SINGLE BASE STATION MOBILE-BASED LOCATION ESTIMATION TECHNIQUE

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ABSTRACT. In Mobile cellular communications, the location of the users is one of the most important things especially in recent years. The satellite positioning system which is named as Global Positioning System (GPS) is a sufficient and reliable technique for coordinating services. However, there are several techniques which can estimate the location of the user based on certain number of base stations (BS) which are depending on some parameters like multi-path components, reflections, diffractions, ducting, scattering …etc. This paper discusses several scenarios of wireless mobile location estimation using only one single base-station by utilizing the environment around the subscribers and the base station. A site of Al-Dhahran city in KSA forms the base map for the proposed scenarios and proper solutions are suggested accordingly. The simulation results performance of the approaches used are complying with the FCC standard readings.

Keywords: Position Localization, Ray Tracer, Triangulation calculation, AoA, ToA, scatterers, Non linear least square (NL-LS) and Location Estimation

INTRODUCTION

In wireless communications, acquiring the location for emergency calls allows a coordinated response in states where users are corrupted, cannot respond or speak, or do not know their positions. On October 2001, a decision was made for emergency calls that use cellular phones by the Federal Communications Commission (FCC). They announced that all calls must have a localized accuracy of 67% within an area of 125 m2 in these cases (Revision of the commissions rules, 1996). In addition, service providers are attracted to wireless applications involving position-localization techniques.

Position-localization capabilities lead the way to a new dimension of relatively unrealized information applications which can be provided to the consumer in addition to the standard telephony services. Moreover, improved public services such as airway booking management, traffic mapping, and real time vehicles services are made possible with position-location systems. To make this all possible, the wireless service providers must have knowledge of subscriber's locations. In order to locate subscriber position, at least three BSs are required to acquire satisfactory precision even in the most complex positioning algorithms.

This paper will perform an algorithm that utilizes only a single BS to locate mobile station (MS) in cellular networks using its own antenna array. Different scenarios will be considered on a site of Al-Dhahran city in KSA which is a regular region. Simulation results are compatible with those of U.S. FCC regulations.

THE APPROCHAND METHODS

There are several methods that were proposed to detect and identify the mobile location. The approaches differ from one another depending on the number of BS's required. Subscriber location can be obtained from various signal parameters e.g. time delay, signal strength, the direction of main beam …etc. A number of locations estimation techniques are provided as follows:

Time of Arrival

Precise position in wireless networks has gained huge interest over the past decades. Without utilizing satellite-based positioning systems (e.g., by Global Positioning System), many wireless positioning techniques have been presented by making use of only its own radio measurements while transmitting. One of these methods is (Time of Arrival) or time difference of arrivals. The basic principle of coordinating a MS depends on the triangular geometrics from a set of constant reference points such as the angular measurements case as shown in Figure 1.
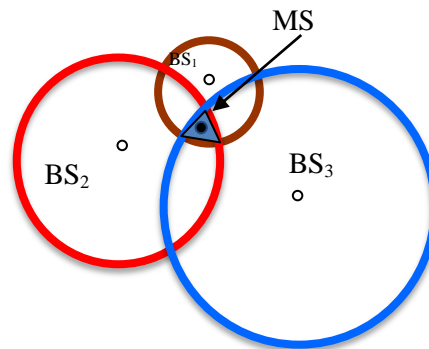

Figure 1. Three BS's in Time of Arrival positioning

It is needed at least three known paths for measuring distances. However, in a more sophisticated wireless networks positioning scenario these distances are not directly recognized, but must be approximated from a larger set of recorded data; typically, those data can be found in the mainstream exchanges between the base station and the mobile station.

$$\hat{x}_{MS} = \frac{x_1 + x_2 + x_3}{3} \tag{1}$$

$$\hat{y}_{MS} = \frac{y_1 + y_2 + y_3}{3} \tag{2}$$

where $\hat{x}_{MS}$ and $\hat{y}_{MS}$ are the esteemed location of the MS.

Angle of Arrival

This technique identifies the MS location by measuring angle of arrival (AOA) to determine a signal from an MS at various BSs through their antennas as shown in Figure 2. Obstacles around the MS and BS will affect the measured AOA. The antennas will depend on a reflected signal if there is no LOS signal component which could not be coming from the direction of the MS. Even when there is LOS component, multipath components will still overlap with the measured angle (Caffery, J. J. & Stüber, G. L., 1998).
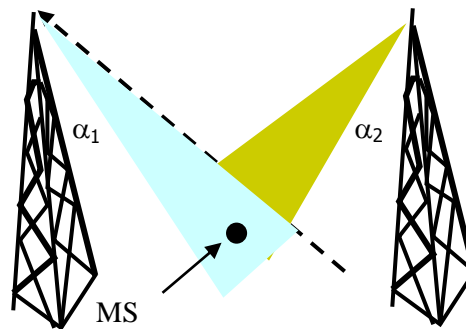
Figure 2. AOA (Angle of Arrival)

Single Base Station Location Technique:

The modern location estimation implemented for microcellular wireless networks utilizes just only one BS. In a microcellular environment, the dominant propagation components contain diffraction, reflections, and scatterings within covered area, in addition to the free space path loss. These multi-path components MPCs are received and processed at the BS, which are then classified according to their time, angle and power. On the other hand, the MPCs arriving at the BS have large angular spread. By utilizing advantage of these features, the subscriber's location will be identified through some of the following demands and operations:

Requirements: The proposed technique uses the antenna array of a single-BS to locate unmodified MSs. Using a single-BS offer many advantages.
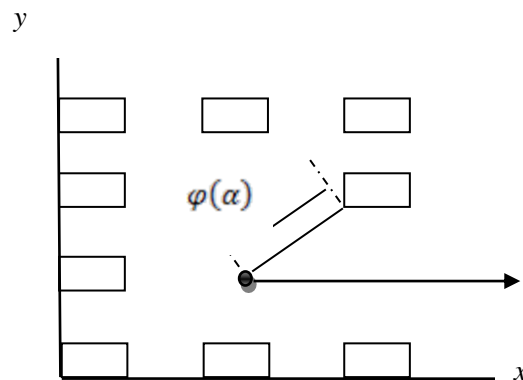

Figure 3. A definition of fundamental function

- Synchronized MS with other BSs is not necessary.
- The problem of several BSs coverage is no longer needed.
- Signalling, (back haul), for internet service requirement is reduced (Porretta, M., 2004).

The algorithm requires some information about the environment around the MS. Moreover, the selected positioning algorithm requires another prerequisite which is the fundamental function $\varphi(\alpha)$ to identify whether the subscriber is LOS or NLOS.

Description of LoS and NLoS:

- **Estimation of LoS Conditions**:

The first MPC received at the BS will have an absolute distance computed as

$$d_i = \sqrt{(c\tau_i)^2 - (h_{BS} - h_{MS})^2} \qquad (i = 1, ..., N) \tag{3}$$

where h_{BS} and h_{MS} are the heights of the BS and MS respectively, while τ_1 is the absolute value of propagation delay of the first MPC reaching the BS. The distance d_i, the $\varphi(\alpha)$ and the AoA of the first impinging MPC α_1 are used to decide whether the MS is in LoS condition or not. If $\varphi(\alpha_1) \geq d_1$ then LoS is assumed and the position of the MS is simply estimated as (Porretta, M., 2003) (Porretta, M., 2004).

$$\begin{cases} \hat{x}_{MS} = x_{BS} + d_1 . \cos(\alpha_1) \\ \hat{y}_{MS} = y_{BS} + d_1 . \sin(\alpha_1) \end{cases} \tag{4}$$

- **Minimization of Algorithm in NLoS Conditions:**

The MS is considered to be NLoS if the previous test $\varphi(\alpha_1) \geq d_1$ is not satisfied. For instance, by minimizing the cost function, the MS position is determined from the received MPCs (Porretta, M., 2004) (Chiu, W. Y. & Chen, B. S., 2009). First through the scatterers, the coordinates are evaluated by the algorithm. Each MPC ray related to these scatterers are points where it has several reflections and/or diffractions before receiving it at the BS. Therefore, the coordinates are obtained as

$$\begin{cases} x_{Si} = x_{BS} + \varphi(\alpha_i) . \cos(\alpha_i) \\ y_{Si} = y_{BS} + \varphi(\alpha_i) . \sin(\alpha_i) \end{cases} i = (1, ..., N) \tag{5}$$

After identifying the scatterer locations, the algorithm computes the vector τ_{Ri} which represents the propagation delays between the MS and the obstacles.

$$\tau_{Ri} = \tau_i - \frac{\varphi(\alpha_1)}{c} \qquad (i = 1, ..., N) \tag{6}$$

this delay will introduce a cost function:

$$F(x, y) = \sum_{i=1}^{N} f_i^2(x, y) \tag{7}$$

with

$$f_i(x, y) = c\tau_{Ri}\sqrt{(x - x_{Si})^2 - (y - y_{Si})^2} \tag{8}$$

Since the MS cannot be more than $c\tau_1$ away from the BS, further minimization to the cost function is applied. So, the estimated position $(\hat{x}_{MT}, \hat{y}_{MT})$ of the MS is chosen as

$$(\hat{x}_{MS}, \hat{y}_{MS}) = \arg \min_{(x,y) \in D} \{F(x, y)\} \tag{9}$$

with

$$D = \left\{ (x, y) | \sqrt{(x - x_{BS})^2 - (y - y_{BS})^2} \leq c\tau_1 \right\} \tag{10}$$

Many techniques for minimizing the cost function are used to solve the nonlinear least square (NL-LS) in Eq. (8) (Porretta, 2004). The following case study will use MATLAB in simulating and computing the estimated MS locations.

CASE STUDY

The selected location technique has been estimated according to the difference between the actual and the expected position:

$$\varepsilon = \sqrt{(x_{MS} - \hat{x}_{MS})^2 - (y_{MS} - \hat{y}_{MS})^2} \qquad (11)$$

where ε is the location error (Porretta, 2003) (Porretta, 2004) (Shixun, Jiping & Shouyin, 2011). If the LOS condition is verified, then the location is estimated by Eq. (4) and otherwise by Eq. (9).

Different scenarios in a regular region will be considered, one assumes the BS is centered and another with it being outer most of the coverage. Also, the impairments of finite-resolution in estimating the channel-characteristics will be covered. Simulation results are compatible with those of U.S. FCC regulations. Our measurements were taken for Al-Dhahran using Google Earth as follows: There are 64 buildings considered. The scenario will take place in the following region:

- Cell coverage area $220 \times 220 \ m^2$.
- Street width $20 \ m$.
- Building height = 30 m, building width = $20 \ m$.
- The MS height is $1.5 \ m$.
- Five meters is assumed as spacing between any two points.

Two different positions are assumed for the BS antenna.

1- Three BSs are located on ($x_1 = 50, y_1 = 50$), ($x_2 = 110, y_2 = 170$) and ($x_3 = 170, y_3 = 50$) Figure. 4.
2- BS is located at ($x = 110, y = 110$) in the middle of a street junction Figure. 5. However, BS can be mounted on the rooftop of a building near the street junction.

Figure 4. 64-buildings in Al-Dhahran with Three BSs

Figure 5. 64-buildings in Al-Dhahran with Single BS located at the centre of the scenario

As a result, 492 actual subscriber locations are available. Six multipath components affecting on the BS have been chosen.

SIMULATION AND EXPERIMENTAL RESULTS

There are two scenarios which are done using some numerical result as seen in following:

First: (The 64-buildings Al-Dhahran environment with BS in the middle of the scenario).

- The actual mobile location (492).
- The BS, MS, Building height.
- Compute the fundamental function distance to know where the MS is LOS (21 MS) or NLOS (471).
- Compute the position of the scattered.
- Estimated the coordinates of the LOS MS by using Eq. (4) and NLOS MS by minimizing the cost function using Eq. (9).
- Compute the error in LOS, NLOS, and overall states.
- Then, to calculate the distribution function CDF.
- Finally, plot the error location with its distribution function.

Second: (BS mounted on a corner of a building) as previously worked but change the position of BS. So, the LOS and NLOS MSs and the error value will change also.

The results shown in Figure 6 indicate that 88% of users will be known within $125\ m$ where less than this value within 79% of them will be identified when the BS located on the corner of one building around the centre of the region as shown in Figure. 7, so the simulated single-BS technique accuracy is comparable to that of the three-BS's method which uses different BS's. On the other hand, the minimization of the chosen cost function to get the best 6 MPCs is important where the farthest point at each building were selected, so that the signals will be diffracted from their edges, as a result Figures. 8 and 9 will illustrate the cost function before and after minimization.
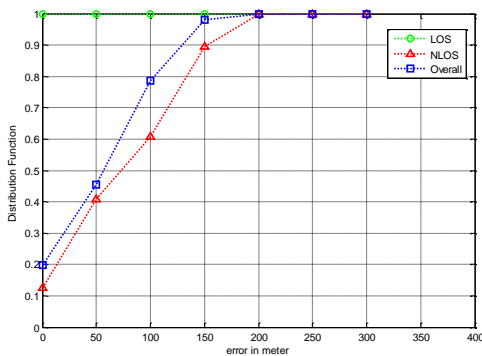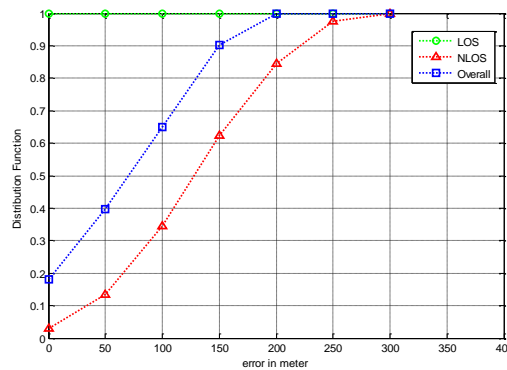

Figure 6. BS is located at centre of the scenario

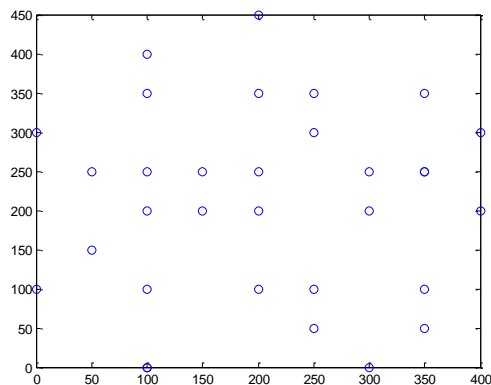**Figure 7. BS is located at the top roof of building in the scenario**

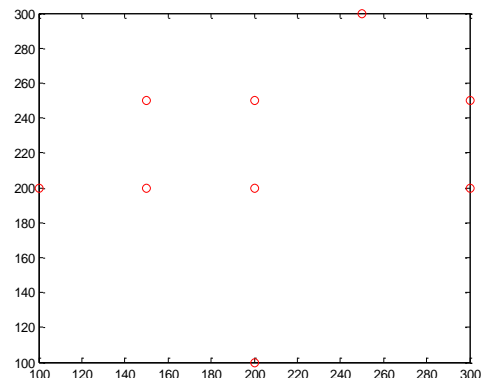**Figure 8. The cost function before minimizing**

Figure 9. The cost function after minimizing

CONCLUSION

In this paper, we demonstrated the main techniques for estimating the location of MS by introducing a number of selected location-positioning metrics. We exploited an algorithm that utilizes a single-BS with directional antenna array, without doing modifications to the MS, in addition to some knowledge about the environment around the BS and MS. The simulation results are shown to estimate the MS location in both LOS and N-LOS cases with a satisfactory precision by applying the selected technique on a site of Al-Dhahran which has a several buildings and streets with similar dimensions. Different scenarios were taken to explore the channel-parameter estimation. A deterministic ray tracer test was taken to verify the employment. In conclusion, the performance of the single-BS localization can be more accurate when having MIMO implemented on both the MS and BS.

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