Localization in Large-Scale Wireless Sensor Networks

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Abstract— A Large Scale Wireless Sensors Network (LS-WSN) based on the large amount of nodes have become a hot topic. "Large scale" refers primarily to a large area or high-density of network. Therefore, the design goal of WSN must adapt well to extend the network range and density of nodes increases. An event detected by a sensor is only useful if information relating to its geographical location is provided. Without this information, these applications would be meaningless. It is therefore necessary to determine for each sensor a position. In this paper, we used a simulator called Shawn that can support a large number of nodes and it's very promising for dense networks simulation.

Keywords- WSN; Large Scale; Localization; Shawn.

I. INTRODUCTION

In recent years, the advances and developments on wireless communication technologies and embedded systems have enabled the deployment of wireless sensor networks. Wireless sensor networks are formed by a large number of small sized devices powered by batteries and distributed over a field where needed to be controlled. Each sensor node is embedded sensing, processing, and wireless communication functionalities. Due to their feasible and flexible cost, wireless sensor network can be used in a variety of applications such as military surveillance, event detection, target tracking, and environmental monitoring [1].

The localization issue in wireless sensor networks attracts a big attention of researchers during the last years; the aim of localization is to assign geographic coordinates to each node with an unknown position in the deployment area. Most applications of WSN require the correlation of sensor readings with physical locations. Moreover, even if the accessible knowledge about positions of nodes is only approximate, there are great opportunities for using various network services, location-based routing, data aggregation, etc [2].

Adding Global Positioning System (GPS) to all nodes in a large scale networks is not a good solution for several reasons [1]:

- The presence of obstacles can block the line-of-sight from GPS satellite.
- The production cost factor of GPS in large scale WSN is an important problem.
- The power consumption of GPS will reduce the battery life of the sensor nodes.

For this reason, collaborative localization algorithms are proposed which assumed that only a small number of sensors have their absolute positions either through manual configuration or using GPS receivers. These sensors are called anchors, and their positions are used as references to estimate the positions of sensors with unknown positions. As the density of anchors, with respect to unknown sensors increases the localization accuracy increases. In addition to anchor density, proper placement of anchors also affects the localization accuracy [3].

The rest of this paper is organized as follows: Section II describes the algorithms used in the simulation. In Section III, we present the simulation results. Finally, we close this paper with a conclusion.

II. LOCALIZATION ALGORITHMS IN WIRELESS SENSORS NETWORKS

Several methods assume that some sensors in networks know their exact positions (by human intervention, GPS). There are two categories among these methods: first, the range-free localization schemes which deduce estimated positions for all nodes in the network with only coordinates of anchors. Second, the range-based localization which use techniques allowing calculating distances between two neighbor sensors [4].

The most popular technologies in order to calculate the range with two neighbor nodes are RSSI, ToA, TDoA and AoA.

A. Measurement technologies

Several technologies allow a sensor to measure the distance that separate adjacent sensors (ToA, TDoA, RSSI) or to measure the angle formed between them with AoA.

1) RSSI (Received Signal Strength Indicator)

RSSI measures the power of the signal at the receiver, with the power transmission information, the effective propagation loss can be calculated and either theoretical or empirical models are used to translate this loss into distance.

2) ToA / TDoA (Time of arrival / Time difference of arrival)

ToA translate directly the propagation time into distance if the signal propagation speed is known. For example, the most basic localization system using ToA techniques is GPS.

3) AoA (Angle of arrival)

AoA estimates the angle at which signals are received and uses simple geometric relationships to calculate node positions. Of course, the accuracy of these measures depends on network's environment. These errors are called measure errors or range errors.

B. Distance estimation techniques

There are three distance estimation techniques: Sum-Dist, DV-Hop and Euclidian In these three techniques, the anchors start by broadcasting their positions.

1) Sum-Dist

This method is the simplest solution for estimating distances to anchors. It adds ranges encountered at each hop during the network flood. Each anchor sends a message including its identity, coordinates and path length initialized to zero. When a node receives this message, it calculates the range from the sender adds it to the path length and broadcasts the message. Thus, each node obtains a distance estimation and position of anchors. Of course, only the shortest distance will be conserved [5]. For example, in Fig. 1 the estimated distance between S and D is:

$d_{SY} + d_{YD}$, and $d_{SD} \leq d_{SY} + d_{YD}$ due to triangular inequality.

Let $x_1, x_2... x_q$, a be a path from:

Node $x_1 \in V \setminus \Delta$ to anchor $a \in \Delta$. The estimated distance can be defined recursively as follow:

$$\hat{d}_{x1a} = d_{x1x2} + \hat{d}_{x2a} \quad (1)$$

Where $\hat{d}$ represents the estimated distance returned by Sum-Dist.

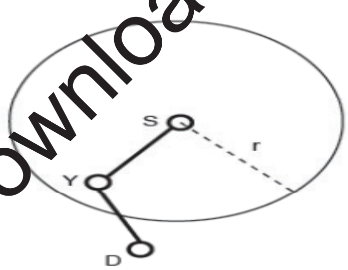

Figure 1. Sum-Dist

Moreover, little computations are required. However, a drawback of Sum-dist is that range errors are accumulated when distance information is propagated over multiple hops.

2) DV-Hop

DV-hop consists of two flood waves. Similarly to Sum-Dist, after first wave, nodes obtained their positions and minimum hop counts to anchors. Second calibration wave allows converting hop counts into distances. This conversion consists in multiplying the hop count with an average hop distance. As soon as an anchor A receives the position of another anchor B during the first wave, it computes the distance between them, and divides it by the number of hops in order to obtain the average hop distance between A and B. A calibrates its distance when it receives the position of anchor. Nodes forward calibration messages (only from the first anchor that calibrates them in order to reduce the total number of messages in the network) [6].

The Fig. 2 represents an example where A estimates the average of hop distance. There are three hops between A and B, and four between A and C. A computes Euclidean distance between AB (75m) and AC (125m). The average of hop distance is equal to:

125+75/ 4+3 = 28.57m.

Node X estimates distances with B and C as following:

$d_{XB} = 2 \times 28.57$ and $d_{XC} = 3 \times 28.57$.

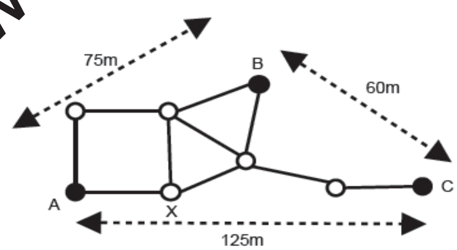

Figure 2. DV-Hop

DV-hop is a stable and predictable method. Since it does not use range measurements, it is completely insensitive to this source of errors. However, DV-hop fails for highly irregular network topologies; the variance in actual hop distances is very large.

C. Derivation position techniques

The classical method to compute the node's position is the multilateration: as soon as a node estimates its distances to at least three anchors, it computes its exact position when anchors are node's neighbors, otherwise, the position is estimated. For example, let X be a node and A, B, C anchors. X wants to compute its position. It knows distances d_{AX}, d_{BX}, d_{CX} and positions of A, B, C which are respectively (x_A, y_A), (x_B, y_B), (x_C, y_C). The following system is solved using a standard least-squares approach in order to give to X its estimated position:

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$$\begin{cases} d^2_{AX}=(x_X-x_A)^2+(y_X-y_A)^2 \\ d^2_{BX}=(x_X-x_B)^2+(y_X-y_B)^2 \\ d^2_{CX}=(x_X-x_C)^2+(y_X-y_C)^2 \end{cases}$$

Among localization methods in wireless sensor networks, the most popular are the methods of [5, 6, 7]. These methods use the same execution scheme. This plan contains three steps: first, anchors broadcast their position. Second, each node estimates distances with anchors. Each node derives an estimation of its position from its anchor distances. Finally, a refinement process is performed in order to improve accuracy of estimations.

III. Simulation Results

The scalability is one of the constraints that affect the sensor networks because the increase in the size of the network implies that the task of managing them will be more difficult in many aspects. So we choose a simulator called "Shawn" [8, 9] which supports large scenarios up to 100000 nodes and has many advantages compared to other simulators.

The Fig. 3 shows the average number of neighbors per node depending on the number of nodes in a scenario characterized by a rectangular topology for various ranges.

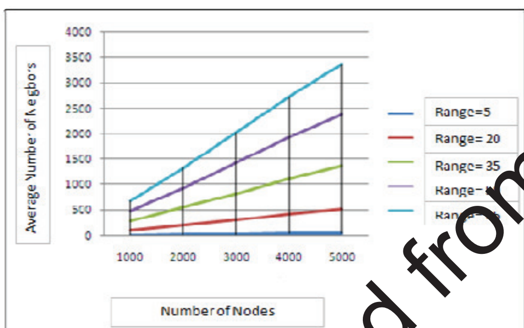


Figure 3. Average number of neighbors per node.

According to Figure 3 we find that the average number of neighbors per node varies proportionally with the number of nodes. We also notice that when the range is lower, thus the average number of neighbors is low.

IV. Visualization

The localization application also has an integrated visualization possibility by producing a postscript output of the topology. Generally, the application simulates the case when most of the nodes in the network do not know their real position. In fact, other ones called anchors know their real location. The localization application implements different ideas of getting the former ones know their real position based on messages exchanged by the anchors.

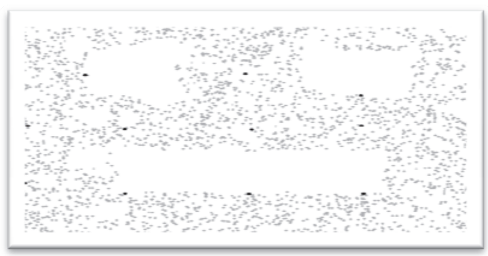
The results in this section represent the simulation of an application that most nodes do not know their actual positions. We choose 4000 nodes including 28 anchors (i.e. 28 nodes that know their positions).

Table 1. Configuration parameters of scenario I

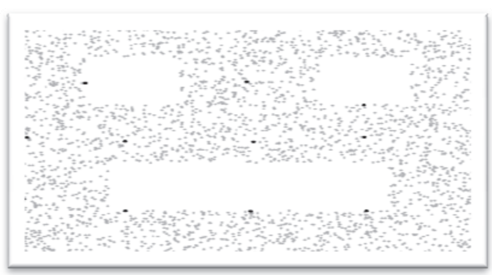
Number of.			Localization algorithms		Topology type
nodes	anchors	holes	dist	pos	
4000	28	3	Sum-dist	Lateration	2D Random

The Fig. 4 shows a random topology with three holes which may be caused by the absence of nodes or the presence of an obstacles. The black points represent the anchors and gray points represent those who calculate their actual positions based on information distributed by the anchors using the algorithms described in Section II. We can see in the first image additional lines from gray nodes to different positions. Here, the gray nodes are located at their real position, and the lines point to the position where the nodes think they are located. In the second figure the nodes are on the positions where they think they are, whereas the third figure shows the real topology.

a) Real and Estimated



b) Estimated



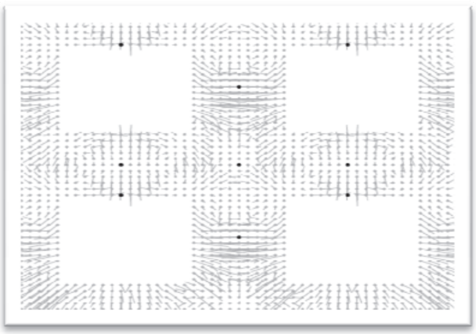
c) Real

Figure 4. Postscript-Output of XML scenario I

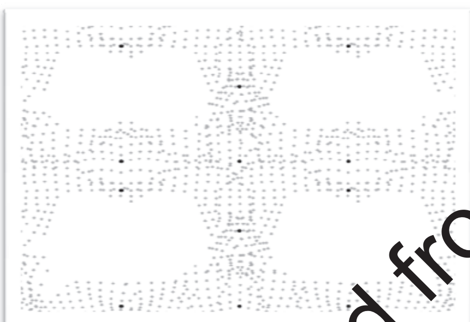
The Fig. 5 illustrates the case of a topology where nodes are uniformly distributed with a spacing of 2 units of measure.

Table 2. Configuration parameters of scenario II

Number of.			Localization algorithms		Topology type
nodes	anchors	holes	dist	pos	
4000	28	4	Sum-dist	Lateration	2D Uniform



a) Real and Estimated



b) Estimated

c) Real

Figure 5. Postscript-Output of XML scenario II

Conclusion

This paper presents the context within which the problem of localization in wireless sensor networks. It offers a description of the principle of localization before focusing techniques that allow sensors to measure distances or angles they form with their neighbors.

The simulator used in this paper called Shawn demonstrates their capacity in terms of scalability, which can simulate different applications as the implementation of new protocol in very large scenarios that can reach 10^5 sensor nodes. The use of anchors has better solve the localization problem by using the algorithms of distance and position.

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