A NEW MACROCELL/MICROCELL SELECTION METHOD IN MULTITIER CELLULAR SYSTEM

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Abstract – In this paper, we propose a new macrocell/microcell selection scheme in multitier cellular system using sojourn time of microcell overlapped region. The proposed scheme has many advantages such as good performance when direction of the MT is varying, efficient user allocation to cells, capability of relatively accurate velocity estimation, easy implementation and low power consumption. Also, comparing the analysis and simulation results with conventional methods, we found that the proposed scheme has better performance than conventional schemes.

I. INTRODUCTION

To provide multimedia services and to support increasing users, the IMT-2000 system is to use a microcell whose diameter is a few hundred meters. By using such a microcell, we can increase the capacity of the system. However, in a microcell system, the number of handoff increases greatly. In the IMT-2000 system, the multitier cellular structure which consists of microcell clusters overlaid with macrocell is noticed as a powerful solution[1]. In this structure, high speed Mobile Terminal (MT)s are serviced in the macrocell and low speed MTs are serviced in the microcell to minimize the number of handoff. And it is important to estimate the speed of the MT precisely for the purpose of selecting macrocell/microcell exactly.

II. EXISTING METHODS

There are various conventional speed estimation methods such as method using Rayleigh fading and method using cell sojourn time. The method using Rayleigh fading has relatively good performance in non-noise circumstances but in real environments, its estimation is badly incorrect. The method using cell sojourn time works without any added H/W (Hardware), and can be easily implemented. Among these methods, we use the method using sojourn time. This method can be classified into three schemes: The Residual Dwell Time scheme (scheme 1)[2], the Power Level Offset scheme (scheme 2)[3], and the Exponential Averaging scheme (scheme 3)[4]. All these schemes select cells by comparing sojourn time with predefined threshold time. The difference among these three schemes is the sojourn time measuring region.

Scheme 1 uses the residual microcell sojourn time of the MT after call origination. The call is handoffed to a microcell or a macrocell based on the amount of time the call is set up in the originating cell until a handoff is required. But the call holding time of the MT in call originating cell does not accurately reflect the speed of the MT because it depends on where the call was originated in the microcell. And the probability of erroneous assignment to macrocell/microcell is high. But this scheme can be easily implemented.

Scheme 2 applies a specific negative offset to the received power level for a specified time period when the MT is entering a microcell and selects macrocell/microcell by comparing call origination time with the specified time period. This scheme also can be easily implemented, but has high probability of erroneous assignment to macrocell/microcell.

In scheme 3, the MT tracks its microcell sojourn time even when it is idle and cell selection is based on the estimated local mean of the sojourn times. This scheme can select cells relatively accurately but has some disadvantages such as complex implementation. Also, in order to get a good performance, the MT must pass sufficient numbers of microcell. In the
recent environments that a power of more than 50% the MTs is off, this property is fatal disadvantage.

In this paper, we propose a new cell selection method using cell sojourn time.

III. PROPOSED SCHEME

In this paper, we propose a new macrocell/microcell selection scheme in multitier cellular system. The proposed scheme selects cells based on the sojourn time of microcell overlapped region such as handoff region. The detecting way of the sojourn time measuring region is the same as that of the handoff region in conventional handoff algorithm. Call origination is first assigned to a microcell. After a call originates, the MT starts the measuring of the overlapped region sojourn time (ORST) when it enters the overlapped region. When a call originates in the overlapped region, the MT measures sojourn time until it arrives at the boundary of overlapped region. In this case that the MT originates call, it receives maximum four paging signals from microcell base stations. The microcell sending the strongest paging signal is determined to be a source microcell and the microcell sending the second strongest paging signal is determined to be a target microcell. The target microcell can be changed if strength of paging signals received from the microcell base stations are changed but the source microcell is unchangeable.

The selection of cell is determined when the MT arrives at the boundary of the source microcell. After cell selection, the MT handoffs to the target microcell or its locating macrocell. If the measured ORST is longer than the threshold time, the MT is estimated to be a low-speed mobile and handoffed to a microcell. Otherwise, the MT is estimated to be a high-speed mobile and handoffed to a macrocell.

The proposed scheme has many advantages. First, we can get good performance not only in the case that MT moves without changing direction but also in the case that direction of the MT is varying. When a fast moving MT changes its direction, the sojourn time of the MT will be long and the MT is regarded as having low speed. The smaller the sojourn time measuring region, the lower the probability of changing direction in that region.

Besides, this scheme allocates users(traffics) to macrocell/microcells efficiently. The capacity of a macrocell is much smaller than that of embedded microcells of the macrocell in the multitier structure. By making the MT to select cells when they are to handoff, we allocate to macrocell only fast moving MTs which requires handoff and can minimize blocking probability of macrocell.

Also, the proposed scheme can be implemented easily and consumes low battery power by reducing the MT’s load. However, when the speed of the MT varies enormously, this scheme has a disadvantage because the sojourn time measuring region is small.

IV. ANALYSIS AND SIMULATION

We analyze and simulate the performance of proposed scheme and compare the results of the proposed scheme with those of existing schemes. Among the existing schemes, we exclude scheme 3 for a fair comparison because scheme 3 is different from other two schemes and the proposed scheme in the view of measuring methodology of sojourn time. For simplifying the analysis and simulation, we define the model as follows:

- Cells are circular with radius R
- The MTs are uniformly distributed in the system
- When the MT moves without changing its direction, the direction is distributed uniformly between $[0, 2\pi)$
- When the MT moves with changing its direction, the direction varies with exponentially distributed interval and is distributed uniformly between $[0, 2\pi)$
- The speed of the MT is assumed to be fixed.

To analyze the proposed scheme when the MT moves without changing its direction, we analyze the overlapped region first. Fig. 1 shows an overlapped region. Let $\phi$ and $\theta$ be i.i.d random variables and
Table 1: The probability of erroneous assignment in the case of moving direction not being changed

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>2</th>
<th>6</th>
<th>10</th>
<th>Ave</th>
<th>14</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme 1(A)</td>
<td>0.090</td>
<td>0.268</td>
<td>0.441</td>
<td>0.325</td>
<td>0.396</td>
<td>0.396</td>
</tr>
<tr>
<td>Scheme 1(S)</td>
<td>0.090</td>
<td>0.268</td>
<td>0.442</td>
<td>0.326</td>
<td>0.399</td>
<td>0.399</td>
</tr>
<tr>
<td>Scheme 2(A)</td>
<td>0.090</td>
<td>0.268</td>
<td>0.441</td>
<td>0.325</td>
<td>0.396</td>
<td>0.396</td>
</tr>
<tr>
<td>Scheme 2(S)</td>
<td>0.090</td>
<td>0.268</td>
<td>0.442</td>
<td>0.326</td>
<td>0.399</td>
<td>0.399</td>
</tr>
<tr>
<td>Proposed Scheme(A)</td>
<td>0.044</td>
<td>0.153</td>
<td>0.366</td>
<td>0.235</td>
<td>0.367</td>
<td>0.367</td>
</tr>
<tr>
<td>Proposed Scheme(S)</td>
<td>0.044</td>
<td>0.154</td>
<td>0.366</td>
<td>0.236</td>
<td>0.365</td>
<td>0.365</td>
</tr>
</tbody>
</table>

A: Analysis Result
B: Simulation Result

uniformly distributed between $[-\frac{\pi}{6}, \frac{\pi}{6}]$. Let base station of the source cell be located in $(0,0)$ and the distance between A and B be $Z$. The coordinate of A and B as well as the value of $Z$ are given by

$$
A = R(\cos \theta, \sin \theta), (-\pi/6 \leq \theta \leq \pi/6)
$$

$$
B = R(\sqrt{3} - \cos \phi, \sin \phi), (-\pi/6 \leq \phi \leq \pi/6)
$$

$$
Z = R \sqrt{(\cos \theta + \cos \phi - \sqrt{3})^2 + (\sin \theta - \sin \phi)^2}
$$

$$
, (0 \leq Z \leq R)
$$

Then, the mean of $Z$ can be found as

$$
E[Z] = \int_{\theta} \int_{\phi} R \sqrt{(\cos \theta + \cos \phi - \sqrt{3})^2 + (\sin \theta - \sin \phi)^2} \cdot f_{\theta+\phi}(\theta, \phi) d\theta d\phi
$$

(2)

Let the distance $Z$ and velocity $V$ of the MT be i.i.d random variable. So, the mean of ORST is found to be

$$
E[T_h] = E[Z]E[\frac{1}{V}]
$$

$$
E[T_h^2] = E[Z^2]E[\frac{1}{V^2}]
$$

$$
T_h = \frac{Z}{V}
$$

(3)

Assume the ORST has a Gaussian distribution. Then the pdf of $T_h$ is given by

$$
f_{T_h}(t) = \frac{1}{\sqrt{2\pi}σ_{T_h}} e^{-[(t-E[T_h])/2σ_{T_h}]^2}
$$

(4)

Then, $P_{em}$, $P_{eu}$ and the threshold time $\tau_0$ can be obtained as

$$
P_{em} = F_{T_h}(\tau_0)
$$

$$
P_{eu} = 1 - F_{T_h}(\tau_0)
$$

$$
\tau_0 = \frac{E[Z]}{V_t}
$$

(5)

where $V_t$ is the threshold velocity.

MTs are consisted of vehicles and pedestrians. In the method based on sojourn time, all pedestrians are allocated to microcell without any erroneous assignment because the speed of pedestrian is almost 0 and the sojourn time is almost infinite. So, we analyze and simulate about only vehicles. In our analysis and simulation (10,000 samples), we assume that $R=300$m, $V_{th}=12$m/s and the MTs have the speeds such as $v_1=2$m/s, $v_2=6$m/s, $v_3=10$m/s and $v_4=14$m/s with a probability at 0.1, 0.4, 0.4 and 0.1, respectively. In the case of changing direction, the direction of the MT varies after the interval distributed exponentially with a mean of 1 sec.

Analysis and simulation results for the case of direct-moving and changing-direction are summarized in TABLE 1 and TABLE 2. In TABLE 1, 'A' means the analysis result and 'B' means the simulation result. $P_{em}$ means the probability that the slow MT is allocated to macrocell and this gives rise to the shortage of macrocell capacity. $P_{eu}$ means the probability that the fast MT is allocated to microcell and this causes the increase of handoff number. From these results, we found that the proposed scheme has better performance than existing schemes. When the MT moves without changing direction, the proposed scheme has about 33% lower probability of erroneous cell assignment than the conventional schemes. When the MT moves with changing direction, the proposed scheme has about 25% lower probability of erroneous cell assignment than the conventional schemes.
Table 2: The probability of erroneous assignment in the case of moving direction being changed

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>$P_{em}$</th>
<th>$P_{ep}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme 1</td>
<td>0.118</td>
<td>0.301</td>
</tr>
<tr>
<td>Scheme 2</td>
<td>0.118</td>
<td>0.301</td>
</tr>
<tr>
<td>Proposed Scheme</td>
<td>0.050</td>
<td>0.196</td>
</tr>
</tbody>
</table>

V. NUMERICAL EXAMPLE

Based on the results shown in TABLE 1 and TABLE 2, we calculate the blocking probability in this system. Let the number of channels per macrocell and microcell be 10 respectively. Assume no channel reservation for handoff calls. Let the call holding time be exponentially distributed with a mean of $\frac{1}{\lambda_m} = 120s$. Let $B_m$ and $B_{\mu}$ be the call blocking probability in macrocell and each microcell and $\lambda_m$, $\lambda_{\mu}$ be the actual call arrival rate to each microcell and macrocell after cell selection. Let the load of a macrocell and its embedded microcell be the same in the case of vehicle traffic. All the pedestrian traffics are allocated to microcell with 100% probability. Because most of the pedestrian traffics have the speed of zero and the sojourn time of zero-speed MT is infinity.

We calculate the blocking probability with changing the total call arrival rate and the ratio of the vehicle and the pedestrian traffic. For example, if the total call arrival rate to a macrocell and its embedded microcells is 1500 calls/h and the ratio of the vehicle and pedestrian traffic is 2:1, the call arrival rate of the vehicle traffic is 1000 calls/h and that of the pedestrian traffic be 500 calls/h. And the load of a macrocell is 91 calls/h and the load of microcell is 141 calls/h which consists of 91 calls/h for vehicle and 50 calls/h for pedestrian.

From these assumptions, the actual call arrival rates to the macrocell and each microcell are

$$\lambda_m = 100(1 - P_{ep}) + 900P_{em}$$  \hspace{1cm} (6)
$$\lambda_{\mu} = 10P_{ep} + 90(1 - P_{em})$$  \hspace{1cm} (7)

$B_m$ and $B_{\mu}$ are obtained by using the Erlang-B formula. First, we calculate $B_m$, $B_{\mu}$ with changing the total call arrival rate from 500 calls/h to 3000 calls/h. The results show that the blocking probability increases as the total arrival rate increases as shown in Figure 2 and Figure 3. In these figures, 'D' means the case that the MT moves directly and 'C' means the case that the MT changes its direction.

Then we calculate $B_m$, $B_{\mu}$ with changing the ratio of the vehicle and the pedestrian traffic. The results show that the blocking probability in macrocell decreases and the blocking probability in microcell increases as the rate of pedestrian traffic increases as shown in Figure 4 and Figure 5. That's because, as the rate of pedestrian traffic increases, the traffic load of macrocell decreases and the traffic load of microcell increases.

These figures show that the proposed scheme has lower blocking probability of macrocell than the conventional schemes and higher blocking probability of microcell than the conventional schemes. We also found that $B_{\mu}$ is almost zero. This means that more users are allocated to microcell in the proposed scheme. Because the capacity of the macrocell is much smaller than that of the macrocell’s embedded microcells, it is evident that the proposed scheme al-
VI. CONCLUSIONS

This paper proposes and describes a new cell selection method in multitier cellular system. The proposed scheme has many advantages such as good performance when direction of the MT is varying, efficient user allocation to cells, capability of relatively accurate velocity estimation, easy implementation and low power consumption. To verify that the proposed scheme has a good performance, we analyzed and simulated the probability of erroneous assignment to macrocell/microcell and compared the analysis and simulation results of the proposed scheme with those of existing schemes. Using these results, we calculated the blocking probability when the total call arrival rate and the ratio of traffic varies. We found that proposed scheme has lower probability of erroneous assignment and better blocking performance than the conventional schemes.

REFERENCES

(5) K. S.Meier-Hellstern et al., "The use of SS7 and GSM to support high density personal communications," in Proc ICC'92, 1992