Mobile Positioning System using Signal Strength Measurement for WCDMA System

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Abstract

The precise position of the mobile station is critical for the ever increasing number of applications based on location . In this paper a new approach for mobile positioning in WCDMA (Wideband Code Division Multiple Access) cellular network is proposed . Radio Received Signal Strength Indication (RSSI) can be measured from a number of nearby base stations . Three proposed approaches (3-BS's , 5-BS's and 7-BS's) are simulated using three propagation models and the rms_{error} is calculated for each model. As a simulation study case, the University of Mosul area is choosed to find the position of a mobile user in the university campus .

Keywords: *positioning systems ,WCDMA ,RSSI, propagation models.*

نظام تحديد موقع الهاتف النقال باستخدام قياس شدة الإشارة في نظام(WCDMA)

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الخلاصة

أصبح تحديد موقع مستخدم الهاتف النقال من الأمور المهمة في الوقت الحاضر وذلك لزيادة عدد التطبيقات المعتمدة على موقع المستخدم . تم في هذا البحث اقتراح طريقة جديدة لتحديد موقع المستخدم في شبكات الجيل الثالث للهاتف النقال (**WCDMA**) حيث يمكن قياس شدة الإشارة المستلمة من محطات القاعدة القريبة والاستفادة منها في تحديد موقع المستخدم باستخدام ثلاث نماذج لفقد الانتشار , ومن ثم تم حساب مقدار الخطأ الحاصل من كل نموذج . تم استخدام ثلاث طرائق لحساب إحداثيات موقع الهاتف النقال , بالاعتماد على ثلاثة محطات قاعدة أو خمسة أو سبعة وقورنت نتائج الطرائق الثلاث بالاعتماد على نسبة الخطأ لإيجاد الطريقة الأمثل . طبق نظام المحاكاة في جامعة الموصل لتحديد موقع مستخدم موجود داخل الحرم الجامعي .

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1. Introduction

Mobile positioning in cellular mobile networks provide several services such as locating stolen / lost mobile, emergency calls network ,self optimizations different billing tariffs depending on where the call is originated and other applications.
Position finding in 2nd generation mobile system (GSM, CDMA) are depends on Time Of Arrival (TOA) from Base Station (BS) to Mobile Station (MS) to calculate the distance between them. BS in these systems is synchronized with MS, but there is no synchronization in WCDMA system (a synchronized) [1].

The main disadvantage of GPS/AGPS(Assisted GPS) and (TOA) systems is that they assume Line-of-Sight (LOS) propagation between the transmitter and the receiver. In general this assumption is not valid in city centers where LOS is often blocked by buildings and other obstacles. The accuracy of these systems is significantly degraded by the multi-path propagation caused by signals bouncing off buildings or other elevated topological features. In mountainous areas characterized by narrow valleys and few base stations, both AGPS and TOA performance may degrade severely. Consequently companies have started to look into other methods of providing location capabilities in multi-path areas and particularly in so-called dense urban environments [2].

In this paper the Received Signal Strength Indication (RSSI) is used to find distance between base station and mobile using outdoor propagation models , where there is no need for TOA (a synchronized system) . Three models are used to find the distance .

2. Working Area

In this paper the simulation is applied to Mosul university for an area of (4kmx2.5km) at Mosul city (Iraq) obtained from Google Earth software as shown in Fig. (1). The NPSW (network planning strategies for wideband CDMA) program is used in simulation with a static simulation program based on MATLAB software and adapted by IEEE [3]. The program requires the following data [4]:

-The topographical map of the area.
-The mobile stations map and base stations map.
These data are added as layers.

The process is to input the digital map to the NPSW program which contains three parameters length, width and colors:

• The first step is to consider just the length and width for the intended area map as a terrain layer.
• The second step is to add the water layer represented by the blue color.
• The third step is to add the streets layer represented by black color.
The resolution of the blue color and black color should be high in order to avoid putting the base station towers in the middle of streets or water areas.
• The forth step is to add the base stations layer to show the BSs locations and the number of antenna sectors .
• The fifth step is adding the MSs Layer to show users distribution and data rate which represent different bit rate.
This picture entered to NPSW for first layer as the topographical map of the area (digital map). The second layer in NPSW is BS layer, with omni directional antenna (25m height) .

Fig. (1): Working Area of (4x2.5 km²) at Mosul city including University of Mosul campus .

3. Mathematical Approach

The MS should lie in the coverage area of at least three BSs in order to determine it's location as shown in Fig. (2) where the coverage of the BSs are represented by a circles centered at the BS. The distance between the MS and the three BSs will be used to solve the following three equations [5]:

$$\left.\begin{aligned}(x-x_1)^2+(y-y_1)^2=d_1^2\\(x-x_2)^2+(y-y_2)^2=d_2^2\\(x-x_3)^2+(y-y_3)^2=d_3^2\end{aligned}\right\} \qquad \ldots\ldots (1)$$

where (x, y) is the mobile's location; (x_1,y_1), (x_2,y_2) and (x_3,y_3) are the coordinates of BS $_1$, BS $_2$ and BS $_3$ respectively; d_1, d_2 and d_3 are the distances from BS $_1$, BS $_2$ and BS $_3$ to the mobile station MS respectively; as shown in Fig. (2),where intersection of three circles represent the location of the MS..

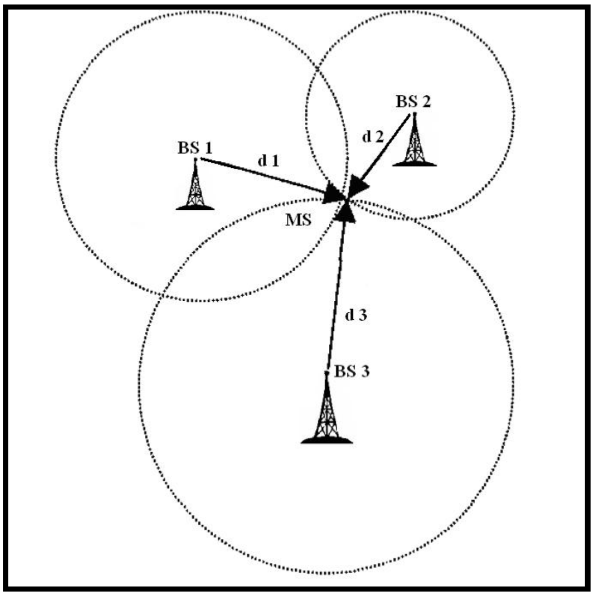

Fig. (2): Mobile positioning using three base stations

4. Propagation Models Simulation

To find the distance d between the MS and BSs, a suitable propagation model should be used. Three propagation models are used in simulation to find d based on RSSI using MATLAB software 7.4 version. Once the distances (d_1 , d_2 and d_3) are obtained, the location (x , y) of the MS can be found using equation (1). The propagation models used in simulation are:

Okumura-Hata model (OH) [3] :

$$path\_loss = 158.3 - 13.82\log(H_{BT}) + (44.9 - 6.55\log(H_{BT}))\log(d) \quad ..(2)$$

UMTS 30.03 model [6] :

$$path\_loss = 40(1 - 4*10^{-3}\Delta Hb)\log(d) - 18\log(\Delta Hb) + 149.3 \quad ...(3)$$

Long distance model [7] :

$$path\_loss = 136.86 + 40\log(d) \quad ....(4)$$

Where (H_{BT}) is BS antenna height , ΔHb is difference between BS antenna height and MS height (1.5m) and (d) is the BS-MS distance .
Three approaches are used in simulation, the first one assumes three base stations (3-BS's) existed in the working area; the second approach uses a five base stations (5-BS's) and the last one uses a seven base stations (7-BS's) distributed around the working area (University of Mosul). Just three base stations are needed in the simulation to find the location of the MS, so the algorithm will choose the highest three signals (i.e nearest BSs) in 5-BS's and 7-BS's approaches (these signals are control channels CPICH (Common Pilot Channel) [3] which are set to 30dBm for all BSs in network and are unchangeable). Fig. (3) shows the working area and the locations of the base stations and table.(1) gives BSs parameters .

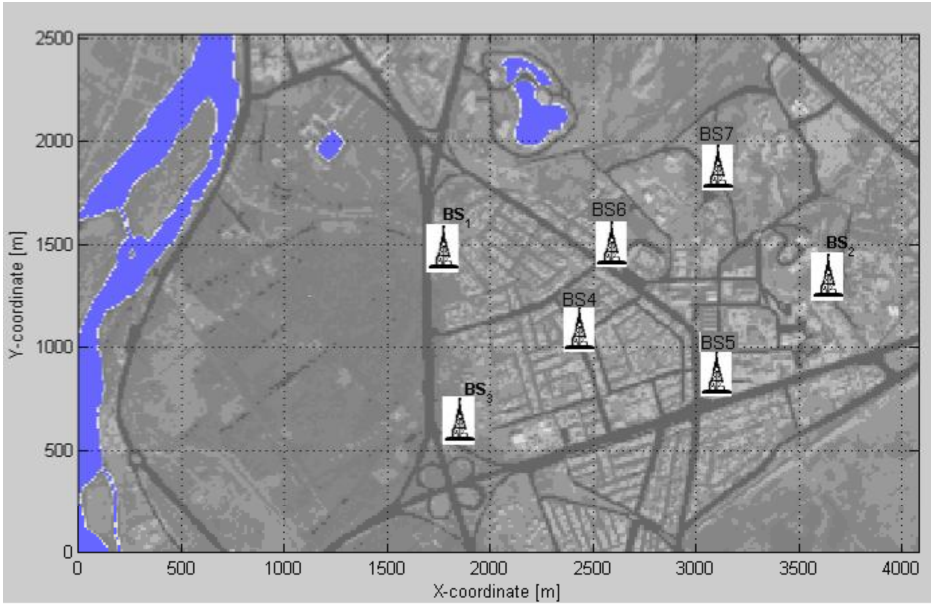

Fig.(3): Working area and the locations of the base stations.

Table 1: Base Stations parameters.

	X pos	Y pos	Ground height	Antenna height	**Power (dBm)**
BS1	1758	1428	227	25	30
BS2	3622	1290	230	25	30
BS3	1863	577	226	25	30
BS4	2444	1000	224	25	30
BS5	3040	760	226	25	30
BS6	2550	1500	227	25	30
BS7	3200	1660	233	25	30

The simulation flowchart is shown in Fig. (4). When a user has to be located, the MS number corresponding to that user is retrieved from the data base and the central unit send a message to all MSs in the coverage area. Just one is intended, which will reply and respond to the location request service, then MS will determine the location after measuring the received signal from nearest BSs, The MS will choose the highest three signals, if 5-BS's and 7-BS's approaches is used, and then calculate the distance from MS to each one of the BSs. After calculation, the MS will send the location to BS then to the central unit to find location, this procedure is presented in Fig. (4). The system will be able to show the route taken by the object or person by plotting the last detected positions and connecting them.

The accuracy of the object positioning is specified as follows [5]:

$$rms_{error} = \sqrt{(X - x)^2 + (Y - y)^2} \quad \text{m} \quad \dots (5)$$

Where: (X , Y) is the object's true location, and (x , y) is the object's predicted location.

5. Simulated Results:

Many random locations of MS are used in simulation to obtain an accurate results, but just five locations are selected randomly and presented in this paper. The real points locations are shown in table (2):

These locations are located on the map and the simulation is run for each location to find the location using one of the three propagation models mentioned before. The rms $_{error}$ is calculated for each model using 3-BS's, 5-BS's and 7-BS's approaches. The results are given in Tables (3-5) :

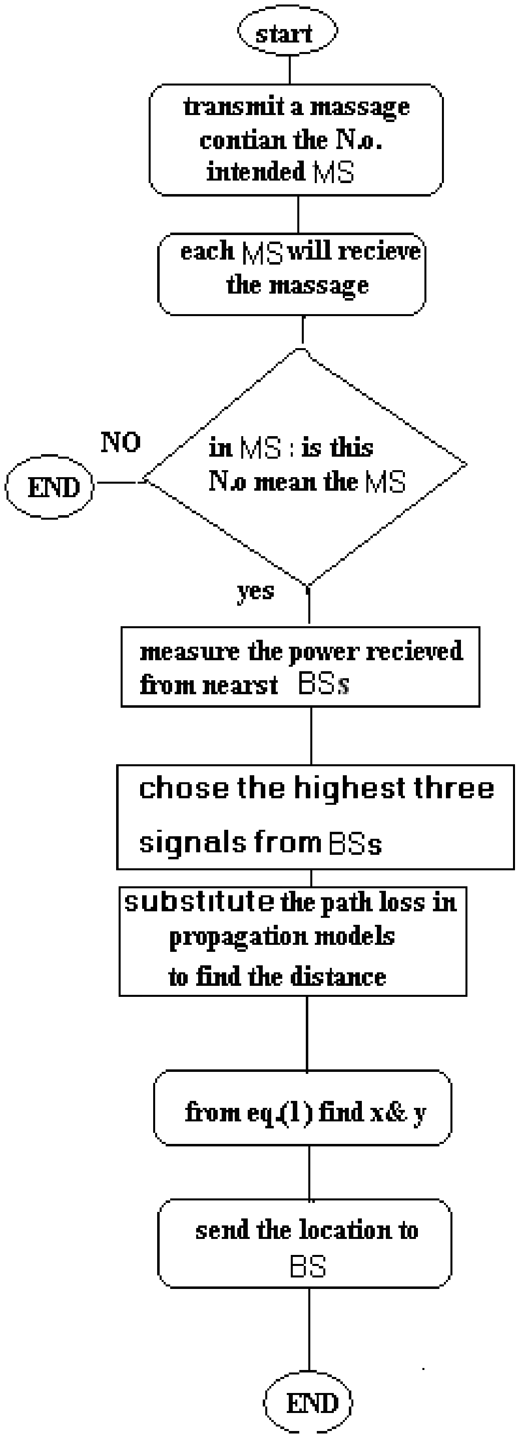

Fig. (4): The flowchart of the location finding algorithm.

Table 2:Real location for mobile

	Location1	**Location2**	**Location3**	**Location4**	**Location5**
x-pos	2200	2600	2000	1500	3500
y-pos	1500	500	1000	1000	2000

Table 3: rms $_{error}$ in UMTS model.

approach	**Location1**	**Location2**	**Location3**	**Location4**	**Location5**
3-BS's	143.3	202.2	310	N. A	862
5-BS's	58	159	86	87.2	267
7-BS's	64	41	6.7	9.8	85.1

N.A : Not Applicable

Table 4: rms $_{error}$ in long-distance model.

approach	**Location1**	**Location2**	**Location3**	**Location4**	**Location5**
3-BS's	445.38	470.48	551.8	N. A	1093
5-BS's	309.4	352.1	176	504.6	623
7-BS's	128.3	153.9	17.4	313.3	719

Table 5: rms_{error} in OH model.

approach	**Location1**	**Location2**	**Location3**	**Location4**	**Location5**
3-BS's	460.7	482.9	563.17	N. A	1096
5-BS's	324.9	365.5	184.7	519.6	632
7-BS's	134.46	164	19.8	328	766

As shown from the results given in tables above, one can see that the UMTS model has the minimum rms_{error} at each location for every approach (3-BS's, 5-BS's and 7-BS's) when compared with OH model and long-distance model.

Also it is seen that the rms_{error} is decreased when the number of base stations is increased , so the 7-BS's has the minimum rms_{error} . At 7-BS's approach the rms_{error} is reduced to (6.7m) in case of using UMTS model at location 3, and (17.4m) in case of using long-distance model while the rms_{error} is (19.8m) when OH model is used.

Fig.(5) shows the effect of increasing the number of base stations in reducing the rms_{error} in UMTS model for five different locations.

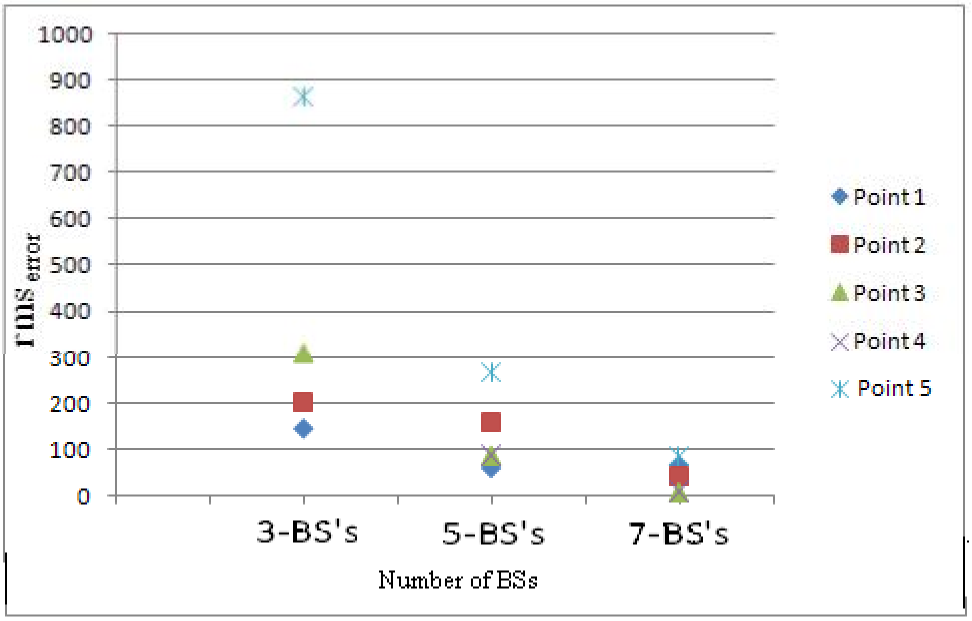

Fig. (5) The effect of increasing number of base stations on rms_{error} in UMTS model.

6. Conclusion

In this paper, a new approach for object positioning and tracking systems is proposed and simulated. The approach based on RSSI in determining the position and tracking MS in the university of Mosul as a study case. Three propagation models are used in simulation and three approaches are applied (3-BS's , 5-BS's and 7-BS's). The rms_{error} is calculated for each model with different number of base stations at five random locations. The results showed that the UMTS model has the minimum rms_{error} when compared with other models. Also it is found that the rms_{error} can be reduced by increasing the number of base stations around the working area. Based on results obtained in this paper , it is recommended to use UMTS model in tracking and finding position algorithms because it has minimum rms_{error} and it is recommended to increase the number of base stations (more than 5) around the working area to reduce the rms_{error} and obtain an accurate results.

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