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Angular Paging in Distance-based Location Registration in Mobile Communication

Jaeyoung Seo*
College of Business and Management
Life University, Cambodia

***Abstract* — In this study, we proposed a new paging method, angular paging, that reduces the paging cost in distance-based location registration (DBR). DBR causes a mobile station (MS) to register its location when the distance between the current base station and the base station in which it last registered exceeds a distance threshold d. When MS travels longer distance and registers a new location area, it tends to move along with dominant angle. In order to apply this dominant angular movement, we suggested new paging method and showed that the proposed angular paging always outperforms the conventional whole paging.**

***Keywords* — Distance-based location registration, angular paging, communication system operations and management, mobile communication, paging cost**

I. INTRODUCTION

In mobile communication, location registration is the process by which the Mobile station notifies the system of its location, status and other characteristics. The MS informs the system of its location and status so that the system pages the MS efficiently, when establishing an MS-terminated call. It is known that there is a trade-off between paging rate and registration rate.

Without registration, the system will not know where the MS is. Then the paging rate is relatively high since system has to page every location areas. On the other hand, frequent registrations allow system to know the exact location of MS and need little paging load. However frequent registrations place a high load in wireless resources. Thus, many researches focus on the optimal location registration methods.

There are several location registration methods were proposed. System updates and processes location registration with certain criteria; in zone-base registration (ZBR) whenever the MS enters a new zone and in distance-based registration (DBR) whenever the MS moves more than a certain distance. In DBR, if a MS goes across the location area then new location area is made as a circle with radius r and sends location registration notification message to the system.

This study presents the characteristics of DBR and suggests new paging method that saves wireless resource.

II. PAGING METHODS

A efficient paging method is one of the most important roles with the aspect of saving wireless resource management in mobile communication.

Ring-structured paging has been widely used in various location management study [1]-[4]; in brief, upon call arrivals, the paging signals is sent ring to ring to all cells surrounding the last updated cell in a shortest distance first order. And system connects between caller and callee. In ring-structured paging, there are two conventional paging methods in ring-structured paging: selective paging method and whole paging method. In selective paging method, when considering delay constraints, we define a maximum paging delay of 2 to mean that the system must be capable of locating the called MT after at most 2 pooling operations so the whole location area is divided into 2 sub-paging areas. In whole paging method, the delay constraints are not considered and therefore the whole location area is not divided into sub-areas. When a call arrives, the system will page all cells within the whole location area.

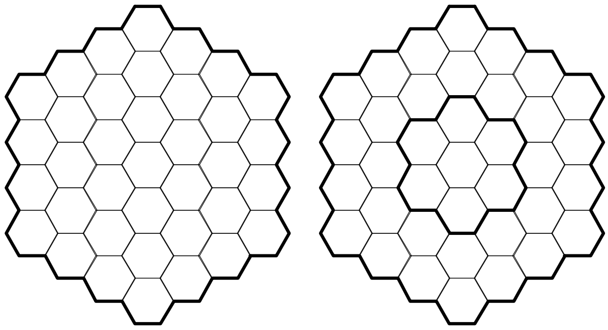

Fig. 1 Whole paging and selective paging in hexagonal ring-structure(when d =4)

Line-paging was proposed in [5]. When a call arrives, the system will sequentially page the location with MT's moving line until the MS is found.

III. DISTANCE-BASED LOCATION REGISTRATION AND ANGULAR PAGING

1D-random walk models and 2D-random walk models were suggested [2] to analyze the characteristic of the DBR. They assumed that MS moves to a distance with an angle. It means that the moving angle is not influenced from other factors, and is completely random. In real situation, it is not correct in DBR. Because of its own characteristic, a MS in DBR has different patterns when the moving distance is relatively longer. If a MS moves a longer distance then MS moves with dominant angle that violates the degree of randomness in moving.
This motivates this study; first we analyze the DBR and find out the characteristics of dominant angle, and secondly we suggest angular paging in DBR.

A. MOVING CHARACTERISTICS IN DISTANCE-BASED LOCATION REGISTRATION

Whenever MS exceeds the distance threshold, MS sends location registration message with current location information. System defines new location area with circle-shape, and MS moves the rest of moving distance. It is drown in Fig. 2 below. MS is now point $X(x_1, y_1)$ and moves distance to the point $Y(x_2, y_2)$.

MS is now point $X(x_1, y_1)$ and moves distance to $Y(x_2, y_2)$. First, MS moves to the border with distance s, and if distance is longer than s, then system makes new location area having radius r. Secondly, MS goes the rest of moving distance(distance – s).

Whenever MS moves right after location registration, it sets the point of contact between line and circle as new origin coordinates and goes from the origin coordinates to the rest (distance – s) with the same angle.
In random walk model, mesh-cell or hexagonal-cell was focused and assumed that MS moves one of four or one of six neighbourhood cell. And the probability to move to the next neighbour cell is same as 1/4 or 1/6. These assumptions are easy to analysis with mathematical method with queuing theory. The probability of moving from r-1 ring to r ring was used for the calculating location registration cost [2, 3]

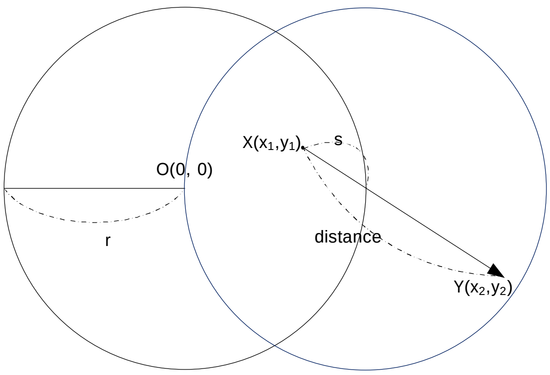

Fig. 2 Moving to the border of current location area and making new location area

In order to analysis the individual movement of MS, let us calculate the distance to the border. As shown in Fig. 3, MS is moving down from the current position $X(x_1, y_1)$ with angle θ. If a line is passing a point with angle θ, then the linear equation is calculated like below;

$$
\begin{aligned}
& ax_1 + by_1 + c = 0 \\
& a = \tan(\theta) \\
& b = y_1 - ax_1 = y_1 - a\tan(\theta) \\
& c = -ax_1 - by_1
\end{aligned}
\quad (1)
$$

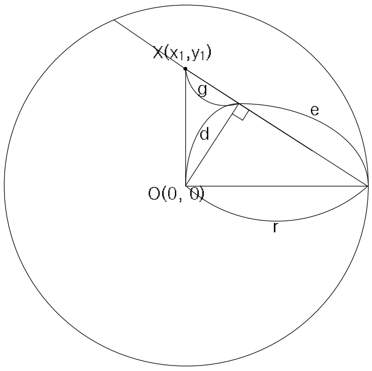

Fig. 3 Distance to the Example of an unacceptable low-resolution image

In the case of a line in the plane given by the equation ax+by+c = 0, the distance from the line to the origin coordinates (0, 0) is

$$d = \frac{|c|}{\sqrt{a^2 + b^2}} \quad (2)$$

The line segment s was divided to e and g. By Pythagorean Theorem, two right triangles have equations like below

$$(x_1^2 + y_1^2) = d^2 + g^2 \quad (3)$$

$$e = \sqrt{r^2 - d^2} \quad (4)$$

The distance to the border s is

$$s = e + g = \sqrt{r^2 - d^2} + \sqrt{(x_1^2 + y_1^2) - \frac{c^2}{(a^2 + b^2)}} \quad (5)$$

Our presented DBR is presents in pseudo code like below;

```
Initialize (x1, y1) to (0,0)   #current position
Initialize s to zero           #distance to the border
Initialize x to zero           #moving distance
Initialize TM to zero          #total moving distance
Initialize angel to zero       #angle with moving
Initialize N to zero           #number of location registration

Input K as expected moving distance

While the user reaches 24Hr tour
    Input x between (0, 2K)
    Input angle between (0, 360o)
    Calculate s with Eq. 5
    if s > x
        Calculate new coordinate(x2, y2)
        Set (x1, y1) into(x2, y2)
    else
        Calculate how many times of the location registration happens Ni
        Add N into N+Ni
        Calculate new coordinate (xn, yn)
        Set (x1, y1) into (xn, yn)
    end if
    Add TM into TM + x
Print N, TM
```

B. DOMINANT ANGLE IN DISTANCE-BASED LOCATION REGISTRATION

In our study we assumed MS goes with random angle at the point of tuning position. However, MS travel to the longer distance, it has tendency to move to the dominant direction. As shown in Fig. 2, first MS moves from X to the border (s) and continues to move on the rest part (distance –s) with the same angle. Whenever MS across the border, MS always travels from the new origin coordinates to the rest with the same direction. We call this the dominant angle movement. In order to analyze this dominant angle movement, we suggest like below;

Whenever MS sent registration message to the system, MS sends current moving angle with location information.

When a call is originated to a particular MS, system pages base stations along with the informed angle. If there is no response, then system page the rest of base stations in location area.

The travel time interval with the same angle after location registration (γ) is measured. If d is 5 and MS moves as following uniform distribution with mean(μ), then γ is result from simulation like Table 1.

TABLE I
TRAVEL TIME INTERVAL WITH SAME ANGLE AND MEAN VALUE

μ	1	2	3	4	5	6	7
γ	0.04	0.12	0.20	0.27	0.36	0.43	0.49

We call this angular paging method in DBR as AP in DBR. Let c_p, d denote the unit paging cost and the maximum number of rings then paging cost for AP in DBR is presented like this;

$$paging\ \mathrm{cost}_{AP} = d \times c_p \times \gamma + (1 + \sum_{k=1}^{d-1} 6k - d) \times c_p \times (1-\gamma) \quad (6)$$

Whereas the paging cost for whole paging is below;

$$paging\ \mathrm{cost}_{Wh} = (1 + \sum_{k=1}^{d-1} 6k) \times c_p \quad (7)$$

Fig. 4 gives a comparison of paging costs with varying the number of ring up to d=7. Both angular paging and whole paging of DBR are compared for given condition that c_p is 1.

As expected, the angular paging in DBR always performs better than whole paging. If the expected moving distance and the number of ring is the same as 3, the performance of the angular paging cost is almost half of whole paging cost.

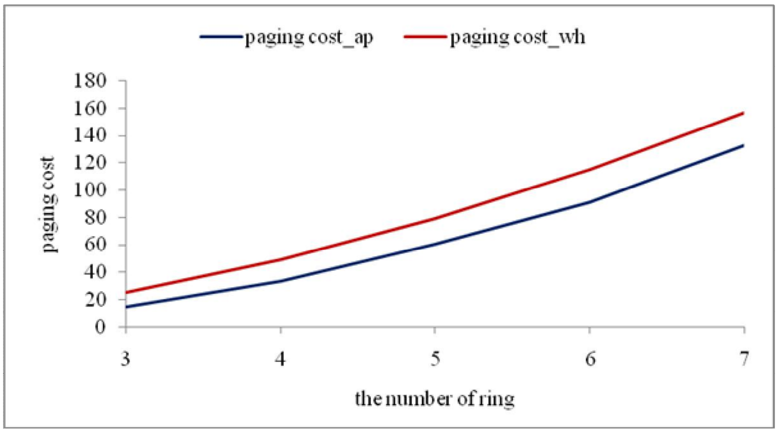

Fig. 4 Paging cost comparison of varying the location area (when expected moving distance is 3)

Fig. 5 demonstrates that whole paging on the same size of location area is same. However angular paging is decreasing as expected moving distance is larger. It means as MS moves longer distance then MS tends to move along with dominant current direction.

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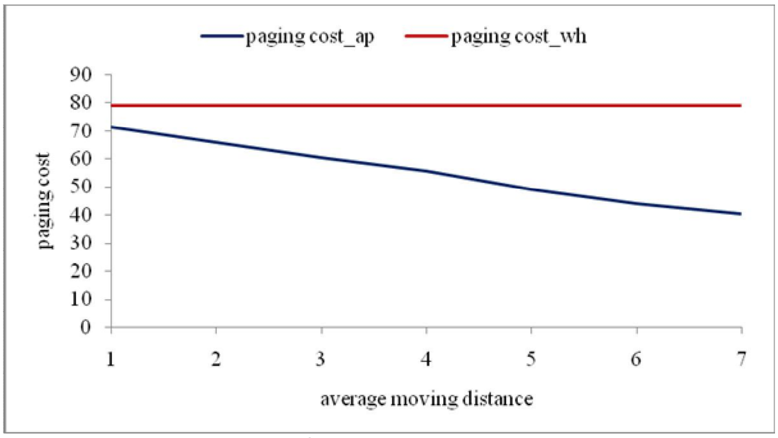

Fig. 5 Paging cost comparisons for varying the average moving distance (d=5)

IV. CONCLUSIONS

This study presented the distance-base location registration method and found the characteristics of MS movement. With mathematical approach, we reviewed DIR with 360 degree movement. We also found that MS tends to move the dominant angular movement when it travels longer distance.

As moving distance is longer with the same direction, the portion of dominant angular movement is larger. It means that when MS travels longer distance without changing directions, the suggested angular paging has better performance than the conventional whole paging, and the results were shown as we expected.

When we use this angular paging method in outskirts of town or high way, the performance would be best.

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