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Cooperative Improved Target Localization in Harsh Environments using Direction of Arrival

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Abstract
Target localization is an important issue for many applications in wireless sensor networks. However, it is rather difficult to maintain the localization accuracy in mixed line-of-sight (LOS) and non-line-of-sight (NLOS) environments as NLOS propagation leads to larger error than what LOS does. In this paper, we propose a new target localization method in mixed environments where NLOS is dominant and only one base node might be in LOS toward target. We use the cooperation between receiver nodes and the direction of arrival (DOA) of received signals to estimate the target's location. The proposed cooperative target localization method tries to identify a base node that has LOS with respect to target node and use the LOS information for precise positioning of target node. We simulate the proposed method to analyze its performance. Simulation results confirm that our proposed method improves the localization accuracy on average by 20 percent in comparison with traditional cooperative methods.

Keywords*: localization, wireless sensor networks, non-line-of-sight, direction of arrival, cooperative*

1. Introduction

In wireless sensor networks each node collects data from its surrounding environment according to the type of installed sensors and sends the gathered information to a center called base node for further processing or decision making [1-3]. This information is useful when the position of nodes is provided with needed accuracy. Finding the position of targets (Localization) in WSNs has attracted a lot of interest in emergency applications [4, 5], traffic control [6, 7], military affairs [8], civil [9] and so forth. Different methods are proposed for node localization in WSNs such as what proposed in [10-12].

In [12], target node positioning is performed by received signal strength (RSS) and path loss exponent. This method is only applicable in indoor line-of-sight (LOS) environments. Some other proposed methods also consider LOS signaling [13, 14]. In [14], authors propose a localization method to improve the accuracy in LOS environments for mobile devices, while in practical scenarios; mobile devices usually experience NLOS signals. In some recent researches, only NLOS signals are considered to localize the target [10], [15-16]. However, by using LOS signals in addition to NLOS ones, the accuracy of localization can considerably be improved [16]. In [18] and [19] the localization of target node is performed using RSS and Kalman filter in the presence of both LOS and NLOS signals. In [17], localization in NLOS environment based on time of arrival (TOA) is studied and it is assumed that the information of NLOS status is completely known. However, this assumption is not applicable in most practical scenarios and synchronization in TOA based methods is a challenging issue. The direction of arrival (DOA) technique is also used for target localization. In [10], hybrid measurements localization (HML) method is proposed for target localization. In this HML method, the cooperative base nodes and combination of DOA and TOA measurements scattered from shared reflectors to several base nodes is used. The above mentioned methods, consider only LOS or NLOS signals and when they face a mixed LOS and NLOS environment, especially when NLOS is dominant, they are unable to identify and use the received LOS signals and consider all signals as NLOS.

In this paper, we propose a new cooperative localization method for mixed LOS and NLOS environments. We use the direction and range measurements and cooperative base

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nodes to identify a base node that is in LOS with target node. The information of this node with LOS toward target is used to weight the final decision and to improve the accuracy of localization task. The reminder of this paper is organized as follows. Section 2, explains the system model. In section 3, we present our proposed method. In section 4, simulation scenario and comparative results are described and finally section 5, concludes the paper.

2. System Model

Two categories of nodes, base nodes and target nodes are usually considered in system model of target localization in WSNs [10]. It is assumed that base nodes are equipped with antenna arrays and are able to estimate the range and DOA, e.g., 4G and 5G mobile base stations with smart antennas. Target nodes are simple transceivers (e.g., cell phones) that have omnidirectional antennas and cooperate with base nodes to support range and DOA measurements. DOA is measured with respect to a reference direction, e.g., with respect to the east.

As depicted in Figure 1, there are two sub scenarios when a target node is positioned by multiple base nodes: 1) there are two or more LOS base nodes; and 2) there is one or no LOS base node. When position of a target node is determined by multiple LOS base nodes, the multi node TOA-DOA fusion presented in [16] could be applied, which is not the focus of this paper. In this paper, the localization problem in the second sub scenario is addressed which is localization of target node with multiple base nodes, when there is only one or no LOS base node.

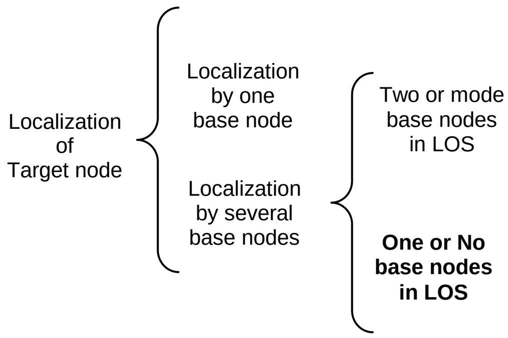

Figure 1. Target Node Localization Categories in Mixed LOS and NLOS Environments.

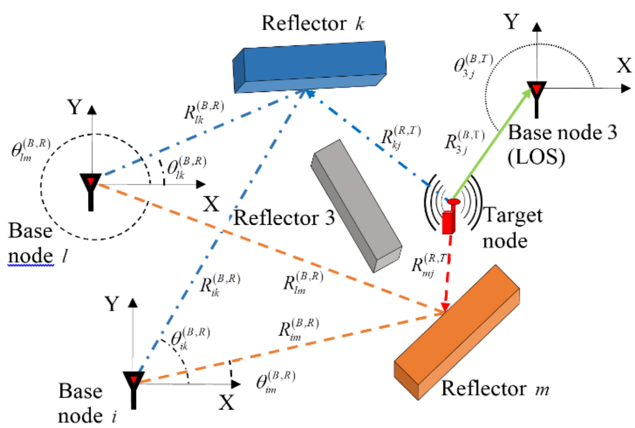

Figure 2. Target Node And Reflection Point Location Estimation

In our model, we assume that only one reflected version of signal is received in base nodes. This assumption is typically fair in urban areas [20]. As the power of multiple bounces signals (multiple reflected version of main signal) is comparable to that of single bounce signal, multiple bounces signals will be considered as single bounce signals. Actually, the receiver only considers the signals that are larger than a specific threshold.

The measurement error of DOA is a zero mean independent Gaussian random variable with variance σ_θ^2. To estimate the target node, we should first calculate the position of shared reflector by two received DOAs. Then, we should estimate the position of target node via the least square (LS) method, using the estimated distance between the target node to the base nodes. This distance could be estimated by TOA or RSS techniques.

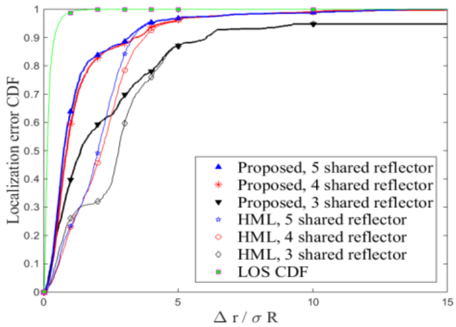

Figure 3. Localization Error CDF, $\sigma_\theta = 1^\circ$

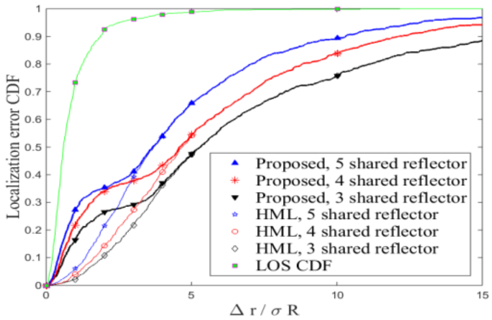

Figure 4. Localization Error CDF, $\sigma_\theta = 2^\circ$

2.1. Shared Reflector Localization

In system model, first shared reflection point is localized and further the data is used to localize the target. The reflection point k or m is shared between base node i and l as depicted in Figure 2.

At base nodes i and l, we have two sets of measurements $(R_{ikj}^{(B,R,T)}, \theta_{ikj}^{(B,R,T)})$ and $(R_{lkj}^{(B,R,T)}, \theta_{lkj}^{(B,R,T)})$ due to the reflection point k. The superscript $(\mathrm{B,R,T})$ represents that the source is a target node (T), the range (distance) and angle are measured at a base node (B) through a reflection point. Based on Figure 2, we have:

$$R_{ikj}^{(B,R,T)} = R_{ik}^{(B,R)} + R_{kj}^{(R,T)}, \theta_{ikj}^{(B,R.T)} = \theta_{ik}^{(B,R)}, R_{lkj}^{(B,R,T)} = R_{lk}^{(B,R)} + R_{kj}^{(R,T)}, \theta_{lkj}^{(B,R.T)} = \theta_{lk}^{(B,R)} \quad (1)$$

The superscript (t) represents the true value. Therefore, we have:

$$\theta_{ik}^{(B,R.T)} = tan^{-1}\frac{y_k^{(R,t)} - y_i^{(B,t)}}{x_k^{(R,t)} - x_i^{(B,t)}}, \theta_{lk}^{(B,R.T)} = tan^{-1}\frac{y_k^{(R,t)} - y_l^{(B,t)}}{x_k^{(R,t)} - x_l^{(B,t)}} \quad (2)$$

In (2), a pair of DOAs ($\theta_{ik}^{(B,R.T)}$ and $\theta_{lk}^{(B,R.T)}$) are used as for the shared reflection point k. Considering (1), and using the true values in (2) instead of the measured DOA, least square estimation is used to address (3) and to calculate the position of the reflection point k labeled as $(x_k^{(R)}, y_k^{(R)})$.

$$\theta_{ik}^{(B,R)} = g_i\left(x_k^{(R)}, y_k^{(R)}\right) = tan^{-1}\frac{y_k^{(R)} - y_i^{(B,t)}}{x_k^{(R)} - x_i^{(B,t)}}, \theta_{lk}^{(B,R)} = g_i\left(x_k^{(R)}, y_k^{(R)}\right) = tan^{-1}\frac{y_k^{(R)} - y_l^{(B,t)}}{x_k^{(R)} - x_l^{(B,t)}} \quad (3)$$

The locations of these reflection points could be used for positioning of target node j. Now we need to localize the shared reflection points based on NLOS identification. First, one set of DOA and distance measurement from the k_i available sets of measurements, ($R_{ikj}^{(B,R,T)}$,) is selected where k is the index of reflection point. Then, another set of measurement from the Kl sets of achieved measurements at another base node l is selected to localize the same target node j, ($R_{lmj}^{(B,R,T)}$, $\theta_{lmj}^{(B,R,T)}$), where m is the index of reflection point. The intersection point of two supporting lines for selected DOA measurements, $\theta_{ikj}^{(B,R,T)}$ and $\theta_{lmj}^{(B,R,T)}$ is the shared reflection point $\hat{x}_{km}^{(R)}, \hat{y}_{km}^{(R)}$ calculated as follows [10]:

$$\begin{bmatrix} \hat{x}_{km}^{(R)} \\ \hat{y}_{km}^{(R)} \end{bmatrix} = [A^T A]^{-1} A^T \cdot b \tag{4}$$

Where $A = \begin{bmatrix} \sin\theta_{ikj}^{(B,R,T)} & -\cos\theta_{ikj}^{(B,R,T)} \\ \sin\theta_{lmj}^{(B,R,T)} & -\cos\theta_{lmj}^{(B,R,T)} \end{bmatrix}$ and $b = \begin{bmatrix} x_i^{(B)} \sin\theta_{ikj}^{(B,R,T)} - y_i^{(B)} \cos\theta_{ikj}^{(B,R,T)} \\ x_l^{(B)} \sin\theta_{lmj}^{(B,R,T)} - y_l^{(B)} \cos\theta_{lmj}^{(B,R,T)} \end{bmatrix}$.

We estimate the distances between shared reflection point and the base node $\hat{R}_i^{(B,R)}$ and $\hat{R}_l^{(B,R)}$, then calculate the distance between share reflectors and target node $R_i^{(R,T)}$ and $R_l^{(R,T)}$ using (5).

$$R_i^{(R,T)} = R_{ikj}^{(B,R,T)} - \hat{R}_i^{(B,R)}, R_l^{(R,T)} = R_{lkj}^{(B,R,T)} - \hat{R}_l^{(B,R)} \tag{5}$$

In the case that the two selected sets of measurements were used from the same reflector (both $\theta_{imj}^{(B,R,T)}$ and $\theta_{lkj}^{(B,R,T)}$ came from reflection point k), namely $m = k$, the point obtained by intersection of lines using DOA measurements would be the estimated position of the shared reflection point.

$$\left(|\,\theta_{ikj}^{(B,R,T)} - \theta_{lmj}^{(B,R,T)}\,| < \theta_{th}\right), \left(\pi - \theta_{th} < |\,\theta_{ikj}^{(B,R,T)} - \theta_{lmj}^{(B,R,T)}\,| < \pi + \theta_{th}\right), \left(2\pi - \theta_{th} < |\,\theta_{ikj}^{(B,R,T)} - \theta_{lmj}^{(B,R,T)}\,|\right) \tag{6}$$

If the angle between the lines that connecting the shared reflection point and base nodes is too small and the measured angles satisfy one of the three inequalities represented in (6), the localization using the intersection of DOA lines causes large errors. This is because the lines connecting the shared reflection point and base nodes become nearly parallel.

2.1.1. The Shared Reflection Point Positioning Error

The shared reflection point positioning error is approximated using the method presented in [21]:

$$\Delta X_k^{(R)} = \left(B^T B\right)^{-1} B^T \cdot \Delta\theta_k \tag{7}$$

In (7), $\Delta X_k^{(R)}$ is the positioning error for reflection point *k* and $\Delta X_k^{(R)} = \left[\Delta x_k^{(R)} \Delta y_k^{(R)}\right]^T$, $\Delta x_k^{(R)}$ and $\Delta y_k^{(R)}$ are linear combinations of DOA estimation errors that are zero mean Gaussian random variables.

The error transformation matrix is denoted by $B = \begin{bmatrix} b_{x,i} \, b_{y,i} \\ b_{x,l} \, b_{y,l} \end{bmatrix}$, and $b_{x,i} = \dfrac{\partial g_i\left(x_k^{(R)}, y_k^{(kR)}\right)}{\partial x_k^{(R)}}$, $b_{y,i} = \dfrac{\partial g_i\left(x_k^{(R)}, y_k^{(R)}\right)}{\partial x_y^{(R)}}$, $b_{x,l} = \dfrac{\partial g_i\left(x_k^{(R)}, y_k^{(R)}\right)}{\partial x_k^{(R)}}$ and $b_{y,l} = \dfrac{\partial g_l\left(x_k^{(R)}, y_k^{(R)}\right)}{\partial x_k^{(R)}}$.

The approximated error of the distance between the shared reflection point *k* and base node *i* is calculated using first order terms of Taylor series (assuming higher order terms are ignorable), which is:

$$\mathrm{cov}(\Delta X_k^{(R)}) = \left(B^T B\right)^{-1} B^T \cdot \mathrm{cov}\left(\Delta\theta_k\right) \cdot \left(B^T B\right)^{-1} B^T \qquad (8)$$

Because of inaccuracy in matrix *B*, $\mathrm{cov}(\Delta X_k^{(R)})$ is erroneous, and the error in $\mathrm{cov}(\Delta X_k^{(R)})$ is propagated to the target node positioning. By defining $ER = \mathrm{cov}\left(\Delta X_k^{(R)}\right)$, the variance of error in positioning of shared reflection point on *x* and *y*-axes and the error covariance is defined as:

$$\sigma_{x_k^{(R)}}^2 = ER(1,1), \sigma_{y_k^{(R)}}^2 = ER(2,2), \mathrm{cov}\left(\Delta x_k^{(R)}, \Delta y_k^{(R)}\right) = ER(1,2) = ER(2,1) \qquad (9)$$

2.2. NLOS Target Node Localization

Assume that the true position of base node is known, and the locations of shared reflection points are calculated as presented earlier. The distance between the shared reflection point and base node could be calculated using (10):

$$R_{ik}^{(B,R)} = f_i\left(x_i^{(B,t)}, y_i^{(B,t)}, x_k^{(R)}, y_k^{(R)}\right) = \sqrt{\left(x_k^{(R)} - x_i^{(B,t)}\right)^2 + \left(y_k^{(R)} - y_i^{(B,t)}\right)^2} \qquad (10)$$

The approximated error of distance between the shared reflection point k and base node i is calculated using first order terms of Taylor series (assuming that higher order terms are ignorable) [10], which is:

$$\Delta R_{ik}^{(B,R)} = \frac{x_k^{(R)} - x_i^{(B,t)}}{R_{ik}^{(B,R)}} \Delta x_k^{(R)} + \frac{y_k^{(R)} - y_i^{(B,t)}}{R_{ik}^{(B,R)}} \Delta y_k^{(R)} \qquad (11)$$

Hence, $\Delta R_{ik}^{(B,R)}$ is a zero mean Gaussian random variable, because $\Delta x_k^{(R)}$ and $\Delta y_k^{(R)}$ are both zero mean Gaussian random variables and the corresponding variance of error is:

$$\sigma_{R_{ik}^{(B,R)}}^2 = \left(\frac{x_k^{(R,t)} - x_i^{(B,t)}}{R_{ik}^{(B,R,t)}}\right)^2 \sigma_{x_k^{(R)}}^2 + \left(\frac{y_k^{(R,t)} - y_i^{(B,t)}}{R_{ik}^{(B,R,t)}}\right)^2 \sigma_{y_k^{(R)}}^2 + 2\left(\frac{x_k^{(R,t)} - x_i^{(B,t)}}{R_{ik}^{(B,R,t)}} \cdot \frac{y_k^{(R,t)} - y_i^{(B,t)}}{R_{ik}^{(B,R,t)}}\right) \mathrm{cov}\left(\Delta x_k^{(R)}, \Delta y_k^{(R)}\right) \qquad (12)$$

Considering (1), when a shared reflector *k* is localized and the distances between reflection point *k* and two base nodes *i* and *l* are calculated, we can achieve two estimations of the distance between the shared reflection point *k* and the target node *j*, $R_{ikj}^{(B,R,T)} - R_{ik}^{(B,R)}$ and $R_{lkj}^{(B,R,T)} - R_{lk}^{(B,R)}$.The error variance of $R_{ikj}^{(B,R,T)}$ and $R_{lkj}^{(B,R,T)}$ is σ_R^2 and the error variance of $R_{ik}^{(B,R)}$ and $R_{lk}^{(B,R)}$ is calculated using (12). The Distance between shared reflection point and target node is calculated using (13) as follow:

$$R_{kj}^{(R,T)} = \frac{\sigma_R^2 + \sigma_{R_{lk}^{(B,R)}}^2}{\sigma_R^2 + \sigma_{R_{ik}^{(B,R)}}^2 + \sigma_R^2 + \sigma_{R_{lk}^{(B,R)}}^2}\left(R_{ikj}^{(B,R,T)} - R_{ik}^{(B,R)}\right) + \frac{\sigma_R^2 + \sigma_{R_{ik}^{(B,R)}}^2}{\sigma_R^2 + \sigma_{R_{ik}^{(B,R)}}^2 + \sigma_R^2 + \sigma_{R_{lk}^{(B,R)}}^2}\left(R_{lkj}^{(B,R,T)} - R_{lk}^{(B,R)}\right) \qquad (13)$$

Therefore, target node can be localized at $\left(x_{nlos}^{(\mathrm{T})}, y_{nlos}^{(\mathrm{T})}\right)$ via LS estimation method.

3. Proposed Method

In this paper, we propose a localization technique using NLOS measurements collected by multiple collaborative base nodes. In proposed method, we assume that only one or no LOS link between base node and target is available. Similar to [10], we assume that at least three reflection points are needed to be shared by the target node and multiple sets of base nodes (each set includes two or more base nodes) are needed to localize the target node. The main assumptions in our proposed method are as follows: 1) The position of base node is known. 2) In order to resolve signals received by base nodes through different paths, the DOA estimation resolution is high enough. 3) The channel between target node and base node is assumed to be LOS or single rebound reflection NLOS.

In our proposed method, we use DOA estimation in LOS localization method presented in [22] and also cooperation between base nodes that are placed in NLOS environments. We identify the base node that is in LOS toward target and use this base node to improve the localization accuracy of target node.

3.1. Identifying the LOS base node

To identify the base node that has LOS toward target node, all DOA measurements should be tested by (14) except those that have been used in the calculation of target node position $\hat{x}_{nlos}^{(\mathrm{T})}$ and $\hat{y}_{nlos}^{(\mathrm{T})}$ that was presented in Sec. 2.2.

$$\hat{x}_{los}^{T} = R_{ij}^{(B,T)} \cdot \cos(\theta_{ij}^{(B,T)}) + x_i^{(B)}, \hat{y}_{los}^{T} = R_{ij}^{(B,T)} \cdot \sin(\theta_{ij}^{(B,T)}) + x_i^{(B)} \quad (14)$$

In this way, we can obtain possible positions of target node. After that, we compare the obtained points with obtained positions by NLOS localization method. The comparison equation is as follows:

$$\sqrt{(\hat{x}_{nlos}^{(T)}, -\hat{x}_{los}^{(T)})^2 + (\hat{y}_{nlos}^{(R)} - \hat{y}_{los}^{(T)})^2} < \beta \quad (15)$$

This comparison is done by (14) and in this way we can identify the node which is in LOS to target point. In (15), β is a threshold and is determined based on standard deviation of range estimation error. In (15) we set $\beta = 2\sigma_R$, where σ_R is the standard deviation of range estimation error. The final target node position is:

$$x_{Fin}^{(T)} = \frac{\gamma(\hat{x}_{los}^{(T)}) + \hat{x}_{nlos}^{(T)}}{2+\gamma}, y_{Fin}^{(T)} = \frac{\gamma(\hat{y}_{los}^{(T)}) + \hat{y}_{nlos}^{(R)}}{2+\gamma} \quad (16)$$

Where γ is set as the weight of LOS estimation of target node pointed in (16).

3. The Pseudocode of Proposed Algorithm

In this part, we explain the proposed algorithm in details using a pseudocode.

Algorithm 1 Proposed Target Localization Algorithm.

Step 1. Choose new measurements of two nodes $\left(R_{ikj}^{(B,R,T)}, \theta_{ikj}^{(B,R.T)}\right)$ and $\left(R_{lmj}^{(B,R,T)}, \theta_{lmj}^{(B,R.T)}\right)$.

Step 2. **If** one of the three constraints in (6) is true,
then Go to Step1. **else**

Step 3. Use $q_{ikj}^{(B,R.T)}$ and $\theta_{lmj}^{(B,R.T)}$ to obtain $\hat{x}_{km}^{(R)}$ and $\hat{y}_{km}^{(R)}$. Calculate the variance of obtained position's error ($\sigma^2_{\hat{x}_{km}^{(\mathrm{R})}}, \sigma^2_{\hat{y}_{km}^{(\mathrm{R})}}$).

Step 4. Calculate $\hat{R}_i^{(B,R)}$ and $\hat{R}_l^{(B,R)}$ using (10), and calculate $\sigma^2_{\hat{R}_i^{(B,R)}}$ and $\sigma^2_{\hat{R}_l^{(B,R)}}$ by (12).

Step 5. **If** $R_{ikj}^{(B,R,T)} < \hat{R}_i^{(BR)}$ Or $R_{lmj}^{(B,R,T)} < \hat{R}_l^{(BR)}$ is true,
then Go to Step 1. **else** Go to Step 6.

Step 6. **If** $\left|\left(R_{ikj}^{(B,R,T)} - \hat{R}_i^{(B,R)}\right) - \left(R_{lmj}^{(B,R,T)} - \hat{R}_l^{(B,R)}\right)\right| < \alpha\sqrt{2\sigma_R^2 + \sigma^2_{\hat{R}_i^{(B,R)}} + \sigma^2_{\hat{R}_l^{(B,R)}}}$,
then Go to Step 7. **else** Go to Step 1.

Step 7. Calculate the position of shared reflection point $\hat{x}_{km}^{(R)}$, $\hat{y}_{km}^{(R)}$ and also the distance between reflector and target node $R_{kj}^{(R,T)}$ with error variance of $s^2_{R_{kj}^{(\mathrm{R,T})}}$.

Step 8. **If** (all receiving angles by all nodes are investigated),

Then Go to Step 9. **else** Go to step 1.

Step 9. Use calculated position of shared reflectors, approximate position of target node $\hat{x}_{nlos}^{(\mathrm{T})}$ and $\hat{y}_{nlos}^{(\mathrm{T})}$ via least squares method.

Step 10. Calculate the position of possible target node $\hat{x}_{los}^{(\mathrm{T})}$ and $\hat{y}_{los}^{(\mathrm{T})}$ using one of the receiving angles to the base node which is rejected from Step 2, Step 5 and Step 6, by (14).

Step 11. **If** equation (15) is true,
then Go to Step 12. **else**Go to Step 10.

Step 12. Put $\hat{x}_{los}^{(\mathrm{T})}$ and $\hat{y}_{los}^{(\mathrm{T})}$ in (16), then position of target node will be re-estimated and final point ($x_{Fin}^{(\mathrm{T})}$, $y_{Fin}^{(\mathrm{T})}$) will be calculated.

Step 13. **Return** ($x_{Fin}^{(\mathrm{T})}, y_{Fin}^{(\mathrm{T})}$).

In Step 6, *α* is a positive number that can be determined by the probability of error and probability of failure in detection of reflector. Error rate between the two base nodes and the target node ($R_{lmj}^{(B,R,T)}$ and $R_{ikj}^{(B,R,T)}$) is independent and i.i.d.. In addition, the error intervals $R_{lmj}^{(B,R,T)}$, $R_{ikj}^{(B,R,T)}$, $\hat{R}_{i}^{(B,R)}$ and $\hat{R}_{l}^{(B,R)}$ are independent.

4. Simulation Results

The performance of the proposed method is evaluated using computer simulations. We have made some common assumptions. Implementation in MATLAB is averaged over 1000 experiments. Target node and reflection points are uniformly distributed in an square area with corners (d,d), $(\mathrm{d},-\mathrm{d})$, $(-\mathrm{d},\mathrm{d})$ and $(-\mathrm{d},-\mathrm{d})$. The target node position is randomly selected. There is one or no LOS path. In the shared reflection point localization process, we set $\theta_{th} = 18^{\circ}$. The weight of LOS estimation, *γ,* is set to 4 and α is set to 3 similar to [10].

In Figure 3 and Figure 4, we compare the CDF of target node localization error between the proposed method and the HML method. The HML method introduced in [10] is one of recent cooperative localization methods with acceptable accuracy of target localization compared to earlier methods. The localization error is defined as the distance between the actual location of target node and its estimated location.

In Figure 3, we set $d = 50\sigma_R$ and $\sigma\theta = 1^{\circ}$ to repeat the simulation. In the case with three shared reflectors, our proposed method achieves $P(\Delta r < 2\sigma_R) = 0.553$ and in HML method $P(\Delta r < 2\sigma_R) = 0.3$. In fact, proposed method increases positioning accuracy by 25.3%. With five share reflectors for our proposed method, $P(\Delta r < 2\sigma_R) = 0.724$ and for HML method $P(\Delta r < 2\sigma_R) = 0.435$ which means 28.9% increase in localization accuracy.

In Figure 4, the range is the same, $d = 50\sigma_R$ but we set $\sigma_{\theta} = 2^{\circ}$. Considering three shared reflector points, in proposed method $P(\Delta r < 2\sigma_R) = 0.264$ and for HML method $P(\Delta r < 2\sigma_R) = 0.108$ and therefore, the localization accuracy increases by 15.6%.

As depicted in Figure 4 and Figure 5, simulation results confirm that the proposed method improves the accuracy of target localization in mixed environments with dominant NLOS in all cases with three, four or five shared reflection points compared to HML method.

5. Conclusion

In this paper, we proposed a new target node localization method for mixed LOS and NLOS environments where NLOS is dominant and only one base node might be in LOS respect to target node. We used the collaboration of base nodes to identify the base node with LOS toward target. We used the information of that base node to improve the accuracy of localization task. We used computer simulation on different scenarios to evaluate the performance of proposed algorithm. Considering measurement errors and different number of shared reflector points, simulation results confirmed that our proposed method improved the accuracy of target localization task on average by 20 percent.

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