Mobile Wireless Sensor Networks Localization

Vasil Dimitrov[1], Rozalina Dimova[2] and Teodora Trifonova[3]

Abstract – **The paper presents mobility influence to wireless sensor network(WSN) applications monitoring, requiring information on the location of the sensor node. Although the deployment of WSN never predicts full static, the mobility is faced range of chalanges, which should be ovecomed.**

In this paper we simulate the mobility of the wireless sensor network using the help of MatLab 7.13 on the different types of movement of the nodes - constant speed and constant speed with random walk. Results improve the accuracy of localization using an algorithm to predict the unknown position. Evaluating error in localization is performed based on the mean square error.

Keywords – **Wireless sensor, Localization, Mobile WSN**

I. INTRODUCTION

Wireless Sensor Networks (WSN) are a technology which allows observing some natural phenomena in time and space. At first the wireless sensor networks were used mostly for military applications, but in time they started to income in applications, comprehending all different areas, including observation, chemical and biological monitoring of the locations, etc. Some of these applications comprehend a wide specter of goals. For example the function of observation goes from finding intruders to whatching patients in old age in their homes [1]. For environmental applications include monitoring on the ground [2], tracing the populations of amphibians [3], and even the early detecting underwater sea earthquakes that form tsunami [4]. Other advaced applications of the WSN include identification and appling of chemical, biological, radiological, nuclear and explosive phenomena and infrastructural monitoring [5]. The technological restrictions imposed by the nature of WSN with the increased need in many applications are fertile soil for research.

Wireless Sensor Networks are built from large number of separate devices (sensors) capable of tracking signals from the environment [6]. The sensors have limited potencial when it comes to communication, processing and storage of information.

Each sensor node contains four basic components: power supply that supports all sensor operations; sensitive unit to collects measurements in the environment and translates the analog signal of the observed phenomena (energy) into a digital signal by an analog-digital converter (ADC), a processor to processes digital signal, and transceiver, which is responsible for all sensor communications [7].

[1]V.Dimitrov is with the Technical University of Varna, ul. Studentska 1, 9010 Varna, Bulgaria (phone: +359-52-383350; e-mail: v_1986@abv.bg).

[2]R.Dimova is with the Technical University of Varna, ul. Studentska 1, 9010 Varna, Bulgaria; (phone: +359-52-383350, e-mail: rdim@abv.bg).

[3]T. Trifonova is with the Technical University of Varna, ul. Studentska 1, 9010 Varna, Bulgaria (phone: +359-52-383350; e-mail: t_t_trifonova@abv.bg).

II. ISSUES ASSOCIATED WITH THE DESIGN OF SENSOR NETWORKS

The technological restrictions of the sensors,combined with the area of application, largly determine the design of WSN. In industrial applications, the sensors are located on specific places compared to interest; the same goes for structural monitoring. In different applications the sensors often combine in one-dimensional array or even relatively network [8]. In many other situations, depending on the situation and equitable relief deployment is neither feasible nor practical. In such cases, methods of deployment are often equivalent to the random placement of sensors. For example, inaccessible area as contaminated land or battleground requires tracking of mobile sensor nodes, which leads to random distribution of sensor locations. In underwater WSN, nodes are usually anchored to the seabed and associated floating buoy, which regulates their positions. The inaccuracy of this method is close to that of the random distribution. Another example for mobile sensor networks is the integration of sensor nodes in order to monitor and measure the properties of materials such as polymeric structures, rock landslides, avalanches, etc..

In general, the sensor network under any distribution must satisfy the two constraints [9]: coverage (all or most of the region of interest to be within the scope of observation and at least one sensor) and coherence (each sensor can communicate with each other directly or through sensor information transmission in neighboring nodes). These restrictions are crucial to wireless sensor networks to be able to perform functional tasks

In this paper we explore issues related to the localization of mobile sensor nodes .

III. NETWORK MODEL

In our analysis we assume that the system is a set of sensors S on an unknown area randomly distributed with density ρ_s within a zone A, and a set of specially equipped nodes L, which we call beacons, and a certain guidance randomly distributed with density ρ_L.

Sensors are equipped with omnidirectional antennas and trasmit power *Ps* and the beacons are equipped with M omnidirectional antennas by the factor of amplification G>1 and can transmit with power $P_L > P_S$. Attenuation of the signal is proportional to the exponent (γ) the distance between two nodes d.

G=1 in omnidirectional antennas and $\frac{P_r}{P_s} = cG^2 d^{-\gamma}$ at

$2 \le \gamma \le 5$, where c is proportional constant and P_r is the minimum power required for communication. If r_{ss} denotes the communication range between two sensors and r_{sL} denotes the communication range between sensor unit and a beacon then:

$$\frac{P_r}{P_s} = c(r_{ss})^{-\gamma}, \quad \frac{P_r}{P_s} = cG(r_{sL})^{-\gamma} \tag{1}$$

It follows that $r_{sL}= r_{ss}G^{1/\gamma}$. In the same way if r_{Ls} asigns the communication between beacon and sensor node and r_{LL} is the range between the thrust bearing unit and another unit has the following relationship $r_{LL}= r_{Ls}G^{2/\gamma}$. For short we asign r_{ss} as r and r_{Ls} as R. Table 1 summarizes the four possible ways of communication.

TABLE 1
COMMUNICATIONS BETWEEN SENSOR AND A BEACON

	Receiver	
Sender	Sensor	Beacon
Sensor	r	$rG^{1/\gamma}$
Beacon	R	$RG^{2/\gamma}$

In order to achieve the ratio $\frac{R}{r}$ the communication range the beacons must have to transmit power $P_L = \left(\frac{R}{r}\right)^{\gamma}(P_S / G)$.

Bearing in mind that the sensors are devices with low power transmitters and supporting units with larger capacities are known following communication options. A typical sensor node has range between 3 to 30 m with a maximum power of transmition Ps=0.75 mW. Hence the beacons have to transmit with power Pg=75 mW, To achieve communication range $\frac{R}{r}$=10 where γ=2 without even using an omnidirectional antennas. Having in mind that the omnidirectional antenna is important for the operating frequency of the sensor, if the design of sensor networks to provide high operating frequency, it will greatly easier to use the directional antennas in the core nodes. At a frequency 2.4 GHz and half-wavelength the size of the cylindrical antenna element 8 will have a radius 8 cm at a frequency of 5 GHz the size of an antenna will be the same tap having a radius of 3.3 cm. As for beacons are allowed more glam dimensions of the sensors, equipping them with directional antennas is possible decision to increase the communication range.

IV. SIMULATION STUDIES OF MOBILE WSN LOCALIZATION

Let's take a look at L beacon with coordinates (x_i, y_i) when i=1,...,L which are randomly arranged in two-dimensional plane (2D) of dimensions (x_{max}, y_{max}). The coordinates of the beacons are well known. During each simulation position K of the support node is a constant. In this valley are also randomly spaced S unknown nodes with coordinates (x_{0i}, y_{0i}) i=1,...,S. From the standpoint of the distribution measurements were made in the condition of direct visibility. The actual distance between a beacon and an unknown node is d_i and it may be difined as:

$$d_i = \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2} \tag{2}$$

Measured distance is:

$$r_{d_i} = d_i + \varepsilon_i \tag{3}$$

where $\varepsilon_i \sim N(0, \sigma_i^2)$ e is the zero mean Gaussian noise with variance σ_i^2

A. Algorithm for tracking the position in the WSN

Our research is based on the following algorithm :

• Step 1: determine the position of each unknown node based on the fixed bearing assemblies.

• Step 2: for all unknown items determining the distance between nodes:

for node $i : \left(\hat{x}^0_{(i)}, \hat{y}^0_{(i)}\right)$, for node $j : \left(\hat{x}^0_{(j)}, \hat{y}^0_{(j)}\right)$

$$\hat{d}^0_{i,j} = \sqrt{(\hat{x}^0_{(i)} - \hat{x}^0_{(j)})^2 + (\hat{y}^0_{(i)} - \hat{y}^0_{(j)})^2} + noise^0_{i,j} \tag{4}$$

• Step 3: For each unknown movable unit determining the distance to the distance L to S

d- for fixed beacons

$d^{(0)}_{i,j}$ - for unknown nodes

• Step 4: Repeat Steps 2-3 S times - reps to refresh the calculation

$$\hat{d}^{\alpha}_{i,j} = \sqrt{(\hat{x}^{\alpha}_{(i)} - \hat{x}^{\alpha}_{(j)})^2 + (\hat{y}^{\alpha}_{(i)} - \hat{y}^{\alpha}_{(j)})^2} + noise^{(\alpha)}_{i,j} \tag{5}$$

In this case, the mean square error MSE [10] for the node i is:

$$MSE_i = \frac{1}{K}\sum_{j=1}^{K}\left[\left(x_0 - \hat{x}{}_0^{(i,j)}\right)^2 + \left(y_0 - \hat{y}{}_0^{(i,j)}\right)^2\right] \tag{6}$$

$$\text{and } MSE = \frac{1}{S}\sum_{m=1}^{S+1} MSE_j \tag{7}$$

The Cramer-Rao lower bound CRB [11] in this case is:

$$CRB = \frac{4\sigma^2}{L+S} \tag{8}$$

Determine the position of the unknown mobile node will be:

$$\hat{x}(t),\ \hat{x}(t+1),\ \ldots,\ \hat{x}(t+10),$$

$$\hat{y}(t),\ \hat{y}(t+1),\ \ldots,\ \hat{y}(t+10)$$

The next step can be predicted. In this case, the speed for the next step cannot be determined by these equations:

$$\hat{v}_x T(i) = \frac{1}{i}\sum_{i=1}^{i}(\hat{x}(i) - \hat{x}(i-1)),$$

$$\hat{v}_y T(i) = \frac{1}{i}\sum_{i=1}^{i}(\hat{y}(i) - \hat{y}(i-1)),$$

which are used to predict the next position of the unknown node $\tilde{x}(i+1)$ и $\tilde{y}(i+1)$.

$$\tilde{x}(i+1) = \tilde{x}(i) + \hat{v}_x T(i)$$

$$\tilde{y}(i+1) = \tilde{y}(i) + \hat{v}_y T(i)$$

So the next step can be predicted with some accuracy. This algorithm can improve performance of the method of steepest descent, and also the accuracy of the system.

Б. Simulation results

In a real environment the unknown node changes its position and having to track the position. Mobility of sensors can be considered as: constant speed and constant speed and random walk. The movement may be divided into ten steps (t=1,..., 10). The first position is t = 1. Therefore, each new step may be represented as: $x(t+1) = x(t) + v_x T$ and $y(t+1) = y(t) + v_y T$, where $v_x T$ and $v_y T$ is the speed on axis X and the speed on axis y. According to $v_x T$ and $v_y T$ the movement is separated in two types:

- Constant speed - $v_x T$ =const and $v_y T$ =const

In this case the velocity of the unknown node is constant for the simulation: v=0.1 (vx=0.1 and vy=0.1). The movement is divided in ten steps. MSE for each step is calculated and shown in Figure 1. Unknown position cannot be determined with sufficient accuracy. There is one peak. As can be seen in Figure 2, where is a predictive algorithm, unknown position can be determined with sufficient accuracy and lines for each step are too close.

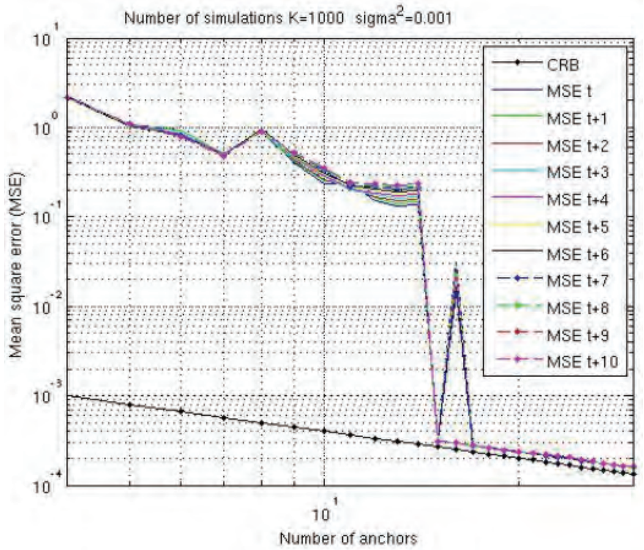

Fig.1. MSE on constant speed.

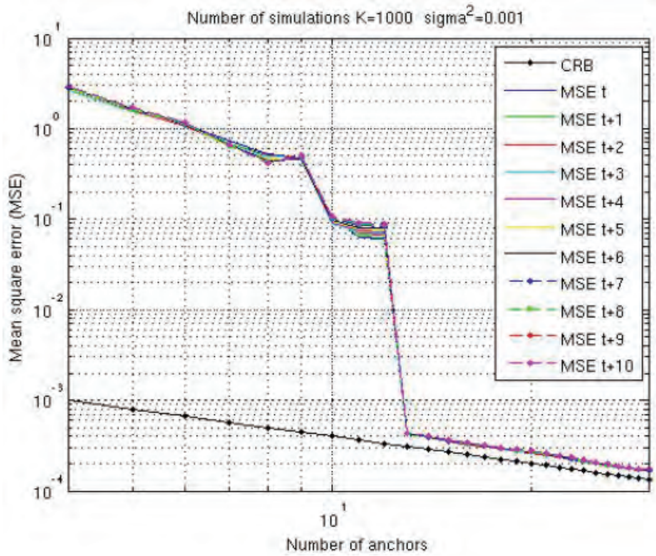

Fig.2. MSE with prediction.

- Constant speed and random walk - $v_x T$ =const+random and $v_y T$ =const+random

This is the most realistic movement, because the path from point A to point B doesn't always a straight line. Figure 3 shows a simulation of this case, without prediction, and the necessary support nodes here is about 19-20. By using the predictive algorithm, shown in Figure 4, the number of abutment assemblies for sufficient accuracy has been reduced to 11, and the position of the unknown node is set at approximately the same accuracy for each step.

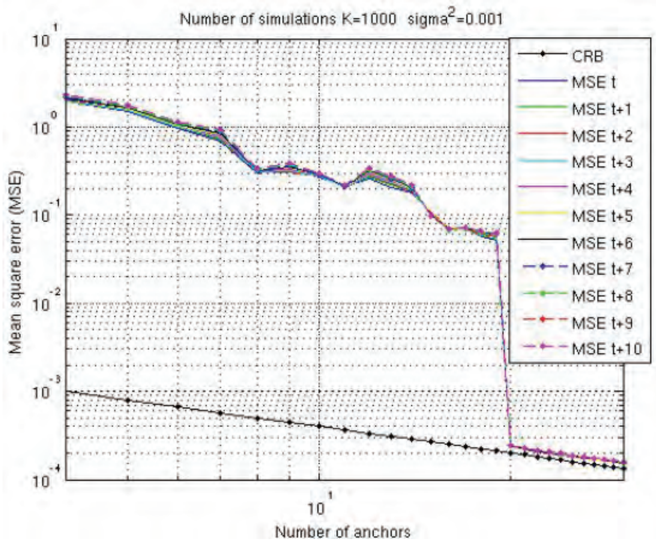

Fig.3. MSE on constant speed and random walk

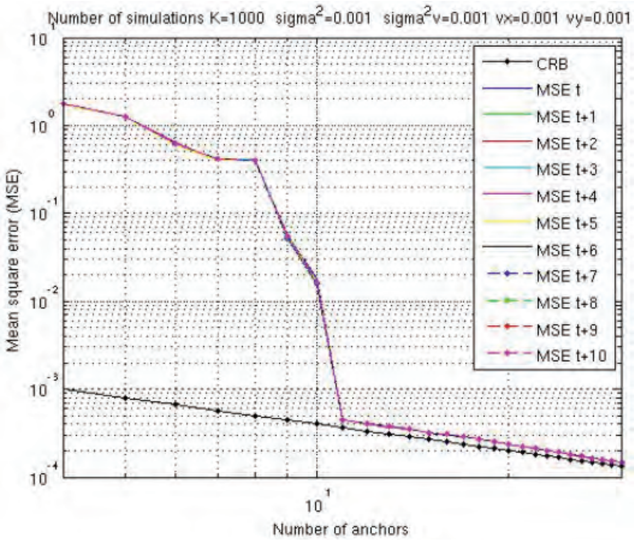

Fig.4. MSE on constant speed and random walk with prediction

V. Conclusion

The mobility of sensor networks helps in monitoring the large number of processes and phenomena. The advantages of mobile WSN over static WSN are better coverage, enhanced target tracking and superior channel capacity.

We examined the localization of the mobile sensor nodes using MatLab 7.13, simulating motion of the nodes - Constant speed and Constant speed with random walk. The algorithm is presented to predict the next position of the sensor node.

The performed tests show that achieved geometric method for determining the position is relatively conveniently locate. The results of the simulations are as follows:

- the number of supporting units for obtaining sufficient accuracy is higher than the theoretical number ;
- increase the number of repetitions to refresh the calculations do not improve accuracy ;
- the prediction algorithm may be applied to improve the localization of unknown nodes .

Future studies, based on these results are to improve communication between mobile sensor nodes and to reduce the cost of the system.

Acknowledgement

This paper is conducted under the grant of the Project BG051PO001-3.3.06-0005, Program ‘Human Resources Development’ and scientific project NP 6, supported by FNI-TU-Varna.

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