A Selective 3-Anchor DV-Hop Algorithm Based On the Nearest Anchor for Wireless Sensor Network

Hichem Sassi, Tawfik Najeh, Noureddine Liouane

Abstract—Information of nodes' locations is an important criterion for lots of applications in Wireless Sensor Networks. In the hop-based range-free localization methods, anchors transmit the localization messages counting a hop count value to the whole network. Each node receives this message and calculates its own distance with anchor in hops and then approximates its own position. However the estimative distances can provoke large error, and affect the localization precision. To solve the problem, this paper proposes an algorithm, which makes the unknown nodes fix the nearest anchor as a reference and select two other anchors which are the most accurate to achieve the estimated location. Compared to the DV-Hop algorithm, experiment results illustrate that proposed algorithm has less average localization error and is more effective.

Keywords—Wireless Sensors Networks, Localization problem, localization average error, DV–Hop Algorithm, MATLAB.

I. INTRODUCTION

WIRELESS sensor networks (WSNs) consist of numerous small, inexpensive, low- power sensor nodes working together to collect some necessary information from an environment [1], [2]. The sensor nodes have perception, processing, and communication ability [3].

In many applications of WSNs, the collected data are of no significance if the locations of sensors are unknown, as the position is necessary to locate events that occurred in WSNs.

Localization algorithms in WSNs can be divided into two kinds: range-based algorithms and range-free algorithms [4], [5]. Range-based algorithm needs to calculate the absolute distance between two nodes. To achieve this, different techniques are used: time of arrival (TOA) [6], time difference on arrival (TDOA) [7], angle of arrival [8], and received signal strength indicator (RSSI) [9], [10]. Range-free algorithm measure the localization of nodes on the basis of the information of hop count or connectivity between anchor node and unknown node. We can note different techniques such as, centroid algorithm, DV-Hop algorithm, APIT algorithm [11], and Sequence-Based algorithm [12].

The range-based approaches offer more precise localization results than the range-free algorithms. Because of the hardware limitations of WSN devices, the range-free localizations are being perceived as a cost-effective alternative

Hichem Sassi is with the National Engineering School of Monastir, 5019 Monastir, Tunisia (phone: 0021696945162; e-mail: hichmsassi@gmail.com).

Tawfik Najeh was with the National Engineering School of Monastir, 5019 Monastir, Tunisia. He is now with the Laboratory of Automatic Image and signal processing (LARATSI) (e-mail: najehtawfik@gmail.com).

Noureddine Liouane is with the Laboratory of Automatic Image and signal processing (ATSI) National school of engineers of Monastir (ENIM), Monastir, Tunisia (e-mail: noureddine.liouane@enim.rnu.tn).

to the more expensive range-based approaches. Consequently, the Range-free localization algorithms have received more and more attention.

The DV-Hop localization algorithm is the most widely used at the present time, for the reason that it is not complicated, and is more practical. For the DV-hop algorithm, which nodes are randomly distributed in a network environment, there is a big error. We have to develop a correction for this.

Recent researches [13] propose an algorithm to correct the position of DV-Hop, based on the estimated distance to the nearest anchor. In [14], improved DV-Hop algorithm consists of selective 3-anchors DV-hop algorithm, based on the connectivity vector. In this paper we will exploit the two last ideas to develop an algorithm in which an unknown node can calculate its position by selecting three anchors with reference to the nearest one.

This paper is organized as follows: in Section II, we will present the localization problem. DV-Hop algorithm is presented in Section III. In Section IV, we will present the relationship between the nearest anchor and the minimal error. In Section V, we will introduce our improved algorithm. Simulation results are provided in Section VI. The last section is to conclude this paper.

II. LOCALIZATION PROBLEM

The difference between the estimated coordinate and the actual coordinate is the location errors given by the following formula:

$$Error_n = \sqrt{(x'_n - x_n)^2 - (y'_n - y_n)^2} \qquad (1)$$

where (x'_n, y'_n) are the estimated coordinates of the node N, and (x_n, y_n) its actual coordinates.

The most important criterion of the localization problem is the localization average error. In this paper, it is expressed in percentage, as follows:

$$AveError = \frac{1}{NR} \sum_{n=1}^{N} Error_n * 100 \% \qquad (2)$$

where R is the communication radius and N is the number of nodes.

III. DV-HOP ALGORITHM

DV-hop is a distributed hop by hop positioning algorithm proposed by Dragos Niculescu and Badri Nath [15]. The algorithm implementation is composed of three steps. After

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:8, No:10, 2014

the first phase, all nodes in the network obtain the minimum hop count values to all anchor nodes.

In the next step, once an anchor gets hop-count value to other anchors, it estimates an average size for one hop. Then the estimated average size is transmitted to the whole network. The average hop-size is calculated using the following formula:

$$Hopsize_i = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}}{\sum_{j \neq i} h_{ij}} \quad (3)$$

where $(x_i, y_i), (x_j, y_j)$ are respective coordinates of anchor i and anchor j. h_{ij} are the hops between anchor i and anchor j.

After all unknown nodes have received the hop-size from anchor nodes which have the least hops between them, they compute the distance to the anchor nodes based on two factors: hop-size and minimum hop count (h_{id}), using the following formula:

$$d_i = h_{id} * HopSize_i \quad (4)$$

In the third step, unknown nodes calculate their position according to the distance to each anchor node obtained in the second step.

Let (x, y) be the coordinates of the unknown node, and (x_i, y_i), the coordinates of anchor i. Let's say d_i is distance between anchor i to unknown nodes, and then we have the following formula:

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = d_1^2 \\ (x - x_2)^2 + (y - y_2)^2 = d_2^2 \\ . \\ . \\ (x - x_n)^2 + (y - y_n)^2 = d_n^2 \end{cases} \quad (5)$$

The formula (5) can be schemed with the following linear equation:

$$AP = B \quad (6)$$

where

$$P = \begin{pmatrix} x \\ y \end{pmatrix}$$

$$A = -2 * \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ .... & .... \\ x_{n-1} - x_n & y_{n-1} - y \end{bmatrix} \quad (7)$$

$$B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ . \\ . \\ . \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix} \quad (8)$$

The position of the unknown node is obtained by using least square method, which can be expressed as:

$$P = (A^T A)^{-1} A^T B \quad (9)$$

IV. THE RELATIONSHIP BETWEEN THE NEAREST ANCHOR AND THE MINIMUM ERROR

In this section we present the principle of our algorithm. We use a typical example of network topology, which operates in a $50*50m^2$ area with 10 nodes randomly distributed inside. The communication range of all the nodes is set to 20m. Between the 10 nodes, there are 4 anchors: A1, A2, A3 and A4, which already know their positions. The normal nodes are N1 N2 ....N6, and they do not know their positions.

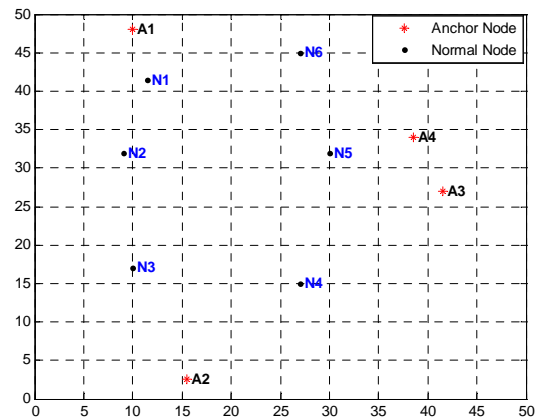The typical example is shown in this figure:

Fig. 1 10 nodes randomly deployed

From the first two steps of the DV-hop algorithm, a normal node can obtain the minimum number of hops, and the distances that separate it from each anchor. Then, the unknown node N_i calculates its estimated position by multilateration.

Let's consider a network of Na anchors. So, instead of using all the estimated values, three distances from three different anchors are sufficient for Ni to calculate its position by trilateration.

From Na anchors, the total 3-anchor groups are $C_{N_a}^3$ groups. So, N_i can obtain $C_{N_a}^3$ estimated positions.

In our example, the number of anchors is four. We can have four 3- anchor groups that are: (1, 2, 3), (1, 2, 4), (1, 3, 4) and (2, 3, 4).

The estimated positions of the unknown nodes of these different combinations are measured by trilateration using (9).

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:8, No:10, 2014

1) Experience:

The following table presents the results of simulations corresponding to location errors for different combinations:

TABLE I
COMPARISON BETWEEN THE VARIOUS ERRORS OF DIFFERENT COMBINATIONS

Nodes \ Combinations	(1, 2, 3)	(1, 2, 4)	(1, 3, 4)	(2, 3, 4)
N1	9.401	3.925	19.941	72.242
N2	14.369	18.456	74.318	37.352
N3	3.527	13.442	115.28	27.906
N4	6.745	9.977	39.355	14.132
N5	1.524	6.456	12.073	3.401
N6	6.538	1.113	6.014	30.563

Table I shows, for each node, different errors from 4 different combinations. We will group in another table, for each node, the minimal error, its corresponding combinations and its nearest anchor. We will present also in the same table the error given by DV-Hop.

TABLE II
RELATIONSHIP BETWEEN THE MINIMAL ERROR AND THE NEAREST ANCHOR

Nodes	DV-Hop error	The minimum error for each node	The corresponding combination	The nearest anchor
N1	8.813	3.925	(1,2,4)	1
N2	12.796	14.369	(1,2,3)	1
N3	8.690	3.527	(1,2,3)	2
N4	7.334	6.745	(1,2,3)	3
N5	3.970	1.524	(1,2,3)	4
N6	3.144	1.113	(1, 2, 4)	4

From this table, we can notice the following:

- There are error values which have a better precision than DV-Hop error.
- The nearest anchor exists in all combinations giving the minimal error except for node 5. All the same, node 5 has, with its closest anchor, an error value of "3,401", which is smaller than that given by DV-hop.
- Node 2 is the only one that has a greater error than indicated by the classical DV-Hop algorithm.

2) Interpretation of Results:

We can interpret these results as follows:

- Many anchors do not, necessarily, always give good results.
- Just three anchors, well-located geographically in relation to the unknown node, are sufficient to improve the accuracy position.
- The number of hops between N2 and anchors A1, A2, A3 and A4 are respectively 1, 2, 3, and 3.
- In order to reduce the number of hops between N2 and anchors 3 and 4, we assume that there is a virtual node N7, which coordinates are the average positions of neighboring anchors:

$$x = \frac{\left(\sum_{i=1}^{m} x_i\right)}{m} \quad , \quad y = \frac{\left(\sum_{i=1}^{m} y_i\right)}{m} \qquad (10)$$

where m is the number of anchors. And (x_i, y_i) their different coordinates.

The following results are found:

TABLE III
RELATIONSHIP BETWEEN THE MINIMAL ERROR AND THE NEAREST ANCHOR WITH ADDITION OF VIRTUAL NODE N7.

Nodes	Minimal error	Minimal error with virtual node	The corresponding combination	The nearest anchor
N1	3.925	3.925	(1,2,4)	1
N2	14.369	**1.1221**	**(1,2,4)**	1
N3	3.527	3.527	(1,2,3)	2
N4	6.745	6.745	(1,2,3)	3
N5	3.401	3.401	(2, 3, 4)	4
N6	1.113	1.113	(1, 2, 4)	4

Bold values are modified by the addition of virtual node N7. The number of hops of N2 to anchors A1, A2, A3 and A4 changes respectively from (1, 2, 3, and 3) to (1, 2, 2, and 2). We can see from these results:

- The contribution of adding a virtual node is very significant on reducing error of node 2.
- The combination, giving the new minimal error of N2, is changed with keeping the same nearest anchor.
- Other nodes maintain the same error values, the same combinations and their same closest anchors.

Note: We can find similar results if we change the communication radius from 20 to 21 meters.

From these results, we can conclude that we can avoid such error when we change the density of network, or the communication range.

V. THE STEPS OF THE IMPROVED ALGORITHM

The algorithm proposed involves 4 steps.

Step 1. In this step we execute firstly DV-Hop algorithm. Each anchor calculates and broadcasts the average distance per hop for the whole network, and every unknown node fixes its nearest anchor, which will be considered as a reference node.

Step 2. Each time, the unknown node chooses any two anchors and is localized by trilateration, along with the reference anchor node. So, we should record the results of all combinations.

Let's suppose that we have 4 anchor nodes, and the nearest anchor of node N1 is A1. Consequently, the different combinations for N1 are: (A1, A2, A3), (A1, A2, A4) and (A1, A3, A4), giving respectively three different positions: N11, N12, N13.

Step 3. Let's calculate these positions' error of N1 using (1) and we will select the least error value.

Step 4. Let's assume that the combination giving the least error is (A1, A2, A4). So, N1 will consider N12 as its estimate position.

VI. SIMULATION AND ANALYSIS OF EXPERIMENTAL RESULTS

To evaluate the performance of the developed algorithm, we use Matlab to simulate the network scenario and determine

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:8, No:10, 2014

the localization results. The experiment region is a square with the fixed size of 50*50m2 and the radio range of sensor nodes (R) is set to 20 meter.
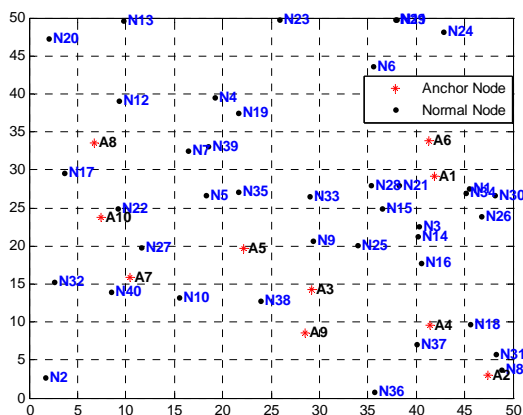

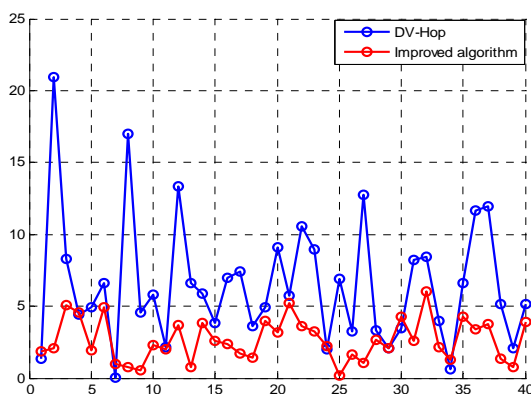Fig. 2 50 nodes randomly distributed, among them 10 are anchor nodes

Fig. 3 The error diagram of the unknown nodes

Fig. 3 represents the error diagrams of DV-hop algorithm and the developed algorithm. These diagrams correspond to the location errors of the nodes of Fig. 2. It is clear that the locations errors calculated by the improved algorithm are smaller than those calculated by the DV-hop algorithm.

1) Experience 1

We deploy 50 sensor nodes randomly in the simulation area. The ratio of anchor nodes is 10%, respectively, 20% ...50%. The simulation results are presented in the following table:

TABLE IV
THE AVERAGE LOCATION ERROR UNDER DIFFERENT PERCENTAGE OF
ANCHOR NODES

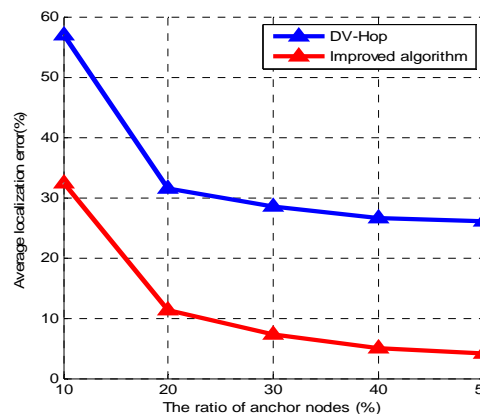| Ratio of anchor	DV-Hop	Developed algorithm
10%	56.98	32.37
20%	31.49	11.25
30%	28.58	07.20
40%	26.66	05.02
50%	26.06	04.15

Fig. 4 The average location error under different percentage of anchor nodes

The algorithm proposed in this paper is an improved DV-Hop algorithm based on the nearest anchor. The evaluation criterion of the localization problem is the average localization error. The experimental results are shown in Fig. 4. In this figure the average location error of the two algorithms shows a decreasing trend at every increase in the proportion of anchor nodes. In the entire process, and in the same conditions, the positioning accuracy of the improved algorithm is superior to the original DV-hop. For example, in the anchor node ratio of 30%, improved DV-hop algorithm is 07.20%; which is lower by 21.38% than the average error of the traditional algorithm. This shows the superiority of the improved algorithm over the original DV-Hop algorithm.

2) Experience 2

In this experience, we keep the parameter of anchor proportion of 20%, and the total number of nodes changes from 20 to 60.

TABLE V
THE AVERAGE LOCATION ERROR UNDER 20% OF ANCHORS AND DIFFERENT
NUMBER OF UNKNOWN NODES

Number of unknown nodes	DV-Hop Algorithm	Developed Algorithm
20	59.56	40.66
30	41.67	22.06
40	37.10	18.90
50	34.78	13.48
60	32.16	10.88
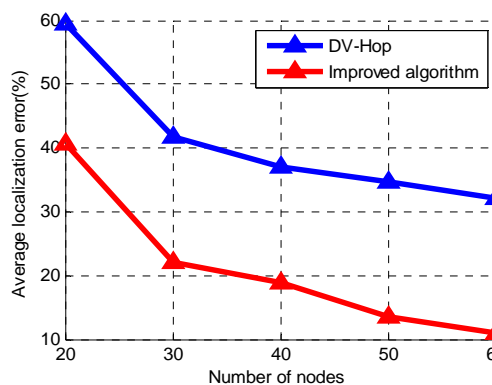
Fig. 5 The average location error when the anchor ratio is 20%

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:8, No:10, 2014

From this figure we can see that with the increase of the number of nodes, the average location error of the two algorithms shows a decreasing trend. The positioning accuracy of the improved algorithm is considerably higher than the traditional DV-hop algorithm. For example, in the number of nodes of 50, the average error is decreased by about 21.30% for the improved DV-hop algorithm, compared to traditional DV-hop algorithm.

VII. CONCLUSION

This paper proposes, a new method for DV-Hop algorithm which can choose three anchors based on the nearest one. The experimental results have proven significantly the validity of our method without the requirement of additional hardware and software. But the deficiency of the algorithm is the increasing cost of calculation. As a result, our future objective will be to propose an algorithm that can decrease the calculation cost while improving the nodes precisions using soft-computing techniques.

REFERENCES

[1] F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey", Computer Networks, Vol. 38, pp. 393-422, 2002.
[2] J. Yick, B. Mukharejee, D. Ghosal, "Wireless sensor netwok survey", Computer Networks, Vol. 52, pp. 2292–2330, 2008.
[3] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey,"Computer Networks, vol.38, no. 4, pp. 393–422, 2002.
[4] M. X. Chen and Y. D. Wang, "An efficient location tracking structure for wireless sensor networks," Computer communications, vol. 32, no. 13-14, pp. 1495–1504, 2009.
[5] Jianning Ding, Li Zhang , Guanggui Cheng, Zhion Ling, Zhongqiang Zhang, Yi Lei "Study on DV-Hop algorithm Based on modifying Hop Count Wireless Sensor Nteworks", IJCSET, Vol 2,Issue 10 1452-1456, October 2012.
[6] X. Wang, Z. Wang, B. O'Bea, "A TOA-based location algorithm reducing the errors due to non-line-of-sight (NLOS) propagation,".IEEE Transations on vehicle Technology,vol. 52, pp.112-116, January 2003.
[7] K. C. Ho, W. Xu,"An accurate algebraic solution for moving source location using TDOA and FDOA measurements,".IEEE Transactions on Signal Processing, vol. 52, pp.2453-2463, September 2004.
[8] M. Bousshaba, A. Hafid, A. Benslimane, "High accuracy localization method using AOA in sensor networks,"Computer Networks, vol .53, pp.3076-3088, August 2009.
[9] H. H. Cho, R. H. Lee, J. G. Park ,"Adaptive Parameter Estimation Method for Wireless Localization Using RSSI Measurements,"Jpurnal of Electrical Engineering& Technology,vol.6,pp.883-887,2011.
[10] L. Cheng, C. Wu, Y. Zhang, "Indoor Robot Localization Based on Wireless Sensor Networks," IEEE Transactions on Consumer Electronics, vol.57, pp.1099-1104, August 2011.
[11] J. Wang. Q. Fu. "Research on APIT and Monte Carlo Method of Localization Algorithm for Wireless Sensor Networks, "International Conference on Intelligent Computing for Sustainable Energy and Environment vol.6329, pp.128-137, Wuxi, 2010.
[12] Y. Yu, C. Jiang, X. Zhao, L. Yun,Z. Li,Y. Ren. "Sequence-based localization algorithm with improved correlation metric and dynamic centroid," Science China Information Sciences, vol.54, pp .2349-2358, November 2011.
[13] L. Gui, "A Improvement of Range-free Localization Systems in Wireless Sensor Networks," Thèse soutenue le mercredi 13 février 2013.
[14] L. Gui, A. WEI, T. VAL, "Improving Localization Accuracy Using Selective 3-Anchor DV-hop Algorithm", IEEE Vehicular Technology Conference (VTC 2011-fall), pp.1-5, San Francisco,September 2011.
[15] D. Niculescu, B. Nath. "Ad Hoc Positioning System (APS)". Proc. of the IEEE GLOBECOM 2001, San Antonio, 2001, pp. 2926-2931.

Hichem Sassi received his License and Master in signal processing and automatic (ENIT) Tunis, Tunisia, 2001and 2003. He is currently teacher of physics at secondary school of Kalaa Elkebira Sousse, Tunisia. His research interests include soft-computing and Improvement of localization in Wireless sensor network.

Tawfik Najeh received his License and Master in Automatic-computer-integrated manufacturing - Productique (ESSTT) Tunis, Tunisia, 2003 and 2006. He is currently teacher of Electrical Engineering at secondary school of Sousse, Tunisia. His research interests include Modeling, Intelligent Control and Monitoring and Monitoring of the robust systems.

Noureddine Liouane is an associate professor in the Engineering Department at the ENIM-Monastir. He received a MSEE degree in 1988 from the ENSET at Tunis University and the PhD degree from Ecole Centrale de Lille, France in 1998. His research interests include evolutionary optimization methods for events systems, computer science and operational research.