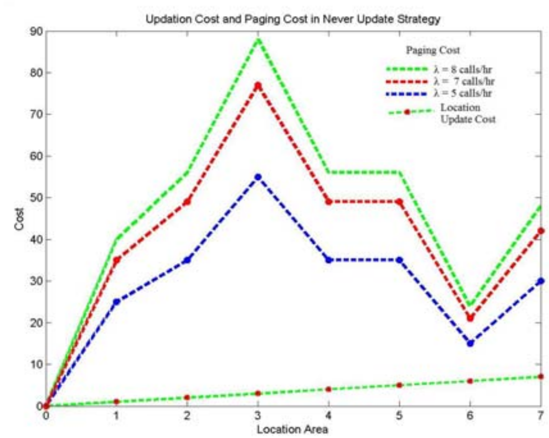

Fig. 4 Location Update and Paging cost of Never-Update strategy

Analysis:

1) *Location Update Cost*
The number of updates is less as compared to always update strategy. Thus there is no location update overhead.

2) *Paging Cost*
This Strategy may result in excessive paging for a large number of cells (N) in a LA or for high call arrival rates.

VI. PROPOSED NEVER-UPDATE USING BLOOM FILTER STRATEGY

From functional point of view this technique is quite similar to that of never-update strategy but surpasses the later because of the use of Bloom filtering method to predict the exact cell in the location area where the user resides. In plain words the cell where the user resides is filtered out from a group of cells. This is illustrated in Figure 3 where the location management cost of the never update strategy using bloom filter is lower than the never update strategy minus the bloom filter.

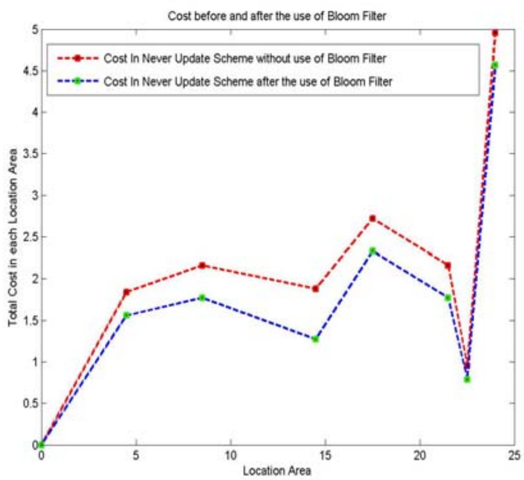

Fig. 5 Cost reduction in Never-Update with the use of Bloom Filter

Analysis:

1) *Location update cost*
It is similar to the updation cost incurred in never update strategy.

2) *Paging Cost:*
Local prediction of the cell to be paged by bloom filtering reduces the paging cost and hence a decrease in total location management cost

Improvement:
Local Prediction of cell decreases the paging cost by 1/N times where N is the number of cells to be paged inside an LA.

VII. CONCLUSION

In this paper we proposed the idea of implementing a paging mechanism called Bloom filtering in the never update strategy that decreases the total cost. Overhead cost penalty for a Bloom filter implementation is very low. Local prediction of the cell makes efficient utilization of the bandwidth and removes the storage and processing requirements of mobile devices. This paging scheme provides an alternative paradigm on location tracking.

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