2-Phase Dynamic Location Management Based on the Mobility of the Terminals

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Abstract: We propose a dynamic location management scheme and named it Virtual Dynamic Location Area(VDLA) scheme. It allocates LA on the basis of terminal mobility. VDLA consists of two phases: VLA allocation and final LA selection phases. In the first phase it allocates primary and secondary VLAs to the terminal. In the second phase the terminal selects one of them using LA selection criterion. Cost analysis of the proposed scheme is performed and its location management cost is compared with those of FLA and DBLA.

1. Introduction

The next generation mobile communication systems will use micro/picocells to provide large capacity. But the smaller cells make the mobile terminals to cross more cell boundaries. And it requires more location updates. Current mobile networks use location area(LA)-based location update (or location registration). LA is a unit of location management which consists of a group of cells. When a terminal enters an LA, location update and reauthentication are required. And when an incoming call arrives, the network should perform terminal paging. Paging is an operation of determining the cell in which the mobile terminal currently resides. Location update is an operation of informing the network about the current location of the terminal. If an LA consists of only one cell, location update cost is increased but terminal's location can be identified without paging. For larger LAs, location update costs are reduced, but paging costs are increased. There is a trade-off between the costs of location update and paging. Thus LA size is important for the network performance.

Several location update schemes are proposed for efficient location management. Most current systems use fixed LA(FLA) scheme, where LA size is fixed and all the same. In the time-based LA(TBLA) scheme, each terminal performs location update at regular intervals. In the distance-based LA(DBLA), each terminal keeps track of the number of cells it passed since the last update and performs update if it exceeds a certain threshold. Dynamic LA scheme determines LA sizes based on the mobility parameters such as velocity, direction and traffic pattern of each mobile terminal[1,4,5].

LA size, mobility of terminals and location update loads ought to be considered for the optimal configuration of LAs.

In this study we propose Virtual Dynamic LA(VDLA) scheme which assigns VLA depending on the mobility parameter of a terminal. There are two kinds of VLAs: primary and secondary. The primary VLA is assigned so as for the terminal to be in its boundary cell as in FLA. The secondary cell is assigned so as for the terminal to be in its center cell. One of the 2 VLAs is selected on the basis of terminal's mobility. Once a VLA is selected, location update is performed by DBLA. Paging is done sequentially. The paging sequence is determined through location prediction on the basis of LA entry time of the terminal.

In section 2, we present location update and paging models of VLDA. In section 3, cost of VLDA is compared with those of FLA and DBLA. Section 4 is a concluding remarks.

2. System description

Following parameters are defined for the analysis of VLDA. Total cost for location management is the sum of *location update cost and paging cost.*

λ : call arrival rates
C_p : paging cost for cell
L_n : number of cells to be paged
L_p : paging cost
C_l : location update cost

2.1 How a word processor works

When a mobile terminal enters a new LA, location update is performed. Here we assume that the velocity and direction of the terminal remain unchanged in the new LA. The velocity of the terminal v is a constant and uniformly distributed over $[0, V_{max}]$ [2]. The direction of the terminal is assumed to be uniform over $[0, 2\pi]$, Then the location update cost of FLA is

$$C_{l\_FLA} = \frac{E[V]P}{\pi S} \tag{1}$$

,where P is a perimeter of an LA and S is an area of an LA. When the number of cells in an LA is k, S becomes kC And cell area C is

$$C = \frac{3\sqrt{3}r^2}{2} \tag{2}$$

If we assume that an LA consists of x_i rings and that a cell is a hexagon as in Figure 1, the perimeter of an LA is

$$P = \begin{cases} 6r & x_i = 1 \\ 6r[3 + 2(x_i - 2)] & x_i \geq 2 \end{cases} \quad (3)$$

, where r is the radius of a cell.

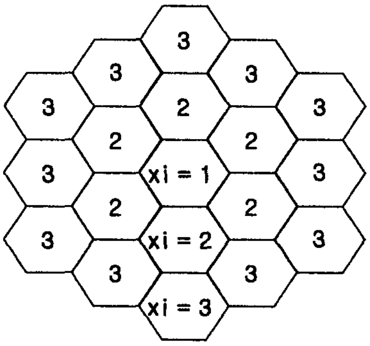


Figure 1. Location area 1

By substituting P in eq. (1), location update cost of FLA is

$$P = \begin{cases} \dfrac{4E[V]}{\sqrt{3\pi k r^2}} & x_i = 1 \\ \dfrac{4[3+2(x_i-2)]E[V]}{\sqrt{3\pi k r^2}} & x_i \geq 2 \end{cases} \approx \begin{cases} \dfrac{2.3lE[V]}{rk} & x_i = 1 \\ \dfrac{2.3l[3+2(x_i-2)]E[V]}{rk} & x_i \geq 2 \end{cases} \quad (4)$$

In DBLA, location update is performed when the terminal goes far more than D cells from the cell of the last update. The new LA is allocated so that the entering cell becomes the center of the LA. Therefore location update cost of DBLA is

$$C_{l\_DBLA} = \frac{E[V]}{R} \approx \frac{E[V]}{0.866(2D-1)r} \quad (5)$$

,where R is the radius of an LA.

2.2 Paging Cost

Paging cost is a cost of determining the location of the mobile user. There are two types of pagings: blanket polling and sequential paging. The blanket polling pages all the cells in the LA. When a blanket paging is performed on the LA consisting of x_i rings, the number of cells to page is

$$\begin{aligned} L_n &= 1 + 6 + 12 + ... + 6x_i \\ &= 1 + \sum_{h=1}^{x_i} 6(h-1) = 3x_i^2 - 3x_i + 1, \quad x_i = 1,2,3... \end{aligned} \quad (6)$$

And the paging cost is

$$\begin{aligned} L_p &= k\lambda C_p \\ L_n &= k \end{aligned} \quad (7)$$

Since, it becomes

$$L_p = \lambda(3x_i^2 - 3x_i + 1)C_p \quad (8)$$

Sequential paging pages one cell or a group of cells after another in the LA. If the terminal is found in the m th ring in an LA consisting of x_i rings, the number of cells paged is

$$\begin{aligned} L_n &= 1 + \sum_{h=1}^{m} 6(h-1) \\ &= 1 + \sum_{h=1}^{m} 6(h-1) \leq 3x_i^2 - 3x_i + 1, m \leq x_i, \quad x_i = 1,2,3... \end{aligned} \quad (9)$$

So the paging cost of the sequential paging is

$$L_p = k_p \lambda C_p \quad (10)$$

Here k_p is the number of cells searched and $L_p = k_p$

Therefore,

$$L_p = \lambda C_p \left[1 + \sum_{h=1}^{m} 6(h-1)\right] \leq \lambda(3x_i^2 - 3x_i + 1)C_p \quad (11)$$
$$m \leq x_i, \; x_i = 1,2,3..$$

2.3 Cost analysis of VDLA

VDLA consists of two phases. In the first phase a terminal is assigned two VLAs as in Figure 2. The primary LA is allocated so that the current cell is the center of the LA as in FLA. And the secondary cell is allocated so that the current cell is one of the boundary cells of the LA as in DBLA.

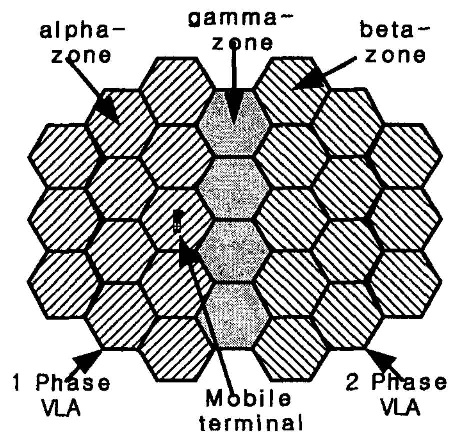


Figure 2. Virtual LAs 1

For each terminal to be allocated LA, VDLA computes an LA selection criterion T_m. It is computed based on the mobility of the terminal. Then the terminal selects one of the VLAs using the LA selection criterion.

LA selection criterion is the expected time for the terminal to travel a predefined distance m_b The probability density function $f_R(t)$ of the time for a terminal with speed v to travel a distance m_b is as follows[3].

$$f_R(t) = \int_0^{\infty} \frac{v^2 t}{m_b\sqrt{m_b^2-(tv)^2}} \frac{vf(v)}{E[V]} dv = \frac{1}{m_b E[V]} \int_0^{\frac{R}{t}} \frac{v^3 t}{\sqrt{m_b^2-(tv)^2}} f(v)dv \quad (12)$$

Therefore the average time $E_R[t]$ that a terminal travelsis m_b as in (13) and $T_m = E_R[t]$.

$$E_R[t] = \int_0^{\infty} tf_R(t)dt = \frac{1}{m_b E[V]} \int_0^{\infty} \int_0^{R/t} \frac{v^3 t^2}{\sqrt{m_b^2-(tv)^2}} f(v)dvdt = \frac{\pi m_b}{4E[V]} \quad (13)$$

The second phase is final LA selection phase. After allocated VLAs in the first phase, the terminal selects one of the VLAs Using T_m. If the terminal goes out of the secondary VLA within T_m, the primary VLA is selected as the final LA of the terminal. If the terminal is in the $\alpha-zone$ (Figure 2) after, T_m, the primary VLA is selected and if it is in the $\beta-zone$, the secondary VLA is selected. If it is in the $\gamma-zone$, either primary or secondary VLA is selected with the same probability. Once the LA is decided, the terminal registers its location through DBLA scheme. Thus in VDLA, location update is performed for the finally selected LA. The location update cost of VDLA is

$$\frac{E[V]}{0.866(2D+1)r} \le C_{l\_VDLA} \le \frac{E[V]}{0.866(2D-1)r} \quad (14)$$

VDAL uses sequential paging. Paging sequence is determined based on the terminal velocity v and moving time t of the terminal. If paging is to be done before T_m, it is done on the primary VLA. If paging is to be done after T_m, it is done on the selected LA. Paging mechanism tries to guess the cell where the terminal resides at the time of paging. Paging starts at one of the guessed cells farthest from the original location of the terminal and it proceeds to the nearer cells. Location prediction parameter $\phi(=x_i)$ is computed as in (15).

$$\phi = (tE[V]/2r)+1 \quad (15)$$

And the number of cells paged is as follows.

$$L_n = 1 \qquad if\ x_i = 1$$
$$6(\phi-1) \le L_n \le 3x_i^2 - 3x_i + 1, \quad \phi = x_i, x_i-1, x_i-2 \ldots 1 \qquad if\ x_i > 1 \quad (16)$$

Paging is done from the outermost ring of the LA to the inner rings. And the paging cost is as follows.

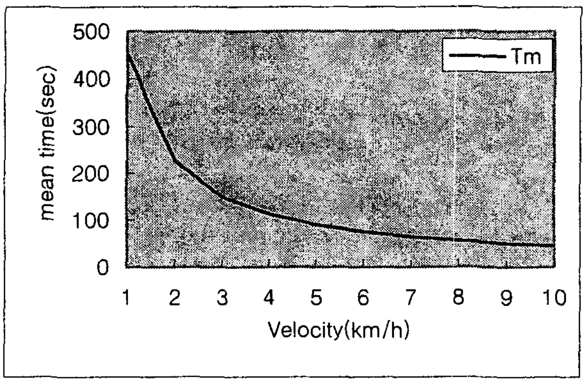
$$6\lambda(\phi-1)C_p \le L_p \le \lambda(3x_i^2 - 3x_i + 1)C_p, \quad \phi = x_i, x_i-1, x_i-2 \ldots 1\ if\ x_i \ge 2 \quad (17)$$

3. Numerical Analysis Footnotes

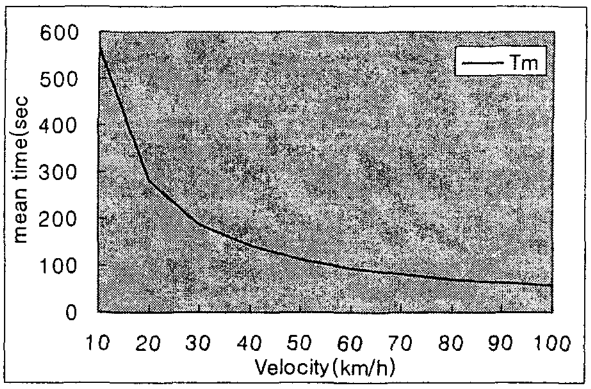
We assume micro/macrocell environments and that paging cost per cell (C_p) equals to 1. And we also assume that distance D in DBLA and VDLA equals to x_i. Figure 3 shows T_m obtained from eq. (13). In Figure 3a, terminal velocities are 1 ~ 10 km/h and the cell radius is 800 m. And in Figure 3b velocities are 10 ~ 100 km/h and cell radius is 1 km. In both cases is assumed to be twice the cell radius. Figure 4 shows total location management costs of FLA, DBLA and VDLA. In Figure 4a, terminal velocity of 10 km/h, cell radius of 80 m, and $\lambda = 0.5$ are assumed. In Figure 4b, 100 km/h, 1000 m, and 0.5 are assumed respectively. LA size is assumed to be less than 20 cells. In Figure 5 total costs are plotted against cell arrival rates. Here terminal velocity of 10 km/h, cell radius of 100 m, and LA size of 10 are assumed.

4. Concluding remarks

We propose a dynamic location management scheme and named it Virtual Dynamic Location Area(VDLA) scheme. In the first phase of the location update, primary and secondary VLAs are allocated to a terminal. And one of them is selected in the second phase depending on the terminal mobility. Therefore VDLA provides more flexibility and adaptability in allocating LAs than FLA and DBLA. Location update is followed by sequential paging process. Location prediction based on the terminal velocity and moving time is used to determine the most probable cells. Paging starts from the most probable cells. Analysis results show that as LA size increases VDLA's cost becomes much lower than those of FLA and DBLA.

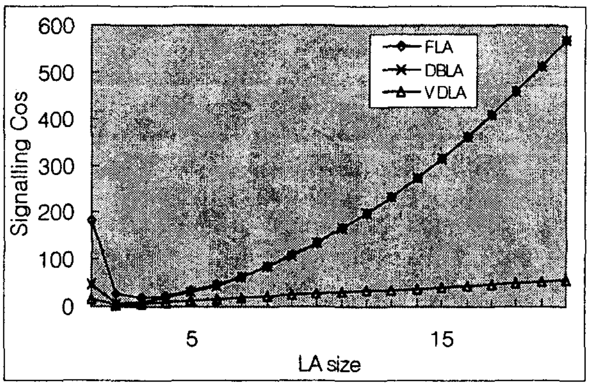


(a)

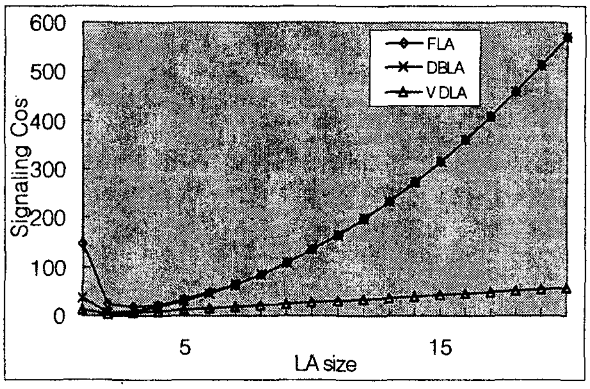


(b)

Figure 3. T_m vs. terminal velocity



(a)



(b)

Figure 4. Total location management costs

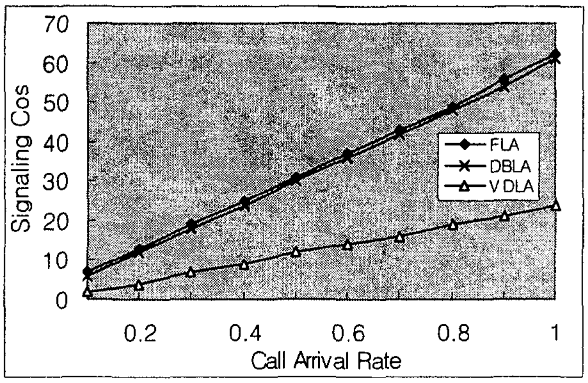


Figure 5. Total cost vs. call arrival rate

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