A Cost-Effective Location Management Strategy Based on Movement Pattern of Active Users in a Heterogeneous System

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Abstract

This paper proposes a cost effective location management method for location update and paging in heterogeneous wireless systems. The proposed location update method generates dynamic location area (LA) list. It provides accurate and up-to-date location information of each user and their probabilities of visiting each LA and cells within a LA. This list is updated according to user movement. Probable short term traffic in each LA can be forecasted using the probabilistic information in the LA list. The proposed selective paging minimizes call delivery cost. Overall 48%-65% improvement in total cost in location management has been achieved than previous approaches.

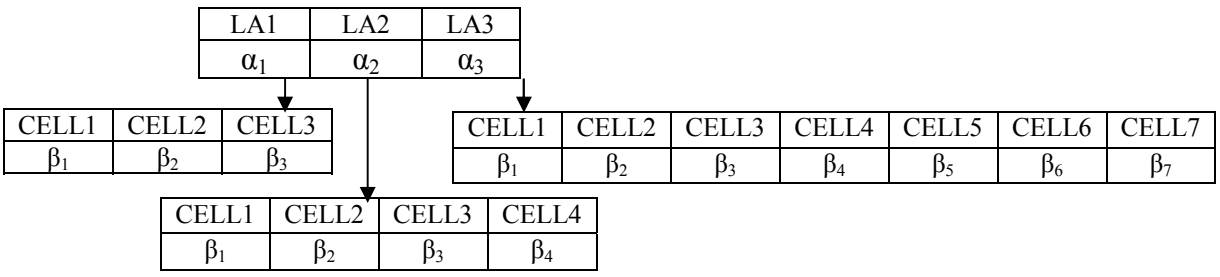
1. Introduction

Location management and short term traffic forecasting are two major issues in the area of mobile computing. The process of tracking the location of a mobile terminal (MT) is referred as location management. Basic operations involved in location management are location update and paging. The information regarding the location of mobile terminals is stored in two types of databases: Home Location Register (HLR) and Visitor Location Register (VLR). To predict the recent behavior of user short term information is recorded. Location tracking method proposed by S.Tabbane reduces the traffic due to mobility management by predicting user movement patterns but introduces huge cost in paging[1]. Another strategy 'A Cost Efficient Location Management Technique for Mobile Users with Frequently Visited Locations' proposed which reduces location management cost using replication[2]. But it requires to update HLR each time it enters into a new location area and replicas are required to be maintained which introduces high storage cost. Aim of this paper is to provide a location management method which will be cost effective and will help in short term traffic forecasting by predicting the movement pattern of active users. Another point to highlight is this paper considers a heterogeneous system which refers here a network consists of location areas containing different number of cells of different sizes and MT with different speed in different LAs.

2. Proposed Location Management Strategy

This paper introduces a new location management method for location update and paging. The network contains a number of location areas $a_1, a_2, a_3, \ldots\ldots, a_k$ and the probability of the user located at $a_1, a_2, a_3, \ldots\ldots, a_k$ are $\alpha_1, \alpha_2, \alpha_3, \ldots\ldots, \alpha_k$ respectively and $\sum_{i=1}^{k} \alpha_i \leq 1$. Each LA contains a number of cells. The probability of the user located at $cell_1, cell_2, cell_3, \ldots\ldots, cell_n$ in a particular LA a_i are $\beta_1, \beta_2, \beta_3, \ldots\ldots, \beta_n$ respectively and $\sum_{j=1}^{n} \beta_j \leq \alpha_i$.

Table1: Profile containing LA list and corresponding cell list



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The probability of locating user at these location areas and the cells within a particular location area changes with time. Paging cost is determined here using selective paging and considering the received signal strength of the mobile terminal. Selective paging consists of iterative steps. In each step, a subset of cells is searched. Paging process terminates as soon as the mobile terminal is found out. A dynamic LA list is maintained for individual user. It is a list of location area IDs(LAIDs) with probabilities of visiting them in decreasing order. This list is updated when a location update takes place. Each LAID points to a cell list containing the cell IDs with probabilities of visiting them in decreasing order. This list is updated when a cell update takes place. Let there are three location areas with IDs LA1, LA2, LA3 and probabilities of visiting those LAs are $\alpha_1,\alpha_2,\alpha_3$ respectively and $\alpha_1>\alpha_2>\alpha_3$. The number of cells in the LA1, LA2 and LA3 are 3,4,7 respectively. For example, LA1 points to cell list consists of the IDs of the cells(CELL1, CELL2, CELL3) contained in it with probabilities of visiting those cells(β_1,β_2,β_3 where $\beta_1>\beta_2>\beta_3$). This LA list and corresponding cell lists are updated when a location update takes place. When a cell update occurs within an LA, the corresponding cell list is updated.

Number of LAs visited by the MT yet is denoted by LAC and the total number of LA in that network is denoted by MAXLAC. LAIDC (a_i) contains the number of times an LA a_i has been visited by the MT. CELLIDC ($cell_i$) contains the number of times the MT visits a particular cell ($cell_i$) in the current LA.

Location Update :- A)When an MT enters into a new LA a_i: 1.Set a counter CELLC=0. 2.Compare LAC and MAXLAC: i)If LAC<MAXLAC, Set LAC=LAC+1. ii)Else, if LAC ≥MAXLAC, Set LAC=1. 3.Rearrange the LA list: i)LAIDC (a_i) = LAIDC (a_i) + 1. ii)If LAC≠1, set α_i= LAIDC (a_i)/LAC. iii)Else set α_i= 1 and set probability of visiting other LAs to 0. iv)Reorder the LA list according to the decreasing order of probability of visiting the LAs. 4.Update: i)MT's current location (LAID and Cell ID) is updated to the current VLR. ii)After updating location, current VLR sends a message to inform the MT the total number of cells in current LA of the MT. iii)After receiving that message, MT stores the value at MAXCELLC and set CELLC=CELLC+1. iv) Reorder cell list: a)Set $cellp_i$= α_i and set probability of visiting other cells by this MT to 0. b)Rearrange the cell list according to the decreasing order of probability of visiting the cells of that LA by the MT. v)Current VLR sends a message to the old VLR asking to delete all records of that MT and after receiving the message the old VLR deletes all records of that MT. vi)When an MT leaves its current cell and enters into a new cell (within the same LA): (I)Compare CELLC with MAXCELLC: a)If CELLC<MAXCELLC, set CELLC=CELLC+1. b)Else if, CELLC=MAXCELLC, set CELLC=1. (II)It checks current time instant(t_c) and time instant of last cell update(t_{cu}) and feasible time interval for cell update(t_m): (1)If (t_c-t_{cu})> t_m, [i]Do Cell update: (a) MT updates its current Cell ID (CELLID) to the VLR. (b)VLR stores that cell ID visited by that MT in a cache along with the previous cell ID or IDs. (c)Rearrange cell list: I)CELLIDC ($cell_i$) = CELLIDC ($cell_i$)+1. II)Set $cellp_i$= α_ix(CELLIDC ($cell_i$)/CELLC). c) Reorder the cell list according to the decreasing order of probability of visiting the cells of that LA. [ii] Else, No Cell update will be done. B)Location of the MT is updated at HLR at the end of the day.

Prediction of movement pattern of users :- Profile of each active user is checked to predict the movement pattern of a particular user within a cell and transition to other cells within each LA as well as movement pattern of that user to each LA and transition to other LAs. Profiles of all active users are checked and their movement patterns are determined. From this information probabilities of the users of visiting each cell within a LA and probabilities of visiting each LA is determined to predict the probable number of users located in each LA at a particular time which helps to predict short term traffic in each location area at a particular time.

Paging :- According to this strategy instead of paging LAs sequentially, selective paging is done here. As the quality of service is assumed good, the current received signal strength (CRSS) is greater than the minimum received signal strength (MRSS) of the mobile terminal is assumed. When a call arrives for an MT, CRSS and MRSS of is checked. A) If CRSS ≥ MRSS, paging will be performed. B) If CRSS<MRSS, after a specific time the signal strength will be checked. If now CRSS≥MRSS, then only paging will be performed. The paging procedure is as follows: 1. VLR/MSC sends a broadcast message to the cells of the last registered LA maintained in cache and a timer is set. 2. If the MT is within these cells it responses and the call is delivered to that MT. 3. If the timer expires but no response is received, then the message is broadcasted to the rest of the cells of that LA. 4. The MT responses and the call is delivered to that MT. 5.If no response is received a call failure message is generated.

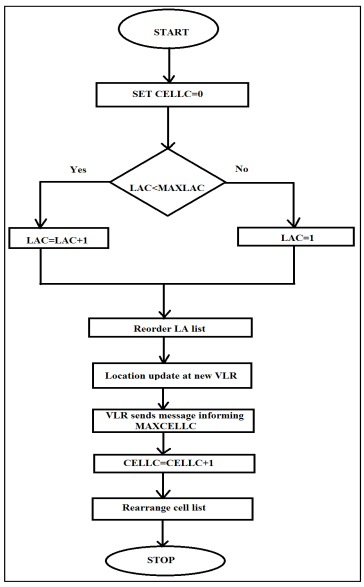

Figure1: Flowchart of location update

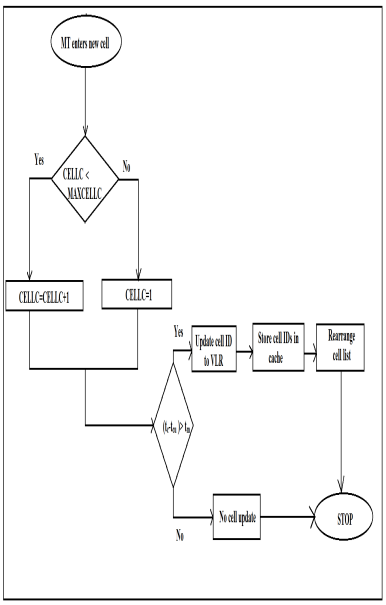

Figure2: Flow chart of cell update

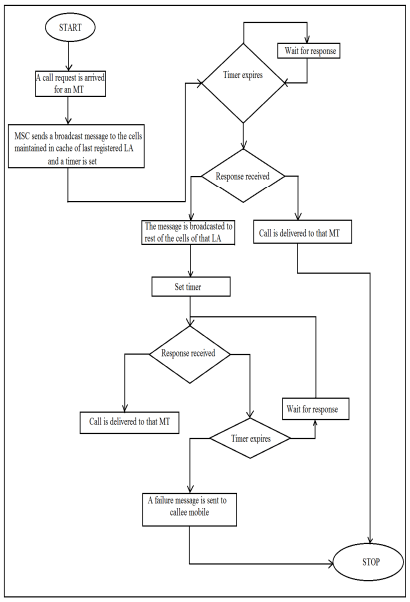

Figure3: Flow chart of paging

3. Results and Discussions

Assumptions are :- a) Heterogeneous system, b) Different MT with different speed, c) Cost is represented in terms of messages.

Parameters are :- N_z=Number of LAs, N_i=Number of cells in LA a_i, R_i=Side of a hexagonal cell in LA a_i, v_i= Average speed of MT, α_i=Probability of locating MT at LA a_i, Ncs_i= Number of cells in LA a_i searched in selective paging, Nbl_{cost1}= Number of bytes or messages generated by a location update at VLR, Nbl_{cost2}= Number of bytes or messages generated by a cell update, Nbl_{cost3}=Number of bytes or messages generated by a location update at HLR, Nbp_{cost1}=Number of bytes or messages generated by a successful paging, Nbp_{cost2}=Number of bytes or messages generated by a unsuccessful paging, Ph=Probability of success in selective paging, CA=Total number of call attempts per hour, MPL= Mobility Predictability Level, k=Total number of location areas=N_z, A_i=Cell movements in current LA a_i by a user, MR=Movement Rate, $Cost_{Lu}$=Location update cost, $Cost_{pg}$=Paging cost, $Cost_{total}$=Total cost, CMR= Call to Mobility Ratio. The mathematical expressions of MPL and MR are given by,

$$MR = \frac{A_i}{N_i} \tag{1}$$

$$MPL = \sum_{i=1}^{k} (\alpha_i / i) \tag{2}$$

Location update cost for each subscriber is calculated here considering the location update cost at VLR(first term), cell update cost(second tern), location update cost at HLR(third term) and cost for maintaining dynamic LA list(fourth term) multiplied by the probability of location update(fifth term). Therefore total location update cost is given by multiplying the location update cost for each subscriber with the number of subscriber(sixth term),

$$Cost_{Lu} = \frac{1}{k}\sum_{i=1}^{k} [\{(Nbl_{cost1} x[\frac{1}{3}.\frac{8}{\pi}(v_i/[R_i.(N_i)^{1/2}])]) + Nbl_{cost2} x1 + Nbl_{cost3} x(1/24) + N_z\}.(1-\alpha_i)].N_{sub} \tag{3}$$

Paging cost is calculated here considering the number of call attempts, probability of successful and unsuccessful attempts in selective paging. So, paging cost is given by,

$$Cost_{pg} = [CA.[(Ph.N_{csi}).Nbp_{cost1} + \{(1-Ph).(N_i - N_{csi})\}].Nbp_{cost2}] \tag{4}$$

Total cost is the sum of location update cost and paging cost given by,

$$Cost_{total} = Cost_{Lu} + Cost_{pg} = \frac{1}{k}\sum_{i=1}^{k}[\{(Nbl_{cost1} x[\frac{1}{3}.\frac{8}{\pi}(v_i/[R_i.(N_i)^{1/2}])]) + Nbl_{cost2} x1 + Nbl_{cost3} x(1/24) + N_z\}.(1-\alpha_i)]N_{sub} + [CA.[(Ph.N_{csi}).Nbp_{cost1} + \{(1-Ph).(N_i - N_{csi})\}].Nbp_{cost2}] \tag{5}$$

The first term represents location update cost calculated using equation (3) and second term represents the paging cost calculated using equation (4).

CMR is represented as,

$$CMR = \frac{CA}{MR} \tag{6}$$

CMR represents the ratio of number of call attempts (CA) and movement rate (MR).

4. Performance Analysis of Proposed Method

In this section some cases are considered where this strategy is applied for location tracking. Paging cost, location update cost and total cost is calculated depending on different data sets. Total cost is plotted here with respect to MPL, MR and CMR. These results are compared with previous approaches and it is presented that it performs better than previous schemes.

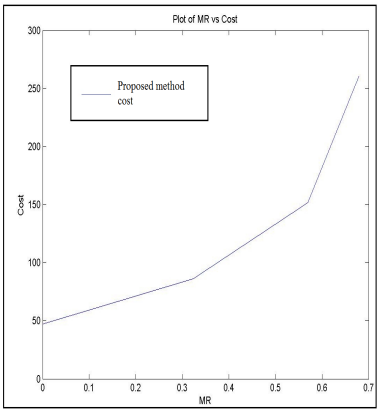

Figure4: Proposed method cost vs. MR

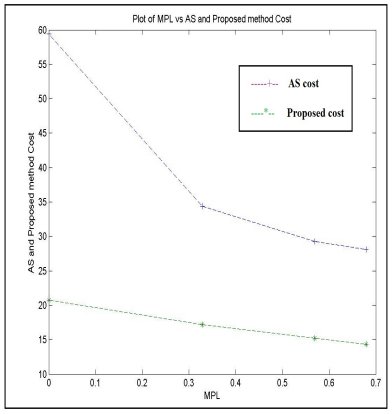

Figure5: Comparison of AS and proposed method performance

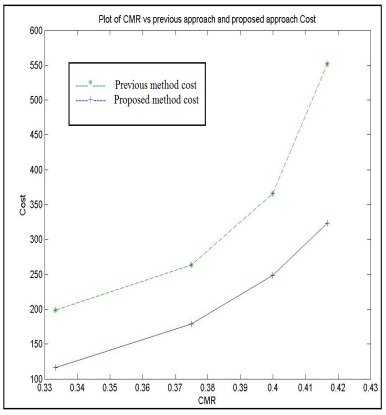

Figure6: Comparison of Previous and Proposed method performance

In figure 4, total cost calculated using equation (5) is represented with respect to MR evaluated using equation (1). Figure 5 shows that depending on different data sets the total cost in proposed method using equation (5) with respect to MPL evaluated using equation (2) gives 48%-65% improvement than 'An Alternative Strategy for Location Tracking' (AS) by Sami Tabbane[1]. Figure6 shows depending on different data sets the cost calculated using equation (5) involved in location management (with respect to CMR calculated using equation (6)) in proposed scheme much less than (31%-41%) the existing approach [2].

5. Conclusion

The proposed method for cost effective location management in a heterogeneous wireless systems will help in short term traffic forecasting. The proposed location update method serves two purposes-a) To preserve up-to-date location of a MT, b) Dynamic LA list generation and update this list when a location update takes place. Probabilistic information maintained in the LA list helps to present an idea of movement pattern of active users within an LA and transition to other LAs as well as its movement in a cell within an LA. This movement information assists to forecast the probable short term traffic in each LA. The proposed paging method uses selective paging and considers the signal strength of the MT. It minimizes call delivery cost and delay. Overall 48%-65% improvement in total cost has been achieved as compared to the existing scheme (AS) with respect to MPL.

6. References

1. S. Tabbane, "An Alternative Strategy for Location Tracking", IEEE Journal in Selected Areas in Communications 13, June 1995, 880-892.

2. Rashed Khalil, Wail Elkilani, Nabil Ismail and Mohie Hadhoud, "A Cost Efficient Location Management Technique for Mobile Users with Frequently Visited Locations," Proceedings of the 4th Annual Communication Networks and Services Research Conference (CNSR'06), 2006.