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# New proposal algorithm for localization at WSN

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***Abstract*—finding the exact nodes positioning is a principal problem for reducing the overall localization time duration for all nodes in network. Different methods are applied to try to reduce the convergence time of network but as well to conserve a good performance and energy in sensor nodes. The localization techniques need to have some nodes in network that know their positions and then those will help in identifying the location of other nodes. In this paper are demonstrated some existing algorithms and it is introduced as well a theoretical proposal in order to somehow reduce interference in wireless communication. The experimental results allow us to compare our algorithm performance with other algorithms.**

***Keywords-localization, algorithms, sensor nodes, interference.***

## I. INTRODUCTION

Wireless Sensor Network (WSN) is made of some small device used for an advanced monitoring of different environment parameters like: temperature, pressure, humidity, etc. The information collected from the nodes is accessible out of the local network through one or more gateway nodes. There are many challenges that WSN face as: energy conservation, a low quality of communication, limited resources, data elaboration, and scalability. In this work are described different existing algorithms that are used for localization. Processing and extraction of meaningful knowledge and achieving an accurate calculation of node position in less possible time is a very important problem. A solution to saving time would be to use different schemes and methods that reduce the time of convergence, but it is needed to maintain also a good performance and energy conservation in nodes the longest possible. It is important that every node might know its own position. We will address a technical variant for localization connected with the problem. Every node must be aware of its position and orientation close to its neighbors. This variant is particularly suitable for applications where sensor nodes in a network needed to move in a cooperative way. The use of Global Positioning System (GPS) for localization in a large scale WSN is not cost effective and may be impractical in closed spaces. On the other hand, a group of pre-existing nodes with globally recognized positioning may not always be affordable. To enable these issues, we propose a technique for localization based on relative movement of neighboring nodes in a sensor network without GPS equipped infrastructure.

Localization in such network assumes the availability of a digital compass in each sensor node. In section II, it is presented some existing algorithms and it is brought also a new theoretical proposal for reducing the interference during wireless communication between sensor nodes, and it will remain as a case study for future work. Through experimental results it is shown and compared the new algorithm with other existing ones. Through simulations in Section III is demonstrated that the proposed algorithm provides a convergent localization over time with less errors than the two other algorithms. This new proposed algorithm is tested in presence of some errors introduced by nodes that are in motion and the distance estimation between these nodes. Some final conclusions are brought in section IV and some ideas for future work are introduced in section V.

## II. LOCALIZATION ALGORITHMS

It is considered a WSN with $n$ sensors that are randomly distributed in $d$ dimensions ($d$ = 2 or 3) zone and where there is no information about the location [4, 5]. To have the absolute coordinates there are used a few anchors added to the network $m$ ($m$<<$n$) and they know their position. Let it be $N$ $(N= n+m)$ the total number of sensors considered, $X=\{x_i$: i=1…$N\}$ $x_i \epsilon R^d$ is the vector of actual coordinate of sensor and $X=\{x_i$:$I$=1…$N\}$ $X_i \epsilon R^d$ is the vector with estimated coordinate of the nodes. Measurements of the connection range $\{\delta_{ij}$: $i,j$ = 1..$N\}$ are given or measured by the device. Localization problem stands in evaluation of the coordinates vector $\{x_i$: $i$=1…n$\}$ and the vector of the connection distance $\{\delta_{ij}$: $i \neq j$ and $i,j$ = 1..$N\}$. It is supposed that all the measured vector of the connection distance $\{\delta_{ij}$: $i \neq j$ and $i,j$ = 1..$N\}$ are known and $\| \delta_{ij}\|=\|\Delta_{ji}\|$ ($\|.\|$ is a norm-2). Below is described MLE (Maximum Likelihood Estimator) and PPE (Push-Pull Evaluation) algorithms, our new theoretical propose is based on them.

**a) *Maximum Likelihood Estimator*** (MLE) is a centralized algorithm based on a model. It can be used to estimate the location by using ToA, RSS, and connectivity as far as a statistical model is valid. MLE algorithm does not show any analytical choice for optimization and the possibility function is implemented by following an iterative mode. In

free space the signal strength decreases and it is inverse proportional with $d^2$ where $d$ is the distance between the transmitter and receiver. In real communication channel the multipath signal and the multiple reflections are two main sources of error in the estimation of nodes distances. The distance between the neighbor nodes helps in their localization through the usage of RSS or ToA, the signal propagation within a wireless medium depends on environment conditions and obstacles it finds in its way. There are many signals with differences in phase and amplitude and those all arrive at the receiver. The signals are summed to the line of sight signal at the receiver in a constructive or in deconstructive manner depending this on their phase and by causing like this a selective frequency fading. The effect of this kind of fading can be reduced by applying a spread spectrum technique (for instance the direct sequence or frequency hopping). It performs the averaging of received signal power over a wide range of frequencies. A spread spectrum receiver is an acceptable choice because the spread spectrum methods reduce the interferences in free band of frequencies where actually operates the wireless sensors.
So MLE uses the statistical model, where the sum of the average power at distance $d$ is expressed as:

$$\bar{P}(d) = \Pi_0 - 10n_p \log \frac{d}{\Delta_0} \tag{1}$$

The difference between the measured received power and the sum of the average is because of the shadowing effect so the signal will be modeled with a log-normal dispersion function (if the power is expressed in dB it is a Gaussian dispersion function). The log normal comes from a vast variety of measurements results and analytical proves. Standard deviation of the received power (is expressed in dBm), $\sigma$ has a unit in dB and it is relatively constant with the distance. So the received power at sensor $i$ is transmitted from $j$, $P_{i,j}$ its dispersion is, Eq.2:

$$f\left(P_{i,j=p|\theta}\right) = N(p; \bar{P}(\|z_i - z_j\|), \sigma_{dB}^2) \tag{2}$$

Where N(x, y, z) is the symbol for the value of $x$ of the Gaussian pdf with $y$ as average and $z$ as variance, $\theta$ is the vector of coordinate parameter from and to the actual distance between transmitter-receiver $\|z_i-z_j\|$ it is shown as in Eq.3:

$$\|z_i - z_j\| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{3}$$

The position coordinates in two dimensions space are $z_i=[x_i,y_i]^T$.

***Received Signal Strength,*** (RSS), is defined as the equivalent measured power, so the squared value of the signal force. Wireless sensors communicate with the other neighbor sensors and RSS of RF signals can be measured in each receiver during the normal communication of data without showing any demand for bandwidth or additional energy [9]. The RSS measurements are relatively cheap and simple to be implemented in hardware. Those are suitable to be used in localization problem but from the other side the measurements performed with RSS are very unpredictable. Those are part of a powerful localization system where it is important to find the sources of errors and for MLE the RSS can be defined as in Eq.4:

$$\{\hat{z}_i\} = arg_{\{z_i\}} min \sum_{i=1}^{N} \sum_{j \in H(i)_{j<i}} (ln \frac{(\delta_{i,j}^{MLE})^2}{\|z_i - z_j\|^2})^2 \tag{4}$$

where: δi,j is a function of gained governing *Pi,j*. Differently from MLE based on ToA measurements, RSS MLE shows to be influenced especially from a unique reference and only one unknown device location, the chain estimation between the two devices is $\delta_{1,2}$ and its average is shown at Eq.5:

$$E[\delta_{1,2}] = C\|z_1 - z_2\| \tag{5}$$

Where: C is a multiplicative meeting factor. Typically for a channel its value is C ≈ 1.2, by adding an influence of 20% of the range a pseudo-MLE can be defined:

$$\{\hat{z}_i\} = arg_{\{z_i\}} min \sum_{i=1}^{N} \sum_{j \in H(i)_{j<i}} (ln \frac{(\delta_{i,j}^{BC})^2}{\|z_i - z_j\|^2} \tag{6}$$

***Range evaluation with RSS*** between $i$ and $j$ devices can be estimated from $P_{i,j}$. First it is shown the most likelihood logarithm with $P_{i,j}$ probability when $d_{i,j}=\|z_i-z_j\|$ is known as given in Eq.7:

$$\log f\left(P_{i,j}|\theta\right) = c_1 - \frac{[P_{i,j} - \bar{P}(\|z_i - z_j\|)]^2}{2\sigma_{dB}^2} \tag{7}$$

***ToA,*** the time delay between sensor nodes $i$ and $j$ is $T_{i,j}$ it is modeled following a Gaussian dispersion function. Generally the evaluation of most likelihood probability is the parameter that maximizes the probability function. Otherwise the equivalent one that minimizes the negative part of log-likelihood function. So the measurements of ToA in MLE is as in Eq.8:

$$\{\hat{z}_i\} = arg_{\{z_i\}} min \sum_{i=1}^{N} \sum_{\substack{i \in H(i) \\ j<i}} [v_p(T_{i,j} - \mu_T) - \|z_i - z_j\|]^2 \tag{8}$$

**b) Push-Pull Evaluation.** The original idea of the method is that there might exist a way to remove the noise of the measurements by averaging, the noise level in the received signal depends on the distance and direction [1,2]. The method used is based on geometric calculation it evaluates the sensor coordinates by modeling the noise measurement in pull and push vectors of force. By supposing that noise is considered as Gaussian, it is applied the PPE algorithm and it is analyzed step by step as follows. Let us assume that a random node in a WSN, if the coordinates of all the other nodes are known it is easy to estimate the nodes coordinates from three neighbor nodes that create a triangular *j*, *k* and *l*, as shown in Fig.1. There are estimated the real distances between *i* and *j, k, l* nodes. Noise is present during the measurement and it influences and changes the distances of connections by making them larger or shorter. So it is not possible to have a good estimation of nodes position like this. This can be achieved only if it will be possible to use localization information of more than three neighbor nodes.

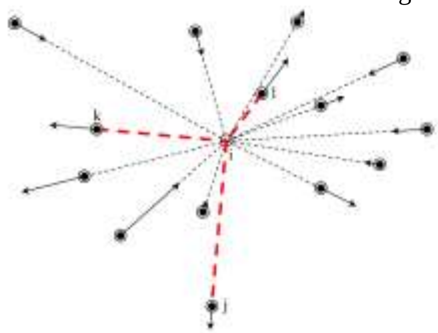



Fig.1. Errors between the given distances and their estimated that correspond to the node *i* are modeled as error vector.

Let us assume that {dij : i≠j and j = 1...N}, and {δij: i ≠ j and j = 1..N}, the actual distance and the distance vector of the measured connection where the starting node is node *i* and ending node is *j* respectively. For a random node *i* there is a group of error vector that models the errors in distance and direction like this:

$$\Delta_{ij} = \delta_{ij} - d_{ij}, \forall\, i \neq j, j = 1..N \qquad (9)$$

Some of distance vector size of the connection measured may be bigger than the other distance vectors. It is important to normalize the errors in size for the measured distance vectors connection. It is proposed a normalizing method that divides the error with the distance size of the actual connection vector. $\hat{\Delta}\ ij: i \neq j \text{ and } j = 1 \ldots N$ Shows the normalized error vector that will be:

$$\widehat{\Delta_{ij}} = \Delta_{ij}\frac{\|\delta_{ij} - d_{ij}\|}{\|d_{ij}\|}, \forall i \neq j, j = 1..N \qquad (10)$$

Where $\|.\|$ is the Euclidian norm. If $\hat{\Delta}$ij>0 it creates a pushing vector and if $\hat{\Delta}$ij<0 it creates a pulling vector. The sum of these two vectors pushing and pulling $f_i$ will describe the sum of the measured errors that influence in the node *i* position estimation:

$$f_i = \sum_{i\neq j, j=1}^{N} \widehat{\Delta_{ij}} = \sum_{i\neq j, j=1}^{N} \Delta_{ij}\left\|\frac{\delta_{ij} - d_{ij}}{d_{ij}}\right\| \qquad (11)$$

As a consequence the sum of these push-pull vectors $f_i$ will move the sensor to a new location as shown in Fig.2. Let us assume the function of these push and pull vectors in the case when the measurements of connection range include the noise influence and also most nodes location are unknown. In this case it will be a distance vector of the actual connection {dij : i≠j and j = 1...N}, and the evaluated one is {$\tilde{d}$ij:i≠j and j=1...N}.

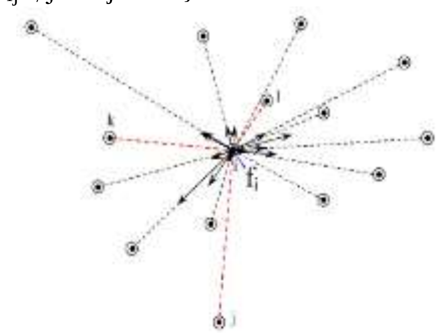



Fig.2. The sum of the error vectors that influence at the node *i*, results in a push-pull vector starting from node *i.*

Where:

$$\tilde{d}_{ij} = \tilde{x}_j - \tilde{x}_i, \forall j \neq i,\ j = 1..N \qquad (12)$$

So the push-pull vector:

$$\hat{\Delta}_{ij} = \Delta_{ij}\frac{\|\delta_{ij} - \tilde{d}_{ij}\|}{\|\tilde{d}_{ij}\|},\ \forall\ i \neq j,\ j = 1..N \qquad (13)$$

And the sum of push-pull vectors:

$$f_i = \sum_{i\neq j, j=1}^{N} \hat{\Delta}_{ij} = \sum_{i\neq j, j=1}^{N} \Delta_{ij}\frac{\|\delta_{ij} + \tilde{x}_i - \tilde{x}_j\|}{\|\tilde{x}_i - \tilde{x}_j\|} \qquad (14)$$

For each node in network the sum of all the push vectors is not the same with that of pull vectors ($f_i \neq 0$). The force vectors will make the nodes to move gradually there where the node state is more balanced. The smaller is the $\| f_i \|$ the better becomes the localization estimation. The problem of localization now becomes the minimization of $f_i$ as shown below:

$$\widetilde{x}_i = \underset{\widetilde{x}_i}{\operatorname{argmin}} f_i(\widetilde{x}_i) \tag{15}$$

Or:

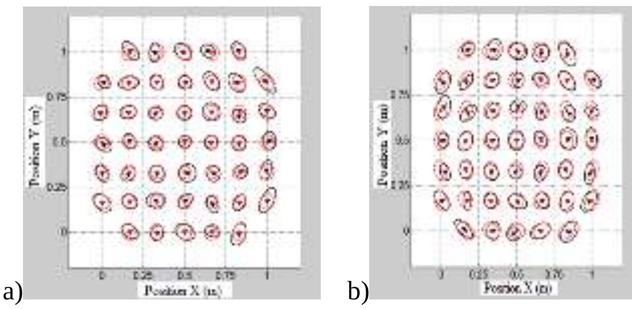
$$\widetilde{x}_i = \underset{\widetilde{x}_i}{\operatorname{argmin}} \sum_{i \neq j, j=1}^{N} \triangle_{ij} \frac{\|\delta_{ij} + \widetilde{x}_i - \widetilde{x}_j\|}{\|\widetilde{x}_i - \widetilde{x}_j\|} \tag{16}$$

## III. SIMULATION AND PARAMETERS SETTINGS

The most challenging aspect of localization problem in WSN is the noise that causes the signal suppression due to: the signal spread power in an uneven way, the obstacles, the collisions and the multipath effects [3, 5, 6]. All these factors create the channels that suppress the signal and it affects heavily the accuracy. In order to evaluate the performance of the algorithm there are applied the measurements of RSS and ToA. In the experiments there are 40 sensors that are spread in an area with 14x13 $m^2$ and the zone is divided with a wall of 1.8m of highness. To simplify the estimation it is chosen a reference node or an anchor node, and four other sensors that are situated in the corners of the spreading zone. The other 40 remaining nodes are normal devices without any information regarding their positioning. A real database gives the input of the algorithms, the coordinates of the four anchor nodes and the distances of the connection are calculated from the RSS and ToA measurements. The connection distances based on RSS are estimated with the corrector influence of MLE by performing the averaging of 10 measurements of RSS for every couple of devices. The connection distance is calculated based on ToA by doing the averaging of 10 delays measured, these delays are divided between 5 transmitters *j* and 5 receivers *i*. It might be noted that the measured distances are greater than the real ones more than 200% this due to channel suppression effect.

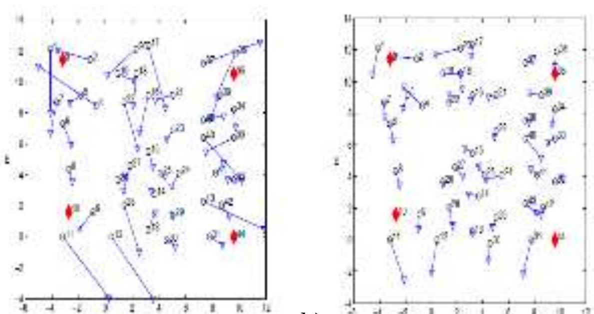
***MLE analysis.*** MLE algorithm is tested for the RSS and ToA through simulation of a sensor network with a 7x7 area, where in the corners are positioned the reference nodes as is shown, Fig. 3.a, with N=25 and L=1m. In simulations all the sensors are supposed to be within the range of all the other sensors and it allows the RSS and ToA measurement. RMS is 0.0637 m. The Root Mean Square (RMSE) is used to calculate the error between the estimated coordinates and the real coordinates for all the nodes. The results of simulation for MLE algorithm are brought in Fig.3.b, for the case of RSS measurement and ToA measurement.

With the black triangle is shown the actual positioning of nodes. With the red dot is shown the estimated positioning of nodes. In this case the estimated RMS is 0.0637m. In all the cases the estimated localization error in the center of the network is lower than in the corners of the network. This is so because for any specific sensor, it will be advantageous to have a lot of nodes around itself with known positioning.



a) b)

Fig.3. MLE algorithm: a) RSS; b) ToA



a) b)

Fig.4. PPE algorithm: a) RSS; b) ToA

***PPE algorithm.*** To estimate the performance of PPE algorithm, we use the RSS and ToA applied in simulations. In the experiment are considered 44 sensors that are spread in a zone of 14x13$m^2$ area divided with walls of highness of 1.8m. The actual location and the one estimated from PPE algorithm in the case of RSS measurement with RMS=2.4381m is shown in Fig.4.a. The actual location and the one estimated from PPE algorithm in the case of ToA measurement is RMS=1.1028m shown in Fig.4.b.

***Comparison of the two algorithms.*** From the comparison of the two algorithms that are examined so far it is reached in the conclusions that for measuring the RSS is more accurate with MLE, instead for the case of measuring the ToA it is better the estimation achieved with PPE algorithm, Table 1.

Table I. Comparison of MLE and PPE

| | MLE | PPE |
|---|---|---|
| RSS | 2.18 m | 2.44m |
| TOA | 1.23m | 1.10m |

***Localization and coordinate estimation of an object through wireless sensors.*** Building of an Object Localization Algorithm

Step 1: Parameters setting. It is decided the network scale N-number of anchor nodes and their coordinates.

Step 2: It is generated randomly the nodes positions which communicate through the wireless.

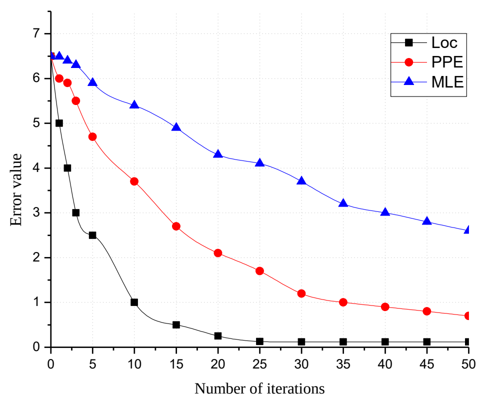



Fig.5. Error value in node localization for PPE and MLE algorithms, object localization through sensor nodes

## IV. Conclusions

In this work is studied and estimated the localization and detection of the objects in a wireless sensor network through simulations with different methods of localization. It observed and compared the real positioning simulated and the estimated one by applying different algorithms like MLE and PPE. The sensor nodes considered in this work are different some of them serve as anchor nodes and the rest are normal devices that do not know their positioning. Through the measuring of RSS and ToA it is possible to estimate nodes positioning in network and then those are compared to the real positioning after the simulation have ended. The differences between the two values are expressed as a vector and then are applied to find and estimate the RMSE. The network built like this reduces the energy consumption and cost as there are needed fewer nodes in network equipped with GPS. As well it was concluded that our theoretical proposed algorithm brings a convergent localization of the object with the passing of

Step 3: The Euclidian distance is estimated between the anchor nodes and the other mobile nodes.

Step 4: It is performed the estimation of other nodes positioning in network.

Step 5: Estimation of RMSE error for nodes localization.

Simulations are done in MATLAB and every simulated case is done with a considerable number of proves to have accurate results. The parameters values are: number of anchor nodes N=4, network area 100. Fig.5 shows the comparison and the error value of the two position localization algorithms MLE and PPE and as well the other one proposed from us.

time also with the introduction of some errors from the moving nodes and distance estimation. As a future work and study it can continue in finding the position of more objects and as well in following their movement.

## V. Future work

Other remaining points for a future study are: the issue of algorithm efficiency from the energy consumption level in nodes, communication improvement which will bring reduction of network convergence time by joint locations, etc. These parameters will be studied by comparing the performance of the existing algorithm with the new proposal introduced by us in this work.

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