MPDV-HOP:An improved localization algorithm for wireless sensor networks

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Abstract: In wireless sensor network applications,location information of sensor nodes is critical in the life of the entire network.It is a hot issues to design localization algorithm with higher accuracy and lower cost.In this paper,we propose an improved DV-Hop localization algorithm that improves the localization accuracy.The method is based on the traditional DV-HOP, the average hop distance calculation method is further improved and optimized, in the positioning results are looking for optimization of optimal solution, solution here mainly adopts the latest bat algorithm for optimization problems. The experiment result shows that the more the existing positioning methods,MPDV-HOP can effectively improve the average hop distance estimation,and reduce the positioning error.

Key–Words: WSN,DV-HOP,Location Node,Location Error.

1 Introduction

Wireless sensor networks (WSN) are currently used to monitor a wide range of military,environmental,civil,and health-care applications.It is composed of sensor nodes connected to each other via wireless links.Figure 1 shows a basic configuration of the WSN'nodes which are randomly distributed in the monitoring area,all nodes are able to send and receive data with other nodes and have functions of discovery and maintenance for the others'route.WSNs are constituted by a series of sensor nodes,adopt a method of multi-hop relay to transmit the data monitored to the sink node,finally,via Internet or other communication method information will be sent to the management nodes.Knowledge of positions of sensors can provide the context to the information which has been collected by sensors in wireless sensor network (WSN).And then,many attractive applications such as routing,tracking assets and et. al, can be available through knowing the locations of sensors in WSN.Positioning algorithms are classified in either centralized or distributed.Centralized method is that the calculation is performed by a server whereas in distributed algorithms all the nodes are able to calculate their own position.The localization problem usually means estimating positions of the nodes in WSN based on a mixture of mutual distance,angle or proximity.This paper will address the network topologies of randomly distributed nodes and improves DV-Hop algorithm,finally we will analyze performance through simulation.

The remainder of this paper is structured as follows.The different Internet traffic classification methods including those using cluster analysis are reviewed in Section 2.Section 3 outlines the theory and methods employed by the clustering algorithms studied in this paper.Section 4 and Section 5 present our methodology and outline our experimental results,respectively.Section 6 discusses the experimental results. Section 7 presents our conclusions.

2 Related work

Wireless sensor network localization algorithm can be divided into range-based positioning and range-free positioning. Range-based localization algorithm uses absolute point to point distance estimates or angle estimates for location estimation[8, 13] such as the received signal strength indicator (RSSI)[5],the time of arrival (ToA)[19] and the angle of arrival (AoA)[14] of the signal. While range-based localization algorithms require extra hardware to sensors,thus which will result in expensive cost.Range-free localization algorithms are based on nodes connectivity and hop information without extra hardware resource,so Range-free algorithms are more and more paid attention such as centroid algorithm[2],DV-Hop algorithm [10, 6],Amorphous algorithm[9] and APIT [5](approximate point-in-triangulation test) algorithm,in centroid algorithm,the anchor node (node known location) broadcasts a beacon packet to the adjacent node periodically,a beacon anchor nodes consist in the packet identification number and location information.When a node receives an unknown anchor node from a different beacon packet,the centroid position of a polygon is determine.Centroid algorithm is entirely based on the network connectivity,it is easy realized, but this method is affected by the density of the anchor nodes.APIT algorithm uses a new region-based method to perform location estimation,the basic idea of the algorithm is assuming there are n anchor node which can communicate with the unknown node,the algorithm will traverse C_n^3 different triangles,and calculate the centroid of the overlap of the triangles as the evaluated location of the unknown node.APIT algorithm has high positioning accuracy and stable performance,but APIT has higher requirements for connectivity of the network.DV-Hop algorithm is currently the most widely used positioning algorithm.In this paper,we focus on range-free algorithms(DV-HOP) which can be centralized or distributed.The DV-Hop algorithm is similar to the traditional routing schemes based on distance vector. Simplicity, feasibility, cost-effectiveness,and high coverage are the advantages of DV-Hop algorithm.It works well in isotropic networks. In DV-Hop algorithm, an unknown node determines its minimum hop count from anchor node and then computes distance from anchor node by multiplying the minimum hop count and average hop distance. Finally, the node estimates its location by using a triangulation scheme or maximum likelihood estimators.Major drawback of DV-Hop algorithm is its poor positioning accuracy. Researchers have proposed many methods to improve location accuracy of DV-Hop algorithm.Paper [1, 12, 11, 16, 15] make respectively some improvement to the DV-Hop algorithm.Average hop distance of anchor node is made improvement in paper [4],and average hop distance for all anchor nodes is the average value, which can reduce the positioning error at a certain extent,the literature [7] will consider unknown node as a virtual anchor nodes in positioning process, the improved algorithm the utility model has the advantages of small anchor node density effect on the position of the process, but the disadvantage is that the unknown nodes as anchor nodes will cause error accumulation;literature [18] is the evaluation of the positioning system has been improved, established for error analysis model.

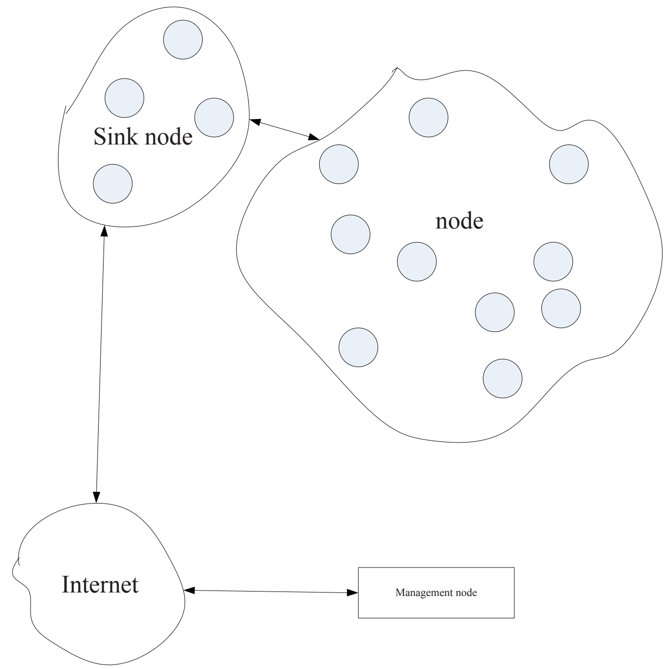

Figure 1: data transfer of wsn

3 DV-HOP algorithm

The DV-Hop localization algorithm is algorithm based on range-free.The algorithm is composed of steps as follows:

firstly, an anchor i floods a message containing its ID,coordinates,and the variable $HopSize_i$ initialized to zero.On receiving beacon packet, each node i in the network maintains a table(x_i,x_j, $hopSize_i$) for every anchor node ,the value of the $HopSize_i$ that a sensor stores about anchor i represents the minimum number of wireless hops between that sensor and the anchor i.If a received packet contains lesser hop count value to a particular anchor node, hop count value of the table is replaced with hop count value of received packet,and this packet is forwarded in the network with increased hop count value by 1; otherwise this packet is ignored. By this mechanism,all nodes in the network obtain minimum hop count value from every anchor node.

in second step,once the anchor node obtains minimum hop count relative to other anchor nodes,then each anchor nodes can compute the average hop distance according to equation(1)

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

Where (x_i, y_i) ,x_j, y_j represents the known coordinates of beacon nodes i,j, the true beacon nodes coordinates , hi j is the number of hops between anchor nodes i and j.After calculating hop-size, each anchor node broadcasts its hop-size in the network by using controlled flooding.When an unknown node receives this hop-size information,it saves only the first arrived message (hop-size) and then transmits it to neighbor nodes.By using this method,most of the nodes receive hop-size from the anchor node,which is at minimum hops between them.When an unknown node receives hop-size information from one anchor node,it calculates the distance between itself and the anchor node by Eq.(2).

$$d_{pk} = HopSize_i \times hop_{pk} \tag{2}$$

In the third step, each unknown node estimates its position by polygon method. Let the position (coordinate) of unknown node p is (x, y),position of ith anchor node is (x_i,y_i), and distance between anchor node i and unknown node p is d_i.Assuming n anchor node estimate the location of the unknown node p,the estimation of the location is done by Eq 3

$$\begin{cases} (x-x_1)^2+(y-y_1)^2=d_1^2 \\ (x-x_2)^2+(y-y_2)^2=d_2^2 \\ \vdots \\ (x-x_n)^2+(y-y_n)^2=d_n^2 \end{cases} \tag{3}$$

To make this system of equations linear,subtract last equation from first (n.1) equations.We get a system of (n . 1) equations as shown in (4).

Rewriting in the form of AX = B,where A, B,and X are given by equations (5),(6),and (7), respectively.

$$A = \begin{pmatrix} 2(x_1-x_n) & 2(y_1-y_n) \\ 2(x_2-x_n) & 2(y_2-y_n) \\ \vdots & \\ 2(x_{n-1}-x_n) & 2(y_{n-1}-y_n) \end{pmatrix} \tag{5}$$

$$B = \begin{pmatrix} x_1^2+y_1^2-x_n^2-y_n^2+d_n^2-d_1^2 \\ x_2^2+y_2^2-x_n^2-y_n^2+d_n^2-d_2^2 \\ \vdots \\ x_{n-1}^2+y_{n-1}^2-x_n^2-y_n^2+d_n^2-d_{n-1}^2 \end{pmatrix} \tag{6}$$

$$X = \begin{pmatrix} x \\ y \end{pmatrix} \tag{7}$$

Solving by the method of least square,we get the location of node by Eq.(8).

$$X = (A'A)^{-1}A'B \tag{8}$$

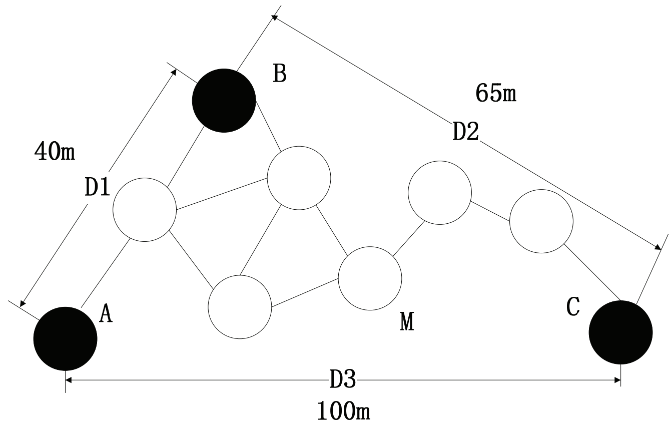

Figure 2: DV-HOP algorithm procedure

3.1 Positioning error analysis

Based on the analysis of characteristics of localization algorithm,we can find that it follows the reasons of error:
1,between the anchor nodes and unknown nodes represent the distance error will vary with hops increases.Because the trajectory distance between two nodes is not necessarily a straight line,between the hop number,error is large,the positioning accuracy is low.
2,the average per hop estimation accuracy value. For the WSN location of the range free algorithms, the actual distance is the average per hop estimate and the hop product was used to calculate the. Therefore, the location estimation error is mainly from the average hop distance.The positioning accuracy of the unknown nodes will largely by the average per hop estimate effect. Method for calculating.
3,positioning.In the estimated anchor node average hop value, generally can use three side positioning method or maximum likelihood estimation of node positioning processing method, wherein three side positioning method is affected by the ranging error is large.If the use of maximum likelihood estimation of location,can be converted to AX=b in the form of solution, finally can be solved by the least square method.The matrix A and B will produce certain error to the desired X, thus affecting the final positioning accuracy.

4 Improved DV-Hop algorithm

In this section, we discuss improved DV-Hop algorithms[4] which are generally based on traditional DV-Hop algorithm. We also discuss on main drawbacks of these algorithms. In [4],the authors tried to improve the location accuracy of DV-Hop algorithm

$$\begin{cases} x_1^2 + y_1^2 - x_n^2 - y_n^2 - 2(x_1 - x_n)x - 2(y_1 - y_n)y = d_1^2 - d_n^2 \\ x_2^2 + y_2^2 - x_n^2 - y_n^2 - 2(x_2 - x_n)x - 2(y_2 - y_n)y = d_2^2 - d_n^2 \\ \vdots \\ x_{n-1}^2 + y_{n-1}^2 - x_n^2 - y_n^2 - 2(x_{n-1} - x_n)x - 2(y_{n-1} - y_n)y = d_{n-1}^2 - d_n^2 \end{cases} \quad (4)$$

by focusing on second and third steps.In the second step,each anchor node broadcasts a packet that contains its hop-size and identifier in the network. Format of the packet is (Id,HopSize).If a node receives this packet, it adds this information in its table and broadcasts it to neighboring nodes.Unknown node receives hop-size of every anchor node that is estimated by anchor nodes in the second step of DV-Hop algorithm. Unknown node calculates average hop-size of different anchor nodes by using Eq.(9).

$$HopSize_{avg} = \frac{\sum HopSize_i}{n} \quad (9)$$

where n is the number of anchor nodes. By using this average hop-size, unknown node estimates its distance from the anchor nodes by Eq.(10).

$$d_i = Hops \times HopSize_{avg} \quad (10)$$

where hops is the number of hops between unknown node and ith anchor node. In the third step,2-D hyperbolic location algorithm[3] is used in place of traditional triangulation algorithm to estimate the location of unknown nodes. In the second step of this algorithm, unknown node receives the hop-size from all anchor nodes and forwards it to their neighbor nodes to estimate the average hop-size.In receiving and forwarding hop-size messages from all anchor nodes,communication cost of the algorithm increases.Therefore,the improvement in localization accuracy as compared to DV-Hop costs increased communication.

5 New improved DV-Hop algorithm

Our proposed algorithm is based on DV-Hop algorithm.The first step of our algorithm is same as DV-Hop algorithm.In the second step,we make a little change to the DV-Hop.We focus mainly on third step;it is quite different from the third step of DV-Hop algorithm. In the second step,each anchor node broadcasts a packet containing its hop-size and Id (Id of anchor node).Hop-size is estimated by DV-Hop method in the first step.When an unknown node receives packets from anchor nodes,it saves this information (hop-size and Id) in its table and broadcasts the received packet to its neighboring nodes.If an unknown node obtains the packet of same Id,it discards this packet. After receiving hop-size from the anchor nodes,unknown node p calculates the distance from the anchor nodes by using hop-size and the number of hops from the anchor nodes as in Eq.(16).

Through the analysis and description of the problems above,this section proposes the MPDV-HOP algorithm based on the error correction.The algorithm structure as shown in algorithm 2.

5.1 Algorithm description

MPDV-HOP node location called,refers to the low energy consumption and high precision of node positioning algorithm using multiple anchor nodes are aided positioning.MPDV-HOP (Multi Probability DV-HOP) forms are defined as follows. Definition 1 given multiple anchor node set P=(P1,P2,...,Pc) At present,the existing literature with multiple anchor node as a reference node for auxiliary node location in order to improve the accuracy of the node localization,however,this method does not consider the problem of energy consumption required for positioning, optimize only the precision,this paper will be of high precision and low energy consumption as the goal of the algorithm design. Definition 2 assumes that the h_{ij} is the number of minimum hop between the node i and node j,d_{ij} for node i and node j distance,C_i anchor node i of the average hop distance, which can be expressed as:

$$c_i = \frac{\sum_{i \neq j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{i \neq j} h_{ij}} \quad (11)$$

5.2 using the bat algorithm to optimize the location

In node positioning, optimization results using bats can locate algorithm, based on the error adjustment, quick to find the optimal solution. The bat algorithm is a meta heuristic optimization algorithm,is Yang Xinshe in 2010 proposed algorithm[17].The bat to bat (microbats) algorithm for micro foundation of echolocation behavior,using pulse emission rate and the loudness of different.First assume the bat I at time

T-1 the speed of Vi^{T-1},the position is x_i^{t-1},then the bat I at time t speed and position can be used to type 3 and 4 expressed as:

$$f_i = f_{min} + (f_{max} - f_{min})\beta \tag{12}$$

$$v_i^t = v_i^{t-1} + (x_i^{t-1} - x*)f_i \tag{13}$$

$$x_i^t = x_i^{t-1} + v_i^t \tag{14}$$

The f_i, f_min, f_max respectively,the acoustic frequency current bats emit,minimum and maximum frequencies,v_i^t and x_i^t respectively,the bat at time t speed and position,beta is a random number between [0,1],x* is the best solution found in the. The WS-N node localization optimization process with the bat algorithm: according to the fomula 13 and 14 to update the velocity and position itself,each iteration bats are continuously,eventually finds the optimal solution of the target.Specific steps are as follows:

Step1:Initialization position of bat populations is set x_i,initialization speed is v_i
Step2:Unknown node is represented as (x,y),the coordinates of N anchor nodes are expressed with (x_1,Y_1), (x_2,y_2),... ,(x_n,y_n),d_1, d_2,... d_n represents distance between the unknown nodes and each anchor node.So we can complete the calculation of distance between unknown nodes and anchor nodes by the Eq 15:

$$\begin{cases} \sqrt{(x-x_1)^2 + (y-y_1)^2} = d_1 \\ \vdots \\ \sqrt{(x-x_n)^2 + (y-y_n)^2} = d_n \end{cases} \tag{15}$$

Let $f_i = \sqrt{(x-x_i)^2 + (y-y_i)^2}$,then object function is expressed as $F(x) = \sum_i (f_i - d_i)^2$ The d_i is the distance of actual measurement,the optimal solution of the objective functions is the location coordinates (x,y) when F obtains the minimum value
Step3:Position of each bat and the target fitness function of F(x) will set the relation.
Step4:The position and velocity are updated by search for bat(Eq 13-14)
Step5:According to the location evaluation,the bad individual is replaced by good individual.
Step6:If the fitness is better by searching or the maximum iteration number has been reached,a termination condition is satisfied,the iteration is terminated.Or turn to Step2
Comprehensive above the average hop distance was improved,the pseudo code of MPDV-HOP algorithm is described as follows:

Algorithm 1: BAT algorithm

```
// Preprocessing stage
Objective function f(x),x = (x_1, ..., x_d);
Initialize the bat population x_i (i = 1,2, ..., n) and v_i;
Dene pulse frequency f_i at x_i;
Initialize pulse rates r_i and the loudness A_i;
while t<Max number of iterations do
    Generate new solutions by adjusting frequency;
    and updating velocities and locations/solutions [equations (13) to (14)];
    if (rand< r_i) then
        
    Select a solution among the best solutions;
    Generate a local solution around the selected best solution;
    Generate a new solution randomly;
    if (rand < A_i and f(x_i) < f(x*)) then
        
    Accept the new solutions;
    Increase r_i and reduce A_i;
    Rank the bats and ?nd the current best x*;
```

Algorithm 2: MPDV-HOP algorithm

```
// Preprocessing stage
Initialize network;
anchor nodes'position are broadcasted,number of hop is set as 0 ;
for i=number of unknown node,i=0,i++ do
    if unknown node have received anchor nodes then
        contrast the all the anchor nodes,get the min hop number;
    save the anchor nodes information;
    if anchor node number of unknown node ≥ 3 then
        compute the distance between anchor nodes;
        compute the average distance and error;
        add weight of average distance,and get the improved average distance;
        using the bat method to locate the unknown node;
```

6 Experiment Results and Analysis

6.1 Simulation metrics

in this paper,the localization error is defined as (LE) function illustrated as follows equalization by Eq 16.

$$LE_i = \frac{\sqrt{(x_i - \widetilde{x_i})^2 + (y_i - \widetilde{y_i})^2}}{r} \quad (16)$$

where x_i,y_i respectively represent real location,while $\widetilde{x_i}$,$\widetilde{y_i}$ show the measure location value.then average localization error is expressed as (ALE) function by Eq 17.

$$ALE = \frac{\sum_{i=0}^{n} LE_i}{r} \quad (17)$$

6.2 Impact of node scale

In the real scenario, radio signals are affected by the environment. Therefore, communicating radius of the sensor nodes does not make standard circle, it is an anomalous polygon. On the basis of the communication ranging error, we evaluate the performance of our proposed algorithm in three different scenarios and found that our algorithm provides better position estimation in all scenarios. These three different scenarios consider communication ranging to be 20,25,30,35,40.Under these scenarios,we evaluate and compare the performance of our proposed algorithm with DV-Hop and improved DV-Hop.Simulation results of these scenarios for varying of total nodes from 150 to 450 are shown in Figs. 4-8,respectively.In Figs.4-8,it can be observed that as the total number of nodes increases in the region, localization error of DV-Hop, Improved DV-Hop,and MPDV-Hop algorithm decreases.This is because the node density (average number of nodes per node radio area) in the network increases as the number of unknown nodes increases. As a result, the average number of neighbors for each node increases and thus the network becomes well connected. It improves the chances that the unknown nodes lie on the line joining anchor pairs. The average hop-size of the anchor nodes becomes more accurate, and the estimated distance between anchor node and unknown node turns into closer to its actual distance.Therefore,location error of the algorithm decreases with increasing number of unknown nodes.

6.3 The Impact of Beacon Scale

Figure 9-13 show the variation of the average location error with respect to the ratio of beacon nodes which is changed from 0.05 to 0.4.As shown in Figure 9-13,with the increasing of beacon nodes,the average location errors of two algorithms present a downward

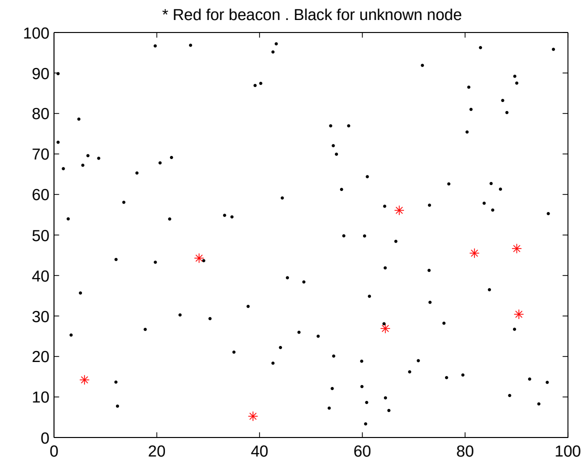

Figure 3: Distribution map of network node

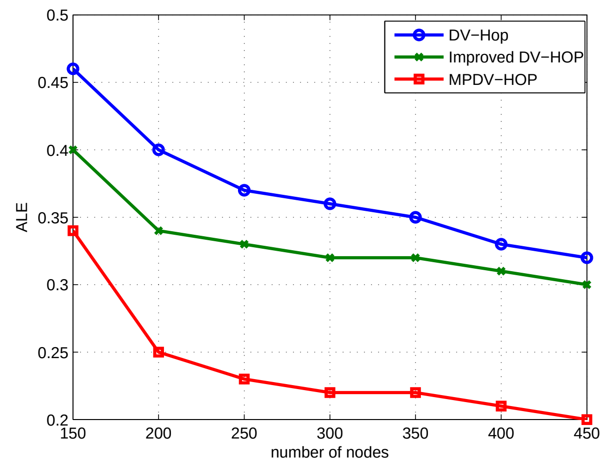

Figure 4: Total number of nodes versus ALE in communication range 20m

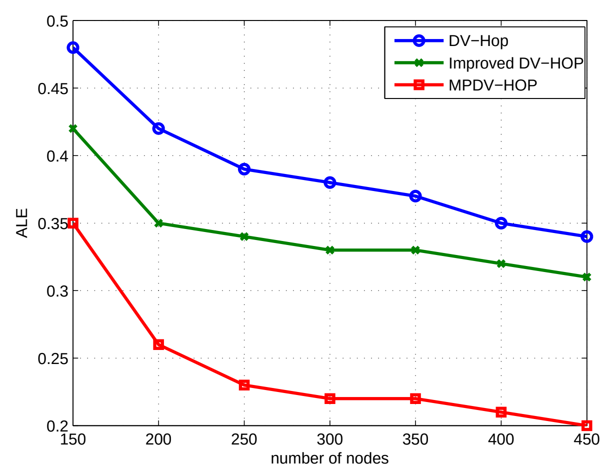

Figure 5: Total number of nodes versus ALE in communication range 25m

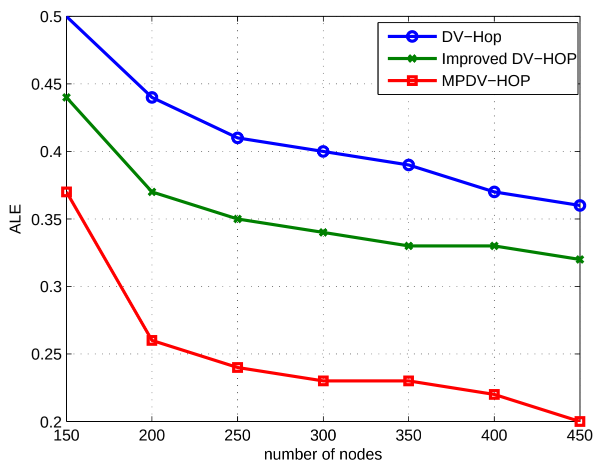

Figure 6: Total number of nodes versus ALE in communication range 30m

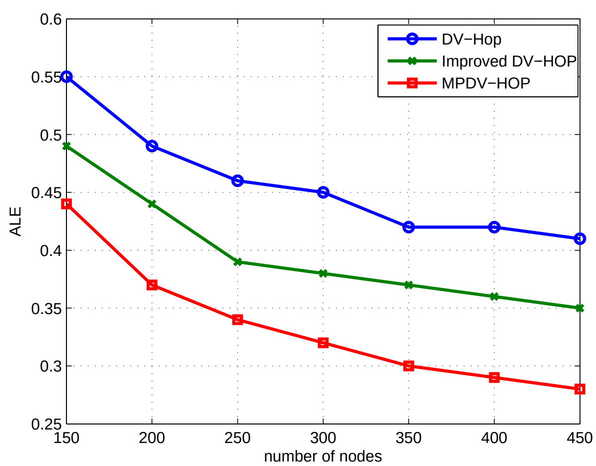

Figure 7: Total number of nodes versus ALE in communication range 35m

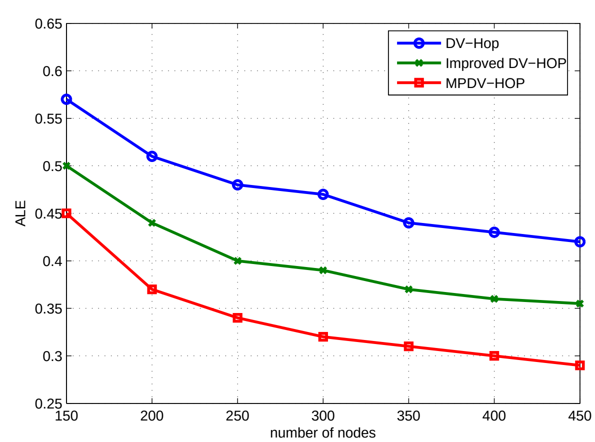

Figure 8: Total number of nodes versus ALE in communication range 40m

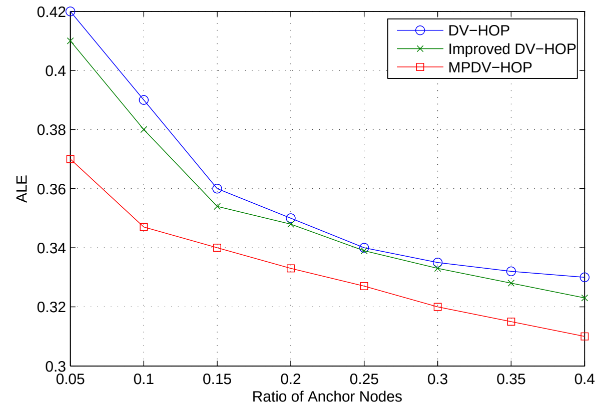

Figure 9: Localization Error vs. Ratio of Beacon Nodes in communication range 20m

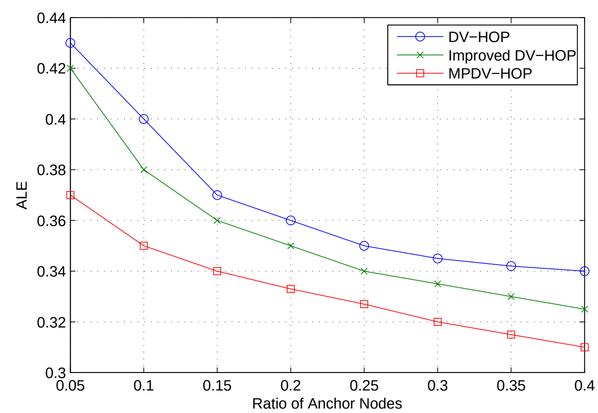

Figure 10: Localization Error vs. Ratio of Beacon Nodes in communication range 25m

and the present algorithm has a better performance that that of DV-Hop algorithm.For example,as in Figure 13,the proposed algorithm has an average localization error of about 34.2% when the beacon nodes ratio is 15% whereas the DV-Hop has an average localization error of about 41%.

7 Conclusions

In this paper,we propose the MPDV-HOP algorithm that reduced the localization error without requiring additional hardware cost.Proposed algorithm improves the computing method for average hop distance and adopts the bt method to optimize the location results.Validity of our method is confirmed by showing the simulation results with various conditions.It is observed that the proposed scheme has lower localization error in comparison with traditional DV-HOP.

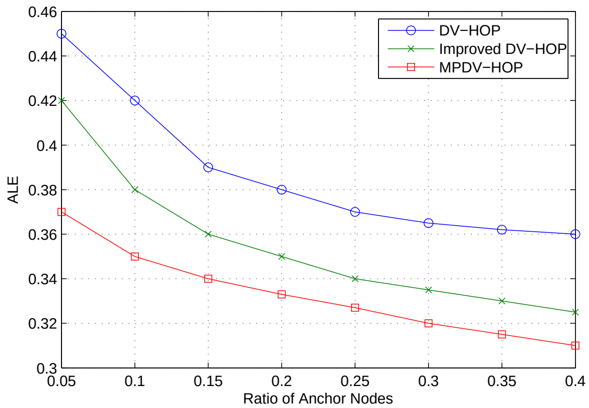

Figure 11: Localization Error vs. Ratio of Beacon Nodes in communication range 30m

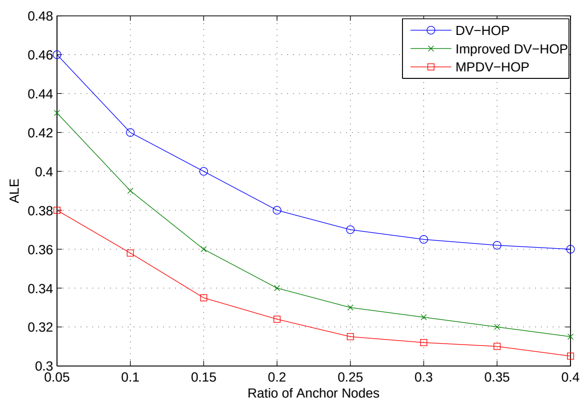

Figure 12: Localization Error vs. Ratio of Beacon Nodes in communication range 35m

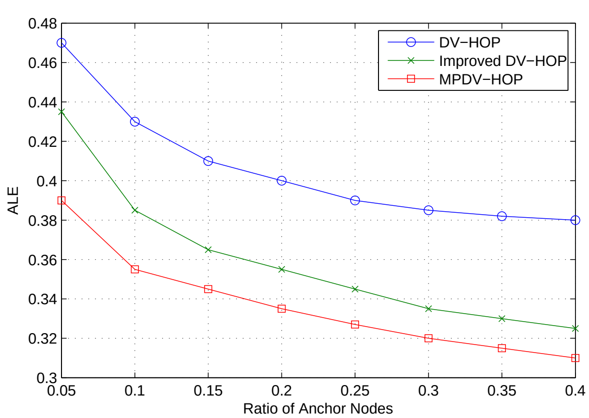

Figure 13: Localization Error vs. Ratio of Beacon Nodes in communication range 40m

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