

# Reduction of power cost in DV-hop Localization Algorithm for Wireless Sensor Networks

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## *Abstract*

**Several localization algorithms for Wireless Sensor Network (WSN) have been proposed and implemented for determining the physical location of sensor nodes. In this paper, we propose a scheme to reduce the power cost consumed during the DV-Hop localization algorithm. The simulation results show that the proposed scheme decreases the energy consumption than the normal DV-Hop algorithm.**

## *Keywords*

Wireless Sensor Networks, localization, DV-Hop, Power cost

## I. INTRODUCTION

A Wireless sensor network (WSN) is composed of plenty of sensor nodes. These nodes have the ability of sensing, computation, and wireless communication. Due to its powerful function and low energy cost, the WSN has been widely used in various domains; such as military affair, environment inspection, traffic management, long distance control of dangerous region, and so on. In WSN, the position information is crucial. When an abnormal event occurs, the sensor node detecting the event needs the position information to locate the abnormal event and report to the base station. Therefore, numerous applications rely on the geographic information (e.g., location) of the sensor to identify the position of the tracking object, to assist in delivering packets to the fields of interests, to reduce the number of packets flooding the network for route discovery, and to provide sensor deployment for mitigating coverage overlap [1].

Various localization approaches have been proposed in the literature. These schemes are categorized as range-based and range-free, depending on the use of distance or angle estimate [2,3]. The range-based algorithm uses absolute point-to-point distance estimates or angle estimates for calculating the location. The range-free algorithm makes no assumption about the availability or validity of such information. This scheme does not require any technology or equipment to measure the distance or bearing between nodes, they just apply the communication among nodes to localize unknown nodes. Due to hardware limitations of WSN devices, solutions in range-free localization are being pursued as a cost-effective alternative to more expensive range-based approaches.

In this paper, we proposed a new scheme for reducing the power cost in DV-Hop Localization Algorithm. The proposed scheme minimizes the power cost during the process of localization. Simulation results show that the performance of this scheme is superior to the original DV-Hop algorithm. The rest of the paper is organized as follows: Section II discusses the related work in localization for wireless sensor networks, in section III we review the existing DV-hop algorithm based localization schemes. Section IV presents scheme for reducing the power cost. The experimental results are provided in Section V. We conclude the paper in Section VI.

## II. RELATED WORK

Many works in the literature propose schemes and methods for localization in WSNs for many purposes. In the range-free localization algorithms, Niculescu et al. [4] propose the DV-Hop localization scheme, which is similar to the traditional routing schemes based on distance vector. In their DV-Hop scheme, the node firstly counts the minimum hop number from the anchor node and then computes the distance between the node and anchor node by multiplying minimum hop number and average distance of each hop. At last, the node estimates its position through triangulation algorithm.

He et al. [3] propose an Approximate Point-In Triangulation test (APIT) algorithm. Using three anchors, APIT employs an area-based method to estimate node position. Amorphous algorithm [6] is similar to the DV-Hop, but it assumes to know the network density in advance, and uses offline hop-distance estimations. It proposed to generate a relatively accurate coordinate system on distributed processors via local information. Triangulation is also used to estimate a node's location.

Centroid algorithm [7] is a simple range-free localization algorithm. The node receives signals of anchors in its communication area and makes its coordinates as the centroid of these anchors. Additional devices of localization are not required in this algorithm.

Centroid, DV-Hop, Amorphous, APIT are all distributed algorithms. They are characterized by simple computing, low traffic and scalable ability. Range-free localization schemes are little affected by environmental factor, and additional

range modules are not needed. These characteristics make them suitable to WSNs of simple node, low cost and large scale.

### III. DV-HOP ALGORITHM

Niculescu et al. [4] have proposed the DV-Hop, which implementation is comprised of three steps. In the first step, each anchor node broadcasts a beacon to be flooded throughout the network containing the anchors location with a hop-count value initialized to one. Each receiving node maintains the minimum hop-count value per anchor of all beacons it receives. Through this mechanism, all nodes in the network get the minimal hop-count to every anchor node. In the second step, once an anchor gets hop-count value to other anchors, it estimates an average size for one hop, which is then flooded to the entire network. After receiving hop-size, unknown nodes multiply the hop-size by the hop-count value to derive the physical distance to the anchor. The average HopSize<sub>i</sub> is estimated by anchor i using the following formula:

$$\text{HopSize}_i = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} h_{ij}} \quad (1)$$

Where  $(x_i, y_i)$  and  $(x_j, y_j)$  are coordinates of anchor i and anchor j,  $h_{ij}$  is the hops between beacon i and beacon j. Each anchor node broadcasts its HopSize to network using controlled flooding. Unknown nodes receive HopSize information, and save the first one. At the same time, they transmit the HopSize to their neighbor nodes. This scheme could assure that the most nodes receive the HopSize from beacon node who has the least hops between them. In the end of this step, unknown nodes compute the distance to the beacon nodes based on hop-length and hops to the beacon nodes.

Let  $(x, y)$  be the unknown node  $\mathbf{p}$  location and  $(x_i, y_i)$  the known location of the i'th anchor node receiver. Let's say the i'th anchor node distance to unknown nodes is  $\mathbf{d}_i$ . We obtain the following equation system [8, 9]:

$$\begin{cases} (x_1 - x)^2 + (y_1 - y)^2 = \mathbf{d}_1^2 \\ (x_2 - x)^2 + (y_2 - y)^2 = \mathbf{d}_2^2 \\ \vdots \\ (x_n - x)^2 + (y_n - y)^2 = \mathbf{d}_n^2 \end{cases} \quad (2)$$

We get, from (2) the following equation:  $\mathbf{A}\mathbf{p} = \mathbf{B}$

Where  $\mathbf{A}$  is  $(n-1) \times 2$ ,  $\mathbf{B}$  is  $(n-1) \times 1$  and  $\mathbf{p}$  is  $2 \times 1$  matrix

$$\mathbf{A} = \begin{bmatrix} 2(x_1 - x_n) & 2(y_1 - y_n) \\ 2(x_2 - x_n) & 2(y_2 - y_n) \\ \vdots & \vdots \\ 2(x_{n-1} - x_n) & 2(y_{n-1} - y_n) \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} x_1^2 - x_n^2 + y_1^2 - y_n^2 + \mathbf{d}_1^2 - \mathbf{d}_n^2 \\ x_2^2 - x_n^2 + y_2^2 - y_n^2 + \mathbf{d}_2^2 - \mathbf{d}_n^2 \\ \vdots \\ x_{n-1}^2 - x_n^2 + y_{n-1}^2 - y_n^2 + \mathbf{d}_{n-1}^2 - \mathbf{d}_n^2 \end{bmatrix}$$

$$\mathbf{p} = \begin{bmatrix} x \\ y \end{bmatrix}$$

The coordinates of  $\mathbf{p}$  is computed by the following formula:

$$\mathbf{p} = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T \mathbf{B} \quad (3)$$

### IV. SCHEME FOR REDUCING POWER COST IN DV-HOP

During the DV-Hop process of localization, Power is consumed during communication (transmission and reception of packets) and computation [10].

We considered:

$N$ : Number of nodes (unknown nodes and anchors)

$Na$ : Number of anchors.

$C_{avg}$ : Average of connectivity

$D$ : Dimension of the space

#### A. Communication Cost

- Each node in the network will broadcast an average of  $Na$  hop count packets.
- Each node in the network is considered to have an average of  $C_{avg}$  neighbors. Hence, each node in the network will receive an average of  $Na * C_{avg}$  broadcasts of hop count packets.

Then the Total Number of Packets ( $TNP$ ) Transmission (emission and reception) is:

$$TNP = N*(Na + Na * C_{avg}) \quad (4)$$

Since every anchor already contains its own hope count, we subtract the number of the  $Na$  anchors of the total number of the  $N$  nodes.

The formula (4) becomes:

$TNP = (N-Na)*(Na + Na * C_{avg}) + Na*(Na + (Na-1) * C_{avg})$   
Because each anchor will receive  $(Na-1) * C_{avg}$  and broadcast  $Na$  packets.

Thus:

$$TNP = N*(Na + Na * C_{avg}) - Na * C_{avg} \quad (5)$$

#### B. Computational cost

Forming the matrix  $\mathbf{A}$  requires  $D*(Na-1)$  subtractions

Forming the matrix  $\mathbf{B}$  requires  $(D+1)*(Na-1)$  subtractions,  $D*(Na-1)$  additions and  $(Na-1)*2*(D+1)$  multiplications.

For compute the estimation position [5], the processor consumes:  $Na*((Na-1)*D^2 + D^3/3)$

Each node will perform  $Na$  multiplication in order to compute  $Na$  extended ranges and  $Na$  least-squares operations for each anchor.

Thus:

The sum of these formulas gives:

Thus:

$$Na + Na[(Na-1)(5D+3) + (Na-1)D^2 + D^3/3]$$

$$Na[1 + (Na-1)(D^2+5D+3) + D^3/3] \quad (6)$$

Finally, the total computational cost is:

$$Na[1 + (Na-1)(D^2+5D+3) + D^3/3]*F \quad (7)$$

Where  $F$  is the cost in power of a single flop and is system-specific.

In DV-hop Normal every nodes calculates, A, B, and p.

In our scheme, the matrix A will be calculated only one time in the anchor that will receive in first all other anchor packets.

(6) Becomes:

$$D(Na-1)+Na[1 + (Na-1)(D^2+4D+3) + D^3/3]$$

For all nodes:

$$D(Na-1)+N*Na[1 + (Na-1)(D^2+4D+3) + D^3/3]$$

Finally, (6) becomes:

$$(D(Na-1)+N*Na[1 + (Na-1)(D^2+4D+3) + D^3/3])*F \quad (8)$$

#### V. SIMULATION RESULTS

We simulated the DV-Hop and our proposed scheme to calculate the communication and the computational power cost.

The experiment region is a square area with the fixed size of 50 x 50 m<sup>2</sup> and the radio range of sensor nodes  $R$  is set to 10 meters. We assume that anchors are chosen randomly within the same area. As shown in (Fig.1), we deploy 100 sensor nodes randomly in a two-dimensional space ( $D = 2$ ).

We suppose that:

- The network of sensors is static (no mobile nodes).
- Nodes are homogeneous: nodes are similar in their capacity of treatment, communication, energy and storage.
- Channels of communications are bi-directional (if a node N1 can receive a message of the node N2 then N1 can send a message to N2).
- Every node has at least one neighbor

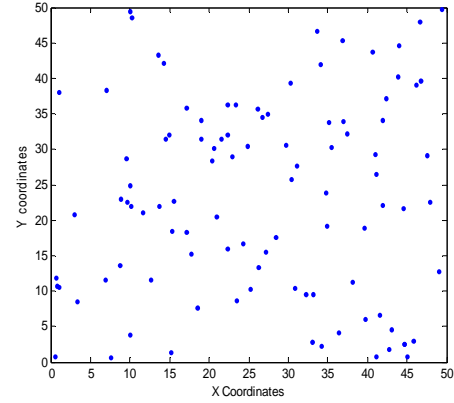


Fig.1. Random deployment topology

Fig. 2 shows the communication link between nodes (10% Anchors, R=10m). It gives an idea about the shape of the network topology isotropic or un-isotropic. In our case, the topology is isotropic that means the network is the same in different directions.

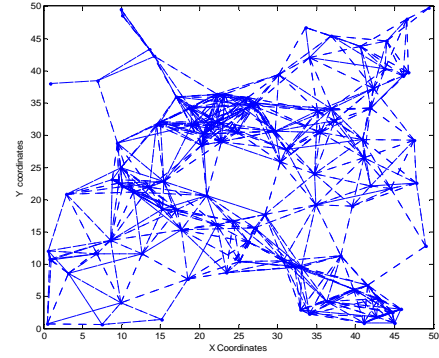


Fig.2. Communication link between nodes (5% Anchors, R=10m).

Fig.3 and Fig.4. Shows the Total Number of Packets Transmission during all the process of localization, according to formula (7), it is clear that the TNP increases when the ratio of anchors increases and when the connectivity increases.

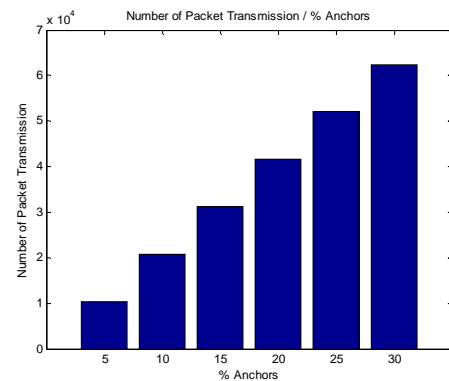


Fig.3. Number of packet transmission.

## VI. CONCLUSION

In this paper, we have presented the power cost necessary for all nodes to be located with DV-Hop algorithm and we proposed a new scheme for minimized the power cost during the process of localization.

Our scheme works with a small number of communications between nodes, minimize de computational cost and keeping a better accuracy.

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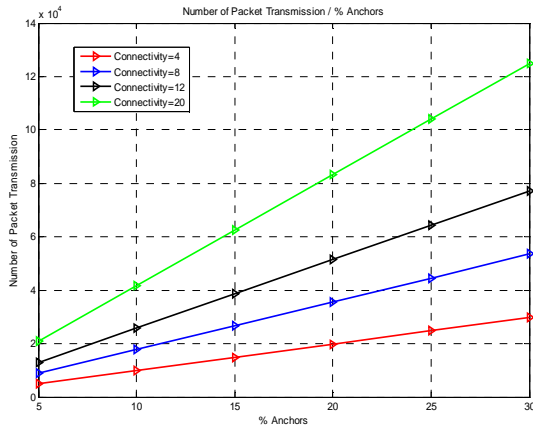


Fig.4. Number of packet transmission.

We notice that when the connectivity increases, the network consumes a lot of energy and if the connectivity decreases will have a problem of communication between nodes, therefore it is necessary to choose an optimal value of connectivity (adapted better the radio range). From the simulation results of Fig. 5, our scheme achieves better performance than the DV-Hop algorithm, because it consumes less energy when the ratio of anchors increases.

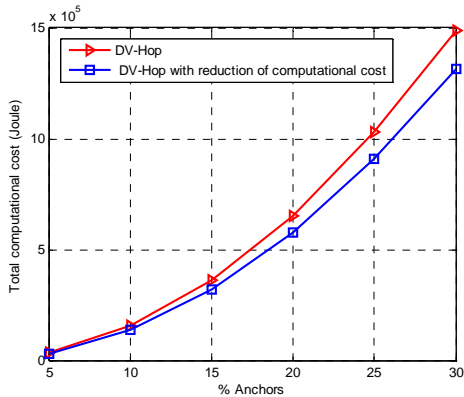


Fig.5. Total computational cost / % of anchors.

Fig.6. Shows the energy consumed during computation, when the number of nodes increases. Our scheme consumes less energy than the normal DV-Hop.

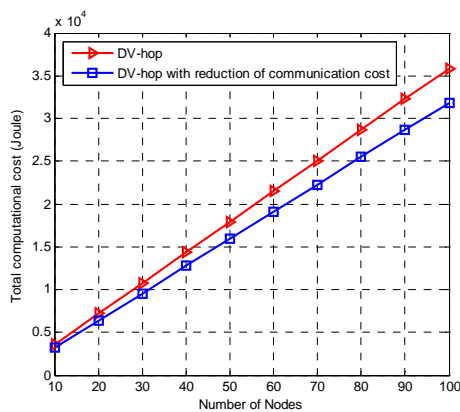


Fig.6. Total computational cost / Number of nodes.