Performance of an Overlapped Macro-cell Based Location Area Scheme

Kuo-Hsing Chiang*, Nirmala Shenoy**
*School of Electrical and Computer Systems Engineering, RMIT University,
GPO Box 2476v,Melbourne, Victoria, 3000, Australia
**Information Technology Department, Rochester Institute of Technology, Rochester NY 14623,
Email: ns@it.rit.edu, Tel: +1 716 475 4887 Fax: +1 716 475 2181

***Abstract*-In this paper, we define a new "location area" for location management in wireless networks. Location management schemes comprise of location update and terminal paging. Efforts to introduce efficient location update schemes results in increased paging costs and vice-versa. Dynamic Location Area (LA) schemes, which are per-user and mobility pattern based were proposed to overcome the problems of frequent location updates made by users in the LA boundary. In this work we propose a Base Station Controller (BSC) based scheme, which is a static scheme, but reduces the effect of frequent location updates at the boundary, by using the 'overlap' concept. The proposed LA, normally under the control of one BSC overlaps with adjacent LAs. We evaluate the scheme and compare it with other popular schemes like movement-based and distance-based LA schemes, which are more complex to implement. Though this type of BSC- based overlapped LA would result in minimal paging costs also, if the paging control were maintained at the BSC, the results of paging analysis have not been provided here due to space limitations. This scheme is simple to implement and has considerably reduced signalling traffic and associated costs. Another major contribution in this work is the extension of a mobility model, to study the location update rates in an 'overlapped LA' approach, which is difficult to analytically model.**

I. INTRODUCTION

Work on 3G networks and its deployment is progressing steadily while 4G is emerging with its broadband and high bit rate capabilities. With IP undisputedly being accepted as the core network, this will make available numerous Internet applications and resources to the mobile users. Number of mobile users and their demands on various Internet services and applications will also grow. Efficient location management schemes have been a major area of study in mobile networks. With this developing scenario, with IP as core network, it will become more important to have optimal location management schemes, which will perform location management functions fast with reduced complexity, reduced signaling traffic and associated costs. The focus of this work is to study such a location management scheme.

Location registration (or update) and *terminal locating* (or paging) are the two main operations performed under location management. The two-level database strategy, based on Home Location Register (HLR) and the Visitor Location Register (VLR), used in current cellular networks continue to be the base for newly proposed location management strategies. A Mobile Terminal (MT) initiates a location update message to the network when it crosses a pre-defined Location Area (LA) boundary. A number of LA schemes, static and dynamic have been proposed and analyzed.

The static LA scheme has the drawback that a user who often roams across fixed LA boundaries would trigger a number of location updates. This will generate significant signalling traffic for some classes of users. The dynamic LA schemes such as movement-based LA [2,3], distance-based LA [3,5] and timer-based LA [3] schemes were proposed to overcome such frequent update problems in conventional mobile network. In a dynamic LA scheme [1-5], the LA profile is based on an algorithm that is per-user-based on the user's profiles (eg. call and mobility pattern).

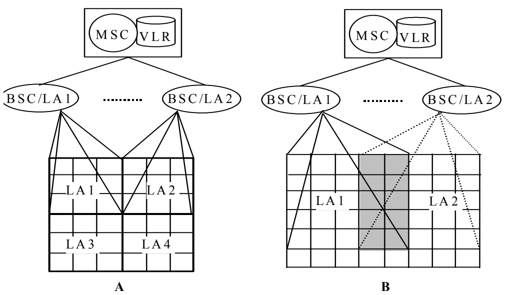
All the above-cited schemes have been evaluated for their efficiency. However one finds in the analysis, the dependency of the total signaling costs on the network architecture is not taken into account. In other words, a per-user based LA which is efficient for a given scenario can result in more signalling traffic if the LA spans a number of BSC or VLR. The issue that there could be quite a number of mobile users, who fall in this category can result in heavy signalling traffic. Besides, it well known that when estimating signaling costs, there is a trade-off between the location update costs and paging costs ie schemes for reducing location updates costs invariably lead to increased paging costs and vice-versa. So it was decided to conduct studies on a simple scheme which will optimise the total location management costs ie the location update costs plus the paging costs. The BSC based LA was one such proposal.

In this work we extend a BSC based LA coverage area to overlap with the adjacent LAs. This is another effective way of reducing frequent updates at the boundary. We study the location update costs encountered in this scheme and compare it with the location update costs encountered in a distance-based scheme and the movement-based scheme, keeping in mind the network architecture. For analysis purposes we have used a mobility model introduced by us in [7]. The mobility model proposed in [7] has been extended and the application of it to the study of an overlapped LA case is detailed in this work. A simple costing analysis has been provided taking into account the probability of inter-VLR and intra-VLR spanning effects in the LA schemes. Results show that the BSC-based overlapped LA is very efficient in terms of reduced location updates costs and simplicity of implementation.

This paper is organized as follows. Section II describes the proposed scheme briefly, with the network architecture. The location update information flows for the different scheme under different scenarios are presented in Section III. The random walk mobility model to study overlapped LA scheme is discussed in section IV. Section V provides the mathematical analysis involved. Performance comparison is given in section VI. Conclusion follows in section VII.

II. PROPOSED SCHEME

Fig. 1A illustrates the signaling network architecture for a BSC based LA location management proposed by the author in [6]. The significance of this approach is that a BSC coverage area (also a macro-cell coverage area) is a LA. VLR is collocated with a Mobile Switching Center (MSC) and several BSCs are connected to a MSC/VLR. The paging control is distributed at the BSC level. Fig 1B illustrates the architecture for the extended/overlapped macro-cell based LA approach. Each macro-cell is extended to cover a larger area. The shaded area in Fig. 1B represents the overlapped area between two LAs LA1 and LA2.



Overlapped area for LA1 and LA2

Fig. 1 Network Architecture

Because of overlap, the LA boundary crossing rate decreases considerably as the size of the LA has expanded. Since the total number of LAs is the same as when no overlapping is applied, the average number of mobile users per LA is the same for both overlapped and non-overlapped approaches.

III. LOCATION UPDATE

In the information flow diagrams given below, standard terminology and descriptive message names have been used hence no detailed explanation is provided. The information flows provided for dynamic LA schemes are applicable for both movement-based and distance-based schemes.

A. Intra VLR- Dynamic LA update:

Fig 2 shows the simplified information flow for intra VLR location update based on a dynamic LA approach. Because the LA is assigned dynamically, it could be covered by different BSCs. Hence two scenarios, which could effect signaling are

(a) Part of old LA and new LA under the same BSC

(b) Old LA and new LA are under different BSC

Information flows marked (a) refer to case (a). Information flow marked (b) refer to case (b). BSC_{old}/LA_{new} identifies the case, where the user has moved into a new LA from the old LA, but is still under the coverage of the old BSC. BSC_{new}/LA_{new} identifies the case when the user moves into a new LA, he also moves into a new BSC.

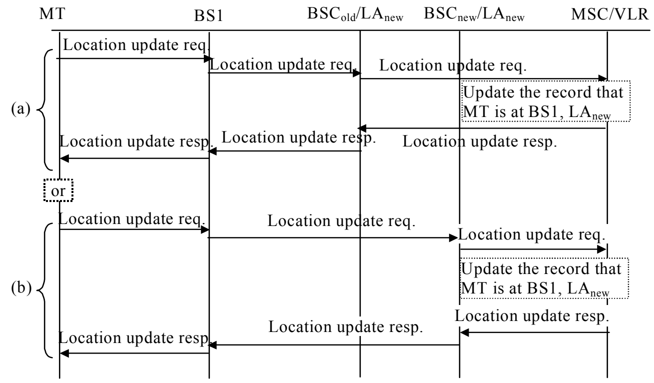


Fig. 2 Information Flows for dynamic LA based update (intra VLR movement)

The MSC/VLR in the case of dynamic LA needs to record the MT's last contacted BS and a list of probable BSs in the new LA for intelligent or sequential paging. The MSC/VLR can also just record all of BSs in the new LA for blanket paging. This is essential in the dynamic LA schemes as the paging control is at the VLR. Determining and maintaining a list of probable BSs can consume considerable processing-time and requires geographical knowledge of BSs.

B. Intra VLR -BSC based LA update:

The information flow for the BSC based LA update is shown in Fig. 3. In this scheme only a simple pointer update at MSC/VLR is required to track the roaming MT. If an intelligent paging algorithm were to be applied then the BSC/LA simply records the last contacted BS of the MT.

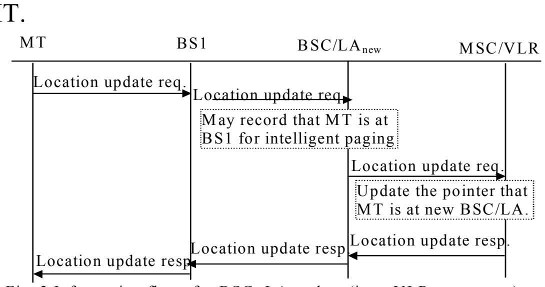


Fig. 3 Information flows for BSC -LA update (intra VLR movement)

C. Inter VLR – Dynamic LA update :

Fig.4 shows the simplified information flows for inter VLR location update based on a dynamic LA approach. Because the LA changes dynamically, one LA could be covered by different VLRs. Fig 4 shows the case when a user moves to a new LA, he also moves into a new MSC/VLR. STP is a one level Signalling Transfer Point (STP) via which the HLR is reachable. STPs are part of the Signalling System No. 7. The new VLR will record the MT's last contacted BS and a partial list of probable BSs for paging, and the HLR may also record the last contacted BS and a whole list of probable BSs for paging that could be covered by the different VLRs. The issue of LAs spanning VLRs/BSCs hitherto has not been considered for the analysis of the schemes.

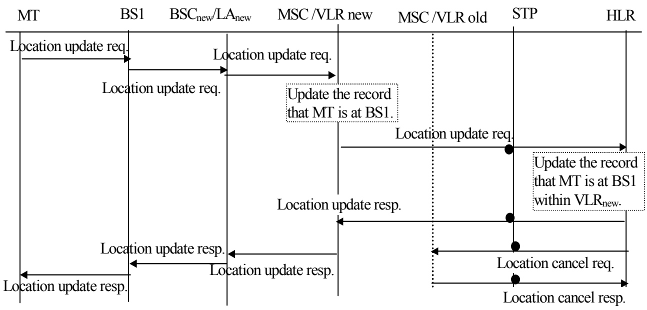


Fig. 4 Information flows for dynamic LA based update - inter VLR

D: Inter VLR – BSC based LA update:

The information flow for BSC based LA update is shown in Fig. 5. Only two pointers need to be updated in MSC/VLR and HLR (STP with some extra functions, acts as a HLR agent in this case and holds a pointer information [7]) to track the roaming MT. If an intelligent paging algorithm is applied then the BCS/LA simply records the last contacted BS of the MT. The approach is simple.

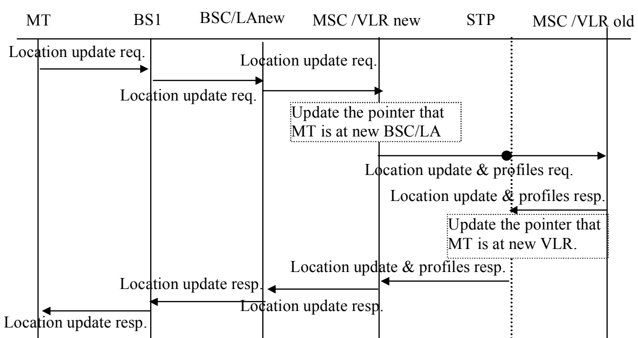


Fig. 5 Information flows for BSC based LA update inter-VLR

IV. MOBILITY MODEL

In this section the random walk mobility models used for studying the performance of the overlapped macro-cell based LA and the other schemes are explained. The mobility model application to the overlapped LA scheme is explained in detail, using the non-overlapped BSC-based LA scheme to ease in explanation. In the subsequent sub-section the model has been applied to the distance-based scheme to obtain the average number of location updates. Average number of location updates calculation for the movement-based scheme is straightforward. For comparison purposes each LA is assumed approximately to equal a 25 micro-cell coverage area. Note that in the case of the overlapped LA, though the actual LA is 25 cells, because of the overlapped concepts, the virtual LA will cover more than 25 cells.

A. BSC Based LA Scheme

Fig 6. shows the micro cells under an LA for the BSC based LA and for the overlapped LA concepts. The cells in each case are numbered. Cells, which have identical numbers are those cells, from where the mobile user would have similar movement properties in the LA. The cell numbering refers to the states in the Markov model. Fig.6A shows that there are six such states for the 5 * 5 square shaped micro-cell LA. States with identical numbers will be aggregated to use the lumped process property in Markov chains. From the figure aggregate states 4, 5 and 6 can be seen to be the boundary states. Fig. 7 is the state transition diagram for the mobility of the user in the BSC-based LA. In the state transition diagram the asterisk states 4^*, 5^* and 6^* represent the boundary states in adjacent LAs. The concept of these states is the novelty of the mobility model, which helps simplify the analysis. The model further has the unique property that it wraps back when a boundary is crossed and the user starts moving in the new LA. This can be noticed in the transitions from the asterisked states back to the normal states. In this work we have assumed that a mobile terminal has equal probability of moving in each of the four directions only. For example, in Fig. 6A, when users crosses from cell 6 in BSC5 to cell 6 in either BSC2 or BSC4, then as shown in the transition diagram fig. 7, he would enter state 6*. This is indicated by the transition probability ½ (assuming equal transition probabilities of 1/4 in the four directions only).

From state 6 in BSC2, the user may go back to 6 of BSC5 or 6 of BSC1, which is again a boundary transition. This is shown by a transition probability of ½ to self in state 6*.If instead the user started moving in cell5 in BSC2, then he is considered to perform movement in the new LA of BSC2 and looking at the state transition diagram, we find that there is ½ probability from 6* to state 5, and the model is said to wrap back with the user movement to continue in BSC2.

B. Overlapped Macro-cell Based LA Scheme

After having applied the mobility model to the simpler BSC based LA, we now attempt to apply it to the overlapped macro-cell LA. The overlapped-BSC based LA configuration is shown in Fig. 6B and 6C. Fig. 6C will be used to explain the state transition diagram when the MT crosses from one overlapped LA to another, in this case from LA5 to LA3. In Fig. 6A, the original macro-cell or BSC boundary area is defined by the bold lines and each macro-cell is identified as BSC1, BSC2, etc. In Fig. 6B bold broken lines have been used to show the extended location area LA5 for the overlapped scheme.

In the case of an overlapped-BSC LA such as LA5, there are 10 aggregate states as can be seen in Fig. 6B. The state transition diagram for the MT movement within and across the boundary of the overlapped LA is given in Fig. 8. Fig. 8A shows the transitions within the overlapped LA and Fig. 8B shows the transitions from one overlapped LA to an

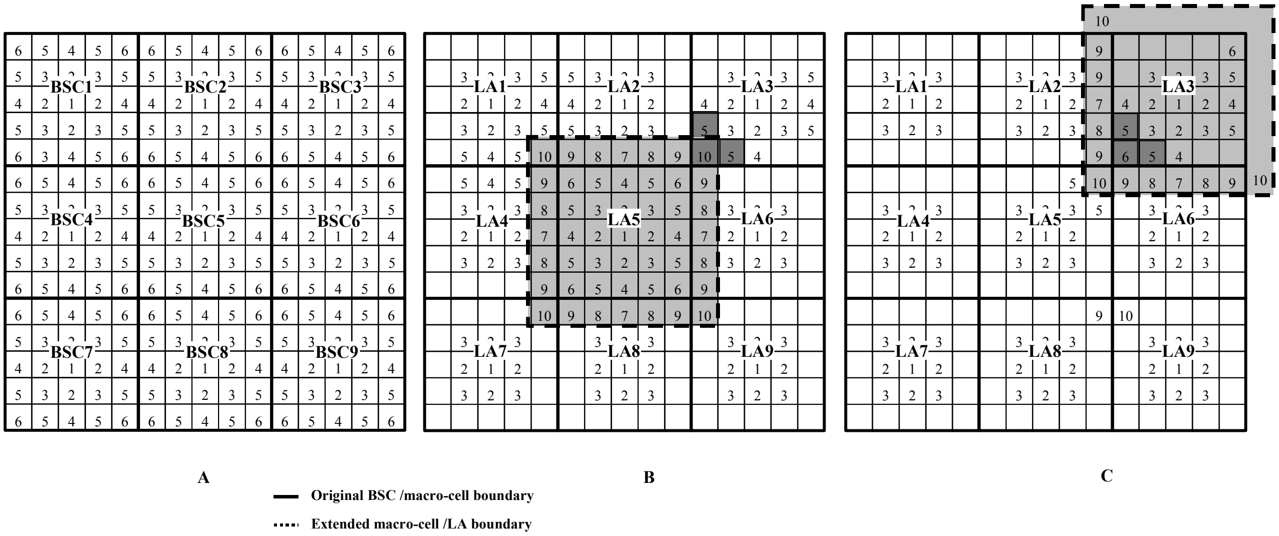


Fig. 6 Cell layout for Macro-cell overlapping concept

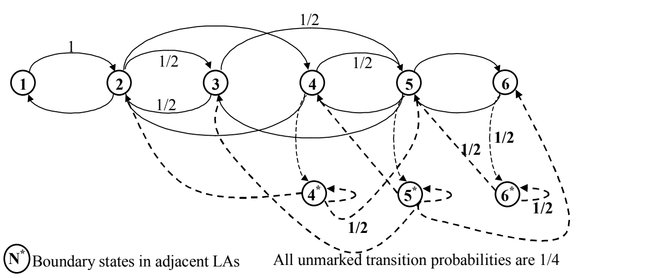


Fig. 7 State transition diagram for 5 * 5 square shaped model

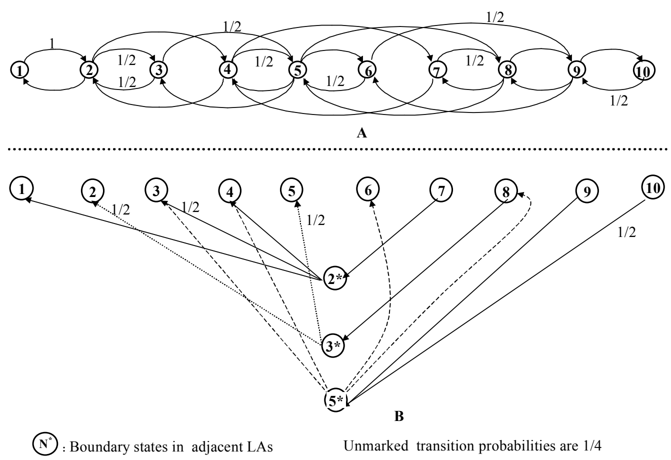


Fig. 8 State transition diagram for extended macro-cell based LA

adjacent overlapped LA. Similar to the BSC-based model study asterisk states 2^*, 3^*, and 5^* shown in Fig 8B represent the boundary states of adjacent LAs.

A brief explanation of the state transition diagram is given here. For a more detailed understanding the reader is referred to [7]. Focusing on LA5 and LA3 in Figs. 6B and 6C, we explain the state transition diagram of Fig. 8. When a user is in state 10 in LA5, he can transition to state 5 in (dark shaded cells) LA3 with a ½ probability. This is indicated as a transition from state 10 to state 5* in Fig. 8B with ½ probability. He can also move to state 9 within LA5 itself with ½ a probability, which is shown in Fig. 8A. Once the user has entered LA3, he is considered to be in the extended LA3 coverage area. Hence if one refers to Fig 6C, The LA3 extended area is explicitly shown. The dark shaded cells in Fig. 6C correspond to the dark shaded ones in Fig. 6B. We notice that the cell numbered 10 in the dark shaded cells of Fig. 6B is now a cell numbered 6 in the new LA (LA3) coverage area in Fig. 6C. From Fig. 6C the user in state 5 has a 1/4 probability of moving into state 3, 4, 6 or 8 which is indicated by the transition from 5* to state 3, 4, 6 and 8 in Fig. 8B. This explanation can be extended to understand how the transition diagram was derived.

V. Mathematical Analysis

Each LA has 5 * 5 cells where the cells are identified to different states in the Markov model depending on the mobility pattern. The Markov chain models illustrated in Figs. 7 and 8 have no transient sets but only a single ergodic set with only one cyclic class, hence the regular Markov chain properties can be applied to analyse the behaviour of the proposed model.

Let **P** be the regular transition probability matrix, then the steady state (limiting) probability vector $\boldsymbol{\pi}$ can be solved from the following equations:

$$\begin{cases} \pi P = \pi \\ \sum_{i=1}^{m} \pi_i = 1, \text{ (m = number of states)} \end{cases} \quad (1)$$

The *fundamental matrix* for the regular Markov chain determined by **P** is:

$$\mathbf{Z} = [\, z_{ij} \,] = (\mathbf{I} - \mathbf{P} + \mathbf{A})^{-1} \quad (2)$$

where: 1. **A** is limiting matrix determined by **P**, and the powers $\mathbf{P}^n$ approach the probability matrix **A.**
2. **I** is the identity matrix.
3. Each row of A has the same probability vector $\pi = \{\pi_1, \pi_2, \dots, \pi_n\}$, that is $\mathbf{A} = \xi\pi$, where ξ is column vector with all entries equal to 1.

The matrix **Z** can be used to study the behaviour of the regular Markov chain and is applied as shown below.
Let $y_j^{(k)}$ be the number of times that process is in the state S_j in the first k steps, then the mean number of times the process is in state S_j starting from state S_i is given by

$$M_i\,[y_j^{(k)}] \rightarrow (z_{ij} - \pi_j) + k\pi_j \qquad (3)$$

The total number of boundary updates in k steps starting from state S_i can be computed by the total number of times that process is in the exterior asterisk boundary states (for e.g. 2*, 3* and 5* in Fig 8) starting from state S_i.

$$U_{updates} = M_i\,[y_{2*}^{(k)}] + M_i\,[y_{3*}^{(k)}] + M_i\,[y_{5*}^{(k)}] \qquad (4)$$

The regular transition matrix for BSC based LA in Fig. 7 is

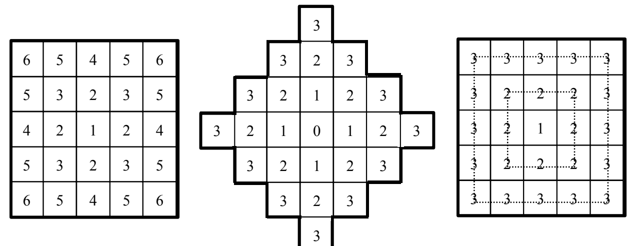
$$\mathbf{P}_{\mathbf{BSC}} = [\,p_{ij}\,] = \begin{array}{c} \\ 1^* \\ 2^* \\ 3^* \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array}\!\!\begin{array}{c} \begin{array}{ccccccccc} 1^* & 2^* & 3^* & 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left(\begin{array}{ccccccccc} 1/2 & 0 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 1/4 & 0 & 1/4 & 1/4 & 0 & 0 \\ 0 & 0 & 1/4 & 0 & 1/2 & 0 & 0 & 1/4 & 0 \\ 1/2 & 0 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 1/4 & 0 & 1/4 & 1/4 & 0 & 0 \\ 0 & 0 & 1/4 & 0 & 1/2 & 0 & 0 & 1/4 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 1/2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/4 & 1/2 & 0 & 1/4 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{array}\right) \end{array}$$

The regular transition matrix derived for the overlapped LA model in Fig. 8 is

$\mathbf{P}_{\mathbf{E\text{-}Macro}} = [\,p_{ij}\,] =$

$$\begin{array}{c} \\ 2^* \\ 3^* \\ 5^* \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \end{array}\!\!\begin{array}{c} \begin{array}{ccccccccccccc} 2^* & 3^* & 5^* & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \end{array} \\ \left(\begin{array}{ccccccccccccc} 0 & 0 & 0 & 1/4 & 0 & 1/2 & 1/4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/4 & 1/4 & 0 & 1/4 & 0 & 1/4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1/4 & 0 & 1/2 & 1/4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/4 & 0 & 0 & 1/2 & 0 & 1/4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/4 & 1/4 & 0 & 1/4 & 0 & 1/4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 & 1/2 & 0 \\ 1/4 & 0 & 0 & 0 & 0 & 0 & 1/4 & 0 & 0 & 0 & 1/2 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 & 0 & 1/4 & 0 & 1/4 & 0 & 1/4 & 0 \\ 0 & 0 & 1/4 & 0 & 0 & 0 & 0 & 0 & 1/4 & 0 & 1/4 & 0 & 1/4 \\ 0 & 0 & 1/2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1/2 & 0 \end{array}\right) \end{array}$$

Based on the model given above and from equation 4, the average number of location updates between two calls for BSC based scheme and the extended macro-cell based LA can be calculated.
We now study the distance based and the movement based schemes for the average number of location updates.
Fig. 9 gives the LA configurations for a coverage area of approximately 25 cells for the different schemes. The BSC



LA boundary
A. Square-shaped model for BSC based LA

B. LA configuration for movement- based approach (d=4)

C. LA configuration for distance-based approach (d_t=3)

Fig. 9 LA configurations for different approaches

configuration is repeated for ease of reference. Fig. 9A shows the six aggregate classes for the BSC-based approach. Fig. 9B and 9C show 3 aggregate classes with a movement threshold value d= 4 for the movement-based scheme and movement threshold d_t =3 for the distance- based scheme respectively. The distance-based and movement-based mechanisms were studied with respect to the Call-to-Mobility Ratio (CMR) in [2]. We have instead used a parameter called Movements Per Call (MPC), which carries similar information as CMR but is its inverse. The MPC reflects the number of movements made by the MT between two calls.
Hence if we consider an example of a user who makes 20 steps (crosses 20 cells) between two call arrivals.

1. Average number of location update for proposed BSC based scheme is 3.8 [7].
2. Average number of location updates for movement based approach is 5 (i.e 20/4)
3. For the distance-based approach, average number of location updates was estimated applying the same mobility model and is explained briefly below

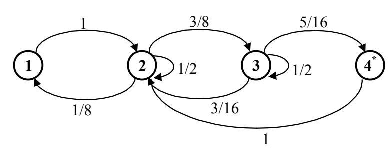


Fig. 10 State Transition Diagram for distance based mobility

Fig. 10 gives the state transition diagram for a mobile user moving in a distance-based scheme. 4* is the cell (not shown in Fig 9C) in the adjacent LA, when the user moves out of the boundary. The transition probability matrix for this mobility is given below, from which the probability that the user goes into the adjacent LA namely state 4* can be determined. Equation similar to 4 can be used for this purpose. This will give the location update rate. These values along with the average number of location updates for the BSC based, and overlapped schemes have been used for the location update cost estimates in all 4 cases and are given in table 3 & table 4.

$$
\mathbf{P} = [\, p_{ij} \,] = \begin{array}{c|cccc}
 & 1 & 2 & 3 & 4^{*} \\
\hline
1 & 0 & 1 & 0 & 0 \\
2 & 1/8 & 1/2 & 3/8 & 0 \\
3 & 0 & 3/16 & 1/2 & 5/16 \\
4^{*} & 0 & 1 & 0 & 0
\end{array}
$$

VI. Performance Analysis

Table 1. signalling and database processing cost

MT – BSC	a
BSC – MSC/VLR	b
MSC/VLR – MSC/VLR	2c
MSC/VLR -- HLR	d
Database processing cost	DB
Pointer update cost	P

Table 1 provides the signalling and database costs to be used for estimating the location update costs. Table 2 provides the cost estimation as obtained from the information flow diagrams of fig 2, 3, 4 and 5.

Table 2. Location update cost

Dynamic LA (intra VLR)	2a+2b+DB
Dynamic LA (inter VLR)	2a+2b+4d+2DB
BSC based LA (intra VLR)	2a+2b+P
BSC based LA (inter VLR)	2a+2b+4c+2P

From the above values the costs for the different schemes can be estimated. Two cases are plotted here based on the probability of having a an inter-VLR LA span. The values for a= 1, b=1, DB=2, P=1, c=1, d= 1.5 have been used in both the cases

Case a: inter-VLR span probability = 0.2

TABLE 3

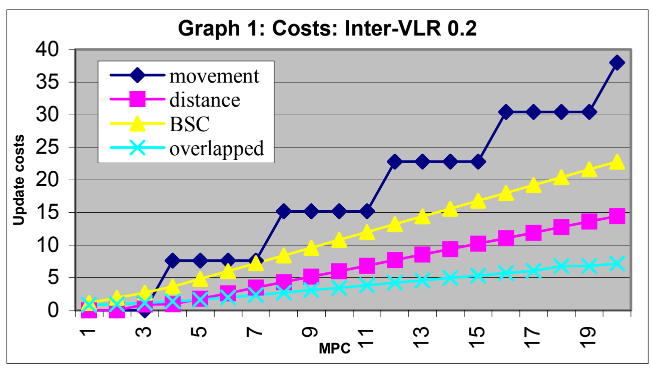
MPC	1	2	3	4	5	6	7
movement	0	0	0	7.6	7.6	7.6	7.6
distance	0	0	0.87	0.94	1.778	2.62	3.466
BSC	1.152	1.92	2.688	3.648	4.8	6	7.2
overlapped	0.828	0.936	1.152	1.368	1.644	1.98	2.352
MPC	8	9	10	11	12	13	14
movement	15.2	15.2	15.2	6.84	7.69	8.54	9.38
distance	4.309	5.153	5.996	12	13.2	14.4	15.6
BSC	8.4	9.6	10.8	3.834	4.206	4.578	4.95
overlapped	2.724	3.096	3.462	15.2	22.8	22.8	22.8
MPC	15	16	17	18	19	20	
Movement	10.22	11.07	11.91	12.75	13.59	14.44	
Distance	16.8	18	19.2	20.4	21.6	22.8	
BSC	5.322	5.694	6.06	6.804	6.804	7.176	
overlapped	22.8	30.4	30.4	30.4	30.4	38	

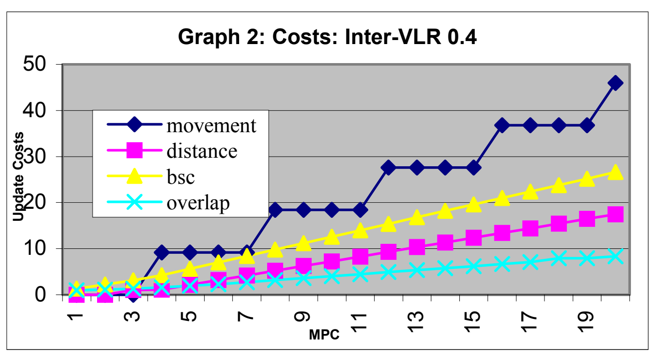
Form the graphs, one finds that the location update costs for the movement based scheme is the highest and it has a step type characteristics, which is due to the fact that the location area is defined with a movement threshold of d=4, and hence once it is in a LA, at least 4 steps have to be made before a location update gets initiated. In the case of the distance based scheme, it is better than the simple BSC based one with lower update costs, but if more of the LAs were across VLRs than one would notice that the costs for distance based scheme will have a steeper rise than the BSC based as can be seen in graph 2. The overlapped BSC based scheme affords the best possible option with very low costs, though one finds that if the MPC values below 4, this has some costs as compared to the other schemes. However, if the paging costs were also to be considered then, the BSC based overlapped costs would be very low as the option of macro-cell paging can be used. Elsewhere we show that even with a relative increased signalling costs of 10 times the micro-cell signalling, the macro-cell based paging will be cheaper than any sequential scheme. We are however not able to include those results here due to space limitations.

Case b: inter-VLR span probability = 0.4

MPC	1	2	3	4	5	6	7
movement	0	0	0	9.2	9.2	9.2	9.2
distance	0	0	1.058	1.132	2.153	3.174	4.195
BSC	1.344	2.24	3.136	4.256	5.6	7	8.4
overlapped	0.966	1.092	1.344	1.596	1.918	2.31	2.744
MPC	8	9	10	11	12	13	14
movement	18.4	18.4	18.4	18.4	27.6	27.6	27.6
distance	5.216	6.238	7.259	8.28	9.310	10.33	11.35
BSC	9.8	11.2	12.6	14	15.4	16.8	18.2
overlapped	3.178	3.612	4.039	4.473	4.907	5.341	5.775
MPC	15	16	17	18	19	20	
Movement	27.6	36.8	36.8	36.8	36.8	46	
Distance	12.37	13.39	14.42	15.44	16.46	17.48	
BSC	19.6	21	22.4	23.8	25.2	26.6	
overlapped	6.209	6.643	7.07	7.938	7.938	8.372	

TABLE 4





VII. Conclusion

In this paper, we have introduced a new Location Area scheme called overlapped BSC based LA. This approach is an enhancement from our previous proposed scheme, which was BSC based LA. The intention of this work was to have the BSC also as paging control and thereby optimize the total location management costs i.e. the location update costs plus the paging costs. Hence paging control is to be distributed at the BSC level. The proposed approaches make it easy for implementing in a micro-cells/macro-cell overlaid architecture. Only one VLR and BSC is involved during the location management procedures in the proposed schemes, which null the any network architecture effects which can be felt in the other approaches. We have limited the presentation in this work only to the location update cost estimates of the 2 proposed schemes and two more popular schemes like the movement-based and the distance-based schemes. The costs estimates indicate a very high performance of the BSC-based overlap scheme, for varying values of call to mobility ratio. Keeping in mind that the scheme is simple and straightforward to implement, this scheme optimizes location management costs from different aspects. We have further introduced a new random-walk model, an extension of our previous work, which has enabled the analysis of the overlapped LA scheme. The details of this model are also presented.

References

[1] I. F. Akyildiz and J. S. M. Ho, "Dynamic mobile user location update for wireless PCS networks," *ACM-Baltzer Journal of Wireless Networks*, vol. 1, no. 1, July 1995, pp.187-196.

[2] I. F. Akyildiz, J. S.M. Ho and Y. -B. Lin, "Movement-based location update and selective paging for PCS networks," *IEEE/ACM transactions on Networking*, vol. 4, no. 4, Aug. 1996, pp. 629-638.

[3] A. Bar-Noy, I. Kessler, and M. Sidi, "Mobile users: To update or not to update?," *ACM Baltzer Journal of Wireless Networks*, vol. 1, no. 2, July 1995, pp. 175-186.

[4] I. F. Akyilidiz, J.Mcnair, J. S. M. Ho, H. Uzunalioglu and W. Wang, " Mobility management in next-generation wireless system," proceedings of the IEEE, vol. 87, no.8, Aug. 1999, pp. 1347-1384.

[5] J. S. M. Ho and I. F. Akyildiz, "Mobile user location update and paging under delay constraints," *ACM/Baltzer*, *Journal of wireless Network,* vol. 1, no. 4, December 1995, pp. 413-425.

[6] K. -H. Chiang and N. Shenoy, "Architecture and schemes for intelligent mobility management in future mobile telecommunication systems," *Proceedings of IEEE GLOBECOM'00*, Nov. 2000, pp. 1463-1467.

[7] K. -H. Chiang and N. Shenoy, "A random walk mobility model for location management in wireless networks," IEEE PIMRC'2001.