Analysis on DV-Hop Algorithm and its variants by considering threshold

Amanpreet Kaur[1], Padam Kumar[1], Govind P Gupta[2]
[1] Department of Computer Science & Engineering
Jaypee Institute of Information Technology, Noida, India
[2]Department of Information Technology
National Institute of Technology, Raipur, India
amanpreet.kaur1410@gmail.com

Abstract—**Wireless Sensor networks is a network of low-priced, small sized and energy constraint sensor nodes where each sensor node is programmed to sense the events and send it to the Base station using multi-hop communication. In almost all applications of Wireless Sensor Networks, event detection information is required along with the location of the event. Thus, to find the location of event, node localization plays an important role. Many researchers have put tremendous efforts in designing localization algorithms. In the literature, it is confirmed that DV-Hop algorithm and its variants are the most suitable range-free based algorithms for node localization, due to its cost effectiveness, simplicity and feasibility for medium to large scale networks, but these algorithms consume very high energy. The DV-Hop algorithm works in three phases. The first phase allows all the nodes to get their distance from few localized nodes called anchors in terms of hop. The hop is the count of neighboring nodes between two nodes. Then in second phase, the anchor nodes find out their approximate distances from every node. The third phase computes the location of node using the information obtained from first two phases and by applying trilateration method. The high energy is consumed due to transmission of large number of packets in the first two phases by anchor nodes. In order to reduce communication overhead of the first two phase of DV-Hop, an improved DV-Hop is proposed that considers only k-hop transmission of the anchor packet which reduces the communication overheads to the large extent. Simulation experiments and results prove that the proposed method reduces the energy consumption by approximately 50% compare to the traditional DV-Hop algorithm.**

Index Terms— **DV-Hop; Localization; Threshold; Wireless Sensor Networks.**

I. INTRODUCTION

A typical Wireless sensor network (WSN) contains a collection of low-priced, small, and energy constraint sensor nodes which are used to detect some events in the target area of the interest [1]. These sensor nodes identify event and pass this information to the base station by means of their neighboring nodes [1]. WSNs are broadly utilized for different applications, for example, military and national security application, environmental observing, health application, air control, pollution control, fire location, etc[1-2]. In most application of WSNs, any event data without its location is good for nothing. For instance, in military application, both event (intruder) and place (location) where intruder is recognized are required. In this manner, Localization is a critical requirement in almost all application of WSNs.

In literature, numerous algorithms have been proposed in recent decade. According to cost, the localization algorithms have been arranged into two classes: Range-based and Range- free methods [3]. Range-based localization methods require costly equipment to localize the sensor node with high exactness. Some of Range-based methods are: received signal strength indicator (RSSI) [4], time of arrival (TOA) [5], time difference of arrival (TDOA) [6], and angle of arrival (AOA)[7], and so on. On the other hand, Range-free methods apply estimation techniques to decide node's location and do not require any costly equipment. They utilize few anchor nodes that have knowledge about their position. There are many Range-free methods, for example, Centroid [8], DV-Hop [9], Amorphous [10], MDS [11] and APIT [12].

Although Range-based algorithms give precise results, Range-free based method is favored because of their ease and less cost. In this paper, we concentrate on Range-free DV-Hop algorithm and its variants that are popular because of its simplicity, feasibility for small to large scale WSNs and useful for those nodes that are having less than three neighbors [13]. But, DV-Hop has a few drawbacks, for example, low localization precision, high power utilization and high communication overhead. In this paper, we have focused in reducing the communication overheads of the first two-phase of the traditional DV-Hop [9] algorithm and its variants by proposing an improvement to restrict the transmission of packets by using threshold parameter. Simulation experiments demonstrate that the proposed method reduces energy consumption approximately 50% when compared with traditional DV-Hop [9] algorithm.

This paper makes following two contributions to the localization issue in WSNs:
i) An improved DV-Hop is proposed that considers only k-hop transmission of the anchor packet which reduces the communication overheads to the large extent. .
ii) Performance analysis and its comparison with the traditional DV-Hop [9] and Weighted-DV-Hop [14] algorithm in terms of energy consumption are discussed in detail.

The remaining part of the paper is composed as follows. Section 2 gives the survey of related work. In Section 3, the proposed method is clarified. Section 4 shows the simulation results and main findings of the paper. At last, we put the concluding remarks in Section 5.

II. RELATED WORK

A. *DV-Hop algorithm*

The DV-Hop was proposed by D. Niculesco et al. [9]. It can be described using three steps as described below.

i. *Getting the smallest number of hops*

In this phase, each anchor node broadcast an anchor message in the network. The organization of the anchor message is {*id, x_i, y_i, hops$_i$*}. The *hops$_i$* is used to find the shortest path between anchor and the node by counting least number of hops between these two. The beginning value of *hops$_i$* is 0 at the anchor. Each receiving node maintains an anchor data table and keeps the smallest number of hops from different anchor nodes in the table. After a time frame, all nodes in the system will have the smallest number of hops from every anchor node.

ii. *Estimation of the distance amongst Anchors and non-anchor nodes*

In this phase, the anchor nodes get distance of different anchor nodes in terms of hop count using Step 1 of DV-Hop. After the first step, anchor node *i* finds average distance per hop ($AvgHopDistance_i$) by using smallest hops and distance between anchors. Formula for calculating the $AvgHopDistance_i$ is described as follows:

$$AvgHopDistance_i = \frac{\sum_{i=1\ i\neq j}^{m} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}}{\sum_{i=1\ i\neq j}^{m} hops_i} \qquad (1)$$

Where *m* is quantity of anchor nodes, *hops$_i$* is the smallest number of hops between anchor nodes i and *j*, (x$_i$,y$_i$) and (x$_j$,y$_j$) are the locations of anchors *i* and *j*, respectively.

Each anchor communicates its *AverageHopSize* to the entire system. Each non-anchor node gets all anchors' AvgHopDistances and chooses the *AvgHopDistance$_j$* of a nearest anchor as its *AverageHopDistance$_j$*. In the end, it calculates the distance (d_i) from each anchor *i* by using Eq. (2) as follows:

$$d_i = AvgHopDistance_j \times hops_i \qquad (2)$$

iii. *Estimation of location.*

In the final step, the non-anchor nodes can estimate their positions by applying either trilateration [9] or multilateration mechanism [9].

B. *Improved Variants of DV-Hop*

Numerous researchers have proposed numerous improvements to improve performance of the DV-Hop algorithm. In this section, we have discussed some improved variants of DV-Hop algorithm.

In [14], the weighted centroid based algorithm (Weighted DV-Hop) was proposed to reduce computational complexity and consumed energy of DV-Hop. It used the weight factor that was inversely proportional to smallest number of hops to find the location (*x$_{nb}$,y$_{nb}$*) of the non-anchor by applying equation (3).

$$x_{nb} = \frac{\sum_{i=1}^{m} w_i x_i}{\sum_{i=1}^{m} w_i}, \ y_{nb} = \frac{\sum_{i=1}^{m} w_i y_i}{\sum_{i=1}^{m} w_i} \qquad (3)$$

where $w_i = \frac{1}{hops_i}$, is the weight of each anchor *i*. The weight factor gives higher priority to nearest anchor. This algorithm has low computational complexity as it skips one step involving computing average distance per hop by anchors and broadcasting it to other nodes. Also, it consumes less energy due to broadcasting of fewer packets (required only for first step).

Another improved weighted centroid algorithm (IWCA) was proposed in [14] which consist of three steps. The refinement is done in the second step by taking average of average-hop-distances (say, *HopSize*). In the third step, the weight factor is determined by applying Equation (4).

$$w_i = \left(\frac{1}{hops_i}\right)^{\frac{r}{HopSize}} \qquad (4)$$

Where *r* is the transmission radius of the sensor node. This algorithm achieves higher localization accuracy, but consumes more energy due to broadcasting of more number of packets.

In [15], G.Song et al. designed an improved weighted centroid DV-Hop (IDWCA). This algorithm uses Equation (5) to get weight value by non-anchor sensor node.

$$w_i = \frac{\sum_{i=1}^{m} hops_i}{mhops_i} \qquad (5)$$

In [16], the algorithm adds a fourth step (correction step) to enhance its localization precision. In [16], one more algorithm was introduced that picks only three best anchors to locate a sensor node in the last step of the DV-Hop algorithm. In [17], the algorithm adds a minor change by taking the difference of average hop distance and transmission radius, while computing distance between nodes to get more accuracy. In [18], the algorithm adds a coefficient in the distance between various nodes to reduce error. In [19], genetic algorithm was used with DV-Hop for better accuracy. G.Song et al. [14] designed one more algorithm that substitutes hyperbolic method in the last step of DV-Hop to achieve better results in terms of accuracy. In [20], three algorithms were introduced. The first two algorithms added one more step that uses trigonometry to achieve higher accuracy. The third algorithm replaces the linear problem into non-linear problem in the last step and then solves it by applying quadratic programming method. In all above algorithms, the first two steps are same and consumes large amount of energy due to broadcasting. If somehow, this transmission is controlled, then energy consumption can be significantly reduced.

Despite the fact that all the related work mentioned above improves the localization accuracy, but very few works have concentrated on reducing consumed energy. In this paper, we have proposed an improved DV-Hop algorithm which reduces the energy consumption of the network.

III. PROPOSED METHOD

In this section, we present an improvement in the first two steps of the DV-Hop algorithm, by restricting the broadcasting of the anchor message to few hops. The assumption used is that the anchor nodes are distributed uniformly in the WSN area and their percentage is at least 10% of total nodes in the WSN. A detail discussion of improved DV-Hop is given beneath:

A. *Improved DV-Hop Algorithm*

The proposed improvement in the DV-Hop algorithm works as follows:

Step 1: In the first step, anchor packet is only forwarded to a specified number of hops from each anchor node. This specified number of hops is called threshold value which is defined as *k*- hops. By limiting the broadcasting of the anchor packet to a threshold value (i.e. *k*- hops), we can lessen the energy consumption of the network which relies on the number of packets transmitted in the network. The working of the first step is as follows:

At first, each anchor node *i* communicates its position (x_i, y_i) to all non-anchor nodes in the form of packet that are forwarded to a fixed number of hops i.e. *k*. . The packet constitutes $<x_i,\ y_i,\ hops_i>$ information. The $hops_i$ is initialized to 0. Each sensor nodes saves information about all the anchor nodes that lies in a threshold region in its hop table containing $<i,\ x_i,\ y_i,\ hops_i>$ for each anchor *i*. When the packet is received by a particular node, the node verifies it with its hop table, and if the received $hops_i$ value is less than stored $hops_i$ value in the table and the $hops_i$ is less than *k*, then it saves the new $hops_i$ value in the table, and forwards the packet with incremented $hops_i$ value to other nodes, otherwise it discards the received packet. In this manner, after the first step, all sensor nodes get smallest number of hops from all anchors that lie in their threshold region.

Step 2: This step is like the second step in the traditional DV-Hop [9] algorithm with the difference that broadcasting is done within threshold region. Here, each anchor node *i* computes average distance per hop ($AvgHopDistance_i$) utilizing Equation (1). The value of *m* in Equation (1) is number of anchor nodes that are within a threshold region. After this, each anchor node *i* communicate it to different sensor nodes that are within a threshold range (i.e. *k-hop*). By considering this improvement, the energy consumption is further reduced. The non-anchor nodes estimate their distance from anchor nodes by applying Equation (2). The sensor nodes now have distances from only those anchor nodes that are within threshold range. By restricting broadcasting to the threshold (only within k hops) range, the anchor nodes transmit now fewer packets and thus reduce energy consumption.

Step 3: The third step is similar to the third step of the traditional DV-Hop [9] algorithm.

Similarly, other variants of DV-Hop Algorithms can be improved by refining their first two steps.

IV. SIMULATION RESULTS AND FINDINGS

To prove the effectiveness of the improved DV-Hop and its variants, the algorithm is simulated in Matlab2013. In this section, we presented the results in terms of consumed energy. The consumed energy depends upon the number of packets transferred between nodes in the network. It may be expressed as:

$$\text{Consumed Energy} = 2 \times (n - 1) \times m \times En \qquad (6)$$

Where *n* is total number of nodes, *m* is the total number of anchors, *En* is the average energy used to transmit a packet.

The simulation experiment compares the proposed improved algorithm with other two algorithms (DV-Hop [9] and Weighted DV-Hop [14]) on the basis of consumed energy by changing total number of anchors. 500 nodes are deployed in a 500×500 WSN network and the communication radius is assigned to 100. The count of anchors is increased from 50 to 200 to see the effect on consumed energy for different values of threshold (i.e. *k*) value. Performance comparison between algorithms for different values of threshold (i.e. *k*) value is shown in Figure 1 to Figure4.

The simulation parameters used for the experiment are displayed in Table 1.

Table 1
Simulation parameters

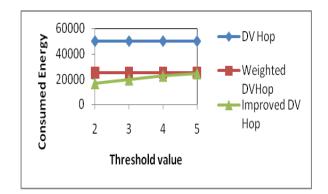| Simulation Parameters	Value
WSN Area	500×500 m^2
Total Nodes	500
Anchor Nodes	Vary from 50 to 200
Total iterations	50
threshold value(k)	Vary from 2 to 5
Communication radius	100

Figure 1: Comparison by varying threshold value (total anchors=50)

Figure 1 shows the performance analysis of the proposed improved DV-Hop with the traditional DV-Hop [9] and Weighted DV-Hop [14] algorithm in terms of energy consumption by varying the threshold value k from 2 to 5. In this experiment, total 500 nodes are deployed and 50 of them are anchor nodes. It is observed from the figure 1 that proposed improved DV-Hop algorithm takes less energy compare to the other two algorithms, traditional DV-Hop [9] and Weighted DV-Hop[14]. This is due to fact that proposed method transmits less communication overheads compare to the other methods.

During experiments, it is observed that for k=2, traditional DV-Hop [9] and weighted DV-Hop [14] transmits 50,000 and 25000 packets, respectively, whereas our proposed method broadcasts 10000 packets. As the value of *k* increases, the proposed method starts consuming more energy and is equal to Weighted DV-Hop[14] for k=5.

Figure 2 shows the result for the WSN network with 100 anchor nodes. It is shown that the proposed algorithms consume packets from 30000 to 50000 for different values of k. The proposed algorithm consumes almost 70% less energy for k=2 when compared with DV-Hop and 20% less energy when compared with Weighted DV-Hop.
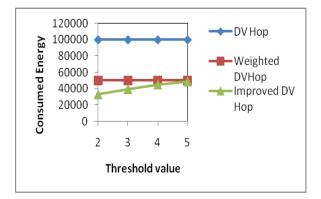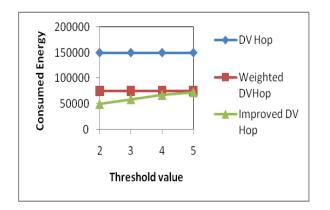
Figure 2: Comparison by varying threshold value (total anchors=100)

For the results as shown in Figures 3 and 4, the anchor nodes are raised to 150 and 200 respectively. The performance of the proposed algorithm is best for k=2 in terms of energy consumption. In Figure 3, the proposed algorithm improves by 66% in terms of energy reduction when compared with DV-Hop[9] and by 33% when compared with Weighted DV-hop[14 when k is equal to 2. Figure 4 shows that the proposed algorithm reduces energy by 75% when compared with DV-Hop[9] and by 33% when compared with Weighted DV-Hop[14] algorithm when k is equal to 2.
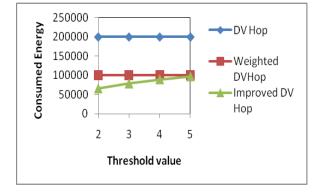

Figure 3: Comparison by varying threshold value (total anchors=150)

Figure 4: Comparison by varying threshold value (total anchors=200)

From the result as shown in from Figure 1 to Figure 4, it is proved that proposed algorithm performs better in terms of energy consumption. It is also observed that the consumed energy in traditional DV-Hop [9] and Weighted DV-Hop [14] algorithms depends upon the total numbers of nodes and anchor percentage. Thus the consumed energy is constant for both algorithms in each experiment for fixed

number of nodes and a fixed number of anchors. The Weighted DV-Hop skips packet transmission in its second phase, so it consumes energy equal to half as that traditional DV-Hop [9]. In the proposed algorithm, the consumed energy increases with the increase in threshold (k) value. Thus we should take the minimum value of k is 2 as an optimum threshold value to minimize energy consumption. It is also observed that with the increase in threshold value, the energy consumption increases.

V. CONCLUSION

This paper gives the summary of issues of DV-Hop algorithm and its variants. The primary issues are low accuracy and high energy consumption. In order to reduce energy consumption, we have proposed an improved DV-Hop algorithm which reduces the power consumption by limiting the transmission of the anchor packet to the maximum k-hop.
Through simulation results, it is demonstrated that the improved algorithm performs superior to other algorithms in terms of consumed energy. In the future, we will plan to expand this work for 3D WSNs.

REFERENCES

[1] Nayak and I. Stojmenovic, "Applications, Models, problems, and Solution Strategies", in Wireless Sensor and Actuator Network, Ed. New Jersey: Wiley, ch. 1, pp. 3-4, 2010.
[2] J. Zhao, W. Xi, Y. He, Y. Liu, X.-Y. Li, L. Mo, and Z. Yang," Localization of Wireless Sensor Networks in the Wild: Pursuit of Ranging Quality" ,IEEE/ACM Transactions on Networking, vol 21, no.1,pp 311-323,Feb 2013.
[3] H.Chen, K.Sezaki, P.Deng and H.C.So, "An improved DV-hop localization algorithm for wireless sensor networks," In Proceedings of IEEE Conference on Industrial Electronics and Applications, Singapore, pp.1557-1561, 2008.
[4] L. Girod, V. Bychobvskiy, J.Elson and D. Estrin,".Locating tiny sensors in time and space: a case study.", In Proceedings of the 2002 IEEE International Conference on Computer Design: VLSI in Computers and Processors, Los Alamitos , pp. 214–219,2002
[5] A. Harter, A. Hopper, P. Steggles. A. Ward and P. Webster, "The anatomy of a context-aware application", Wireless Networks, Vol 8, no.2, pp.187–197,2002
[6] X. Cheng, A.Thaeler, G. Xue, and D. Chen, "TPS: a time-based positioning scheme for outdoor wireless sensor networks," in Proceedings of the 23rd IEEE Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM '04), pp. 2685–2696, Hong Kong, China, March 2004.
[7] D. Niculescu, and B. Nath," Ad hoc positioning system (APS) using AoA" , In Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies, Vol. 3, pp.1734–1743,2003.
[8] N. Bulusu , J. Heidemann , D. Estrin ,"GPS-less low cost outdoor localization for very small devices", IEEE Personal Communications Magazine, Vol 7, no. 5, pp. 28–34,2000.
[9] D. Niculescu and B. Nath," Ad-hoc positioning system.", In IEEE on Global Telecommunications Conference,Vol 5, pp. 2926–2931, 2001.
[10] R. Nagpal ," Organizing a global coordinate system from local information on an amorphous computer", A.I. Memo1666, MIT A.I. Laboratory,1999.
[11] Y. Shang andW. Ruml, "Improved MDS-based localization," in Proceedings of the IEEE Conference on Computer Communications (INFOCOM'04), pp. 2640–2651,HongKong, March 2004.
[12] T. He, C. D. Huang, B.M. Blum, J.A. Stankovic, and T. Abdelzaher, "Range-free localization schemes for large scale sensor netowrks," in Proceedings of the 9th the Annual International Conference on Mobile Computing and Networking, pp. 81–95, ACM, San Diego, Calif, USA, 2003.
[13] L.Gui , T. Val, A. Wei, R. Dalce," Improvement of range-free localization technology by a novel DV-hop protocol in wireless sensor networks",Ad Hoc Networks, 2015.
[14] B. Zhang, M. Ji, and L. Shan, "A weighted centroid localization algorithm based on DV-hop for wireless sensor network," in

Proceedings of the 8th International Conference on Wireless Communications, Networking and Mobile Computing , Shanghai, China, pp. 1-5, 2012.

[15] G. Song, D. Tam," Two Novel DV-Hop Localization Algorithms for Randomly Deployed Wireless Sensor Networks", International Journal of Distributed Sensor Networks, 2015.

[16] L.Gui , T. Val, A. Wei, R. Dalce," Improvement of range-free localization technology by a novel DV-hop protocol in wireless sensor networks", Ad Hoc Networks, 24, pp.55-73, 2015.

[17] X.Fang,"Improved DV—Hop Positioning Algorithm Based on Compensation Coefficient.", Journal of Software Engineering, Vol. 9(3) (2015), pp.650-657, 2015.

[18] W.Yu, H. Li, "An Improved DV-Hop Localization Method in Wireless Sensor Networks," In Proceedings of Computer Science and Automation Engineering (CSAE), (3), pp. 199-202, 2012.

[19] B. Peng, L. Li, "An improved localization algorithm based on genetic algorithm in wireless sensor networks", Cognitive Neurodynamics, Vol. 9(2), pp. 249-256 2015.

[20] S. Tomic, and I. Mezei, "Improvements of DV-Hop localization algorithm for wireless sensor networks." Telecommunication Systems, pp. 1-14, 2016.

[21] T. Ahmad, X. J. Li, and B.C Seet, "A self-calibrated centroid localization algorithm for indoor ZigBee WSNs", in 8th IEEE International Conference on. Communication Software and Networks (ICCSN), 2016..

[22] T.Ahmad, X. J. Li, and B.C. Seet, "3D localization based on parametric loop division and subdivision surfaces for wireless sensor networks", in 25th. IEEE Wireless and Optical Communication Conference (WOCC), 2016.

[23] A. Kaur, P. Kumar, and G. P. Gupta. "A Weighted Centroid Localization Algorithm for Randomly deployed Wireless Sensor Networks", Journal of King Saud University-Computer and Information Sciences, 2017.

[24]] A. Kaur, G.P.Gupta, P.Kumar, " A survey of Recent Developments in DV-Hop Localization Techniques for Wireless Sensor Network", Journal of Telecommunication, Electronic and Computer Engineering, Vol. 9(2), pp. 61-71, 2017.

[25] A.Kaur, P.Kumar, G.P.Gupta," A novel DV-Hop algorithm based on Gauss-Newton method", In IEEE International Conference on Parallel, Distributed and Grid Computing,pp. 625-629, 2016.