A New 3-dimensional TOADV-Hop Localization Algorithm

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Abstract

Wireless sensor network (WSN) is used in many recent trends in wireless application, where its nodes needed to localize him before sending any data. Nodes are defines their coordinates in localization process, through coordinates they localize himself. There are various algorithm proposed in localization based on 2D works on two plane, it provides accuracy but in real world needed all three planes for correct estimation and more accuracy in localization. The 2D works on flat terrain, we need to deploy WSN in harsh terrain also, so we needed to define algorithm on 3D, a new 3-D TOADV-Hop localization algorithm is proposed by analyzing the lack of existing 3-D localization algorithm, extending the rang-free algorithm Time of Arrival based DV-hop (TOADV-Hop) to 3-D space, and improving the aspects of traffic, positioning error.

Simulation results show that this algorithm can position the sensor nodes in the 3-dimensional environment effectively, the beacon nodes' density and communication radius has little effect on the positioning error, the coverage and energy consumption, the positioning accuracy, coverage and energy consumption relative to other algorithms have improved significantly.

Keywords: *TOADV-Hop Algorithm, Mobile Agent, Coordinate Translation Method (CTM), Draw Circle Method (DCM), Total Least Squares (TLS)*

1. Introduction

Wireless Sensor Network consists of autonomous devices which called as node. Node is used to sense or monitor the environment, where it gathered the data through it, and send to the user through base stations. Its applications used in military as battlefield surveillance, habitat monitoring, environmental monitoring, and health application etc. [1] Sensor network send the data to neighbor node or base station, but before it they need to know their own location, because the data have no meaning without location information from where the data is coming. Nodes are large in numbers it’s difficult for base station to calculate the node position, so it need for individual node to send the location information with their collected information, form it provide exact location information to the user. Therefore, node needed to localize himself.

The term “Localization” means to find the exact location in any geographical area with the help of references node. Localization can be done earlier by using manual configuration and by GPS system. In manual configuration localization is done by human interaction and calculation. Where it deploys by using human being and calculation is done through it. But in real world human interaction is not always possible just like in military field, we need airplanes for deployment and the calculation is not always correct. Another is GPS system, which is done by satellite. It is not feasible for all nodes because by using GPS its antenna increases the sensor node size factor, but Sensor nodes are required to be small. The power consumption of GPS will reduce the battery life of the sensor nodes and also reduce the effective lifetime of the entire network; cost factor of GPS is also increases in the network. Also In the presence of dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites, so GPS cannot be implemented. Therefore we need to implement a localization algorithm for every node. Localization algorithm uses the reference node, just as neighbor node and anchor node (which known their position earlier with the help of GPS) for localization. In localization algorithm mostly works on 2-dimensional plane, i.e. x and y plane. In a 2D system, the process of estimation is less complex and requires less energy and time. In 2D plane provide good accuracy is on flat terrains and is difficult to estimate in harsh terrains. It provides accurate distance when more node density and anchor nodes are present. By using 3-dimensional plane added one extra plane called as height i.e. z plane, concept is to it provide more accurate result using height. It can be used in harsh and hilly terrains to provide good accuracy in it. Using 2-dimensional algorithms on a system the position estimate by using point in the plane i.e. x and y plane, where the x and y coordinate are the same as the real position of the surface and altitude is fixed. But when mapping these estimated positions to the real world an error can occur, because it consists of all three planes. Any angle between the reference plane and the ground where it present result may be an error during mapping. By using a localization system for 3D this problem is eliminated completely.

2. Related Work

In a 2D space, three anchor nodes are uniquely determine a coordinate system. In a 3D space, four anchor nodes are required. In 3D localization same method uses as define in 2D. Range-based and range-free method is defined for localization process. In which range-based provide point-to-point information with reference node. It provides higher accuracy, but it need additional hardware and through it needed continuous update of information. In there it increases size and cost. Range-free scheme is used where no additional thing needed, node organize by own self. On comparison range-based provide better accuracy, but it is affected by obstacles and through it accuracy is decreases. There are some techniques is present for localization i.e. distance, angle and position techniques. It is done by using anchor or anchor-free scheme.

Range-based Localization Algorithms: The foundation of numerous localization techniques is the estimation of the Distance measurement, It uses the anchor node or position of known node for calculation where it uses three anchor nodes in 2D whereas four anchor nodes in 3D such as RSSI, is a measurement of the signal power coming in a received node. It calculates distance using received signal. Advantage is easy to estimate. Main drawback is the power is decrease when the node present at long distance. Power strength is fading in distance. It is also affected from obstacles. Accuracy is affected from it. Good accuracy is in less distance, Reference [2] proposed Time of arrival (TOA), This uses a packet for sending from the anchor node to other node. Packet consist of time when it was transmitted, in there the perfect clock synchronization needed between the nodes. The distance formula is calculated between them, i.e. *Distance= speed * time,* Where time is the difference between one node to other node and speed of light is used here because the packet travelled with the speed of light. The advantage of using ToA it is not affected from fading of signal, but if synchronization between the nodes is not their then it cannot be useful, TDoA, distance measurement depends upon the difference in time between two waves, or one wave with two destinations. ToA uses two frequency and estimate distance through it. One is radio frequency another is ultrasonic frequency. If unknown node uses one frequency signal, then source sends same RF signal to two different anchor nodes. These two known nodes calculate the difference of time arrival of the signal and calculate the distance between themselves and source node. Similar process used in ultrasonic frequency. If unknown node use two different signal then two destination nodes are not required only one destination can calculate distance using two different signals. Node sends RF and ultra sonic signal at same time. But known node will receive these two signals with time difference because speed of RF signal is higher than ultrasound signal and calculate difference of time of two signals receive with time difference between them, $Distance = \Delta t * \Delta S$ Where, Δt is the difference between sending and receiving signal between two nodes. ΔS difference in two signal received by other node. $\Delta S = (s1 * s2)/ (s1 - s2)$, Angle measurement, Calculation is done using information about angles instead of distance, for determining the position of an object such as Angle of Arrival (AoA): Nodes uses Omni-direction antenna. It estimate angle with the help of known reference axis and with signal is send to another node and Position Computation, Calculation is based on anchor node position from it estimate his own position such as Lateration, In 2D three or more non collinear anchors node are present whereas in 3D four or more non collinear anchor nodes are present and position calculation is done through this non collinear anchor node and estimate the location using the calculated value.

Range-free Localization Algorithms: It calculates using number of hop receive the signal by the sender. The number of hop receive the signal is calculate the distance between them, Academic community has proposed a number of 3-D positioning algorithm in WSN currently, for example, reference [3] proposed APIS algorithm, it made the beacon nodes to the center of sphere, and made the distance between beacon nodes to the radius, divided the network to N concentric spheres, determined whether the unknown nodes in the region of these concentric spheres or not, finally find a series of the thinnest spherical shell which contain the unknown nodes, and take the gravity center of these spherical shell's intersection area to be the unknown node' coordinate. But the beacon nodes have a greater impact to positioning accuracy and the coverage. Reference [4] proposed Constrained 3-D algorithm, deployed the beacon nodes in the same plane, and made this plane to the center positioning by the way of up or down. Therefore, the positioning coverage of this algorithm has a large degree of limitations. Reference [5] proposed 3D-MDS algorithm which based on multi-dimensional scaling, it established a dissimilarity matrix which combined the experience attenuation model of RSS and shortest path, used lightweight matrix decomposition algorithm to locate, then used iterative optimization algorithm to refine the initial position coordinates. The computation and communication capacity of this algorithm are very large, and have a relatively high requirements in the hardware.

By analyzing the lack of these algorithms, this paper proposed a new 3-D TOADV-Hop algorithm , it is mainly expanded the traditional TOADV-Hop algorithm [6] into 3-D space, and on this basis to positioning by those way of introducing the mobile agents, using the mean square error and normalized weighted to deal with the average jump distance, determining the effectiveness of beacon nodes which involved in positioning, and depending on the situation using total least squares method, translation coordinate method and draw circle method for positioning.

3. TOADV-Hop Localization Algorithm

The positioning process of the traditional TOADV-Hop algorithm can be divided into the following phases:

First, getting the smallest hop count between the nodes and the beacon nodes. each beacon nodes broadcasting a data packet in the network which containing its location message and hop count (initialized it to 0), all of the nodes in one hop saving this packet, increasing the hop count by 1 and forwarding to the next hop neighbor nodes, until every nodes getting the coordinates of other beacon nodes and the minimum hops between those nodes.

Second, any node that has hop-count equal to one can determine the distance between it and anchor nodes using the measured signal propagation time and the known signal velocity.

Third, calculating and obtaining the average per-hop distance of the unknown node. Beacon node by saving the coordinates of other beacon nodes and the minimum hop count, using the formula (1) to calculate the average per-hop distance in the network:

$$C_i = \sum_{i \neq j} \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{i \neq j} hop_{ij}} \tag{1}$$

Which*: (xi, yi)* , *(xj , yj)* is the coordinates of beacon nodes *i and j, hopij* is the minimum hop count between the beacon node *i* and *j*.

When calculated the average per-hop distance of the beacon node, added this value to the data packets and broadcasted it, the unknown node saved the first received average per-hop distance and forwarded this packet immediately, dropped all subsequent packets to ensure that this received average per-hop distance is the nearest beacon node recent from it. To use this average per-hop distance and the previously saved hops' information to calculate the distance between nodes and beacon nodes, using maximum likelihood estimation to calculate the coordinate of the unknown node.

4. Three Coordinate Calculation

4.1 Total least squares (TLS)

We directly using the maximum likelihood estimation method (MLE) to calculate the coordinates of the unknown nodes in the TOADV-Hop algorithm. However, the method of least squares in MLE only considered the matrix B in the linear equation $AX = B$ exist the measurement error. In fact, the beacon nodes using Global Positioning System (GPS) to positioning themselves also have errors, that is to say, the error of the matrix A is also present.

Then we can use the total least squares method (TLS) [7] to reduce the impact of positioning when the matrices A and B exists the error simultaneously.

4.2 Draw circle method (DCM)

Take the distance between the unknown node *m (x, y, z)* and the two beacon nodes *p1 (xi, yi , zi), p2 (xj , yj , zj)* in the 3-D space to the radius drawing circles in the XY plane, XZ plane and YZ plane successively.

(1) If in the XY plane, the two circles intersect at one point, indicating that the unknown node and the beacon node in one line, so the point of intersection is the coordinate *(x11, y11)* of m in the XY plane, if the two circles also intersect at one point in the XZ plane and the YZ plane, the intersection coordinates are *(x12, z12)* and *(y13, z13)*,then the coordinate of m is:

$$(X_1, Y_1, Z_1) = \left(\frac{x_{11} + x_{12}}{2}, \frac{y_{11} + y_{13}}{2}, \frac{z_{12} + z_{13}}{2}\right) \quad (2)$$

(2) If in the XY plane, the two circles intersect at two points (x_{11}, y_{11}) and (x'_{11}, y'_{11}), so taking $(\frac{x_{11}+x'_{11}}{2}, \frac{y_{11}+y'_{11}}{2})$ as the coordinate of m in the XY plane.Then we can get the coordinates in the XZ plane and the YZ plane are $(\frac{x_{12}+x'_{12}}{2}, \frac{z_{12}+z'_{12}}{2})$ and $(\frac{y_{13}+y'_{13}}{2}, \frac{z_{13}+z'_{13}}{2})$. So the coordinate of m is:

$$(X_1, Y_1, Z_1) = \left(\frac{x_{11} + x'_{11} + x_{12} + x'_{12}}{4}, \frac{y_{11} + y'_{11} + y_{13} + y'_{13}}{4}, \frac{z_{12} + z'_{12} + x_{13} + z'_{13}}{4}\right) \quad (3)$$

4.3 Coordinate translation method (CTM)

In the 3-D space, assuming p1, p2, p3 for the three selected beacon nodes, the coordinates are *(xi, yi, zi)*, which *xi, yi, zi > 0 (i = 1, 2, 3), (x, y, z)* is the coordinate of the node m which to be positioned, translation transformation the original 3-D coordinate system, and make *p1* to be the origin of the new coordinate system, so *that p1, p2, p3* all in or near in the XY plane, the schematic as shown in Figure 1.

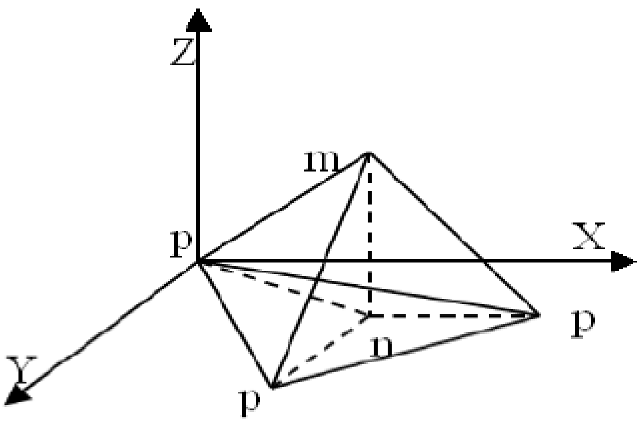

Fig.1: Translation coordinate method schematic

5. The Improved Algorithm

By analyzing the lack of the existing 3-D positioning algorithm in this paper, extending the rang-free TOADV-Hop algorithm to the 3-D space, making the corresponding improvements to the shortcomings, such as large amount of network communication, the low positioning accuracy, energy consumption and coverage and so on, proposed a new 3-dimensional TOADV-Hop localization algorithm. The concrete steps are:

5.1 Computing the minimum hop counts between the unknown nodes and the beacon nodes.

After extending the TOADV-Hop algorithm to the 3-D space, except for broadcasting the beacon nodes 'information, calculating the average per-hop distance, it also need to communicate between the nodes frequently, so the network traffic increased greatly, in order to solve this introducing the mobile agent.

Mobile agent has many features like exibility, autonomy and mobility, it can perform operations autonomously which depended on the specific reality environment, changes with the environment dynamically, and responded accordingly, so that the whole system can remain in the normal working condition, can ease the network load and reduce the network delay in the certain extent [8]. After adding mobile agents, all beacon nodes sent the mobile agent to the other nodes, mobile nodes recorded the coordinates of the beacon nodes and the number of hops between two nodes (initialized it to 0) through the moving process, increased the hop count by 1 ,then continue to move in the direction except for the source of the neighbor nodes. That may exist many paths between the two nodes, at this time, the nodes only saved the mobile agent whose hop counts is the smallest, and discarded others, thus ensured the path between the beacon nodes and the nodes is the shortest one, until all nodes in the network have the coordinates of each beacon node and the minimum number of hops. The mobile agents built a bridge between the nodes and the beacon nodes, and collected the location information of the beacon nodes and the hops between the nodes, eased the flow of data in WSN greatly, thus reduced network traffic.

5.2 Calculating the average per-hop distance and measurement error

Calculated the average per-hop distance of the beacon nodes, and dealt with the measurement error of the beacon nodes' average per-hop distance by the mean square error. After each beacon node obtain the location information and the minimum hop counts of the other beacon nodes, and then the average per-hop distance of the beacon node can calculate by the formula (4):

$$C_i = \sum_{i \neq j} \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}}{\sum_{i \neq j} hop_{ij}} \tag{4}$$

Which: $(x_i; y_i; z_i)$; $(x_j ; y_j ; z_j)$ is the coordinates of beacon nodes *i* and *j*, hop_{ij} is the minimum hop count between the beacon node i and j.

Although the measurement mean error of C_i is zero by adoption of the formula (4), the error obeys the Gaussian distribution under normal circumstances, so using the mean square error to calculate error is more reasonable [9]. Then it can obtain by minimizing the formula (5):

$$f = \frac{\sum_{i \neq j} S_{ij}^2}{N-1} \quad (5)$$

Which: S_{ij} is the measurement mean error between the beacon node i and j $(i \neq j)$, namely the difference between the actual distance D'_{ij} and measure distance D_{ij} of the beacon nodes I and j.

$$S_{ij} = D'_{ij} - D_{ij} \quad (6)$$

Which: The actual distance D'_{ij} of the beacon nodes i and j is the Euclidian distance of the (x_i, y_i, z_i) *and* (x_j, y_j, z_j), can calculate by the formula (5). The measure distance D_{ij} is the product of the average per-hop distance C_i between the beacon node i and j which obtained by the formula (1) and the minimum hops between two beacon nodes, namely:

$$Dij = Ci \times hopij \quad (7)$$

Set $\partial f/\partial C_i = 0$, so the average per-hop distance based on minimum mean square error criterion is:

$$C_i = \frac{\sum_{i \neq j} hop_{ij} \times D'_{ij}}{\sum_{i \neq j} hop_{ij}^2} \quad (8)$$

After calculating the average per-hop distance of the beacon nodes, broadcasted this value in the whole network, the unknown node saved all the average per-hop distance of the beacons nodes which can receive, and forwarded to other neighbor nodes, then used these average per-hop distances and the previously saved hops information to calculate the distance between the beacon nodes.

5.3 Calculating the average per-hop distance of the unknown node

If extended the TOADV-Hop algorithm to the 3-D space simply, then the unknown node will only save the first received average per-hop distance of the beacon node, so that only the information of the most recent beacon node was used. The deployment of nodes in the WSN is random, so the single average per-hop distance of the beacon nodes may be had deviation of the average per-hop distance of the whole network, then there is a big error existed in the final positioned coordinate of the unknown node.

It will save all the beacon nodes' average per-hop distances which received by the unknown nodes, and used normalized weighted to dealt with it [10]. Assumed the unknown node m has been saved and put weight λ_i $(1 \leq i \leq N)$ to the average per-hop distances of the N beacon nodes, and satisfied:

$$\sum_{i=1}^{N} \lambda_i = 1$$
$$\lambda_i = \frac{(hop_{mi})^{-1}}{\sum_{j=1}^{N} (hop_{mj})^{-1}} \qquad (9)$$

Then the average per-hop distance of the unknown node is:

$$C_m = \sum_{i=1}^{N} \lambda_i C_i \qquad (10)$$

5.4 To determine the effectiveness of the beacon nodes and positioning the unknown nodes

When the nodes in the same plane, the small measurement errors will lead to a larger location error, that is to say, the guarantee to achieve the uniqueness of positioning is the beacon node involved in positioning is not in the same plane. Therefore, when to choose the beacon nodes participate in positioning, must verify the validity of the beacon nodes.

5.4.1 The number of the beacon nodes is greater than 4

Set the number of the beacon nodes in the communication range of the unknown node m is k, and the beacon nodes are $p_1, p_2, \ldots\ldots, p_k$ respectively, then: When $k \geq 4$, get the four most recent beacon nodes $p_1(x_1, y_1, z_1)$, $p_2(x_2, y_2, z_2)$, $p_3(x_3, y_3, z_3)$, $p_4(x_4, y_4, z_4)$ away from the unknown node $m(x, y, z)$ then the mixed product of p_1p_2, p_1p_3, p_1p_4 is:

$$(p_1p_2, p_1p_3, p_1p_4) = 2 \begin{pmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \\ x_4 - x_1 & y_4 - y_1 \end{pmatrix} \qquad (11)$$

(1) If the mixed product = 0, then the beacon nodes p_1, p_2, p_3, p_4 are coplanarity.

i) If $k > 4$, then removed the beacon nodes p_4 which is the farthest away from m, re-selected the nearest beacon node p_5 away from m except p_1, p_2, p_3, p_4, and judgment the four nodes are coplanarity or not by using the formula (11), until these four selected beacon nodes are not in the same plane.

ii) If $k = 4$, then calculated the cartesian product of the vector p_1p_2 and p_2p_3, p_1p_2 and p_2p_4, p_1p_3 and p_3p_4 , p_2p_3 and p_3p_4 respectively.

1) If all of the cartesian products are 0, then these 4 nodes in the one line, so can sure about that p_1, p_2, p_3, p_4 and m in the same plane. Located the coordinate of m used by the DCM.

Take the distance between the two beacon nodes (a total of 6 situations) and m as radius respectively, successively to draw circle in the XY plane, XZ plane and YZ plane. According to the intersection situations of the two circles in the three planes, selected formula (2) or (3) to obtain the coordinates of the unknown node (X_1, Y_1, Z_1) in one case, then can get the coordinates of the unknown node m *(X_i, Y_i, Z_i)* in the other five cases similarly, so the final positioning coordinate of m is:

$$(x,y,z)=\left(\frac{X_1+\cdots+X_6}{6},\frac{Y_1+\cdots+Y_6}{6},\frac{Z_1+\cdots+Z_6}{6}\right)$$

2) If not all of the cartesian products are 0, then choose any set of three beacon nodes whose Cartesian product is not 0, and positioning coordinate used by CTM.

(2) If the mixed product ≠0, then the beacon nodes p_1, p_2, p_3, p_4 are not coplanarity. Then directly used TLS to calculate the coordinates of the unknown nodes.

5.4.2 The number of the beacon nodes is equal to 3

If $k = 3$, then calculate the cartesian product of the vector p_1p_2 and p_2p_3.
(1) If the cartesian product =0, then p_1,p_2,p_3 in the same line, positioning coordinate used by DCM
(2) If the cartesian product ≠0, then positioning coordinate used by CTM.

5.4.3 The number of the beacon nodes is less than 3

(1) If the number of the beacon nodes $k = 2$, then used DCM to positioning coordinate;
(2) If the number of the beacon nodes $k < 2$, then can not locate the unknown node.

6. Simulation and Analysis of this Algorithm

In order to test the effectiveness and availability of this proposed algorithm, introducing the APIS algorithm and 3-D DV-Hop algorithm (simply extended the DV-Hop algorithm to 3-D space), using MATLAB 7.0 to simulate these three algorithms. In the processing of the simulating experiments, 200 nodes are randomly deployed in a *100m×100m×100m* area, and the communication radius R of the nodes are *20* and *30*.

The evaluation criteria of these three algorithms' simulation results are the positioning coverage, energy consumption and location accuracy. And the positioning coverage is the percentage of the number of the positioned nodes in all the unknown nodes, energy consumption is the number of messages taken to localize an unknown node. Positioning accuracy also called the average location error, is defined as the ratio of the sum positioning error of all nodes and the communication radius, namely:

$$\text{Accuracy}=\frac{\sum\sqrt{(x_i-x_i')^2+(y_i-y_i')^2+(z_i-z_i')^2}}{R}$$

Which the real coordinate of the unknown node is (x_i,y_i,z_i), the located coordinate is (x_i', y_i', z_i').

Change the number of beacon nodes, gradually increasing it from 10 to 45 (added 5 each time), compared with the average positioning accuracy and positioning coverage of the algorithm in this paper, the APIS algorithm and the 3-D DV-Hop algorithm in the case of the different beacon nodes, run the simulating program 50 times randomly, comparison of these averages and the coverages by calculated, the simulation results shown in Figure 2 - Figure 7.

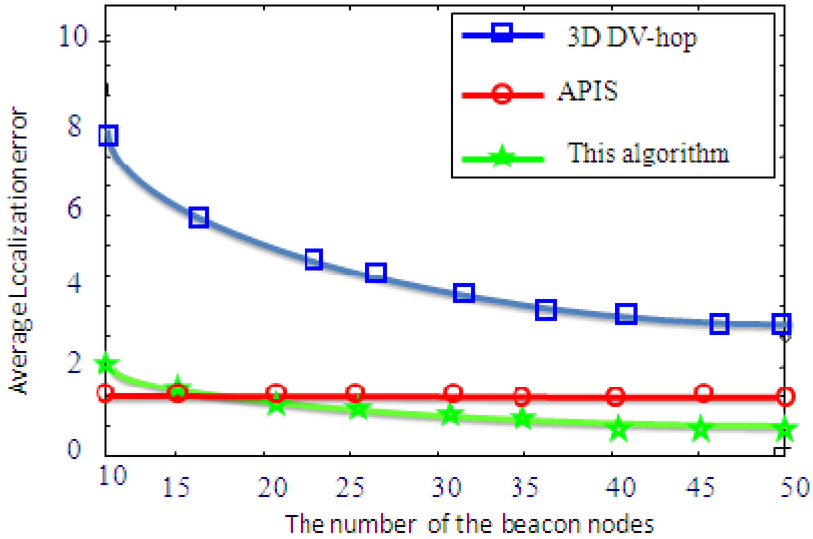

Fig. 2: The average positioning error of the three algorithms in the different number of the beacon nodes(R=20)

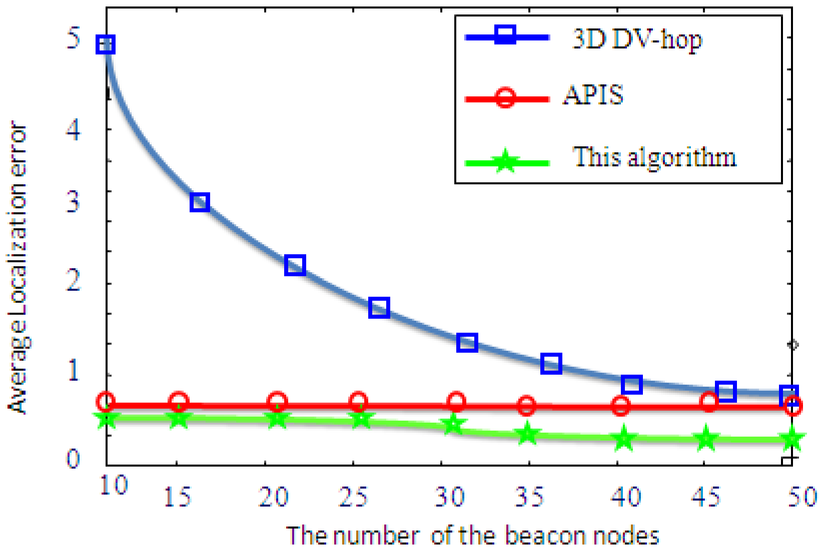

Fig. 3: The average positioning error of the three algorithms in the different number of the beacon nodes(R=30)

From Figure 2 and 3 we can know that, in the case of R is 20 and 30, the positioning accuracy of three algorithms is rise by increasing the number of beacon nodes, when the beacon nodes' number is more than 30, the positioning accuracy gradually stabilize. The average positioning error of 3D TOADV-Hop and the APIS algorithm is lower than the 3D DV-Hop algorithm, although in the Figure 2, when the beacon nodes is 10, the improved algorithm' positioning accuracy is slightly lower than the APIS algorithm, with the increasing of the beacon nodes' number, the improved algorithm' average positioning error is smaller, and the positioning accuracy curve is more stable

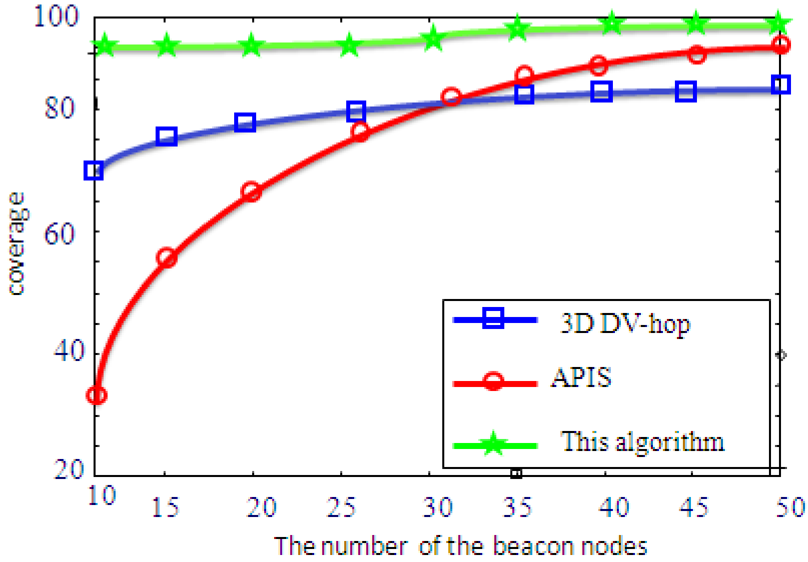

Fig. 4: The positioning coverage of the three algorithms in the different number of the beacon nodes(R=20)

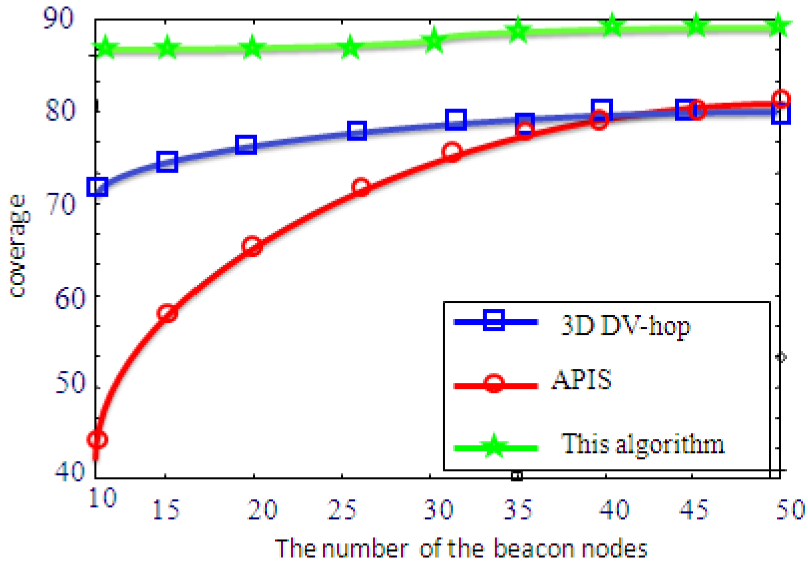

Fig. 5: The positioning coverage of the three algorithms in the different number of the beacon nodes(R=30)

The Figure 4 and 5 show that, in different communication radius, the positioning coverage of the three algorithms is rise by the increasing of the beacon nodes' number. There is a bigger effects on the positioning coverage of APIS by changing the beacon nodes' number, and the other two algorithms' positioning coverage are more stable, while in the case of the same beacon nodes, the improved algorithm' positioning coverage are higher than the other two algorithms.

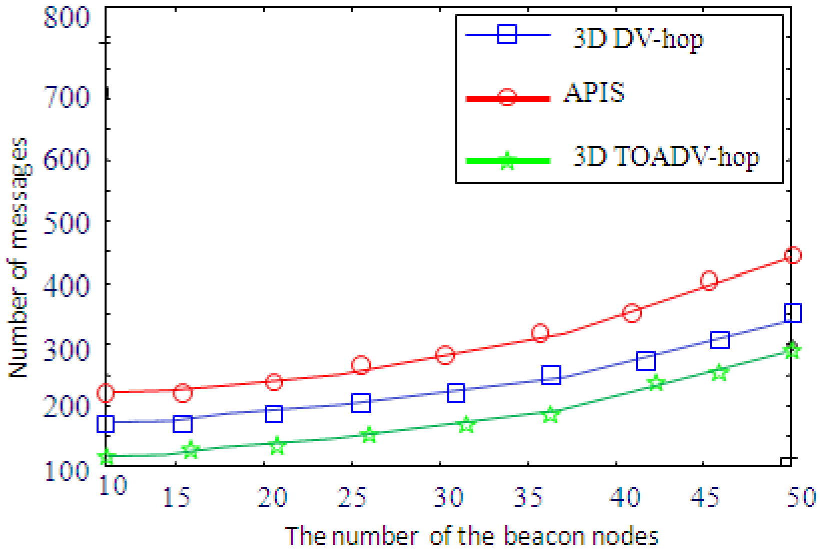

Figure 6: The number of messages of the three algorithms in the different number of the beacon nodes(R=20)

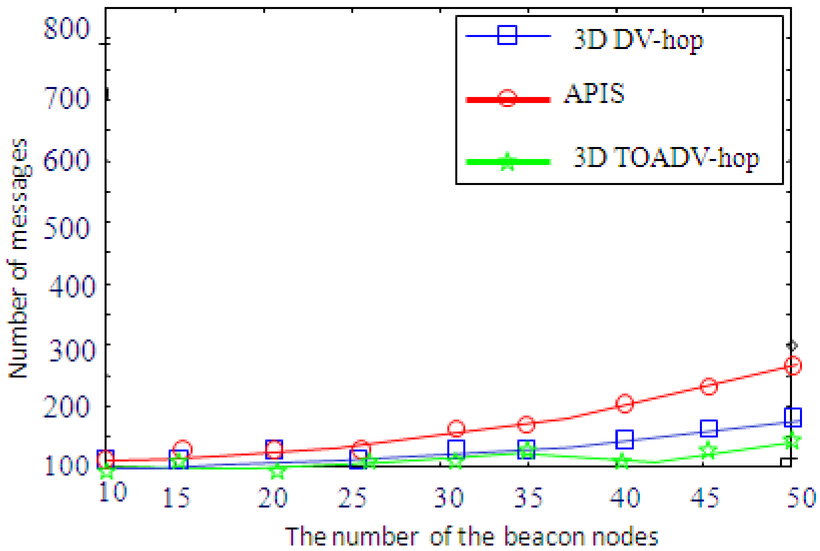

Figure 7: The number of messages of the three algorithms in the different number of the beacon nodes(R=30)

From Figure 6 and 7 we can know that, in the case of R is 20 and 30, number of messages of three algorithms is rise by increasing the number of beacon nodes, the number of messages in 3D TOADV-Hop algorithm is lower than APIS and 3D DV-Hop algorithm with the increasing of the beacon nodes' number. mobile agents in 3D TOADV-Hop built a bridge between the nodes and the beacon nodes, and collected the location information of the beacon nodes and the hops between the nodes, thus reduced number of messages , network traffic and eased the flow of data in WSN.

7. Conclusion

The proposed algorithm in this paper extended the TOADV-Hop algorithm from 2-D to 3-D successfully, and improved the aspects of the communication, the positioning accuracy and so on, to ensure that this algorithm can locate the vast majority of the unknown nodes in the entire network successful. The simulation results show that this algorithm can not only maintain the advantages of the DV-Hop algorithm, but also showed some advantages in the positioning accuracy, energy consumption and coverage especially in the larger space which exists a lot of obstacles, and can adapt the requirements of the low-cost and low-power. However, there is a higher computational complexity in this algorithm, and increased the cost of the algorithm, either, so how to reduce the computational complexity by the guarantee of unchanged in the algorithm' accuracy, energy and coverage, and it will be the next focus of the study.

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