Friendly Anchor Based Range Free Localization (FABL) in Anisotropic Wireless Sensor Network

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1 Introduction

The accurate distance estimation between anchor nodes and sensor nodes based on the hop count information is an important research problem in Wireless Sensor Networks (WSNs). The location information is indispensable in topology control, geographic routing protocols and clustering [1]. In anisotropic network where the transmission path between anchor nodes and sensor nodes is not straight but curved, Euclidean distance between a pair of sensor nodes is not always proportional to their hop count distance, which undermines the assumption of many existing range free localization algorithms. Most of the existing works focus on increasing the accuracy by using the heuristics or mathematical techniques. In this paper, we show that the selection of some good anchor nodes (which we call friendly) instead of using all the anchor nodes for accurate localization is a very important factor especially in anisotropic network. we devised the method of selecting friendly anchor nodes for each sensor node in order to get accurate localization. Compared with the existing approach, our approach does not require global knowledge of network topology for boundary recognition nor uniform distribution of anchor nodes. Therefore our approach is robust and applicable in practical environments. Extensive simulations are performed and comparative studies with the state-of-the-art hop-count based localization methods show that the proposed approach is superior.

2 Related Work

Many range free approaches have been proposed to determine sensor locations in WSNs. DV-Hop [2], employing a constant number of anchors. The system estimates the average distance per hop from anchor locations and the hop count among anchors. Each node measures the hop count to at least 3 anchors and translates these into distances. By triangulation, the location is then calculated. APIT [3] lets each node estimate whether it resides inside or outside of several triangular regions bounded by the anchors and refines the computed location by overlapping the regions a sensor could possibly reside in. For accuracy, APIT needs many anchors and assumes that the anchors have radio ranges that are 10 times larger than those of ordinary nodes. Another pattern driven localization scheme is proposed in [4] to tolerate network anisotropy. The paper proposes three different methods of anchor-sensor distance calculation based on three patterns. Another work solves the localization problem in a centralized manner by using optimization techniques such as convex optimization [5]. However distributed localization systems such as [6] are most likely to be used in WSNs.

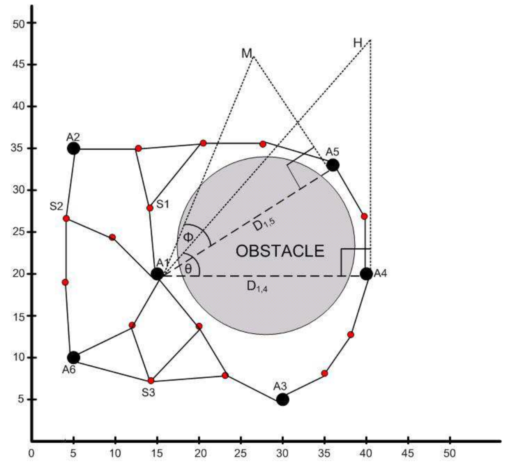

Fig. 1. Friendly anchor selection strategy in a simple scenario with an obstacle inside

3 Proposed Method

We consider one simple anisotropic scenario as shown in Fig. 1. The anchor nodes are denoted by A_i, where $i = \{1, 2, \ldots, 6\}$, and sensor nodes are denoted by S_j, where $j = \{1, 2, \ldots, 14\}$. To determine the friendly anchor sets, we utilize the angle of the curved transmission path between anchors and based on the small value of angle, the anchors are sorted in ascending order and the friendly anchors are on top of the sorted list. To determine the angle of the curved transmission path , we present one example as follows:

Suppose the anchor nodes $A_i's$ positions are $(15, 20)$, $(5, 35)$, $(30, 5)$, $(40, 20)$, $(36, 33)$ and $(5, 10)$ respectively. The Euclidean distance between anchor node A_1 and A_2 is 18 (approximately), A_1 and A_3 is 21, A_1 and A_4 is 25, A_1 and A_5 is 24 and A_1 and A_6 is 14. The corresponding hop count is 3, 3, 6, 4 and 2 respectively. Then A_1 can calculate its Average Hop Distance (AHD) as follows:

$$AHD_{A_1} = \frac{18 + 21 + 25 + 24 + 14}{3 + 3 + 6 + 4 + 2} = 5.72$$

After calculating the average hop distance, it can calculate the transmission path distance by multiplying AHD_{A_1} and the number of hop between A_1 and other anchors. For example, the transmission path distance between A_1 and A_4 is $5.72 \times 6 = 34.32$, which is greater than the Euclidean distance (25) between them. So A_1 can assume that, the transmission path is not straight but curved. To calculate the angle, of the curved transmission path, we draw the line A_1H from A_1 to H and draw another line from A_4 to H in such a way that, the triangle A_1A_4H is a right angle triangle. The length of the line A_1H is equal to the length of the transmission path, i.e., in our example, 34.32. The angle of the curved transmission path is θ. From triangle A_1A_4H, we know that,

$$\theta = \cos^{-1}\left(\frac{D_{1,4}}{A_1H}\right) \quad (1)$$

where $D_{1,4}$ is the Euclidean distance between Anchor A_1 and A_4. From (1), anchor A_1 can calculate the curved angle θ.

In a similar way A_1 can calculate the angle between A_1 and A_5 and so on. If the transmission path is less than or equal to Euclidean distance, then the value of θ is set to 0^o. After calculating all the angles, A_1 then sort the angles in ascending order. The purpose of sorting in ascending order is to make sure to put the unfriendly anchors in the last of the list. After sorting the anchor sets, each anchor will broadcast the average hop distance and the ID of first eight anchors in the sorted list, i.e., friendly anchors. We choose the threshold eight since eight is beneficial to mitigate the bad geometry effect of anchors [3].The sensor node will receive such information from every anchor node but will keep only that information which is coming from nearby anchor node (in terms of hop number) and discard all others. Because the friendly anchor sets of a nearby anchor is the same as the friendly anchor sets of a nearby sensor. Then each sensor will apply multilateral mathod to calculate its location.

4 Simulation Results and Performance Analysis

To evaluate the performance of our proposed scheme in anisotropic WSNs, where anchor nodes are deployed randomly and a series of simulations are conducted. We simulate in C-shape anisotropic network as shown in Fig. 2. We perform 25 rounds of running the simulation and take the average over 25 runs, during which the quantity of the deployed sensors nodes are kept unchanged. However, the topology of the network varies because we establish connectivity between pair of sensor nodes randomly. To measure the accuracy of localization, the average localization error is used. We consider $10m \times 10m$ network area, 200 sensor nodes, 20 anchor nodes and radio range of sensor and anchor nodes are set to be $2m$.

As can be seen from Fig. 3 that in anisotropic network condition our proposed algorithm perform better than [2] and [4]. This is because the transmission paths are more curved and our proposed algorithm carefully select friendly anchor nodes using angular information.

5 Conclusion

In this paper we mainly focus on the impact of selecting good anchors, which is a critical factor for accurate localization specially in anisotropic WSNs. However in anisotropic network the average hop distance is also a critical factor for accurate localization. This opens up a new challege for creating an intelligent localization algorithm which can calculate the average hop distance in detour transmission path accurately and combine the anchor selection strategy for satisfactory localization accuracy will be our future investigation.

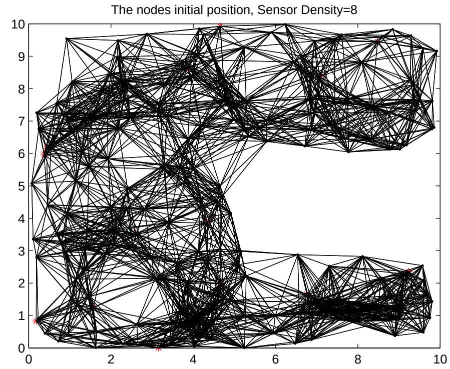

Fig. 2. Initial node deployment in anisotropic C-shape network.

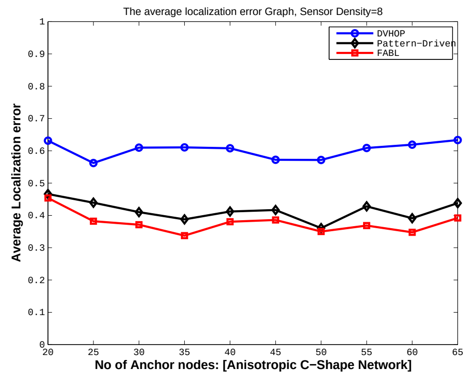

Fig. 3. Location error vs. number of anchor nodes.

References

[1] A. K. Paul and T. Sato, "Effective data gathering and energy efficient communication protocol in wireless sensor network," in *Wireless Personal Multimedia Communication (WPMC'11)*, Brest, France, October 2011, pp. 1–5.

[2] D. Niculescu and B. Nath, "Dv based positioning in ad hoc networks," *J. Telecommun. Syst.*, vol. 22, no. 1-4, pp. 267–280, January 2003.

[3] T. He, C. Huang, B. M. Blum, J. A. Stankovic, and T. Abdelzaher, "Range-free localization schemes for large scale sensor networks," in *Proc. of the ACM MobiCom 2003*, San Diego, 2003, pp. 81–95.

[4] Q. Xiao, B. Xiao, J. Cao, and J. Wang, "Multihop range-free localization in anisotropic wireless sensor networks: A pattern-driven scheme," *IEEE Transaction on Mobile Computing*, vol. 9, no. 11, pp. 1592–1607, November 2010.

[5] L. Doherty, K. S. Pister, and L. E. Ghaoui, "Convex position estimation in wireless sensor networks," *IEEE Conference on Computer Communications*, vol. 3, pp. 1655–1663, April 2001.

[6] A. K. Paul, T. Muhammad, L. Yanwei, and T. Sato, "Range free angle calculation (rfac) based sensor localization in wireless sensor networks," in *International Conference on Modeling and Simulation Technology, JSST-2011*, Tokyo, Japan, October 2011, pp. 5–8.