A Novel Cost-Effective and High-speed Location Tracking Scheme For Overlay Macrocell-Femtocell Network

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Abstract

In this paper mobile cloud computing based an innovative location tracking strategy is proposed for overlay macrocell-femtocell based network. In the proposed approach a database is maintained in cloud for each macrocell base station to notify the presence of each user within the macrocell or femtocell. The recently visited femtocell IDs are also stored in the database. By maintaining the recently visited femtocell IDs by a user in the database, the paging cost and delay are reduced to 37.07-41.99% and 27.69-42.07% respectively than previous location tracking method for overlay macrocell-femtocell network.

1. Introduction

Femtocell is a latest development in the field of mobile computing. Femtocell [1-2] is a low power base station (BS) which provides good coverage at indoor environment. It can be easily deployed in plug-and-play manner and connected with the network through a broadband connection. Femtocell has coverage of approximately 10m where the coverage of macrocell is of 1-20km. Thus in overlay macrocell-femtocell based LTE (Long Term Evolution) network [3], the femtocells are deployed within a macrocell to provide good coverage at indoor or boundary region [1]. On the other hand due to the explosive increase in the number of mobile users cost-effective location tracking has become a major challenge in the era of mobile computing. In our previous work [4-5] cost effective location tracking methods have been proposed for predicting the movement of active users in a heterogeneous mobile network. For overlay macrocell-femtocell network we have proposed a new selective paging scheme in [3]. In this scheme a database DM (De-Mukherjee) is maintained by the macrocell BS to contain the information about whether each MT is located inside an active femtocell or not. Although in this scheme the femtocell containing the mobile terminal is not known and hence all the femtocells contained within a macrocell are required to search to locate a mobile terminal (MT). This in turn increases paging cost and delay both. To overcome this problem in this paper mobile cloud computing (MCC) based a new paging scheme is proposed where the recently visited femtocell IDs by a MT are maintained in the DM database stored inside the cloud.

2. Proposed Paging Method

A mobile network contains a number of location areas (LA) and each LA contains a number of cells. Each cell contains a base station. When a MT enters into a new LA, a location update for the MT is done. When a call arrives for the MT, the cells contained in that LA are searched which is referred as paging. In the proposed approach each LA contains macrocells and femtocells both where femtocells are assigned within each macrocell. A dynamic location area list and cell lists are maintained in the profile of individual user [3-5]. The location area IDs (LAIDs) and the probabilities of visiting each LA by a particular user are maintained in the list in descending order. Each field of the LA list points to a cell list containing the probabilities of visiting each macrocell within the corresponding LA by the user in descending order [3-5]. The probability of visiting current LA is given by [3],

$$\alpha_i = LAIDC\ (a_i)/LAC \tag{1}$$

where LAIDC (a_i) contains the number of times LA a_i has been visited by the MT and LAC denotes the number of LAs visited by that MT. The probability of visiting current macrocell is calculated as [3],

$$\beta_j = CELLIDC\ (cell_j)/CELLC \tag{2}$$

where CELLIDC ($cell_j$) contains the number of times the macrocell $cell_j$ located in LA a_i has been visited by the MT and CELLC denotes the number of macrocells visited by that MT within LA a_i. When the user enters into a new LA, a location update is performed and the LA list is updated accordingly. For each macrocell visit the cell update is not

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performed as it increases the traffic. Thus macrocell update for a MT is done at a fixed time interval or when a call arrives for the MT as stated in [5]. When a macrocell update occurs within the LA at a fixed time interval or a call arrives, only the corresponding cell list is updated [5]. A cache is maintained to hold the recently visited macrocell IDs by the MT [5]. In the proposed scheme the DM database [5] in maintained inside the cloud and the macrocell BS is connected to the cloud as shown in Fig.1. DM database stores the information about whether a MT is located inside a femtocell or not as well the recently visited femtocell IDs by the MT. When a MT registered under an active femtocell, then the corresponding flag is set to 1. When it leaves the femtocell the corresponding flag is set to 0. When for the first time a MT accesses cloud through a femtocell or a call arrives to the MT or a call is made from the MT through the femtocell, the femtocell ID is updated to the DM database. Now it may occur that the MT can move to another femtocell within the same macrocell coverage. Then frequent update of femtocell ID to the DM database in cloud can result in congestion. Thus a fixed time interval is considered for femtocell update. If the MT moves to a new femtocell then the ID will be updated to DM at that time interval. The DM database structure is shown in Table1.

Table 1. DM Database Structure

MT ID	**Flag value**	**Recently Femtocell ID**
M_1	$Flag_1$=1	F_1, F_3
M_2	$Flag_2$=0	F_1, F_6
M_3	$Flag_1$=0	F_1, F_2
M_4	$Flag_2$=1	F_1, F_4
….	….	….
….	….	….
….	….	….
….	….	….
….	….	….
M_{m-4}	$Flag_m$=1	F_5, F_6
M_{m-3}	$Flag_m$=1	F_5
M_{m-2}	$Flag_m$=1	F_1, F_2, F_6
M_{m-1}	$Flag_m$=1	F_4
M_m	$Flag_m$=1	F_3

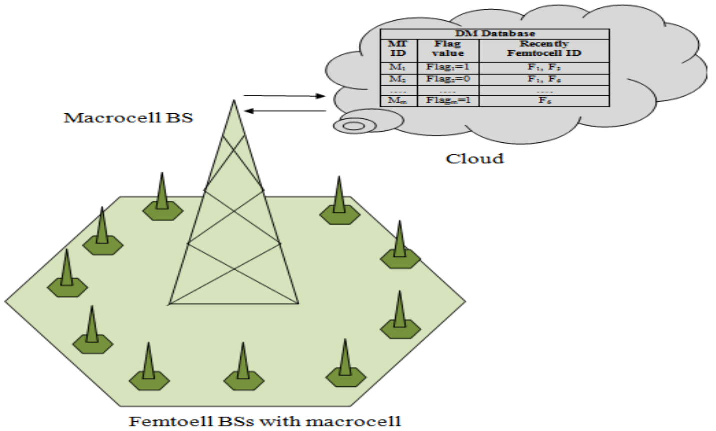

Fig.1. Macrocell BS connected to the DM database in cloud

When a new call arrives for the MT, the flag status corresponding to the MT is checked. If flag status is 1, the recently accessed femtocells whose IDs are maintained in DM database, are searched. If the MT is not found within these femtocells, rest of the femtocells are searched. Else if the flag status is 0, the coverage of the macrocell BS excluding the femtocells is searched. So, here three cases are considered to track the MT: i) MT is found within the recently accessed femtocells whose IDs are maintained in DM database, ii) MT is found within the rest of the femtocells, iii) MT is found within the macrocell coverage excluding the femtocells. Considering these three cases the paging method is proposed as follows:

Considerations:

- Location update for the MT is performed when a new LA is visited by the MT or a macrocell is visited at a fixed time interval t_f
- A Cache (C_1) is maintained to store the recently visited macrocell IDs by the MT within the currently visited LA at a fixed time interval t_f
- A database DM is maintained in cloud connected to the macrocell BS to store the ID of the MTs currently present within the macrocell coverage along with a flag for each MT to notify whether the MT is registered under an active femtocell or not and the recently visited femtocell IDs by the MT at a fixed time interval $t_f^{/}$
- The last updated time instant for the MT for macrocell update in C_1 is t_{l1}, for femtocell update is t_{l2}, current time instant is t_c

Method:

1. **Start**
2. **When** a call arrives for a MT,
   The VLR/MSC broadcasts a query message to the macrocell BSs whose IDs are maintained in the cache C_1
3. **Set** a timer
4. **If** a macrocell BS containing the MT responds before the timer expires, go to step 5
5. The macrocell BS containing the MT accesses the DM database to check whether the flag corresponds to the MT is set to 1 or not
6. **If** the flag is set to 1,
7. The macrocell BS sets a timer and broadcasts a query message to the recently visited femtocells whose IDs are maintained in DM database
8. **If** a femtocell containing the MT responds before the timer expires,
9. Call is delivered to the MT through the femtocell
10. **If** $t_c - t_{l2} \geq t_f^{/}$,the ID of the femtocell currently containing the MT is updated in DM database
11. **Else** no femtocell update is done at DM database
12. **End If**
13. **Else** the macrocell BS sets again a timer and broadcasts the query message to rest of the femtocell BSs contained in the macrocell BS
14. **If** a response is received from a femtocell BS before the timer expires, execute step 9 to 12
15. **Else** generate a message that the MT is not found
16. **End If**
17. **End If**

18. **Else** the macrocell BS searches the MT within its own coverage excluding the femtocells
19. **If** the MT is found, go to step 20
20. **If** current received signal strength of MT> minimum received signal strength,
21. Call is delivered to the MT
22. **If** $t_c - t_{l1} \geq t_f$,the MT updates current macrocell ID to the current VLR
23. VLR stores the macrocell ID visited by that MT in cache C_1
24. Update the cell list according to the probabilities of visiting the macrocells in the LA by that MT in the descending order
25. **Else** no macrocell update is done
26. **End If**
27. **Else set** a timer
28. **If** current received signal strength> minimum received signal strength after the time expires, execute step 21 to 26
29. **Else** a call failure message is generated
30. **End If**
31. **End If**
32. **Else** generate a message that the MT is not found
33. **End If**
34. **End If**
35. **Else** the VLR/MSC broadcasts a query message to the rest of the macrocell BSs contained in that LA and sets a timer
36. **If** a macrocell BS responds before the time expires, go to step 5
37. **Else** generate a message that the MT is not found
38. **End If**
39. **End If**
40. **End**

The parameters used in paging cost and latency calculation are: N_i= Number of macrocells in LA a_i, R_i= One side length of a hexagonal macrocell in a_i, R_f= One side length of a hexagonal femtocell, N_m= Number of macrocells whose IDs are maintained in cache C_1, N_f= Number of femtocells whose IDs are maintained in DM database, Num_s= Number of messages generated by a successful paging, Num_{uns}= Number of messages generated by an unsuccessful paging, p_1= MT is found within the recently accessed femtocells whose IDs are maintained in DM database, CA= Number of call attempts per unit time, N_{fA}= Number of active femtocell within macrocell $cell_j$, T= Time delay for one message transmission, D_a= Delay in accessing the DM database per call, Num_a= Number of messages for accessing the DM database per call.

The coverage area of a femtocell is given by,

$$A_f = (3\sqrt{3}/2)\cdot R_f^2 \quad (3)$$

The coverage area of a macrocell is given by,

$$A_m = (3\sqrt{3}/2)\cdot R_m^2 \quad (4)$$

The probability of presence of the MT under the coverage of an active femtocell is given as [3],

$$p_f = N_{fAj} A_f / A_m \quad (5)$$

The probability of presence of the MT under the coverage of the macrocell i.e. not within the femtocells is given as [3],

$$p_{nf} = 1 - p_f \quad (6)$$

The probability of finding the MT under the coverage of the selected femtocells whose IDs are maintained in DM database is given as,

$$p_1 = N_f A_f / N_{fA} A_f = N_f / N_{fA} \quad (7)$$

The probability of finding the MT under the coverage of the selected macrocells whose IDs are maintained in cache C_1 is given as,

$$p_m = N_m A_m / N_i A_m = N_m / N_i \quad (8)$$

The cost consumed in successful paging is given as,

$$Num_{pgs} = CA\cdot([\{(p_1\cdot N_f)+(1-p_1)\cdot(N_{fA}-N_f)\}\cdot p_f + p_{nf}]\cdot[p_m\cdot N_m])\cdot Num_s \quad (9)$$

By the term successful paging denotes that the MT is found within the macrocells whose IDs are maintained in cache C_1. The cost consumed in unsuccessful paging is given by,

$$Num_{pguns} = CA\cdot([\{(p_1\cdot N_f)+(1-p_1)\cdot(N_{fA}-N_f)\}\cdot p_f + p_{nf}]\cdot[(1-p_m)\cdot(N_i-N_m)])\cdot Num_{uns} \quad (10)$$

By the term unsuccessful paging denotes that the MT is not found within the macrocells whose IDs are maintained in cache C_1. The total paging cost is given by,

$$Num_{pg} = Num_{pgs} + Num_{pguns} + (CA\cdot Num_a) \quad (11)$$

The delay in successful paging is given as,

$$D_{pgs} = T\cdot CA\cdot([\{(p_1\cdot N_f)+(1-p_1)\cdot(N_{fA}-N_f)\}\cdot p_f + p_{nf}]\cdot[p_m\cdot N_m])\cdot Num_s \quad (12)$$

The delay in unsuccessful paging is given by,

$$D_{pguns} = T \cdot CA \cdot ([\{(p_1 \cdot N_f) + (1 - p_1) \cdot (N_{fA} - N_f)\} \cdot p_f + p_{nf}] \cdot [(1 - p_m) \cdot (N_i - N_m)]) \cdot Num_{uns} \quad (13)$$

Thus the total paging delay is given by,

$$D_{pg} = D_{pgs} + D_{pguns} + (CA \cdot D_a) \quad (14)$$

The total paging delay is determined using equation (14).

3. Performance Analysis of Proposed Method

In this section the paging cost and delay of the proposed scheme are determined considering different data sets and compared to that of the previous approach [3]. The paging cost of the proposed approach is calculated using equation (11) and then converted into the number Kilo bytes to compare the proposed paging cost with the previous approach [3]. Fig.2 presents the calculated paging cost in Kilo bytes is shown in Fig.2 with respect to the number of active femtocells in macrocell-femtocell based network. Fig.2 presents that using the proposed paging scheme 37.07%-41.99% of the paging cost can be reduced.

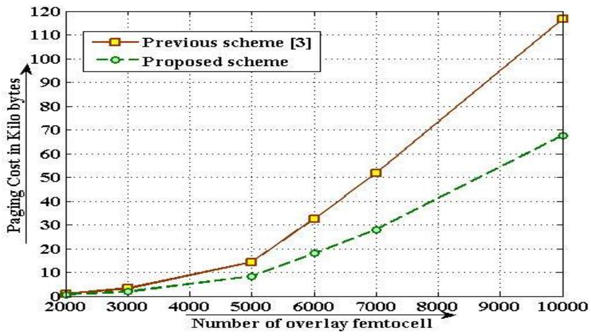

Fig. 2. Number of active femtocells vs. paging cost

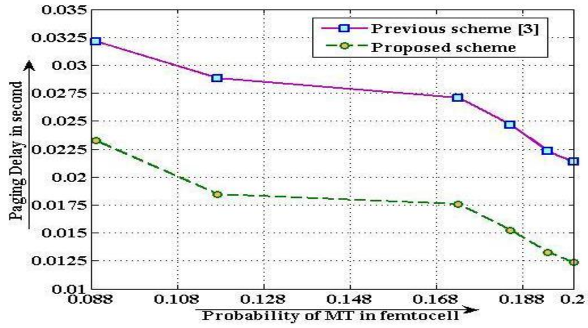

Fig. 3. Probability of MT in femtocell vs. paging delay in second

Fig.3 presents the delay involved in paging calculated using equation (14) and presented with respect to the probability of locating the MT in femtocell calculated using equation (5) for overlay macrocell-femtocell based network. Fig.3 demonstrates that proposed scheme reduces 27.69%-42.07% of paging delay than the previous paging scheme [3] for macrocell-femtocell based network. As the recently visited femtocells by a MT are maintained in the DM database, the probability of successful paging is increased as well less number of femtocells is required to search.

4. Conclusion

In this paper based on mobile cloud computing a cost-effective and high speed location tracking strategy is proposed for overlay macrocell-femtocell based network where femtocells are deployed within the macrocells. The recently visited femtocells by a MT are maintained in a database DM stored inside the cloud connected to the macrocell BS. By maintaining recently visited femtocell IDs in DM database, the paging cost and delay can be reduced to 37.07-41.99% and 27.69-42.07% respectively than previous approach for macrocell-femtocell network. Hence the proposed approach is referred as cost-effective as well high-speed location tracking scheme.

5. References

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