Mixing and Combining with AOA And TOA for the Enhanced Accuracy of Mobile Location

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Abstract

The position location has become a hot issue over the past few years in wireless communication. Providing the accurate location information of the Mobile Station (MS) is necessitated by the Emergent 911 call in United States. The Angle of Arrival (AOA), Time of Arrival (TOA), and Time Difference of Arrival (TDOA) techniques have been proposed for providing location services in wireless networks [1]. In this paper we present a method for the enhanced accuracy of mobile location. This method is mixing and combining with AOA and TOA in wireless networks and picks out mobile location with large deviation to enhance the accuracy of location estimation. Numerical results demonstrate that the proposed location scheme gives much higher location accuracy than the method that only used TOA and AOA location technique.

I. Introduction

With the increasing market penetration of cellular telephones, the number of E-911 calls placed by cellular telephones has grown considerably. This growth in E-911 calls led to a 1996 FCC ruling requiring that all cellular, PCS, and SMR licensees provide location information for the support of E-911 safety services. The provision of such location information is to be implemented in two phases. Phase I, whose deadline has already been passed, requires that wireless carriers relay the caller s telephone number along with location of the cell site and/or sector serving the call, to a designated Public Safety Answering Point (PSAP). This information allows the PSAP to return the call if disconnected. Phase II, is much stringent and requires that the location of an E-911 caller be determined and reported with and *rms* location accuracy of 125 m in 67% of the cases.

Common radiolocation techniques used for MS location estimate include: signal strength measurement, time of arrival (TOA), time difference of arrival (TDOA) and angle of arrival (AOA), where the time based techniques (TOA and TDOA) are most feasible. In this paper, instead of terminal based GPS system, a network based position system that could be overlaid on current cellular networks with few modifications in BS is considered [2].

The underlying idea of data fusion [3] is the combination of disparate data in order to obtain a new estimate that is more accurate than any of the individual estimates. These data fusion procedures may use either non-adaptive algorithms or adaptive algorithms as Kalman filters and artificial neural networks [4].

In this paper, TOA and AOA techniques are mixed and combined to calculate mobile location and we choice the best performance of estimate mobile location. Sections 2 describe several position estimation techniques and calculate solution of mobile location algorithm. A method that can be utilized for improving position estimation is introduction in section 3. Section 4 shows the performance of proposed method can meet the FCC requirements. Conclusions are given in the final section.

II. Position Location (PL) Techniques

A. Time-of-Arrival (TOA) PL

The time-of-arrival (TOA) technique is based on the TOA measurements of incoming signals, which are emitted from the target MS and received by BS. The amount of TOA measurement means the propagation delay between the target MS and the associated BS based on the knowledge that the electromagnetic waves propagate at the speed of lights, the distance between them can be determined once the TOA is measured. It follows that the location of the MS is on the perimeter of the circles, which has the BS as the center and the measured distance as the radius and then position of user is available by calculating unique point of intersection of circles at least three measured distances with respect to different BSs in Figure 1.

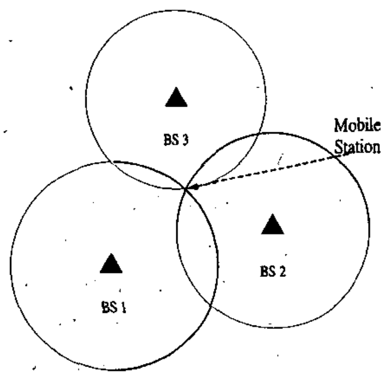

Figure 1 :Location determinations based on time of arrival (TOA) PL technique

B. Angle-of-arrival (AOA) PL

In Figure 2, AOA techniques utilize the Direction of arrival (DOA) of the incoming signal to estimate the MS location. Based on the measured DOA, a straight line of DOA between the target MS and corresponding BS can be determined. Accordingly, the location of the MS can be found by the intersection of two straight lines of DOAs, which are measured by two different BSs, so at least two BSs are required in determining the longitude and latitude positions in this technology. Further more, should you wish to determine the height of the position, a minimum of three BSs is required.

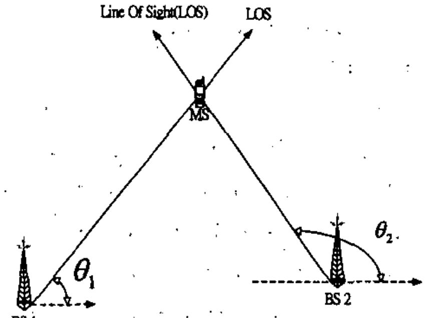

Figure 2: Location determinations based on angle of arrival (AOA) PL technique

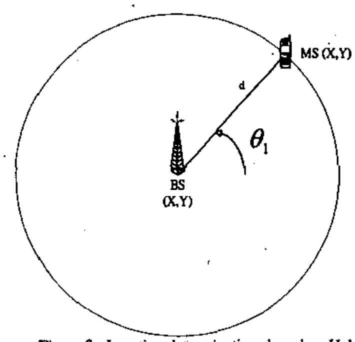

Figure 3 : Location determinations based on Hybrid of TOA/AOA PL techniques

C. Hybrid of TOA/AOA (HTAP) PL

It is possible to combine different types of position location techniques to estimate the MS location, in Figure 3. When range measurement d and DOA θ are available at a certain BS, whose coordinate is (X,Y), the location (x,y) of MS can be expressed as

$$(x,y)=(d\cos\theta+X,\sin\theta+Y) \quad (1)$$

The major advantage of this hybrid of TOA/AOA PL technique is that it can make position estimation from a single BS [5]. However, the error propagation is its drawback. For locating an MS in two dimensions, the hybrid scheme is to utilize both temporal and spatial information to determine the best estimation of MS location. In consequence, it is a two-dimensional geolocation technique. The idea is to search the minimum norm of the difference between an estimated location of TOA and an estimated location of AOA and, to take the estimated location of TOA, which has the minimum norm, as the location of target MS.

III. Proposed Method for Position Determination

Position estimates are obtained by four different approaches in this model. The first approaches use TOA and AOA data that is input to the geometry least-squares and least-squares position estimator [6]. The second approaches position estimate is based on HTAP PL techniques. The third approaches pick out mobile location with large deviation to enhance the accuracy of location estimation. The final approaches choice best performance for TOA, AOA and HTAP PL techniques.

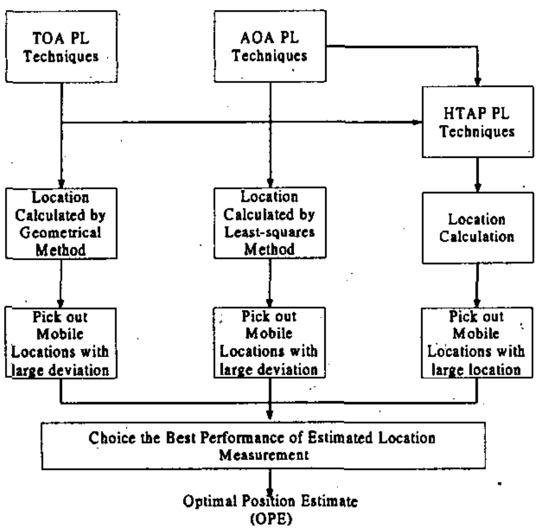

Figure 4 : Proposes model for position estimation

A. The First Step of the Optimal Position Location (OPE) Model

We calculate the position of TOA measurements by geometry least-squares estimator. The geometrical interpretation is presented in which straight lines of position (LOP), rather than the circular LOP. It not only can be programmed and quickly executed but also can get a reliable result than Taylor Series method [7]. The TOA and AOA measurement is considered as an over-determined system. That is, the number of system equations is more than the number of unknown variables. One of the most widely used criteria is to minimize the sum of square of residuals, which is called Least Square (LS) minimization. In the following, we present procedures of LS minimization to determine the location of the MS. On the other hand, HTAP is the combination of TOA and AOA measurements can be calculated by using (1). The position estimates by HTAP very easily.

B. The Second Step of the OPE model

In second step we calculate the mean and variance from TOA, AOA and HTAP estimator. In order to enhance the accuracy of location estimation, we pick out mobile location with large deviation. The procedure is given as follows.

1. Select a fixed threshold δ.
2. Calculate the mean position estimate $(\bar{x}, \bar{y})$.
3. Calculate the distance d_i between the estimated MS position (x,y) and mean position

$$(\bar{x}, \bar{y})\ d_i = (x_i - \bar{x}, y_i - \bar{y}) \qquad ,i = 1,2,\ldots,n \qquad (2)$$

4. Pick out the estimated position when $|d_i| \geq \delta$.

C. The Third Step of the OPE model

The final approaches choice optimal position for TOA, AOA and HTAP PL techniques. It is based on variance of the estimated outputs of the base station. The estimate that exhibits the smallest variance is considered to be the most reliable estimate.

IV. The Simulation and Results

In this section, we evaluate the performance of the OPE model by computer simulation. For both TOA and AOA measurements, the measurement errors are modeled as zero-mean Gaussian distribution with standard deviation of 150m and 1 degree, respectively. In our simulation, 1000 TOA measurements and 1000 AOA measurements are used to test our algorithm. The MS location is random by distributed in the range of BS station.

One MS and five BS are used in the configuration. The BS1 is at the center of a circle that the position is (0,0); the remained four BS are uniformly distributed on the circle with coordination BS2:(5000,0), BS3:(7500,4300), BS4:(2500,4330), BS5:(-2500,4300). The MS location is random by distributed in the range of BS station. For comparing the performance, a widely accepted performance measure on location estimation is the root mean square error (RMSE), defined as follows :

$$RMSE = \sqrt{\sigma_X^2 + \sigma_Y^2} \qquad (3)$$

where σ_x^2 and σ_y^2 are the error variance of the location estimate along x and y direction in Cartesian coordinates,respectively.

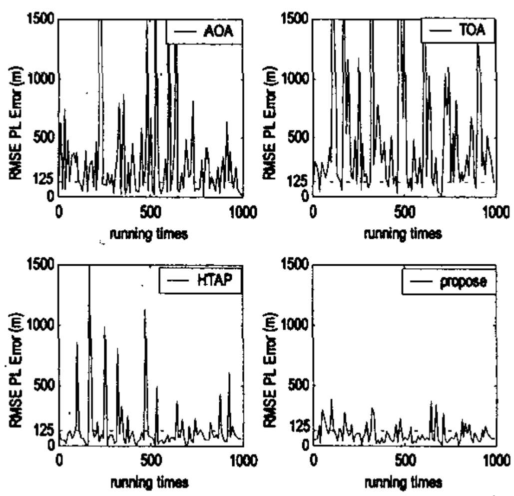

Figure 5:Results of RMSE on four PL

The simulated results by AOA, TOA HTAP and the proposed method are show in Figure 5. It is seen that the simulated results by AOA and TOA are bad. Moreover, the results by HTAP are not good enough to meet FCC requirements. On the other hand, the proposed method is good and the variation is small compared to the other three methods. The cumulative distribution function (CDF) for location error 125m is about 80 % and meets the requirement by FCC show in Figure 6. Finally, the average RMSE is depicted in Table 1. It is obvious that the proposed method has least RMSE. The reasons is as follow : AOA is suitable for one propagation environment. On the other hand, TOA is maybe suitable for another propagation environment. When MS is close to the serving BS, a result by HTAP is better compared with AOA and TOA [8]. As a result, our proposed combining method can be employed in most propagation environments.

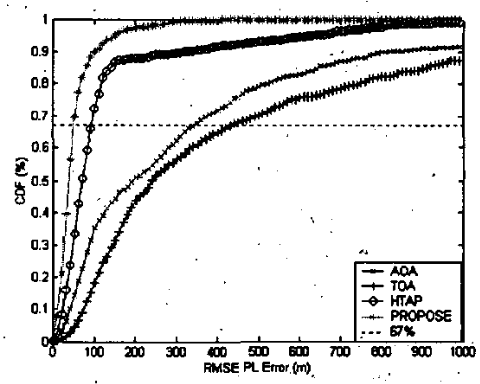

Figure 6:CDF of RMSE on four PL

PL Technique	Total RMSE Average
AOA PL	389.34 (m)
TOA PL	464.13 (m)
HTAP PL	143.24 (m)
Propose PL	103.69 (m)

Table.1.Results of Total RMSE average

V. Conclusion

In this paper, the performance of TOA, AOA and HTAP technique is investigated and new method for choosing the optimal technique in position estimation have been presented. Numerical simulation results show that the location estimation obtained by our proposed method is compatible with FCC requirements. Moreover, our proposed method enhances the accuracy of mobile location compared with TOA, AOA and HTAP techniques. It is concluded that the proposed new method is suitable for the application of position estimate in wireless network.

VI. References

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