Mobile Positioning Technique Based on Timing Advance and Microcell Zone Concept for GSM Systems

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Mobile Positioning Technique Based on Timing Advance and Microcell Zone Concept for GSM Systems

Khalid G. Samarah

Abstract – This paper aims to present an approximate location of a Mobile Station (MS) in Microcell zone concept in GSM system based on retrieving the Timing Advance (TA) from the Base Station (BS). In microcell concept, three or more zone sites are connected to a single BS and share the same radio equipment. Therefore, a MS travels within the cell uses the same frequency band assigned to the cell and served by the zone site with the strongest signal. Unlike sectoring, this method requires no additional hardware and a handoff procedure is not required at the Mobile Station Controller (MSC) when the MS travels between different zones within the same cell. The base station switches the channel to the next zone site. This algorithm is very useful for measuring the TA by the MSC while the MS is at the idle mode, since the BS can switch the channel to a different zone. By doing so and measuring the TA at each time the channel is switched to the next zone, a promising mobile positioning technique can be determined. Matlab simulation based location results and measurements statistics are also provided as MS coordinates, distances from the zone sites and the angles between the MS position and the zone sites. These results using the direct solution approximated the error in calculating the distances between the MS and the zone sites to values between 100 – 133 meters. Copyright © 2016 Praise Worthy Prize S.r.l. - All rights reserved.

Keywords: Cellular Systems, GSM, Microcell Zone, Positioning, Timing Advance (TA)

I. Introduction

Localization of MS’s had been required in the recent years by the FCC (United States Federal Communications Commission) for mobile callers requesting emergency assistance via 911 [1]. Since that time localization of mobile stations (MS) plays an important rule of today’s research area.

The development in cellular communication systems from analogue to digital and the improvement in the data rates as well as the need for mobile multimedia communications arises more capabilities in the cellular network to locate the MS. In this research, positioning the MS in GSM network is presented using new technique that combines the microcell zone concept with the Timing Advance where all mobile position estimation technologies define a locus on which the mobile phone must lie [2]-[6]. A review of different location estimation techniques are presented in [4], [7]. These techniques are based on determining the distance from the mobile to the BS or finding the direction of the MS relative to the BS where the combination of these two techniques estimates the position more accurately. Such techniques are summarized by Received Signal Strength Indication (RSSI), Time of Arrival (TOA), TDOA (Time Difference of Arrival), OTD (Observed Time Difference of Arrival), E-OTD (Enhanced Observed Time Difference of Arrival), AOA (Angle of Arrival), Timing Advance (TA) and Round Trip Time [8]-[12].

The document in [13] examines the possibilities of locating the MS making as few changes as possible to the GSM network and the MS. One of the several ways of implementing the MS location in the GSM can be obtained with the cell identity (Cell ID) method. More accurate location estimate needed in the second and third phase can be based on the already measured Timing Advance (TA) measurement where its accuracy provides location accuracy of one kilometer. In some environments the measurement error caused by the reflected signal may however degrade the location accuracy considerably.

The paper in [14] has described the results of a GSM MS positioning technique in a real propagation environment. The results obtained show that, for the investigated scenarios, accuracy of few hundreds of meters can be achieved. This figure degrades if the estimation algorithm parameters do not fit well the characteristics of the real propagation environment. Furthermore, a forced handover is needed to measure the TA from the different sites used in the estimation.

In general, to reduce the overall positioning errors, improvements in accuracy and resolution of TA estimation algorithms are needed due to this paper.

In this paper, a method of positioning the MS based on a combination between Microcell Zone Concept and Timing Advance is presented. The TA positioning method is based on the existing Timing Advance (TA) parameter whose value is known for the BTS. To obtain
TA values a special call, not noticed by the GSM subscriber (no ringing tone), is set up.

The cell ID of the active cell and the TA is returned as the result of the TA positioning mechanism. This method requires no additional hardware [15], [16].

In order to locate the MS, TAs from the 3 BTSs must be retrieved. TAs are available only for the MSs in connected mode and only with respect to the assigned dedicated channel. In the GSM system, the only way to assign (sequentially) dedicated channels from different BTSs to the same MS (and then to collect TAs from 3 different BTSs) is to switch the communication from one BTS to another. The TA method can be applied with the desired MS using the "Forced Handover" technique [13]. In [14], [17], some indicative results of the performances characterizing a GSM Mobile Station location method based on Timing Advance (TA) are reported.

Using the Microcell Zone Concept combined with retrieving the TA break the tethers of using the "Forced Handover" technique since and advantage of this architecture is that when a MS travels from one zone to another within the cell it remains with the same frequency band. Therefore no handoff procedure is required at the MSC [18].

II. Microcell Zone Concept

William Lee in reference [18] presented a solution for the increased number of handoffs that are required when travelling between BS’s. This solution is based on a microcell zone concept for 7 cell reuse, as illustrated in Fig. 1.

In this concept, each one of the three zone sites or even more than three is connected to a single BS and share the same radio equipment. The zones are connected to the base station using coaxial cable, microwave link, or fiber optic cable making up a cell.

As the MS travels in the cell, it is served by the zone with the strongest signal. This technique is superior to sectoring since antennas are placed at the outer edges of the cell, and any BS’s channel may be assigned to any zone by the base station. Another advantage of this architecture is that when a MS travels from one zone to another within the cell it remains with the same frequency band as mentioned in the introduction.

Therefore no handoff procedure is required at the MSC. The base station simply switches the channel to the next zone site [18]. This algorithm is very useful for measuring the TA by the MSC while the MS is at the idle mode, since the BS can switch the channel to a different zone. By doing so and measuring the TA at each time the channel is switched to the next zone, a promising mobile positioning technique can be determined.

III. Timing Advance (TA)

Mobile signals suffer from time delay in multipath propagation channel, this result from the change in distance between the MS and the BS. The longest the distance the highest is the time delay [19], [20].

In the downlink, all MS’S are synchronized to a clock sent from the BS of interest. However, in the uplink, eight users shared one RF signal. If the mobiles are not accurately synchronized, data of users in TDMA frame will interfere with each other.

The process of finding the TA is that the BS detects a random access CCCH transmission or a message with a long guard period time on a TCH then measure the delay of this signal relative to the expected signal from an MS at zero distance. This delay, called the Timing Advance (TA), is rounded to the nearest bit period and included in a response from the BS when applicable [21].

The timing advance steps are included in 6 bit ordered binary code. These 6 bits assign decimal number values from 0 to 63 in the message IMMEDIATE ASSIGNMENT for all GSM bands [22].

Since TAs are integer numbers, an absolute distance measurement is calculated from the round trip propagation delays, which are rounded to the nearest integer bit period [23]. The bit period is obtained from the frame alignment in the GSM FDMA/TDMA access scheme and given by:

\[ T_b = 48 / 13 \mu s = 3.6923 \mu s \]  \hspace{1cm} (1)

The distance corresponding to the bit period is given by,

\[ \Delta = T_b \cdot c = 1108 \text{ m} \]  \hspace{1cm} (2)

where \( c \) is the speed of light. Thus, the distance for the MS is half the round trip distance modified by the integer number of TA as follows:

\[ d_{TA} = TA \cdot \Delta / 2 = 554 \times TA \text{ m} \]  \hspace{1cm} (3)

As stated in reference [22]; “the immediate assign information contains the complete IMMEDIATE ASSIGN message, which contains the following data:

a) The description of the assigned channel;
b) The information field of the CHANNEL REQUEST message and the frame number of the frame in which the CHANNEL REQUEST message was received;
c) The initial timing advance (TA);
d) Optionally, a starting time indication: “

Due to the unknown distance between the MS and the BTS, an extended guard period is used to compensate for propagation delay. It allows the access burst to arrive up to 68.25 bits later than it is supposed to without interfering with the next time slot. TA is also called a correction factor since it corrects the delay within this guard period.

A special burst type is used for this purpose is the Access Burst, which has the following format [24].

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>THE GSM RANDOM ACCESS BURST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit Number (BN) Length of Field</td>
<td>Contents of Field</td>
</tr>
<tr>
<td>0-7</td>
<td>8</td>
</tr>
<tr>
<td>8-48</td>
<td>41</td>
</tr>
<tr>
<td>49-84</td>
<td>36</td>
</tr>
<tr>
<td>85-87</td>
<td>3</td>
</tr>
<tr>
<td>88-156.25</td>
<td>68.25</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>THE COORDINATES OF THE ZONE SITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z_m (x_m, y_m)</td>
<td>x_m</td>
</tr>
<tr>
<td>Z_1</td>
<td>0</td>
</tr>
<tr>
<td>Z_2</td>
<td>-sqrt(3)/2</td>
</tr>
<tr>
<td>Z_3</td>
<td>sqrt(3)/2</td>
</tr>
</tbody>
</table>

### IV. Problem Statement and Mathematical Notation

This paper aimed to present an approximate positioning technique for finding the coordinates of the MS and the distance from a reference zone site.

The coordinates are calculated in 2D axis (i.e., x, y positioning) using mathematical analysis and a Matlab code. Comparison of the results helps in identifying the errors of distances and coordinates.

The mathematical notation and symbols that are used in this paper are illustrated in Fig. 2.

The fixed positions of the zone sites are labeled as (Z_m) where (m) refers to the mth zone site.

The coordinates of the zone beacon are labeled as (x_m, y_m), which are stand for the positions of the zone sites related to the center of the cell given as (0, 0).

For notational convenience, the coordinates of the zone sites are written as Z_m (x_m, y_m).

The approximate distance between the zone site and the MS is denoted as (r_m), whereas the exact distance is (original) denoted as (r_m). The individual coordinates of the MS, which are the unknown that are solved for in this paper, are denoted as (x, y) and the position of the MS is simply represented by P(x, y). The coordinates of the zone sites are assumed to be fixed for evaluating and testing the solution procedure in this paper are given in Table II. In this paper, approximate distance measurements from the different fixed zone sites are provided as follows:

1) Selecting the MS from the cell ID
2) Reading the TA by switching RF signal between the different zones
3) Calculating the approximate distances or radii between the zone position and the MS position by using the measured TA as follows (d_TA = 554TA m) as shown in section III.
4) Produce an equation for a circle whose radius is the value of (d_TA = 554TA m) and (d_TA+1 = 554(TA+1) m).
5) For a minimum of three zone sites, and two values of distances for each TA reading, eight different possibilities of coordinates are found, where the approximate coordinates and distances are the average value of them.
6) Solving the number of equations produced with trilateration algorithm to find the approximate coordinates and distances [10], [25], [26].

### V. TA-Zone Localization Concept

The obvious approach in solving this positioning problem is to treat the coordinates of the MS P(x, y) as the point of intersection of several circles, whose centers are the locations of the zone sites Z_m (x_m, y_m), where the distances between them (r_m) are the radii of the individuals circles; the equation of any of these circles is given as follows:

\[(x - x_m)^2 + (y - y_m)^2 = r_m^2 \] (4)

The equations of these circles are given as follows:

\[(x - x_m)^2 + (y - y_m)^2 = r_m^2 \]
\[x^2 + x_m^2 - 2x x_m + y^2 + y_m^2 - 2y y_m = r_m^2 \] (5)
\[2(xx_m + yy_m) = x^2 + y^2 + y_m^2 - r_m^2 \]

The sum given as \((x_m^2 + y_m^2 = R^2)\), thus Eq. (5) is rewritten as follows:

\[2(xx_m + yy_m) = x^2 + y^2 + R^2 - r_m^2 \] (6)
This system has \((k-1)\) equations, where \((k)\) is the number of zones and the centre of the cell as a reference, in two unknowns, therefore, theoretically only \((k=3)\) equations are needed to determine the unique position of the MS. These equations are given as follows:

\[
2(x_1 + y_2) = x^2 + y^2 + R^2 - r_1^2 \\
2(x_2 + y_2) = x^2 + y^2 + R^2 - r_2^2 \\
2(x_3 + y_2) = x^2 + y^2 + R^2 - r_3^2
\]  

(7)

The values of \(Z_m(x_m, y_m)\) are obtained from Table II as follows:

\[
2R_y = x^2 + y^2 + R^2 - r_1^2 \\
-\sqrt{3}R_x - R_y = x^2 + y^2 + R^2 - r_2^2 \\
+\sqrt{3}R_x - R_y = x^2 + y^2 + R^2 - r_3^2
\]  

(8)

Solving the three equations together as follows:

Subtracting the 2nd equation in Eq. (8) from the 1st one gives:

\[
2R_y - (-\sqrt{3}R_x - R_y) = \\
\left(x^2 + y^2 + R^2 - r_1^2\right) - \left(x^2 + y^2 + R^2 - r_2^2\right)
\]  

(9)

\[
3R_y + \sqrt{3}R_x = -r_1^2 + r_2^2
\]

Subtracting the 3rd equation in Eq. (8) from the 1st one gives:

\[
2R_y - (\sqrt{3}R_x - R_y) = \\
\left(x^2 + y^2 + R^2 - r_1^2\right) - \left(x^2 + y^2 + R^2 - r_3^2\right)
\]  

(10)

\[
3R_y - \sqrt{3}R_x = -r_1^2 + r_3^2
\]

Adding Eq. (9) to Eq. (10) that is, solving for \(y\) gives:

\[
3R_y + \sqrt{3}R_x + 3R_y - \sqrt{3}R_x = -r_1^2 + r_2^2 - r_1^2 + r_3^2 \\
6R_y = r_2^2 + r_3^2 - 2r_1^2 \\
y = \frac{r_2^2 + r_3^2 - 2r_1^2}{6R}
\]  

(11)

Subtracting Eq. (10) from Eq. (9) that is solving for \(x\) gives:

\[
3R_y + \sqrt{3}R_x - 3R_y + \sqrt{3}R_x = -r_1^2 + r_2^2 + r_1^2 - r_3^2 \\
2\sqrt{3}Rx = r_2^2 - r_3^2
\]  

(12)

\[
x = \frac{r_2^2 - r_3^2}{2\sqrt{3}R}
\]

From the above analysis, the coordinates of the intersection between the three circles is given by:

\[
(x, y) = \left(\frac{r_2^2 - r_3^2}{2\sqrt{3}R}, \frac{r_2^2 + r_3^2 - 2r_1^2}{6R}\right)
\]  

(13)

The distances between the MS and the zone sites using the TA values are given as follows:

\[
0 \leq TA \leq 63 \\
554TA_1 \leq r_1 \leq 554(TA_1 + 1) \\
554TA_2 \leq r_2 \leq 554(TA_2 + 1) \\
554TA_3 \leq r_3 \leq 554(TA_3 + 1)
\]  

(14)

Fig. 2 illustrates the cases where measuring the TA from one zone site and rounding it to the nearest bit period gives a range for possible position of the MS, this range is between TA and TA+1 values.

Assuming the maximum value of TA represents the distance between the zone site and the centre of the cell. For these values, we have eight possibilities (or cases) for the value of TA that is used in calculating the distance between the zone site and the MS. These possibilities are given in Table III.

<table>
<thead>
<tr>
<th>Case</th>
<th>(r_1 / 554)</th>
<th>(r_2 / 554)</th>
<th>(r_3 / 554)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TA_1</td>
<td>TA_2</td>
<td>TA_3</td>
</tr>
<tr>
<td>2</td>
<td>TA_1</td>
<td>TA_2</td>
<td>TA_3+1</td>
</tr>
<tr>
<td>3</td>
<td>TA_1</td>
<td>TA_2+1</td>
<td>TA_3</td>
</tr>
<tr>
<td>4</td>
<td>TA_1</td>
<td>TA_2+1</td>
<td>TA_3+1</td>
</tr>
<tr>
<td>5</td>
<td>TA_2+1</td>
<td>TA_3</td>
<td>TA_1</td>
</tr>
<tr>
<td>6</td>
<td>TA_2+1</td>
<td>TA_3+1</td>
<td>TA_1</td>
</tr>
<tr>
<td>7</td>
<td>TA_2+1</td>
<td>TA_3+1</td>
<td>TA_1+1</td>
</tr>
<tr>
<td>8</td>
<td>TA_2+1</td>
<td>TA_3+1</td>
<td>TA_1+1</td>
</tr>
</tbody>
</table>
The first estimated coordinates are given as follows:

\[
(x, y) = 554 \left( \frac{T_{A_2}^2 - T_{A_3}^2}{2\sqrt{6T_{A_{\text{max}}}}}, \frac{T_{A_2}^2 + T_{A_3}^2 - 2T_{A_1}^2}{6T_{A_{\text{max}}}} \right) \quad (15)
\]

At each combination, a different estimated coordination of the MS is found. The average value of the coordination could be the approximated position of the MS. The coordinates normalized to the distance (554 m) are shown in Table IV and Table V.

### VI. Simulation Results Analysis

The BS measures TA; in this analysis TA will be measured by assuming an actual coordinates and finding the distance between the Zone transmitter and the MS, which corresponds to the measured TA. Given that, all values are normalized to the value 554.

The Matlab code generates random values representing an MS location at \( P(x, y) \), where the radius of the cell is assumed to be \( R = 18 \).

The coordinates of the zone sites are given as follows:

\[
Z_1(0,18) \quad Z_2(-9\sqrt{3},-9) \quad Z_3(9\sqrt{3},-9) \quad (16)
\]

The mobile location found at \( P(-4.406, -5.8204) \) as shown in Fig. 3.
The original distances between the MS and the zone site is given as follows:

\[ r_{1o} = \sqrt{(-4.406 - 0)^2 + (-5.8204 - 18)^2} = 24.2244 \]

\[ 24 \leq r_{1o} \leq 25 \]

\[ r_{2o} = \sqrt{(-4.406 + 9\sqrt{3})^2 + (-5.8204 + 9)^2} = 11.6258 \]

\[ 11 \leq r_{2o} \leq 12 \]

\[ r_{3o} = \sqrt{(-4.406 - 9\sqrt{3})^2 + (-5.8204 + 9)^2} = 20.2457 \]

\[ 20 \leq r_{3o} \leq 21 \]

These values correspond to the TA value. Given that the TA is approximated to the nearest integer where the distance is given in Eq. (14).

Remember that all these values are normalized for simplicity to the value 554.

The TA values measured are then:

\[ TA_1 = 24 \quad TA_2 = 11 \quad TA_3 = 20 \] (18)

Substituting these values in Table III, Table IV and Table V above, gives the intersections of the circles as estimated coordinates for the MS:

The error values are the distance between the original and the estimated position of the MS. The first error between the original and the first estimated coordinate is given by normalized and actual values as follows:

\[ (x_{err}, y_{err}) = (x_o, y_o) - (x, y) = (-4.406, -5.8204) - (-4.4745, -5.8426) \]

\[ (x_{err}, y_{err}) = (0.0685, 0.0222) \times 554 \]

\[ (x_{err}, y_{err}) = (37.949, 12.2988) \text{ m} \]

The result shown in Eq. (19) is found for the rest of the eight different cases of the TA values. These results are shown in Table VI and Table VII.

The error value of the averaged coordinates is found between the original and the estimated average position of the MS is given by normalized and actual values as follows:

\[ (x_{err}^\text{av}, y_{err}^\text{av}) = (x_o, y_o) - (x_{av}, y_{av}) = (-4.406, -5.8204) - (-4.6188, -6.0000) \]

\[ (x_{err}^\text{av}, y_{err}^\text{av}) = (0.2128, 0.1796) \times 554 \]

\[ (x_{err}^\text{av}, y_{err}^\text{av}) = (117.9179, 99.5220) \text{ m} \]

The coefficient of variation (CoV) refers to a statistical measure of the distribution of data points in a data series around the mean.

\[ CoV = \frac{\sigma}{E} \] (21)

The coefficient of variation is a helpful statistic in comparing the degree of variation from one data series to the other, although the means are considerably different from each other.

The CoV enables the determination of assumed variations as compared to the amount of expected value of the estimated measurements:

\[ CoV_{x} = \frac{\sigma}{E} = 0.40299 = -8.725\% \]

\[ CoV_{y} = \frac{\sigma}{E} = 0.53795 = -8.966\% \] (22)

Since the estimated value of x is differ from that of y as shown in Figs. 4, but the degree of variations of estimating both coordinates represented by the CoV is convergent.

The estimated distances and angles between the eight estimated positions of the MS and the centre of each zone are found in Table VIII and Table XI. Those are analysed as shown in the following mathematical analysis:
\[
\begin{align*}
    r_1 &= \sqrt{(-4.4745 - 0)^2 + (-5.8426 - 18)^2} = 24.2588 \\
    r_2 &= \sqrt{(-4.4745 + 9\sqrt{3})^2 + (-5.8426 + 9)^2} = 11.5538 \quad (23) \\
    r_3 &= \sqrt{(-4.4745 - 9\sqrt{3})^2 + (-5.8426 + 9)^2} = 20.3099 \\
    \beta_1 &= \frac{-5.8426 - 18 - 4.4745}{-4.4745 - 0} = 79.37 - 180 = -100.63^\circ \\
    \beta_2 &= \frac{-5.8426 + 9 - 4.4745}{-4.4745 + 9\sqrt{3}} = 15.86^\circ \\
    \beta_3 &= \frac{-5.8426 + 9 - 4.4745 - 9\sqrt{3}}{8 - 8.9435} = 171.0565^\circ
\end{align*}

The values analysed above are illustrated in Fig. 5, showing the original, estimated and the error of estimating these values for both the distance between the MS and the zone site and the angle between them.

Fig. 5. Illustration of the random position of the MS in the cell area

The same as the results shown in Eq. (23) and Eq. (24) are found for the rest of the eight values and found in Table VIII, Table IX, Table X, and Table XI.

### Table IX

<table>
<thead>
<tr>
<th>Case</th>
<th>( r_1 )</th>
<th>( r_2 )</th>
<th>( r_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original (TA)</td>
<td>24.2244</td>
<td>11.6257</td>
<td>20.2456</td>
</tr>
<tr>
<td>Average (TA)</td>
<td>24.4437</td>
<td>11.3842</td>
<td>20.4346</td>
</tr>
<tr>
<td>Original (meters)</td>
<td>13420.321</td>
<td>6440.676</td>
<td>11216.1</td>
</tr>
<tr>
<td>Average (meters)</td>
<td>13541.82</td>
<td>6306.86</td>
<td>11320.755</td>
</tr>
</tbody>
</table>

### Table X

<table>
<thead>
<tr>
<th>Case</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-100.6289</td>
<td>15.8595</td>
<td>171.0565</td>
</tr>
<tr>
<td>2</td>
<td>-102.3378</td>
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<td>170.2887</td>
</tr>
<tr>
<td>3</td>
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<td>7</td>
<td>-99.4989</td>
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<td>8</td>
<td>-101.5450</td>
<td>14.7130</td>
<td>172.0487</td>
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### Table XI

<table>
<thead>
<tr>
<th>Case</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
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<tbody>
<tr>
<td>1</td>
<td>-100.6289</td>
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</tr>
<tr>
<td>7</td>
<td>-99.4989</td>
<td>12.1060</td>
<td>172.8715</td>
</tr>
<tr>
<td>8</td>
<td>-101.5450</td>
<td>14.7130</td>
<td>172.0487</td>
</tr>
</tbody>
</table>
The estimated values of the distances between the MS and the center of the zone sites shows small degree of variations represented by the CoV, which is convergent in the case of distances. While the small standard deviation in calculating the angle in the case of the second zone site is due to the small mean of the estimated values. The mathematical analysis of the CoV is given as follows:

\[
CoV_{r_1} = \frac{0.51638}{24.4437} = 2.1125\%
\]

\[
CoV_{r_2} = \frac{0.38254}{11.3842} = 3.3603\%
\]

\[
CoV_{r_3} = \frac{0.4234}{20.4346} = 2.0720\%
\]

This is illustrated in Figs. 6 and Figs. 7 for the distances and angles respectively.

Although this model was able to develop a useful approximation for the MS coordinates, the errors in the x-axis and the y-axis can still be highly variable, and this is reflected in the behaviour of the MS when it is moved to different places that make different distances from the different zone sites.

\[
CoV_{\beta_1} = \frac{1.009}{100.8992} = 1.00\%
\]

\[
CoV_{\beta_2} = \frac{2.783}{15.2991} = 18.19\%
\]

\[
CoV_{\beta_3} = \frac{1.4643}{171.5633} = 0.85\%
\]

Figs. 6. The Eight Estimated values of the MS Distances to the centre of the Zone Sites

Figs. 7. The Eight Estimated values of the MS Angles with the Zone Sites
In order to quantify the range of variations, we present results that allow proper comparisons to be made between different choices of MS positions by running the simulations for significantly large number of random positions of the MS to average over all possible instances of the position of the MS as shown in Fig. 8.

Fig. 9 shows the distribution of the error of 500 random positions of the MS, which shows that the mean error is very small, whereas the standard deviation of the distribution of errors is approximated by the following:

$$\bar{x}_e = 0.0024842 \times 554 = 1.376 \text{ m}$$
$$\sigma_x = \pm 0.26117 \times 554 = \pm 144.7 \text{ m}$$

$$\bar{y}_e = 0.0057341 \times 554 = 3.18 \text{ m}$$
$$\sigma_y = \pm 0.24408 \times 554 = \pm 135.2 \text{ m}$$

Figs. 10 show the distribution of the errors of the distances between the random positions of the MS and the zone sites, which shows again that the mean error is very small. Whereas the standard deviation of the distribution of errors is approximated by the following:

$$\bar{r}_e = 0.00086425 \times 554 = 0.5 \text{ m}$$
$$\sigma_{r1} = \pm 0.22872 \times 554 = \pm 126.7 \text{ m}$$

$$\bar{r}_2 = 0.016428 \times 554 = 9.1 \text{ m}$$
$$\sigma_{r2} = \pm 0.24708 \times 554 = \pm 136.8 \text{ m}$$

$$\bar{r}_3 = 0.012481 \times 554 = 6.9 \text{ m}$$
$$\sigma_{r3} = \pm 0.24986 \times 554 = \pm 138.4 \text{ m}$$

(28)
VII. Conclusion

All the analysis above are for a cell with radius \( R = 18 \times 554 = 9.972 \) km, running the simulation for different radii of the cell according to the maximum value of \( TA = 63 \) that is corresponds to a distance of \( R_{\text{max}} = 63 \times 554 = 34.902 \) km and calculating the mean error found between the 500 random positions of the MS at each radius gives the results shown in Fig. 12.

Fig. 12 shows that this technique has better performance when applied to cells with radii above \( TA > 3 \) or in distance \( R > 1.662 \) km since for lower distances the intersections of the resulted circles with difference of 554 m for each value of TA like TA = 1 or 2, will have a distance between the MS and the Zone site almost around the estimated value.

This technique shows a good approximation of the distance between the MS and the zone site and then of the estimation of the MS position which is found to be hundreds of meters without the need for forced handovers in practical implementation.

More research is needed to verify the simulation results in real environment. It is supposed that with the help of intelligent processing the mean location error and especially maximum errors can be reduced considerably.
References


Authors' information

Khalid G. Samarah received the B.Sc. degree from Mutah University in Jordan in 1991, and the MSc and PhD from University of Bradford in UK in 2003 and 2007 respectively. From 17/02/2008, he worked as an assistant Professor in Mutah University until now. Khalid occupied the position of head of the electrical engineering department in Mutah University, and chief of coordinators in the military wing of Mutah University. He is interested in radio propagation, OFDM systems in cellular communications.