

Efficient Energy Utilization and Node Localization in Dynamic DV-Hop Algorithm for Wireless Sensor Networks

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Abstract

Objective: This paper deals with the proposed Dynamic DV-Hop technique for wireless sensor node localization is used for the computing node location with better accuracy and less localization error. **Method:** DV-Hop is simply an algorithm of the range-free localization which can help us getting estimation by using the hop-distance. Since there is very low location accuracy found in DV-Hop localization algorithm. By figure-out the DV-Hop problem so it is essential improving the DV-Hop algorithm, a newly and the communication ranges. This method requires no extra supplementary estimated model is propounded by considering the relations in between the node-hop distance hardware support. However, this method can be instrumented in a distributed manner. **Findings:** The simulation work show that the proposed scheme decreases the total communication cost than the normal DV-Hop algorithm so in the proposed Dynamic DV-Hop method it represents less localization errors which is established by the graphs. In the present study, proposed scheme provides efficient energy utilization and management during the Dynamic DV-Hop localization method. **Application/Improvement:** The research work concludes by stating that very low location accuracy found in DV-Hop algorithm but this issue can be improved by proposed Dynamic DV-Hop algorithm and efficient energy utilization and management is performed.

Keywords: DV-Hop, Node Localization, Range-based Algorithms, Range-free Algorithms, Wireless Sensor Network

1. Introduction

The wireless sensor node localization problem has received a huge interest with rapid increase of application in location dependency. These location-dependant applications come-out to be a major factor for sensor networks. However, awareness of location comes-out to be an elementary capability of wireless sensor-nodes. So there is a great importance of accuracy-factor for the sensor-network applications. The range-free localization has become inexpensive alternative to the expensive range-based procedures. Sensor networks are widely

applied in various field of application like monitoring search and rescue operations, disaster related stuffs and relief, tracking of something/object, smart-environmental activities etc. The location of node has come-out to be an important part of its state as it is one of the essential characteristics of these sensor networks. A Wireless Sensor Network (WSN) is a collection of sensor nodes¹. These nodes have the capacity to sense different types of data, various computations and calculations and wireless node communication. Mostly, in modern era, WSN is widely known for its robust functions and low energy consumption using the range based and range free sen-

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sor nodes². However, the only drawback of WSN is that, it can't work without the physical position information of nodes. During practice, usually, sensor nodes are distributed by random best rewind. Therefore, it's being a matter of issue in order to get the information about the position of unknown nodes.

The distances or angles between neighbour nodes are calculated using the range-based algorithms. Then the information is used to localize the nodes. The main range-based algorithm consists of estimation of maximum likelihood³, hoc positioning system⁴, described SDP-based localization⁵, multidimensional scaling algorithms^{6,7}, etc. They have greater accuracy of location but need extra hardware support. And for this, it's a bit expensive using it in wide scale sensor-networks. To localize nodes without absolute range information, distance method is used by range-free algorithm instead of metrical distance.

The node localization algorithm should possess the following properties like robustness, distributed computation, high efficiency and ad hoc network⁸. Studied here a joint routing localization algorithm is used for the emergency situation⁹. Mobility of anchor node is efficiently ways represent performance of localization in Wireless Sensor Networks¹⁰.

Number of proposals has been made for localization in Wireless Sensor Networks in many practical applications. In the range-free algorithms, to localize nodes without need of information regarding absolute range, use of estimated distance is done instead of metric distance. The accuracy of node is less in comparison to the range based algorithm, but usually satisfies many other applications. The range-free algorithms including centroid¹¹, DV-Hop¹², amorphous¹³, Approximate Point-In Triangulation test (APIT), Range-Free Localization in Anisotropic Sensor Networks¹⁴ etc. These algorithms are more appreciable, cost-effective and economical. These can comply with both the low power consumption and low cost equipment. And, by means of which, less accurate positioning performance will occur as compared to the range-based method and is applicable for the large-scale WSN. Represent a differential error correction scheme¹⁵. The scheme proposes about the accuracy of positions of Wireless Sensor Network node. The average value of per-hop distances of the network and the distance error value that is modified are approached.

It can reduce the increasing distance-error percentage and error in the node location that are calculated in the multiple hops and provide node localization in optimised

ways in Wireless Sensor Network¹⁶. The theoretical-analysis gives that 'DV-Hop' algorithm provide a comparatively better algorithm¹⁷. The algorithm makes use of correction value as the beacon distance within unknown nodes and anchor nodes. It is verified and proven that the Dynamic DV-Hop algorithm provides more accuracy in results of localization than the original algorithm as well as other improved algorithms. DV-Hop algorithm provides better accuracy¹⁸. It is mapped from DV-Hop method with helps of weight factor of anchors node for better localization without needing no additional hardware device.

A method based on hop count and minimised error value to reduce the distance error and total least squares method find the unknown node coordinates and the calculation is remarkably enhanced by the help of multi-hop distance and the respective correction value¹⁹.

A new scheme for efficient utilization of energy management is proposed in this paper. The proposed technique handles efficiently the power cost during the node localization. Results clarify the performance of this scheme as a superior one than the original 'DV-Hop' algorithm. The rest of paper is categorized as follows:

Section 2: Review of the existing DV-Hop algorithm based localization schemes and proposed Dynamic DV-Hop method. Section 3 presents efficient energy model and the power cost. In Section 4 provide experimental result. The conclusion part of the paper is described in Section 5.

2. DV-Hop Algorithm and Dynamic DV-Hop Method

DV-Hop²⁰ is used for calculating range between nodes by the help of hop-count value. A minimum of three nodes of reference are required so that they can broadcast the information about their co-ordinates by using the hop-count in the network. One sensor node to other node information is circulated in the entire network. Upon receiving the message regarding the reference node by the neighbouring nodes, the count of hop is incremented. In such way, unknown node is able to find total, the total number of hops that are present remote to anchor nodes. In the 'DV-Hop²¹ implementation' method has been based on these following steps.

The 1st step: Which the anchor locations with hop count value = 1 (to be maintained) that are present in the network is overloaded throughout the whole net-

work. The minimum value of hop-count per anchor for all signals is maintained by the receiving node. By using such mechanism helps all nodes, present in the network, receive hop-count at minimal level to every anchor-node.

The 2nd step: Upon receiving the size of the hop, the unknown nodes finds the physical distance to anchor node by multiplying the hop size by the hop count value. The average hop $size_i$ is estimated by following:

For the reference node (x_i, y_i) , the average single hop distance is estimated by:

$$HopSize_i = \frac{\sum \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum h_j}$$

Where (x_i, y_i) and (x_j, y_j) = coordinates of anchor i and anchor j ,

h_i = hops between i -signal node and j -signal node.

The estimated Hop_i is broadcasted throughout the network to all the sensor nodes. In the 3rd step the distance to the sensor node are calculated by the unknown nodes based upon the length of hop. Consider a set of wireless reference nodes in sensor field $Di = (X_i, Y_i)^T$ $i = 1, 2, 3, \dots, n$, where n = no. of anchor nodes. With representing the hop value between ' i th reference node' and the 'unknown node $X = (X, Y)^T$ ' is L_i . Then, the distance of ' i th reference node' to the 'unknown node' is given by, $d_i = L_i \cdot Hop_i$. Now, the location value of 'unknown node' X can define and represented by the formula (2):

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

Subtracting the n th equation from all 1 to $n-1$ equations of the system of Equation (2).

$$\begin{cases} 2(x_1 - x_n)x + 2(y_1 - y_n)y = x_1^2 - x_n^2 + y_1^2 - y_n^2 - d_1^2 + d_n^2 \\ 2(x_2 - x_n)x + 2(y_2 - y_n)y = x_2^2 - x_n^2 + y_2^2 - y_n^2 - d_2^2 + d_n^2 \\ \vdots \\ 2(x_{n-1} - x_n)x + 2(y_{n-1} - y_n)y = x_{n-1}^2 - x_n^2 + y_{n-1}^2 - y_n^2 - d_{n-1}^2 + d_n^2 \end{cases} \quad (3)$$

Thus, the equation in linear form is $A_x = b$, the coordinates of X is calculated from using formula (4):

$$A = 2 \times \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ \vdots & \vdots \\ x_{n-1} - x_n & y_{n-1} - y_n \end{bmatrix} \quad B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix} \quad (4)$$

Location of the unknown sensor node (x, y) is calculated and represented as:

$$(x, y) = (A^T A)^{-1} A^T B \quad (5)$$

DV-Hop algorithm is a "range-based" method. But, DV-Hop prevails the 'distance-information' by using network topology calculation instead of measurement of radio wave signals.

In third phase, when there are at least three reference nodes and associated with its estimation distances them, 'Multilateration' method is used to computing the location of an unknown node.

Let us consider a reference sensor nodes set represented as $Ri = (X_i, Y_i)^T$ $i = 1, 2, 3, \dots, M$, where M is the no. of anchor node. Here, we take hop value in between unknown node $X = (X, Y)^T$ and i th reference node L_i . Now, the distance of unknown node to i th reference node is,

$$d_i = L_i \cdot HopSize_i \quad (6)$$

The location X of unknown sensor node can be computed now.

2.1 The Proposed Dynamic DV-Hop Algorithm

The precision of conventional DV-Hop node localization algorithm is getting affected in the distance value lies between anchor node and unknown node. The matter of difference in between the Dynamic DV-Hop algorithm and traditional DV-Hop is basically the working effect of the second step of algorithm. The Dynamic DV-Hop algorithm's second step explains that, when all anchor nodes receive a message from other dynamic reference sensor nodes, then each and every dynamic reference sensor node estimate the exact distance from itself to others.

DV-Hop node localization algorithm, the performance of unknown-node location computation factor is fully dependable on the distance factor from at least three dynamic reference nodes (e.g. the distances are got by Hop

Size_i and values of hop-counts). Once unknown sensor node 'U' carries the hop value equals to 1, from a dynamic reference node Rf_i , it must be assured that distance factor of U to Rf_i should be less than that of the communication-range i.e. $\|U - Rf_i\| \leq D$, where " $\|\bullet\|$ " is represent as Euclidean distance factor. Similarly, when U carries the hop value equals to 2, then $D \leq \|U - Rf_i\| \leq 2 \bullet D$

This can be explained much better through an illustration.

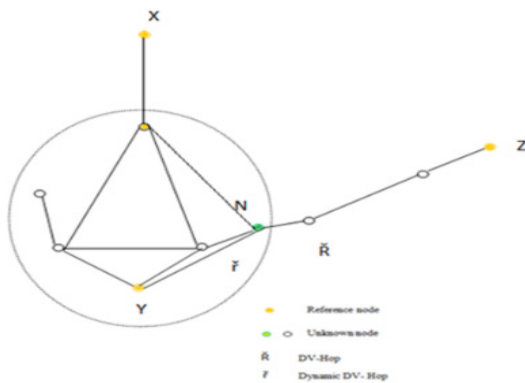


Figure 1. A sensor network.

Figure 1 represents an illustrative Wireless Sensor Network where nodes X, Y and Z are reference nodes. The sensor node N in sensor field is not known. The transmission range of the communiqué in the region of node Y is made known through circle. At the same time when shown in Figure 1, the node N carries hop-1 value to node Y, hop-2 value to node X and hop-3 value to node Z.

The DV-Hop node localization algorithm is represented in the last section, the estimated location of N-node may move out of the circle. Besides, the N-node moves inside the circle (shown in Figure 1). Thus, by using the above observations, it proves the DV-Hop node localization algorithm, denoted as Dynamic DV-Hop method.

For presentation, we consider discussing the localization of an unknown sensor node. Let us consider the unknown sensor node $N_u = (X_u, Y_u)^T$ with a dynamic reference node i . Hop-value involving in the reference node i and $N_u = L_i$. The average distance of single hop = $HopSize_i$, $i = 1, 2, \dots, K$ [K = number of dynamic reference nodes]. Distance from the i^{th} dynamic reference node to N_u is $d_i = L_i \times HopSize_i$. Let it is represented as min value $\{L_1, L_2, \dots, L_K\}$. In wide-ranging,

it represented several reference nodes with equal Hop-value = L_i .

Let these reference nodes as v_j , $j = 1, 2, \dots, K_1$. Now N_u location is computed as:

$$\min \sum_{i=1}^k [(X_i - X_u)^2 + (Y_i - Y_u)^2 - d_i^2]^2 \quad (7)$$

X_u, Y_u
Such that

$$\sqrt{(X_{v_j} - X_u)^2 + (Y_{v_j} - Y_u)^2} \leq D, L_i = 1 \quad (8)$$

Or
 $D \leq$

$$\sqrt{(X_{v_j} - X_u)^2 + (Y_{v_j} - Y_u)^2} \leq LD, L_i \neq 1, j = 1, 2, 3, \dots, k_1 \quad (9)$$

The algorithm is given by the flowchart which is represented in Figure 2.

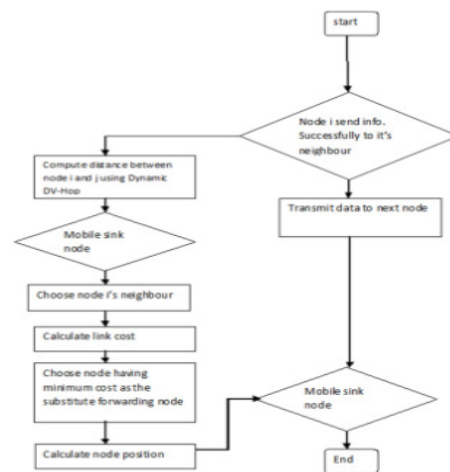


Figure 2 : Flowchart of Dynamic DV-Hop localization Algorithm

Figure 2. Flowchart of Dynamic DV-Hop localization Algorithm.

3. Presents Efficient Energy Model and Reducing the Power Cost Anchor Node Location Switching Time (Output Switching Time)

The Figure 3 shows that delay time of anchor node with respect to input value.

The output response is delayed because it takes finite amount of time for the signal to change. Some of the

important parameters those are used to describe the properties of anchor node is analyzed.

Node is in an electronic circuit by including the power supply voltage (V_{dd}) from sensor node battery. The input voltage ($V_{i0}(t)$) varies with time t and it used to represent a binary variable. In ideal state of Anchor node logic 0 represent O_v and sensing of Anchor node represent logic 1 represent (V_{dd}). Two switching times can be seen by assuming that the output voltage ($V_{i0}(t)$) change like the wave form in Figure 5 given below. The rate of change of output voltage allows V_s to:

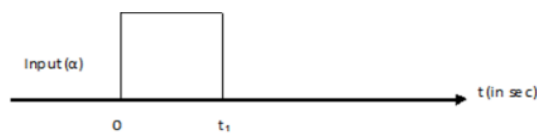


Figure 3. Delay time of anchor node with respect to input.

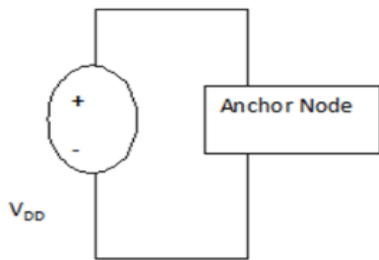


Figure 4. Output transition time for anchor.

- t_{LH} is the node localize output low-to-high time, also called rise time (t_r) is the time measured the transition between 10% to 95% of the voltage level (V_{ss}) as shown in the Figure 5.
- t_{HL} is the node localize output High-to-low time also called as the full time (t_f) is the time measured the transition between 95% to 10% of the voltage level (V_{ss}) (falling edge).

The absolute minimum amount of time needed for the anchor node to switch from logic 0 to a logic 1 voltage level and back again in given by;

$$t_{min} = t_{LH} + t_{HL} \quad (10)$$

The above equation gives the maximum number of logic transitions the anchor node can make in 1 second.

The smaller the value of t_{min} the faster the anchor node evaluate logic input. So the efficient anchor node depends on making of t_{min} as small as possible.

The maximum signal frequency of anchor node is f_{max} is given by:

$$f_{max} = \frac{1}{t_{LH} + t_{HL}} \quad (11)$$

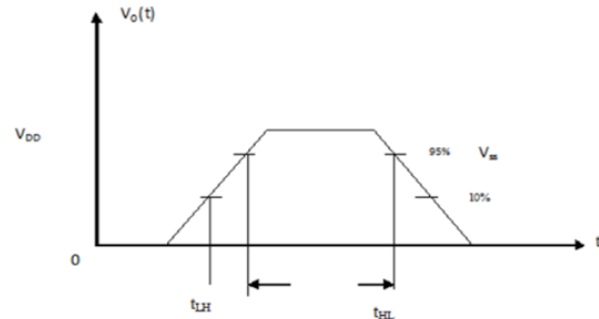


Figure 5. Output transition time for anchor node.

4. The Propagation Delay of Anchor Node

The propagation delay of an anchor node is the average transition delay time in Figure 5 for the signal to propagate from input to output, when the binary signal changes in value. Propagation delay occurs because the output of anchor node cannot respond instantaneously to the change occurs at input. Between input changes and output response there is a short delay of several nanoseconds.

The two propagation delay times are defined as follows:

- t_{PLH} : Delay time is going from logic 0 to logic 1 state (low to high).
- t_{PHL} : Delay time is going from logic 1 to logic 0 state (high to low).
- Propagation delay (t_p) is the average of the two times and location measured in nanosecond,

$$t_p = \frac{t_{PLH} + t_{PHL}}{2} \quad (12)$$

5. Scheme for Efficient Energy Utilization and Management in

DV-Hop

In the sensor node DV-Hop localization method, communication of packets and computation process occurs²².

Here:

N : No. of nodes (unknown-nodes and anchors).

n_x : No. of anchors.

C_{avg} : Connectivity average.

S_d : Space dimension.

5.1 Communication Cost

Each and every node in the network will broadcast an average of hop count packets and each node in the network is considered to have an average of C_{avg} neighbours. Hence, each node in the network will receive an average of hop count packets.

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

$$TP = N \times (n_x + n_x \times C_{avg}) \quad (13)$$

Since every anchor already contains its own hope count, n_x nodes are subtracted from N nodes. The Equation (13) becomes:

$$TP = (N - n_x) \times (n_x + n_x \times C_{avg}) + n_x \times (n_x + (n_x - 1) \times C_{avg})$$

Because each anchor will receive $(n_x - 1) \times C_{avg}$ and broadcast n_x packets.

Thus:

$$TP = N \times (n_x + n_x \times C_{avg}) - n_x \times C_{avg} \quad (14)$$

5.2 Computational Cost

Matrix A present the require value $S_d \times (n_x - 1)$ subtractions,

Matrix B present the require value $(S_d + 1) \times (n_x - 1)$ subtractions,

$S_d \times (n_x - 1)$ additions and $(n_x - 1) \times 2 \times (S_d + 1)$ multiplications.

To calculate the required position [5], the processor uses-up:

$$n_x \times (n_x - 1) \times S_d^2 + \frac{S_d^3}{3}$$

A total of n_x multiplication is performed by each node in order to compute n_x extended ranges and n_x least-squares operations.

Thus:

The efficient formulas related to computational cost are:

$$\left[n_x [1 + (n_x - 1) \times (S_d^2 + 5S_d + 3) + \frac{S_d^3}{3}] \right] \times S_d^3 \quad (15)$$

Now, the total calculated cost is:

$$\left[n_x [1 + (n_x - 1) \times (S_d^2 + 5S_d + 3) + \frac{S_d^3}{3}] \right] \times F \quad (16)$$

Where F = A system represents specific single flip flop power cost.

DV-Hop node localization algorithm, normally each node calculating the value of A, B and p.

In the mention scheme, matrix A is calculated once in anchor node and it will receive the packets first.

(15) Can be represented in given form:

$$\left[S_d (n_x - 1) + n_x [1 + (n_x - 1) \times (S_d^2 + 4S_d + 3) + \frac{S_d^3}{3}] \right]$$

For all nodes:

$$\left[S_d (n_x - 1) + N \times n_x [1 + (n_x - 1) \times (S_d^2 + 4S_d + 3) + \frac{S_d^3}{3}] \right]$$

Finally, (15) becomes:

$$\left[S_d (n_x - 1) + N \times n_x [1 + (n_x - 1) \times (S_d^2 + 4S_d + 3) + \frac{S_d^3}{3}] \right] \times F \quad (17)$$

6. Energy-Efficiency

Lemma 1. Energy conservation is done in the node which has low cycling duty for duration of the timer set.

Proof: Let, N_{sl}

N_{sl} = no. of nodes which have lower level of confidence than the

Threshold value C_{thresh} .

T_{sli} = the low duty cycling time for node i energy is saved by the nodes during

sleep mode,

$$E_{sv} = E_{sl} \times \sum_{i=0}^{N_{sl}} T_{sli}$$

Where, E_{sl} = energy saved by a node uses low duty cycling in unit time (e.g. same for all nodes).

Another method of proposing the algorithm, by means of which efficiency of energy can be calculated is as follows;

The messages regarding the avg. hop-distance may contain information of perceived signals and the starting-point, instead of overflowing to the network and calculates the nodes which are in the path. The transmitted message in sensor region that pursues by now have all the information regarding this.

The most power-consuming operations of sensor-node (as shown in Figure 5) is 'Transmitting' and 'Receiving'. Here, 'TX' denotes transmission-power and 'RX' denotes reception power. Hence, energy is conserved due to the elimination of some of the transmissions. The information-piggybacking to the sensor node messages is comparatively less to sending and receiving messages²³.

In Figure 6, shows the consumption of sensor node's energy.

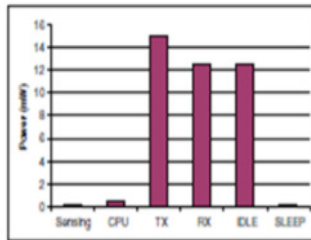


Figure 6. A sensor node's energy consumption as report in¹².

7. Simulation and Result

The Dynamic DV-Hop technique is simulated and proposed scheme has to calculate the both energy cost of communication and the computation of sensor nodes. The WSN node deployment field size is a square area of $100 \times 100 \text{ m}^2$ and radio range of sensor nodes R is 10 meters. Anchor nodes are chosen randomly within the sensor field. 275 numbers of sensor nodes are deployed randomly in a two-dimensional space assuming:

- The network of sensors is static i.e. there is no mobile nodes.
- Nodes are homogeneous means nodes are similar in their capacity of treatment, communication, energy and storage.
- Channels of communications are bi-directional (if a node N_1 can receive a message of the node N_2 then N_1 can send a message to N_2).
- Every node has at least one neighbour.

As per the objective of our research work represents and to find the location of unknown nodes by known node so the Figure 7 shows that randomly deployment of anchor node and unknown nodes in a given sensor field. In this graph we show that red colour node is considered as anchor node and black colour node as normal sensor node (unknown node).

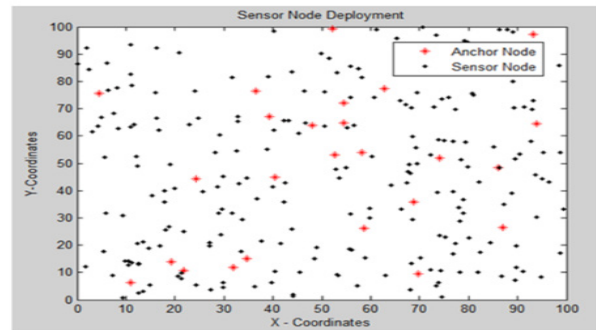


Figure 7. Deployment of sensor node.

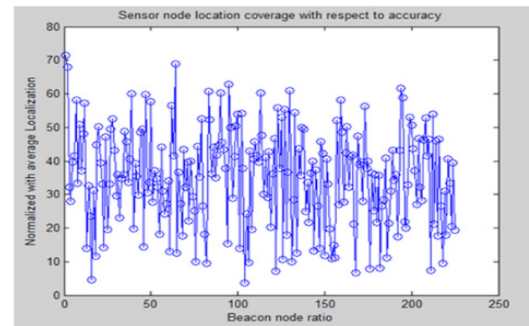


Figure 8. Anchor node (Beacon node) ratio with respect to localization error.

The Figure 8 is compiled result were tested while keeping the node density constant. The results showed that the accuracy of the location determined stayed pretty much constant while increasing the area covered and the number of nodes deployed.

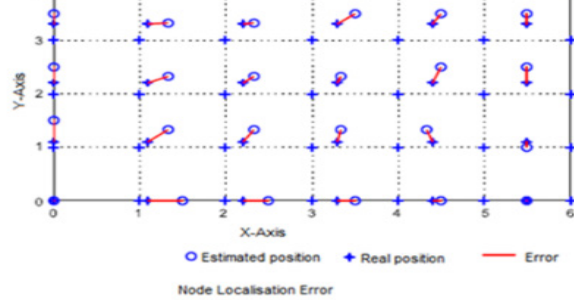


Figure 9. Node localization position.

The Figure 9 proves the proposed method find the average node localization errors in constant of density of nodes. The errors in distance to propagate to the localization error.

Figure 10 shows that the proposed method gives better result than the DV-Hop algorithm. It consumes less energy when the number of reference node is more. This graph is used to show the variation of energy consumption, when it is in less numbers of sensor node. Then the anchor nodes consume more energy and the sensor field contain huge number of nodes then reference node consume less energy during localization process.

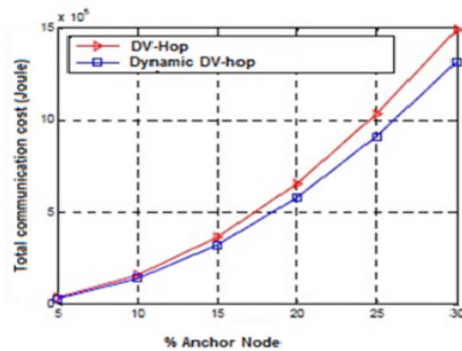


Figure 10. Total computational cost with respect to anchor nodes.

The Figure 11 tells that the energy consumed during data analysis and location calculation process. The proposed method consumes very less battery power so it saves energy than that of DV-Hop.

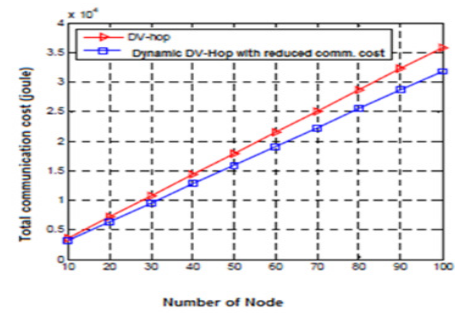


Figure 11: Total computational cost with respect to sensor nodes

Figure 11. Total computational cost with respect to sensor nodes.

8. Conclusion

In WSN, the localization problem presents an important open research problem. Therefore we propose a range free localization algorithm, which uses an innovative scheme to calculate average hop size and increase the performance of original DV-Hop node localization algorithm. In addition to the information about property of the hop size, Dynamic DV-Hop also informs about the provincial property of the hop size. Simulations work confirms that Dynamic DV-Hop gives better accuracy than the original one, with better power cost. It is concluded that the proposed technique suits to the requirement of smaller number of communication node, with minimized computational cost and better accuracy.

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