Peer-to-peer non-line-of-sight localization in multipath environment

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Peer-to-peer Non-line-of-sight Localization in Multipath Environment

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Abstract— Current localization schemes are able to locate a mobile device using Time-of-Arrival (TOA) and Angle-of-Arrival (AOA) information measured at both the mobile device and reference device. This information is used to derive line of possible mobile device position (LPMD). The intersection points of LPMDs are used to estimate mobile position. However these algorithms do not work well in a dense multipath environment with high level of TOA and AOA noises. In addition, these techniques require at least two paths to locate the mobile position. This paper presents novel methods to find the area of mobile device position and a least square estimator is constructed to find the centroid of mobile position. Furthermore, the proposed technique is able to determine mobile device using one LOS path. Simulation results show that our proposed scheme outperforms previous bidirectional localization schemes by a significant margin especially at high levels of TOA and AOA measurement noise.

1. INTRODUCTION

Wireless localization is an important area that receives significant research interest recently. It is required in many sensor network applications, such as transportation systems, personal tracking and navigation [1–3]. Conventional LOS schemes fail to work when there are insufficient RDs in LOS with the MD or when the signals are dominated by NLOS paths [4, 5]. Several NLOS mitigation techniques [6, 7] have been suggested to identify and discard NLOS signals. These techniques are, however, will not perform satisfactorily as they generally require the number of LOS RDs to be more than the number of NLOS RDs.

With the popularity of Multiple Input Multiple Output (MIMO) system using antenna array [8, 9], Non Line of Sight localization (NLOS) techniques have been proposed to tackle the problem of insufficiency of LOS path. In NLOS schemes, NLOS information, like those of one bounce scattering, is not discarded but used to complement LOS information in determining MD position. So far, NLOS information that is contained within one bounce scattering paths can be used to assist LOS paths [10, 11]. However, these methods do not work well in environments when multipath becomes too dominant and distances travelled by multiple-bounce reflection paths become comparable with those of one-bounce reflection, causing weighting factors of multiple-bounce LPMDs to be comparable with those of one-bounce. Also, these methods is unable to locate MD relying only one signal path and the accuracy will be deteriorated when the TOA and AOA measurement noises become larger.

In this paper, we formulate a novel peer to peer localization technique to improve the robustness of the method presented in [10, 11]. Most importantly, our proposed technique does not require any threshold value to select LPMD for localization. The robustness and accuracy of the technique are greatly enhanced by our proposed making only one LOS signal path. Our simulation results have also shown our proposed localization technique outperforms the existing peer-to-peer localization technique especially for large AOA and TOA measurement noise.

2. NOVEL NLOS SCHEME

The area of mobile device position is able to be derived by leveraging on the TOA and AOA of LOS path that are measured at both RD and MD. The jth RD with known location coordinate (x_j, y_j) has a measured data metric AOA θ_j and TOA t_j for the mth received signal path, where $j = 1, 2, \ldots, N$, with N being the number of RDs. The MD with unknown coordinate (x, y) has a measured AOA ϕ_j and TOA τ_j. The measured TOAs are related to the received path lengths in the following manner:

$$d_j = ct_{j,m}, \quad r_j = c\tau_{j,m} \tag{1}$$

where c is the speed of wave propagation.

The AOA and TOA data value are perturbed by the measurement noise:

$$\theta_j = \theta_j^0 + n_{\theta_j},\ \phi_j = \phi_j^0 + n_{\phi_j},\ d_j = d_j^0 + n_{d_j},\ r_j = r_j^0 + n_{r_j},\ n_l = N(0, \sigma_l),\ \ l = \theta_j, \phi_j, d_j, r_j \tag{2}$$

where θ_j^0, ϕ_j^0 and d_j^0, r_j^0 are the true AOA and TOA values of LOS path. n_{θ_j}, n_{ϕ_j} and n_{d_j}, n_{r_j} indicate the measurement noise which are assumed by zero mean Gaussian random variable with known standard deviation σ_l.

Since the noises are assumed to be Gaussian measurement noise, it is possible to know the angular bounds from the statistics of the AOA distribution. That is the LOS path AOA θ_j must in the interval $[\theta_j - 3\sigma_{\theta_j}, \theta_j + 3\sigma_{\theta_j}]$ with confidence level 99.7%. Therefore, the MD position is constrained to an enclosed region overlapped by the two distance and angular bounds, as shown in Fig. 1.

3. RESULT AND DISCUSSION

To test the applicability and accuracy of our proposed localization scheme, we compare our simulation results with those presented in [10]. The authors in [10] presented the accuracy of their algorithm by selecting only the 2 best LOS and NLOS paths based on their weighting factor of LPMD paths. Measurement data metrics (AOA and TOA) were measured by using ray tracing methodology proposed in [12–14]. Three RDs were positioned in the environment at (25, 9), (18, 4), (3, 14). In order to compare with the algorithm in [10], the mobile device was placed at exactly the same position whereby:

For case A, MD is at position (16, 12) in the layout as shown in Fig. 2(a). In this position, the three RDs are in LOS with MD. For case B, MD is at position (14.5, 12) whereby only one RD (3, 14) is in LOS with the MD. Simulation results for case A to B are shown in Fig. 3.

It is observed from the simulation results, as illustrated in Fig. 3, that our proposed technique outperforms the existing peer-to-peer localization technique by a significant margin especially when TOA and AOA measurement noises become large. For example, using $\sigma_d = \sigma_r = 3\,\text{m}$, $\sigma_\theta = \sigma_\phi = 5°$, Fig. 3(a) shows that our proposed scheme achieves an accuracy of 2.6 m for 90% of the time as

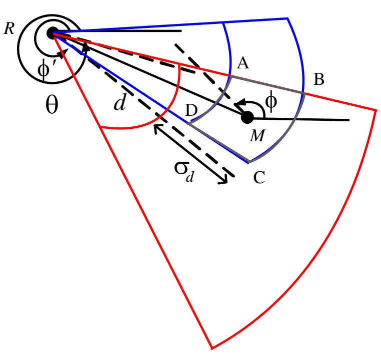

Figure 1: Area of mobile device position.

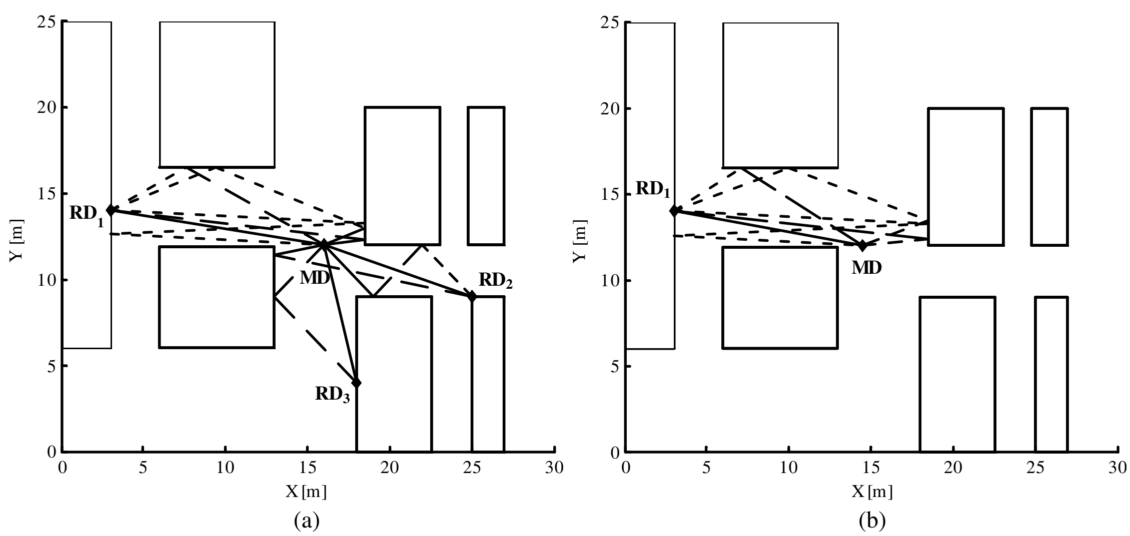

Figure 2: (a) Three RDs are in LOS with MD. (b) One RD is in LOS with MD.

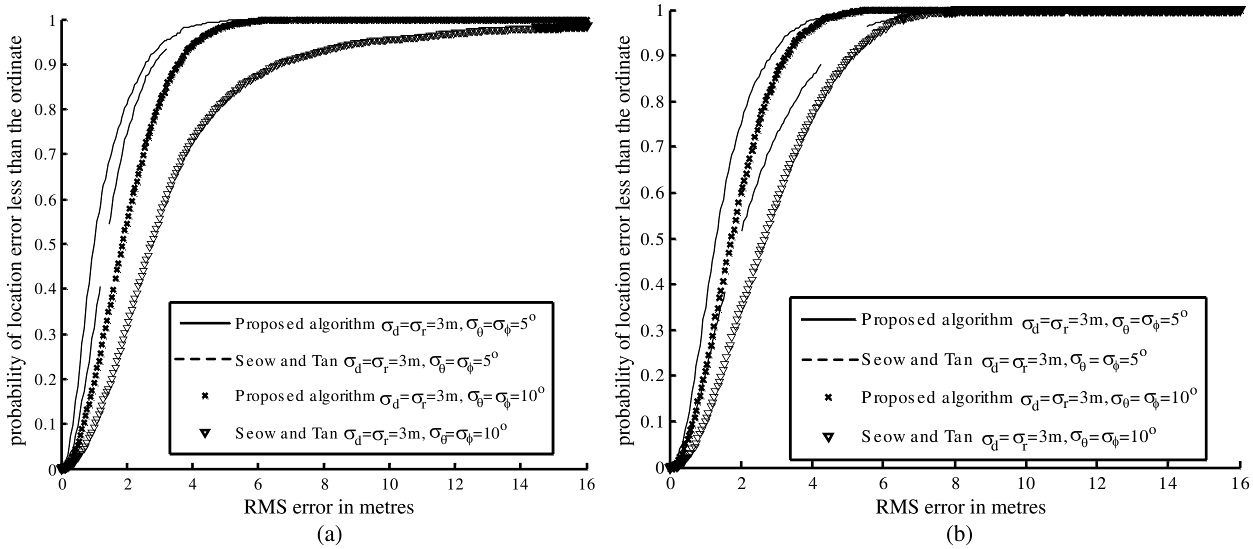

Figure 3: (a) Comparison of the CDF performance for an actual MD located at (16, 12). Three RDs are in LOS with MD. (b) Comparison of CDF performance for an actual MD located at (14.5, 12). One RD is in LOS with MD.

compared 2.8 m of Seow and Tan's method in [10], and improvement of about 7% is shown in Fig. 3(a). This margin increase to 46% using $\sigma_d = \sigma_r = 3\,\text{m}$, $\sigma_\theta = \sigma_\phi = 10^\circ$.

4. CONCLUSIONS

A novel approach to improve the accuracy and robustness of NLOS Peer-to-Peer localization has been proposed. The proposed method was tested and shown to be accurate and robust under various operating conditions. Moreover, the proposed method also significantly outperforms the current NLOS localization technique.

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