Mobile User Tracking Using Weighted Matrix Pencil Direction Finding Method with Distributed Array Antennas

Kasra Chegini, Hossein Zamiri and Mir Mojtaba Mirsalehi
Electrical Engineering Department, Ferdowsi University, Mashhad, Iran

***Abstract*-A direction finding (DF) method is proposed for tracking a mobile user. In this method, the direction of arrival (DOA) of the signal at each base station is estimated using the matrix pencil (MP) algorithm. Also, a weighting method is used to improve the performance of the tracking system.**

I. INTRODUCTION

SEVERAL methods are used for locating and tracking a mobile user [1]. These methods are based on estimating the time or direction of the arrived signal. The time estimators are more complex than the direction estimators. On the other hand, the direction estimators usually search the entire space and are time consuming. There are attractive analytical DF methods that do not search the space. In this paper, we have used the MP algorithm for DF. This algorithm has the advantage of requiring a single, rather than several, snapshot of the arrived signal.

II. WEIGHTED MPDF ALGORITHM

To find the location of a mobile user by DF methods, at least two base stations (BS's) are needed. Also, the mobile station (MS) should be in the line of sight (LOS) of BS's. The location of mobile user is then determined at the intersection of directions found by the two BS's. In practice, more than two BS's are used. Figure 1 shows a case with three BS's. Due to the error in the direction found by each BS, different intersecting points are obtained by each pair of BS's. As a simple method, user location is estimated as the average of these points. However, the direction found by each BS has a different variance. This can be used to obtain a better estimation as described below. A step-by-step description of our proposed method is followed.

1. The angle of arrival of received signals are estimated using MP algorithm [2]. The results are shown by $\hat{\theta}_i$.

2. The power of received signal and noise are measured at each BS and the corresponding signal to noise ration (η_i) is calculated. Using these values, the Cramer-Rao lower bound (CRLB), lower bound of the variance, of $\hat{\theta}_i$ is obtained for each BS as [3]

$$\Delta\theta_i = \Delta\left(\hat{\theta}_i, \eta_i\right) = \frac{12}{(2\pi)^2 M \eta_i \left(\frac{M+1}{M-1}\right) L^2 \sin^2 \hat{\theta}_i}, \qquad (1)$$

where M is the number of array elements and L is normalized length (with respect to the wavelength) of the array.

3. The position of MS is estimated using the DF method. The CRLB of each estimated point (obtained by intersecting the estimated angles of arrival) is calculated [4].

4. It can be shown that the optimum weights corresponding to the minimum mean square error in the estimated coordinates are

$$\begin{cases} \alpha_k = \dfrac{1/\mathrm{var}(x_k)}{\sum_{j=1}^{N} 1/\mathrm{var}(x_j)} \\ \beta_k = \dfrac{1/\mathrm{var}(y_k)}{\sum_{j=1}^{N} 1/\mathrm{var}(y_j)} \end{cases} \qquad k = 1,2,\ldots,N \qquad (2)$$

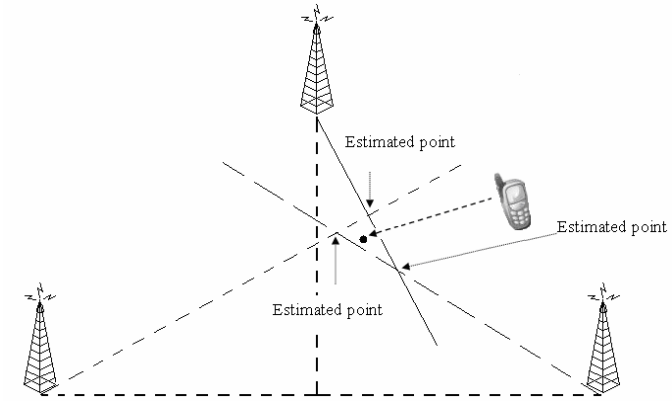

Fig. 1. User positioning using three BS.

where x_k and y_k are the coordinates of the k th intersecting point, N is the number of intersecting points, and var(x_k) and var(y_k) are the corresponding CRLB's of x_k and y_k as calculated in step 3.

5. Using the above optimum weights, the position of MS is determined

$$\begin{bmatrix} \hat{x}_0 \\ \hat{y}_0 \end{bmatrix} = \begin{bmatrix} \sum_{k=1}^{N} \alpha_k x_k \\ \sum_{k=1}^{N} \beta_k y_k \end{bmatrix} \quad (3)$$

6. To improve the performance of tracking, the estimated coordinates of the user are smoothed using a moving average method along the path.

III. RESULTS

The proposed method was simulated for tracking a user whose path is shown in Fig. 2. Three BS's with array antennas of four elements were assumed. The noise power and the transmitted power of MS along the path were assumed constant. Therefore, the SNR at BS's was variable and changed between 11dB and 35dB. A total of 956 snapshots that were uniformly distributed along the path were considered. The results obtained for both the proposed weighted MPDF method and the normal MPDF method are shown in Fig. 3. Also, both smoothed and unsmoothed values are presented.

IV. CONCLUSION

A simple and efficient method is proposed for tracking a mobile user. The simulation results show significant improvement in the user tracking process for the weighted and smoothed case. Since the proposed method is not intensive in computation, the number of snapshots along the user's path can be increased. This results in further improvement in tracking.

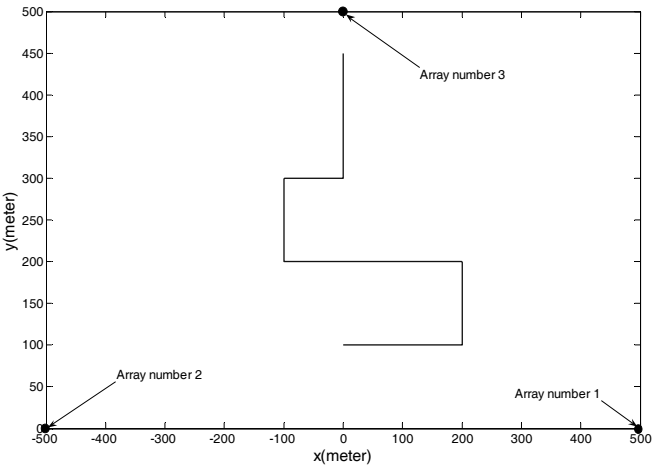

Fig. 2. The mobile user's path and the position of antennas.

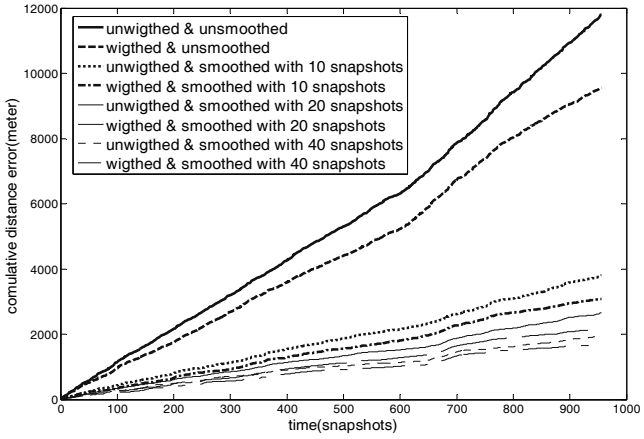

Fig. 3. Cumulative distance error.

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