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EToA: New 2D geolocation-based handover decision technique☆

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Abstract

Position estimation using Time of Arrival (ToA), Time Difference of Arrival (TDoA), and Angle of Arrival (AoA) measurements are the commonly used location techniques. These techniques, using location parameters received from different sources, are based on intersections of circles, hyperbolas, and lines, respectively. The location is determined using standard complex computation methods that are usually implemented in software and needed relatively long execution time. This paper consists of minimizing and simplifying the computing process in the Mobile Station (MS) during its geo-location phase needed especially for handover. This work considers designing EToA as extended version of ToA, following the same principle but using another aspect for the computational process.

Keywords: Geolocation techniques; AoA; ToA; RSS; Handover

1. Introduction

Recently, mobile location estimation has attracted a significant attention. The network-based location estimation schemes have been widely adopted based on the radio signals between the mobile device and the base stations. Currently, given that many buildings are equipped with WLAN (Wireless Local Area Network) access points (shopping malls, museums, hospitals, airports, etc.), it may become practical to use these access points to determine user location in these indoor environments.

A variety of wireless location techniques have been studied and investigated [1–3]. Network-based location estimation schemes have been widely proposed and employed in wireless communication systems. These schemes locate the position of the MS based on the measured radio signals from its neighborhood BSs. The representative algorithms for the network-based location estimation techniques are the Time-of-Arrival (ToA), the Time Difference-of-Arrival (TDoA), and the Angle-of-Arrival (AoA). The ToA scheme estimates the MS's location by measuring the arrival time of the radio signals coming from different wireless BSs, while the TDoA method measures the time difference between the arriving radio signals. The AoA technique is conducted within the BS by observing the arriving angles of the signals coming from the MS. The equations associated with the network-based location estimation schemes are inherently nonlinear. In this paper, an efficient technique for geometric location estimation based on ToA is proposed to determine the MS position.

The rest of this paper is organized as follows: Section 2 provides the computational details of the proposed geolocation technique (Extended ToA) and conducts its performance evaluation. Finally, Section 3 concludes the paper.

2. Extended time of arrival (EToA): Algorithm and implementation

Location-based service is the most significant characteristic of 3G/4G wireless communication systems which leads to support several new applications. ToA localization technique is the most used for MS position estimation. This technique uses standard methods based on complex computing that are generally implemented with software tools [1,4]. However, the

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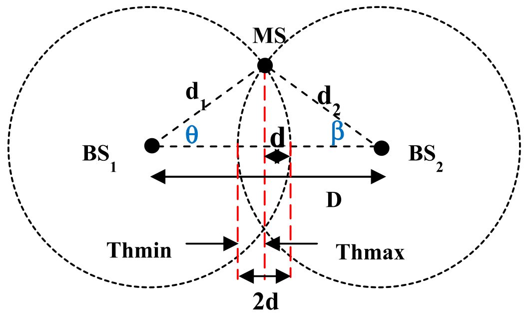

Fig. 1. Basic network architecture for EToA deployment.

main challenge resides on the limited power of the MS that needs to be optimized.

To overcome these limitations, we propose an extended approach of ToA that allows: (a) simplifying intensive and recursive computing of the localization process, and (b) using an implementation environment for acting on the execution time, cost, and therefore power consumption.

2.1. EToA proposal: Convergence with predefined iteration number

Fig. 1 represents the basic architecture of the network topology considered to apply EToA algorithm. The main parameters needed by EToA algorithm are defined by the coordinates (X_j, Y_j) of the jth BS and the radius d_j $(j = 1, 2)$ of the corresponding area. These parameters are illustrated in a local coordinate system as shown in Fig. 1.

$$(X_1, Y_1) = (0, 0) \qquad (X_2, Y_2) = (D, 0).$$

Consider:

- $\boldsymbol{\theta} = (\mathrm{BS1} - \widehat{\mathrm{MS}, \mathrm{BS1}} - \mathrm{BS2})$
- $\boldsymbol{\beta} = (\mathrm{BS2} - \widehat{\mathrm{MS}, \mathrm{BS2}} - \mathrm{BS1})$
- **D** is the distance between BS_1 and BS_2.
- **d** is the distance between $T_{h\min}$ and $T_{h\max}$.

Using the above data and Fig. 1, the angles θ and β can be defined by:

$$\theta = \cos^{-1}\left(\frac{d_1 - d}{d_1}\right) \qquad \beta = \cos^{-1}\left(\frac{d_2 - d}{d_2}\right).$$

The question now is: How do we calculate the coordinates of the MS from these two angles and the parameters mentioned above?

The proposed technique is based on using two vectors $\vec{V}1$ and $\vec{V}2$ whose origin is located at the position of the base station and the end point exist on the circle ζ_i (BS_i, d_i). The principle of this technique consists of rotating these two vectors $\vec{V}1$ and $\vec{V}2$ until crossing in a focal point coordinated by (x_c, y_c).

First, the initial positions (x_1, y_1) and (x_2, y_2) of the ends of the vectors $\vec{V}1$ and $\vec{V}2$ are $(d_1, 0)$ and $(d_2, 0)$ respectively. The initial and final positions of the first vector $\vec{V}1$ are respectively:

$$\vec{V}_1\begin{pmatrix} x_1 \\ y_1 \end{pmatrix} = \begin{pmatrix} d_1 \\ 0 \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} x_1^n \\ y_1^n \end{pmatrix} = \begin{pmatrix} x1\text{conv} \\ y1\text{conv} \end{pmatrix}.$$

This vector undergoes a global rotation with an angle θ that we propose here to study its complete evolution. Elementary rotations with angles θ_i were performed on the vector $\vec{V}_1$ to reach the final position and therefore calculate the MS position with a given accuracy. To simplify the computing complexity, another question can be asked at this level which is: can we approach an angle θ with an accuracy given in advance by decomposing it into a sum of predetermined angles? In other words, can θ be written as (Eq. (1)):

$$\theta \approx \sum_{k=0}^{n} \delta_k \varepsilon_k, \tag{1}$$

where ε_k is a sequence of distinct predefined angles and δ_k is a coefficient that can take the values -1 and $+1$. More specifically, since it is recommended to reach a certain accuracy, we need to define θ as a combination of angles ε_k according to Eq. (2).

$$\left|\theta - \sum_{k=0}^{n} \delta_k \varepsilon_k\right| \le \varepsilon_n. \tag{2}$$

If so, it will be necessary to perform $(n + 1)$ steps for approaching θ to ε_n. This can be done by achieving the following steps:

1. First, the sequence $\sum \delta_k \varepsilon_k$ should converge to θ according to Eq. (2), which requires ε_n tending to 0. In other terms, the useful condition requires that ε_n be a sequence of positive real decreasing to 0 (*Condition 1*). In practice, we choose a sequence ε_n where the series $\sum \delta_k \varepsilon_k$ is absolutely convergent.
2. The convergence of the series $\sum \delta_k \varepsilon_k$ to θ is it always possible whatever the real θ? Actually, no. δ_k can take only the values $+1$ or -1, whether $\theta > \Sigma\varepsilon_n$ or $\theta < -\Sigma\varepsilon_n$. As a result, it is not possible to approach the angle θ with the series $\sum \delta_n \varepsilon_n$.

To approach the angle θ close to ε_n, Eq. (3) should be verified:

$$|\theta| \le \sum \varepsilon_n \quad \text{or} \quad |\theta| \le \sum_{k=0}^{n} \varepsilon_k \tag{3}$$

Limited to the first $(n + 1)$ terms.

Let us see how can we choose the sequence (δ_n)?

Consider $s_i = \sum_{k=0}^{i-1} \delta_k \varepsilon_k$ and build the sequence δ_n as follows:

- If $\theta \ge 0$ then $s_1 = \varepsilon_0$ (approaching to θ starting from ε_0, i.e. $\delta_0 = +1$). If not, $s_1 = -\varepsilon_0$ (approaching to θ starting from $-\varepsilon_0$, i.e. $\delta_0 = -1$).
- If $\theta - \delta_0 \varepsilon_0 \ge 0$, then $s_2 = \varepsilon_0 + \varepsilon_1$ (approaching to θ by adding ε_1, i.e. $\delta_1 = +1$). If not, $s_2 = \varepsilon_0 - \varepsilon_1$ (approaching to θ by subtracting ε_1, i.e. $\delta_1 = -1$).

More generally:

- If s_k is greater than θ, so $s_{k+1} = s_k - \varepsilon_k$ therefore $\delta_k = -1$.
- If s_k is less than θ, so $s_{k+1} = s_k + \varepsilon_k$ therefore $\delta_k = +1$.