Analysis of Node Localization in Wireless Sensor Networks

Sheshmani Yadav[1], Dr.D.B.Ojha[2], Vijendra Rai[3]

[1] M.Tech, EC Department, Mewar University Chittorgarh, Rajasthan, INDIA
[2] Professor, Science Department, Mewar University Chittorgarh, Rajasthan, INDIA
[3] Asstt. Prof., CSE Department, College of Engineering & Rural Technology, Meerut, U.P., INDIA

1. Abstract

Sensor networks are dense wireless networks of small, low-cost sensors, which collect and disseminate environmental data. Sensor nodes are very small, lightweight, and unobtrusive. The problem of localization, that is, "determining where a given node is physically located in a network", can be mainly divided into two parts range-based (fine-grained) or range-free (coarse-grained) schemes. This Paper presents the analysis of range based algorithms on the basis of few network parameters (Network Size, Anchor node Density, Array node density) and tried to find out the best range based algorithms by doing simulation on matlab. The metric selected for the analysis is Standard Deviation of localization error.

Keywords*:* Localization, Range based schemes, Wireless Sensor Networks.

1. Introduction

1.1 Sensor Network

Recent technological improvements have made the deployment of small, inexpensive, low-power, distributed devices, which are capable of local processing and wireless communication. Such nodes are called as sensor nodes. Each node consists of processing capability (one or more micro controllers, CPUs or DSP chips), may contains multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single Omni- directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. Sensor nodes have the ability to measure a given physical environment i.e. pressure, temperature, moister etc in great detail. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion.

Thus, a sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific action. It facilitates monitoring and controlling of physical environments from remote locations with better accuracy

They have applications in a variety of fields such as environmental monitoring, military purposes, health monitoring, home applications and gathering sensing information in inhospitable locations.

Unlike traditional networks, sensor networks depend on dense deployment and co-ordination to carry out their tasks.

1.2 Localization

In sensor networks, nodes are deployed into an unplanned infrastructure where there is no a priori knowledge of location. "The problem of estimating spatial-coordinates of the sensor node is referred as localization." OR "It is the process of assigning or computing the location of the sensor nodes in a sensor network".

Solving the localization problem is crucial, and some where it is absolutely necessary such as in the case of:

- Efficient Targeting: When sensors are aware of their location, they can either trigger the partial silencing when activities that have to be measured are not present or the activation of some parts of the network when they are detected.
- Target Tracking: When the purpose of the network is to track (possibly moving) targets in its deployment area, node localization is absolutely necessary, especially when the network must be able to restructure itself, or to adapt to node failures, target movements or security breaches.
- Self-Deployment: When mobile nodes are considered, the network can use algorithms to maximize its coverage of the deployment area, while ensuring the robustness of its communication network. In such a setting, it is assumed that nodes are aware of their position in the deployment area.
- Routing-Protocols: Communication protocols, such as the Location-Aided Routing (LAR) protocol use location information for efficient route discovery purposes. The location information is used to limit the search space during the route discovery process so that fewer route discovery messages will be necessary.

Localization methods usually follow a three-phase localization model [10].

1. Determine the distances between unknowns and anchor nodes.
2. Derive for each node a position from its anchor distances.
3. Refine the node positions using information about the range (distance) to, and positions of, neighbouring nodes.

In the first phase, each sensor node first uses its communication capability to obtain some measurements such as Time of Arrival (TOA) to its neighbours to estimate the single-hop distances and then estimates multiple-hop distances to anchor nodes using methods such as a distributed shortest-path distance algorithm. In the second phase, each sensor node uses methods like triangulation to estimate its location using distances to three or more anchor nodes. In the third phase, each sensor node fine-tunes its location according to the constraints on the distances to its neighbours.
Most of the proposed localization techniques today, depend on recursive trilateration/multilateration techniques. Trilateration is a geometric principle which allows us to find a location if its distance from other already-known locations are known. The same principle is extended to three-dimensional.

One way of considering sensor networks is taking the network to be organized as a hierarchy with the nodes in the upper level being more complex and already knowing their location through some technique (say, through GPS). These nodes then act as beacons or Anchors, by transmitting their position periodically. The nodes, which have not yet inferred their position, listen to broadcasts from these beacons and use the information from beacons with low message loss to calculate its own position. A simple technique would be to calculate its position as the centroid of all the locations it has obtained. This is called as proximity based localization. It is quite possible that all nodes do not have access to the beacons. In this case, the nodes that have obtained their position through proximity based localization themselves act as beacons to the other nodes. This process is called iterative multilateration. Iterative multilateration leads to accumulation of localization error.

1.2.1 Classification of Localization Techniques

Localization can be broadly classified in two main categories i.e. Fine-grained and coarse-grained.Fine-grained Vs. Coarse-grained Localization methods can be classified as either fine-grained, or coarse-grained [1]. They differ in the information used for localization. Range-based methods use range measurements, while range-free techniques only use the content of the messages.

In fine-grained localization the nodes in the network can measure their distance or angle estimates to (a number of) their neighbors, and thus infer their position. These distance measurements may be prone to error. The range-based algorithms require more sophisticated hardware to measure range metrics such as Time of Arrival (TOA), Time Difference On Arrival (TDOA), Angle of Arrival (AOA) and Received Signal Strength Indicator (RSSI). [7]
In coarse-grained localization only proximity (connectivity) information is available. A node is in the position to detect its neighboring nodes, but it does not possess any information regarding its distance to them, except perhaps an upper bound of it implied by its detection capability range. In range-free schemes distances are not determined directly, but hop counts are used. Once hop counts are determined, distances between nodes are estimated using an average distance per hop, and then geometric principles are used to compute location.Fine-grained and coarse-grained localizations are also known as range- based and range-free localization, respectively [5].
Range-free solutions are not as accurate as range- based solutions and often require more messages. However, they do not require extra hardware on every node.

2. Problem Definition

For the localization problem, the network is modeled as a connected, undirected graph $G = (V,E)$, where V is the set of sensor nodes and E is the set of edges connecting neighboring nodes. Each edge $e(u, v)$ is associated with a value $z \in Z$ (e.g., an RSSI value). Let (x, y) be the unknown coordinates of $u \in V$. Let $A \subset V$ be the set of anchors with known coordinates. The problem of localization is to find coordinates (x, y) of each node $u \in V \setminus A$.
Now the finding of unknown co-ordinates is somehow related to the algorithm used and network parameters. What will be the effect of these parameters on localization when using different algorithm is less analyzed by any paper, so I selected three methods of range-based localization (TOA,AOA and RSSI) for the analysis on the basis of three network parameters(Network Size, Anchor node Density, Array node density) on the metric of standard deviation. The tool used for the simulation is Matlab based Senelex (The Sensor Network Localization Explorer) by OHIO STATE.

3. Analysis & Findings

Let $\sigma^2 xk$ and $\sigma^2 yk$ be the error variance of estimating xk and yk, respectively. I have computed the root-mean squared location error variance or Standard Deviation of each network, SD (σ), by formulae:

$$SD(\sigma) = RMS(\sigma) = \sqrt{1/A \sum_{k=1}^{A} (\sigma^2_{xk} + \sigma^2_{yk})}$$

The value RMS(σ) gives the average lower-bound variance in errors of estimated sensor node locations. The smaller SD(σ) or RMS(σ), the higher confidence we have on the localization result generated by a localization algorithm.

3.1. Effect of network size

I investigate how the localization error variance changes as the network scales in overall size. I evaluate SD (σ) for a number of networks with a fixed density and a fixed percentage of anchor nodes but with varying sizes. Ideally the SD (σ) increases with the increase of network size, which indicates that network size is a negative factor in localization accuracy. But the results in Fig. 1(a) & 1(b) shows that SD(σ) increases when the network size increases till a certain point after that it starts decreasing if we are keeping the density constant. As the Angle algorithm is hiding the details of Time and RSS schemes, Fig. 1(b) is drawn for showing the details of Time and RSS only.

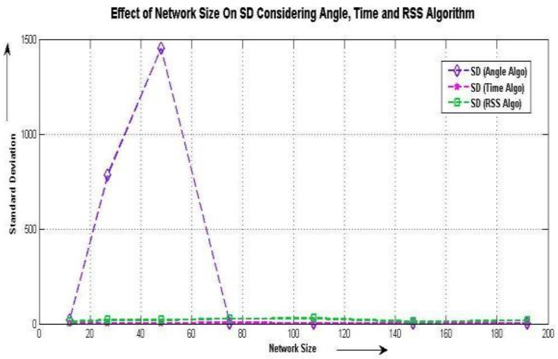

Fig. 1a Effect of network size

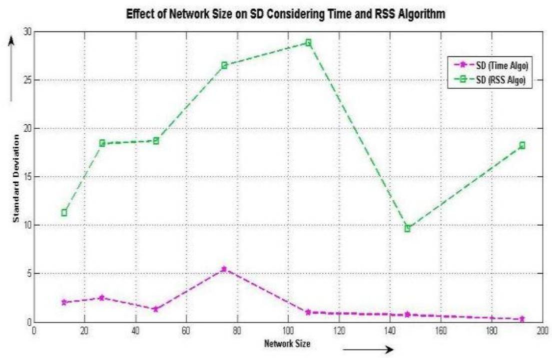

Fig. 1b Effect of network size

If we compare all the three schemes of range-based it is found that the time algorithm gives less deviation from localization error, means it provides better accuracy.

3.2. Effect of network density

Network density or node density, dn, is characterized as the number of nodes per square meter. To generate a network of a density, dn, I generate a* dn nodes placed in the grid network of area a (100m x 100m). In the case of node density only array nodes are increased keeping the source or beacon node constant. Ideally the SD (σ) decreases when density increases. The simulation also shows that SD (σ) decreases when density increases. It is shown in Fig. 2(a) & 2(b).

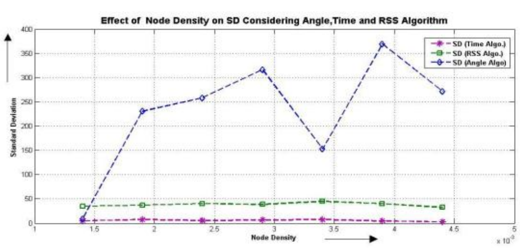

Fig. 2a Effect of network density

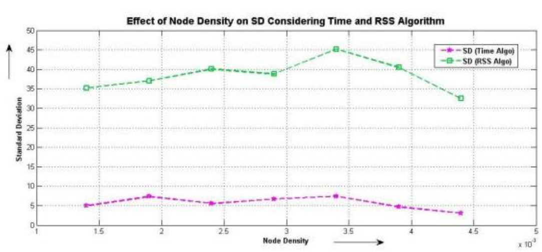

Fig. 2b Effect of network density

In the case of network density also the time algorithm gives less deviation from localization error.

3.3. Effect of Anchor node density

I investigate the effect of percentage of anchor nodes in the network on the localization error variance. Ideally SD(σ) decreases significantly as the density of anchors increases before a saturation point, and it remains the same after the saturation point. Starting with 35 array nodes and two source nodes placed at random on fixed area of 100m x 100 m, I moved to 10 source nodes while keeping the array node constant. The result of simulation shows that in the case of Angle algorithm SD(σ) decreases significantly as the density of anchors increases till a certain point and there after it starts increasing but in the case of RSS and Time it follows the ideal behavior. It is shown in Fig. 3(a) & Fig. 3(b).

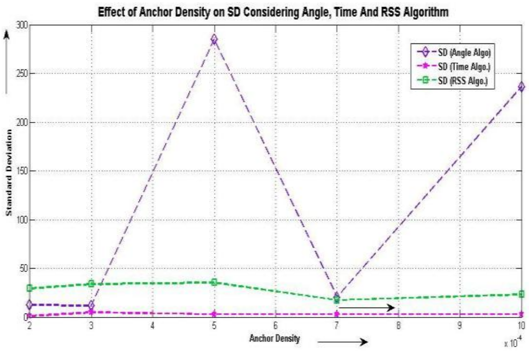

Fig. 3a Effect of Anchor node density

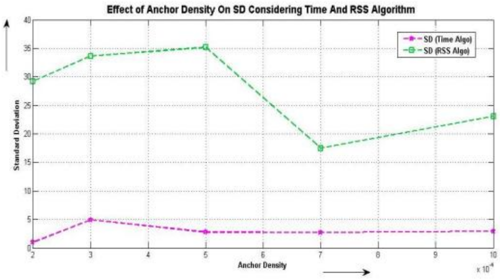

Fig. 3b Effect of Anchor node density

The comparison of all three algorithms shows that here also the time algorithm is providing good results.

4. Conclusion

Localization is a fundamental problem of deploying wireless sensor networks for many applications. Although many algorithms have been developed to solve the localization problem, the fundamental characterization of localization error behaviors still needs to be studied. In this paper, I have analyzed the Standard Deviation of localization errors and have studied the effects of network parameters on localization accuracy, which provides us insights on how to set the controllable parameters of a sensor network for the best possible localization accuracy.I would like to conclude that for most of the network parameters (network size, node density and source node density) the range based Time Algorithm provides the lowest deviation from the mean localization error. This means lower the SD(σ) better the accuracy. So in comparison to RSS and angle one should use Time Algorithm for localization purpose.

References

[1]. Archana Bharathidasan, Vijay Anand Sai Ponduru "Sensor Networks: An Overview" Department of Computer Science, University of California, Davis, CA 95616.

[2]. D. Niculescu and B. Nath. Ad hoc positioning system. Global Communications Conference, IEEE, pages 2926–2931, November 2001.

[3]. M. Brain and T. Harris, "How GPS receivers work," http://www.howstuffworks.com/gps1.htm.

[4]. J. Hightower and G. Borriello, Location systems for ubiquitous computing, Computer 34 (2001).

[5]. Georgios Sarigiannidis,, LOCALIZATION FOR AD HOC WIRELESS SENSOR NETWORKS, TECHNICAL UNIVERSITY DELFT, THE NETHERLANDS, AUGUST 2006.

[6]. D. Estrin, R. Govindan, J. Heidemann, and S. Kumar, Next century challenges: scalable coordination in sensor networks, MobiCom '99: Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking, ACM Press, 1999.

[7]. Byeong-Tae Lee, Sunwoo Kim, Scalable DV-Hop Localization For Wireless Sensor Networks, Department of Electronics Computer and Communication Engineering, Hanyang University.

[8]. N. Bulusu, J. Heidemann, and D. Estrin. GPS-less low-cost outdoor localization for very small devices. Personal Communications, IEEE, pages, Oct. 2000.

[9]. AZZEDINE BOUKERCHE "DV-LOC: A SCALABLE LOCALIZATION PROTOCOL USING VORONOI DIAGRAMS FOR WIRELESS SENSOR NETWORKS, University Of Ottawa Horacio A.B.F. Oliveira, University Of Ottawa, Federal University Of Minas Gerais And Federal University Of Amazonas.

[10]. K. Langendoen and N. Reijers. "Distributed localization in wireless sensor networks: A quantitative comparison". Computer Networks, 2003.

[11]. David Christopher Moore "Robust Distributed Sensor Network Localization with Noisy Range Measurements" B.S., California Institute of Technology (2003)