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RF/Microwave Communication Subsystems for Emerging Wireless Technologies

Cooperative Localization in WSN based on Real-Time Pathloss and Node Selection

Albert Bel, José López Vicario and Gonzalo Seco Granados

Abstract

Cooperative localization in wireless sensor networks based on RSS allows for a reduction in terms of complexity with respect to other ranging techniques such that TOA or AOA. However, RSS-based methods are quite sensitive to the accuracy of the propagation model. In indoor environments, it is difficult to predict this model due to the unwieldy and dynamic nature of the RSS measurements. Existing solutions resort to measurement campaigns in order to properly characterize the propagation scenario. In this work, however, we consider the adoption of a real time method consisting in obtaining the propagation model that fits better with the environment in accordance with real time RSS measurements. In addition, we also include a node selection algorithm in order to improve the propagation model fitting by selecting the set of nodes satisfying similar propagation conditions. Apart from the optimization of the energy consumption, the proposed approach considers a more realistic propagation model and avoids the necessity of assuming an equal path loss exponent for all the nodes in the network. Finally, we present both computer simulations and experimentation results that confirm the validity of the proposed solution.

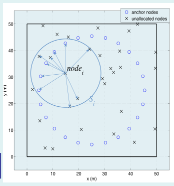
RSS-based location algorithm

We consider a cooperative localization system based on RSS measurements. The location algorithm is divided in two phases:

- Measurement phase:

Nodes obtain distances estimates (δ_{ij}) from those nodes having a RSS higher than an RSS threshold (RSS_{th}). Distance will be obtained through the following propagation model:

$$RSS_{ij}=P_{ij}=P_0-10\alpha\log_{10}d_{ij}-v_{ij}\ (dBm)$$



- LS Cooperative algorithm:

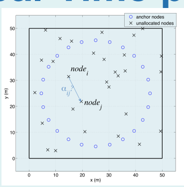
Nodes update their position estimates by obtaining the set of unallocated node positions that minimize the Euclidean distance (eq. a) between measured distances at first phase (δ_{ij}) and estimated distances obtained using such position coordinates (d_{ij}). The minimization is done through a distributed iterative method (eq. b.

$$C_{LS}(x)=\sum_{i=1}^{N_2}\sum_{j\epsilon S_i}||\delta_{ij}-\hat{d}_{ij}||^2 \quad eq.(a)$$

Distributed minimization

$$\hat{\mathbf{x}}_i(t)=\hat{\mathbf{x}}_i(t-1)+\gamma\sum_{j\epsilon S_i}(\delta_{ij}-\hat{d}_{ij})\mathbf{e_{ij}} \quad eq.(b)$$

Real-Time pathloss estimation



The path loss exponent (α) is usually calculated by means of measurement campaigns. In order to avoid this, we introduce a real-time method to estimate this parameter from RSS values. This method also allows for the adaptation of the localization algorithm to scenario variations or unallocated nodes movements.

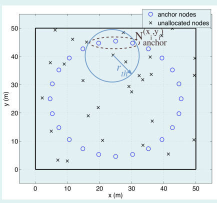
This is done by minimizing the following functions with the help of a robust technique (Levenberg-Marquardt algorithm).

$$(\hat{\alpha}_1,...,\hat{\alpha}_M)=\arg\min_{(\hat{\alpha}_1,...,\hat{\alpha}_M)}\sum_{k=1}^{T}\sum_{j=1}^{M}\left(\hat{d}_{ij}-\delta_{ij}\right)^2 \quad \forall i\in N_2,\forall j\in S_i$$

Selection mechanism

We propose to limit the number of cooperating nodes by adopting a threshold value RSS_{th} designed to optimize positioning accuracy vs. energy consumption trade-off.

Besides, we refine the node selection by taking advantage of the real-time path loss estimation. More specifically, we only select the nodes with better channel conditions (lower α values).



1. By assuming a uniform distribution of the N_2 unallocated nodes, the mean number of anchor nodes (N_m) inside the radio range radius (*r_{th}*) *is:*

$$N_m\sim\sum_{j=1}^{N_1}\pi r_{th}^2\frac{1}{A}=\frac{N_1\pi r_{th}^2}{A}$$

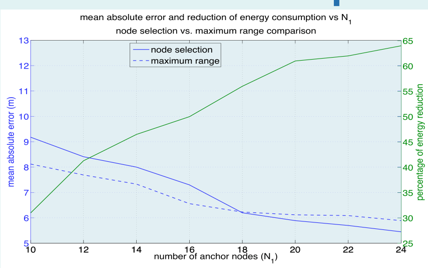
2. We consider the pathloss model dependency in order to establish the relation between the coverage range radius with the RSS threshold:

$$RSS_{th}^{PL}=\left(\frac{N_1\pi P_0^{2/\alpha}}{N_m A}\right)^{\alpha/2}$$

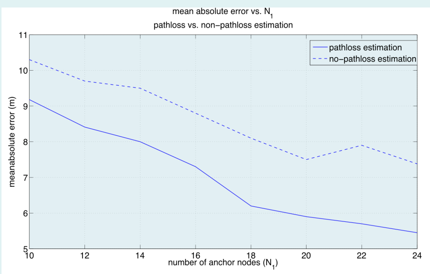
3. With the obtained threshold, only nodes with $RSS>RSS_{th}$ are selected.

4. Finally, the estimated pathloss exponents are used to restrict the selection to the nodes with lower values.

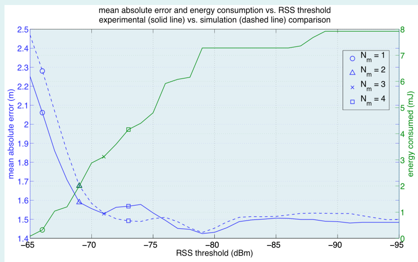
Simulation and experimental results



- Similar performance is achieved when comparing the proposed node selection with the maximum range scheme.
- The proposed scheme significantly reduces the energy consumption (65%@N_1=24 and 30% @N_1=10).



- Including real-time pathloss estimation offers substantial gains w.r.t. the conventional scheme.
- The higher number of anchor nodes the higher difference in terms of error.



- Experimental results validate the proposed scheme.
- Good trade-off in terms of mean absolute error vs. energy consumption achieved at Nm =3.

- We have proposed a node selection algorithm including real-time path loss estimation.
- The proposed strategy offers a significant reduction in terms of energy consumption while keeping almost the same positioning accuracy.

Discussion:

- Creation of common reference scenarios for indoor and outdoor environments.
- Deployment of a large network in collaboration with other partners.