TOADV: TOA-based advanced DV-hop Localization Algorithm for Wireless Sensor Networks

Lamiaa Elsayed[1], Ahmed M. Khedr[1,2] and Ismail Amr[1]

[1]Mathematics Dept., Faculty of Science, Zagazig University, Zagazig, Egypt

[2]Computer Science Dept., Collage of Sciences, Sharjah University, Sharjah ,UAE

, amkhedr@yahoo.com, amr44_2@yahoo.comlamia_elsayed87@yahoo.com

Abstract

A wireless sensor network (WSN) protocols and applications assume the knowledge of geographic location of nodes. In emerging WSN applications, localization is a recent area of research. Requirement of its applications and availability of resources need feasible localization algorithm with lower cost and higher accuracy. Locations of nodes can be estimated by a number of localization algorithms, which inevitably may introduce various types of errors in their estimations. Range-based and Range-free localization are the mainly two types of localization algorithms. In this paper, we locate unknown nodes by proposing a new algorithm named TOA-based advanced DV-hop (TOADV) that incorporates the advantages of the two types of localization algorithms. The proposed algorithm TOADV reduces the localization error and increases location accuracy without requiring additional hardware and computational costs. TOADV has lesser correction factor in the distance between anchor and the unknown node compared with existing algorithms. Simulation results show that the performance of our proposed algorithm is superior to the existing algorithms in all considered scenarios.

Keywords: *Wireless sensor network, Localization, Correction factor, DV-hop, Time of arrival, Weighted least square.*

1. Introduction

WSN is composed of plenty of sensor nodes, these nodes have the ability of sensing, computing, and communication. Due to its powerful function and low energy cost, the WSN has been widely used in various domains, such as national defense and military affair, environment inspection, traffic management, long distance control of dangerous region. 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, the position information is usually embedded in the report message generated by the sensor node. Without position information, WSN cannot work properly. In practice, sensor nodes are often deployed by random bestrewing (airplane bestrewing for example). And for the high-cost, only a few nodes are equipped with Global Positioning System (GPS) which can capture their position after being bestrewed. All the other nodes cannot acquire such information. Therefore, how to obtain the position information of unknown nodes, which is called localization problem, has become a hot topic in WSN. Localization is fundamental for WSN services that rely on the knowledge of sensor positions, including geographic routing and coverage area management. The location of a sensor node can be expressed as a global or relative metric. A global metric is used to position nodes within a general global reference frame, for example, as provided by the GPS (longitudes and latitudes) and the Universal Transverse Mercator (UTM) coordinate systems (zones and latitude bands).

In contrast, relative metrics are based on arbitrary coordinate systems and reference frames, for example, a sensor's location expressed as distances to other sensors without any relationship to global coordinates. Two important qualities of localization information are the accuracy and precision of a position. While it may be infeasible for all sensor nodes in a WSN to have knowledge of their global coordinates, many WSNs rely on a subset of nodes that know their global positions. Techniques that rely on such anchors are called anchor-based localization (as opposed to anchor free localization). A large number of localization techniques (including many anchor-based approaches) are based on range measurements, that is, estimations of distances between several sensor nodes. These techniques, called range-based localization techniques, require sensors to monitor measurable characteristics such as received signal strengths of wireless communications or time difference of arrival of ultrasound pulses. The following section discusses the basics of different localization techniques based on these concepts. Recently, many localization algorithms for WSNs have been proposed. Most of the algorithms assume that the network includes a small number of anchor nodes, which know their own positions beforehand by either using GPS or being manually configured. The other nodes, called unknown nodes, don't know their own position. The anchors can assist the unknowns to locate themselves. When an unknown node knows more than three anchor nodes' position information, it can use trilateral method to figure out its location. These algorithms can obtain good results in theory. However, the results become poor when they are used in practical applications. TOA is one of the simplest methods among all existing algorithms which have been broadly used in many fields. The proposed algorithm incorporates TOA algorithm and advanced DV-hop to implement unknown nodes localization together.

The rest of the paper is organized as follows: Section 2 discusses previous work in localization. Our TOADV algorithm is described in Section 3. Section 4 evaluates the proposed algorithm performance by simulations. And section 5 draws a conclusion of the paper.

2. Related Work

Localization is an important issue for some WSN applications [2-4, 16-19], but not all of such applications require absolute positions of sensor nodes, there are a lot of WSN applications and services that may do quite well with the knowledge of relative positioning of the nodes. For such applications and services, even though some location errors are introduced by the estimation algorithms, this may not be harmful for the applications provided that the relative positioning information is correct. Therefore, there are various localization algorithms proposed for WSNs that do not require use of GPS in every node and that have different error performance. Those localization algorithms can be classified in various ways: range-based algorithms, range-free algorithms (the two main types), region-based algorithms, connectivity-based algorithms and hop-counting techniques. The range-based algorithms need to measure precise distance or orientation between neighbor nodes, and then use the information to localize nodes. Range-free algorithms use estimated distance instead of metrical distance to localize node.

Range-based Localization Algorithms: The foundation of numerous localization techniques is the estimation of the physical distance between two sensor nodes. The estimations are obtained through measurements of certain characteristics of the signals exchanged between the sensors, including signal propagation times, signal strengths, or angle of arrival such as TOA [5, 6], the concept behind it is that the distance between the sender and receiver of a signal can be determined using the measured signal propagation time and the known signal velocity. TOA use absolute point-to-point distance information between neighbor nodes to estimate the location of unknown nodes. This technique use additional hardware, which is more expensive. In [7, 8], Time Difference On Arrival (TDOA) approach uses two signals that travel with different velocities. The receiver is then able to determine its location similar to the TOA approach. In Angle Of Arrival (AOA) approach [7], the direction of signal propagation is determined. The concept behind the received signal strength (RSS) method is that a signal decays with the distance traveled. In [15], Triangulation uses the geometric properties of triangles to estimate sensor locations. It refers to the process of calculating a node's position based on measured distances between itself and a number of anchor points with known locations. In Iterative and Collaborative Multilateration [15], once a node has identified its position using the beacon messages from the anchor nodes, it becomes an anchor and broadcasts beacon messages containing its estimated position to other nearby nodes. Both theoretical and empirical models are used to translate signal into estimated distance. Due to its easy implementation and there is no need for additional hardware, TOA has been widely used. In TOA method, is that the distance between the sender and receiver of a signal can be determined using the measured signal propagation time and the known signal velocity.

Range-free Localization Algorithms: Centroid, Approximate Point in Triangle Test (APIT), Coordinate, DV-hop, Amorphous are all examples of range-free algorithms [9-12]. In Centroid algorithm, the anchors send out beacons which include their position information to neighbor nodes at periodic intervals. A receiver node infers proximity to a collection of anchor nodes. The position of the node is then estimated to be the Centroid of the anchor nodes from which it can receive beacon packets. This algorithm is simple but it needs too many anchors, [9]. In [12], authors proposed APIT in which given three anchor nodes, any unknown node can determine its position if it lies inside the triangle composed by the three anchors. In the localization scheme each sensor node performs numerous APT tests with different combination of audible anchor nodes, and infers its location as the center of gravity of the intersection area of all the triangles in which the node lies in. Coordinate is a GPS-free algorithm with no entire reference frame information in localization because no anchor exists. Each node makes itself coordinate origin to establish a local reference frame after it obtains the distance to neighbor nodes and the distances between neighbor nodes, and then communicates with neighbor nodes to extend the local reference frame. In [13], the authors proposed a distributed algorithm named Virtual Anchor Node-based Localization Algorithm (VANLA), which uses shortest-hop path scheme to upgrade some special unknowns' position as virtual anchor nodes with highly accurate. The virtual anchors, as well as the real anchors, will help the remainder unknown nodes to be localized.

In [14], the DV-hop algorithm was proposed; it 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 its distance from it 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. A few of them are as follows: In [19], the authors used average hop-size on the network in place of individual hop distance of anchor in DV-hop algorithm to calculate the distance between the unknown node and the anchor node. Furthermore, they used 2-D hyperbolic location algorithm in place of traditional triangulation algorithm for location estimation. In [22], the authors proposed an improved DV-hop localization algorithm in which the hop distance is improved by calculating approximate ranging error. The position of a node is estimated by the 2-D hyperbolic location algorithm rather than using traditional triangulation algorithm. In [20], the authors proposed DV-hop localization algorithm for asymmetric distributed WSNs that improves location by improving the hop-size. Hop-size is improved by using differential error term of range as weight coefficient.

DV-hop algorithm assumes that the minimum hop path between nodes is similar to a straight line, this assumption generates an error in the distance estimated by hop count and hop-size. Another main drawback of DV-hop algorithm is due to communication range. The communication range of each node in the network is not a standard circle; it is quite anomalistic polygon, which makes each hop distance different from others. Therefore, if we use the average distance of each hop to estimate the distance between nodes, the error will be increased with the increasing of number of hops.

Finally, algorithm provides low accuracy of nodes localization. In [21] proposed an improvement scheme of localization using local estimation of hop-size and dynamically adjusted the ranging error based on distribution of the unknown nodes around an anchor node. Then proposed algorithm incorporates TOA and Advanced DV-hop to implement localization together, aiming to reduce the estimate error of the nodes which are nearby anchors calculated by Advanced DV-hop algorithm. The new algorithm enforces the unknown node in one hop distance from anchors to calculate its distance to the neighbor anchors using TOA method instead of Advanced DV-hop method this will reduce the estimate error in the network. The proposed algorithm improves location accuracy without increasing hardware cost and communication traffic. We reduce the range measurement error, which is the main cause of localization error of DV-Hop-based algorithms. In the proposed algorithm, localization error is reduced in three ways. First, the ranging error is reduced by measuring the distance using TOA algorithm for unknown nodes neighboring to anchor nodes and advanced DV-hop for the rest of nodes. Second, error in localization of a node is decreased by solving a system of n equations using weighted least square (WLS) to reduce error. Third, up-gradation in localization of node is suggested to reduce localization error. Simulation results show that the performance of our proposed algorithm is superior to typical DV-Hop algorithm [14] and Advanced DV-Hop algorithm [1].

3. TOADV: TOA-Based Advanced DV-Hop Algorithm

DV-hop localization algorithm can work out the position of unknown nodes which are beyond anchors' transmission radius, and it does not need the exact metrical information as described in previous section.

However, the error of average distance per hop is large if it is only computed by hops. For an unknown node that is only one hop away from the anchor, it still needs to compute the location of itself according to average distance per hop. The error will differ based on the route bend degree. The proposed localization algorithm incorporates TOA and advanced DV-hop to implement localization together, aiming to reduce the estimate error of the nodes which are nearby anchors calculated by DV-hop algorithm.

3.1 Algorithm Outline

The proposed algorithm includes the following six steps:

Step 1: Anchors distribute their localization message to the entire network. This message may include fields such as anchor ID, location, and hop-count. hop-limit is defined as the maximum number of hops that a localization message can be alive. Each node receives this message and stores it in its memory, increases the hop-count by one, and forwards this message to neighbors if the hop-count is less than or equal to the hop-limit; otherwise the message will be killed by the sensor node. If a node receives more than one message from an anchor, the shortest path will be considered; the new message will be ignored and the sensor node forwards the message only. According to the fact that the first message from an anchor includes the shortest hop-length, each node considers only the first message from each anchor and ignores the next messages. When a node receives localization messages from 3 anchors, this step will be terminated.

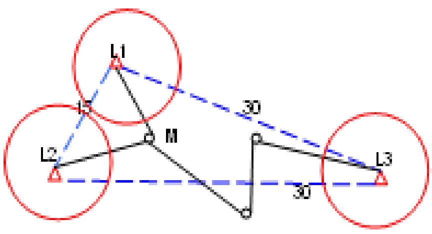

Figure 1: An example to illustrate our TOADV

Step 2: 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, in Fig. 1, node M is one-hop neighbor of nodes L1 and L2, that is, M can receive the packets from L1 and L2 directly, M will compute the distance from L1 and L2.

Step 3: If any anchor receives a localization message from an anchor, it will calculate the average hop length (AHL). For example, in Fig. 1, we have 3 anchors L1, L2, and L3. The distance from L1 to L2 is 15 m, from L2 to L3 is 30 m, and from L1 to L3 is 30 m. The hop-count from L1 to L2 is 2, from L2 to
L3 is 4, and from L1 to L3 is 4. Each anchor calculates its own AHL as follows:

AHL (L1) = (15 + 30) = (2 + 4) = 7:5
AHL (L2) = (15 + 30) = (2 + 4) = 7:5
AHL (L3) = (30 + 30) = (4 + 4) = 7:5

Step 4: Each anchor distributes the AHL to the entire network. Each anchor considers that the first received AHL comes from the nearest anchor. For example, in Fig. 1, node M, the first received AHL from L1 and L2 is 7.5, so the distance from anchors to M is calculated by multiplying the inimum hop number and the average distance of each hop.

$$d_{p,i} = HopSize_i \times h_{p,i} \quad (1)$$

Where $h_{p,i}$ is the number of hops between unknown node p and anchor i and $HopSize_{p,i}$ is the hop-size of anchor.

n - L1 = 7:5 * 1 = 7.5
n - L2 = 7:5 * 1 = 7.5
n - L3 = 7:5 * 3 = 22.5

Step 5: After obtaining these distances, system of n equations will be used to localize M (in the example, the actual distance is 10, but the estimate distance is 7.5) using the DV-hop algorithm. It is obvious that the error reaches twice of the actual distance. After using the system of n equations, the estimate position of M will be detected from actual position. There is a straight-line between M and L1, L2 but the DV-hop uses curvilinear average distance instead of straight-line distance. The proposed TOADV algorithm calculates the distance from other anchors by using average distance per hop which has known before. M will figure out the distance to L3 as 7.5*3=22.5. Then M can locate itself by the system of n equations using 10, 10 and 22.5 instead of 7.5, 7.5 and 22.5.

Step 6: We use a new method to solve the system of n equations to locate the unknown node using n anchor nodes, which is completely different from the model used in DV-hop algorithm. Let (x; y) be thecoordinates of unknown node p.. The coordinates of i^{th} anchor node is(x_i, y_i). Let d_i denotes the distance between p and i^{th} anchor. The location of p will be estimated by solving the following system of equations:

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

where d_i is measured by Eq. 1, it contains error due to error in hop-size. If both sides of the Eq. 2 are squared to estimate (x, y), the error in d_i increases rapidly. Therefore, to reduce the inherent error in d_i, we subtract the last equation from first n − 1 equations, we get a system of n − 1 equations as follows:

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

Then, by squaring both sides and simplifying Eq.3, we get:

$$\begin{aligned}
&-2(x_1+x_n)x-2(y_1+y_n)y+2k=d_1^2+d_n^2-E_1-E_n\\
&-2(x_2+x_n)x-2(y_2+y_n)y+2k=d_2^2+d_n^2-E_2-E_n\\
&\vdots\\
&-2(x_{n-1}+x_n)x-2(y_{n-1}+y_n)y+2k=d_{n-1}^2+d_n^2-E_{n-1}-E_n
\end{aligned}$$

Where $k=x^2+y^2$, $E_i=x_i^2+y_i^2$ for i = 1; 2; 3, …, n writing in the matrix form QZ = H, where Q, H, and Z are given by Eqs. 5, 6, and 7 respectively as follows:

$$Q=\begin{bmatrix} -2(x_1+x_n) & -2(y_1+y_n) & 1\\ -2(x_2+x_n) & -2(y_2+y_n) & 1\\ \cdots & \cdots & \cdots\\ -2(x_{n-1}+x_n) & -2(y_{n-1}+y_n) & 1 \end{bmatrix}$$

$$H=\begin{bmatrix} d_1^2+d_n^2-(E_1+E_n)\\ d_2^2+d_n^2-(E_2+E_n)\\ \cdots\cdots\\ d_{n-1}^2+d_n^2-(E_{n-1}+E_n) \end{bmatrix} \quad (4)$$

$$Z=\begin{bmatrix} x\\ y\\ k \end{bmatrix}$$

To improve the location accuracy, we solve it using WLS method. By applying WLS, we have:

$$Z = (Q'W'QW)^{-1}Q'W'H. \qquad (8)$$

Where W is the weight matrix for the minimum number of hops from unknown node to anchors. For an unknown node p, it can be obtained by Eq. 9.

$$W = \begin{bmatrix} W_{p,1} & 0 & \cdots & i^{th}\ 0 \\ 0 & W_{p,2} & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & W_{p,n-1} \end{bmatrix}$$

Where $W_{P,i}$ is the weight of the unknown $W_{p,i} = \frac{1}{h_{pi,}}$ node p for anchor. It is defined by Eq. 10

where $h_{p,i}$ is the minimum number of hops between p and anchor i. If an anchor is at more hops away from the unknown node, its distance from the unknown node will contain more error due to error in hop-size and as such will have a lower weight. Therefore, weight for an unknown node to anchor is taken as the inverse of the minimum number of hops between them. Using Eq. 8, the unknown node

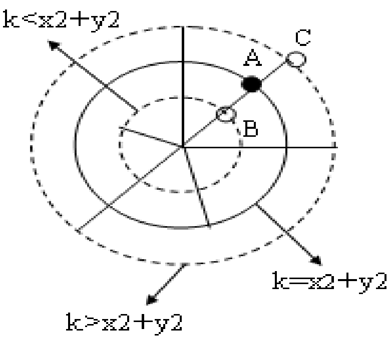

Figure 2: Estimated location of unknown node

obtains its location (x; y) and also gets the value of k. Due to error in d_i, the coordinates (x; y) of the unknown node does not satisfy $k = x^2 + y^2$ of Eq. 4. If $k < x^2 + y^2$, where x and y are estimated coordinates of unknown node, a better estimation of the position of the unknown node may be B and if $k > x^2 + y^2$, the position of the unknown node may be C, as shown in Fig. 2. In Fig. 2, A shows the unknown node's location (x; y) estimated by Eq. 8. Therefore, by using the value of k, the unknown node's location (x; y) is upgraded.

3.2 Upgrading the Location of Unknown Node

Once the values of x, y and k are estimated, the location of the unknown node is upgraded by using the value of k in the following manner. We know from Eq. 4 that k contains x and y. For simplicity, Take x and y of k as x' and y'. Let the estimated coordinate of unknown node p be (x'', y''). Then,

$$x' = t \times x'' \\ y' = t \times y'' \qquad (11)$$

Where t is a parameter. Substituting this value in $k = x'^2 + y'^2$ and t is estimated. Further, by putting the value of t in Eq. 11, x and y of k are arrived at. Finally, the upgraded coordinates of p will be:

$$x = \frac{x' + x''}{2}$$
$$y = \frac{y' + y''}{2} \quad (12)$$

4. Performance Evaluation

In this section using MATLAB 2008b, we evaluate the performance of our proposed algorithm regarding to DV-hop and advanced DV-hop algorithms. The evaluation parameters are the following:

1. The Localization Error: is the Euclidean distance between estimated location (x_e,y_e) and actual location (x_r ,y_r) in relation to the radio range of sensor nodes (R).

$$\text{Localization error} = \sqrt{(x_r - x_e)^2 + (y_r - y_e)^2} \quad (13)$$

2. The Consumed Energy: there are several ways to estimate the consumed energy, but in this paper we consider the time taken to localize an unknown node in the network and the number of packets that have been sent or received by each node.

3. The network overhead: is the traffic that produced for localization, which means the total number of packets generated by anchors. We assume that the radio range of sensor node is 100 m.

We deploy 100 nodes randomly in a two-dimension area of 100 m x 100 m as in Fig. 3. The communication radius of each node is assumed to be 15 m, the anchor nodes are selected from all of the nodes proportionally. We define the criterion for the position error to be the ratio of the DV-hop and the TOADV distances between the real and figured coordinates to the communication radius of nodes. The position error shows the degree of the estimation accuracy the algorithm can perform. The larger the position error is, the poorer the estimation accuracy is. Each simulation is repeated 100 times, and we use the average value as final result.

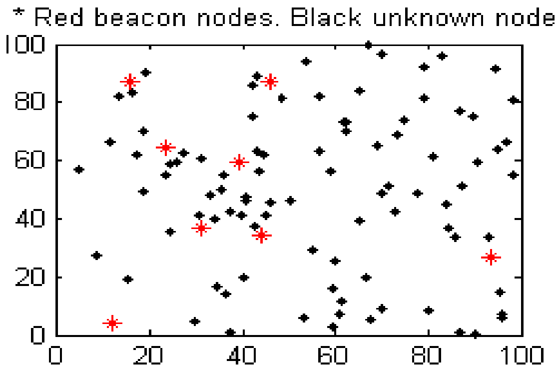

Figure 3: Node Distribution

Evaluating of the Localization Error: In Fig. 4, it can be observed that as the total number of nodes increases in the region, localization error of DV-hop, Advanced DV-hop and TOADV algorithms 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. This improves the chances that the unknown nodes lie on the line joining anchor pairs, then, TOA distance can be used in more unknown nodes, 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, i.e., the TOADV algorithm has lesser localization error.

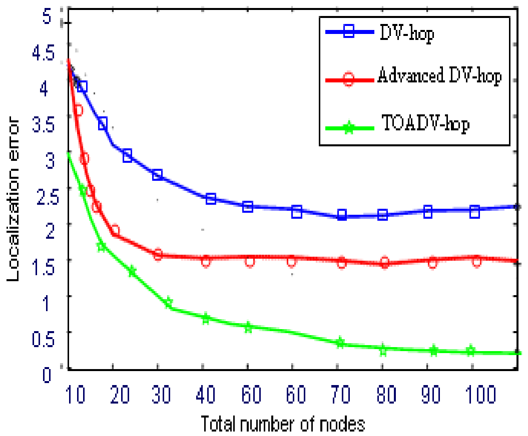

Figure 4: Total number of nodes versus localization error.

Ratio of Anchor Nodes to Total Number of Nodes: In Fig. 5, we can observe that as the ratio of anchor nodes increases in the region, the localization error of DV-hop, Advanced DV-hop and TOADV algorithm decreases. When the ratio of anchor nodes in the network increases for a fixed number of total nodes, the number of hops between the anchor and unknown nodes decreases, as such the unknown node obtains information from more anchor nodes and it increases the chances of using TOA algorithm in most unknown node. i.e., the estimated distance between the unknown node and the anchor node is closer to the actual distance. Hence, location error of the algorithm decreases with increasing ratio of anchor nodes.

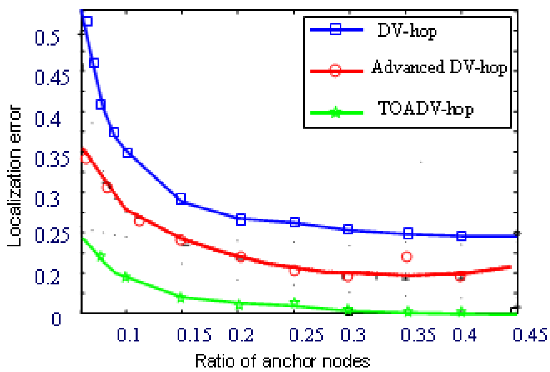

Figure 5: Ratio of anchor nodes versus localization error

Communication Radius of Sensor Node: In Fig. 6, we can notice as the communication radius of sensor nodes increases, the localization error of DV-hop, Advanced DV-hop and TOADV algorithm decreases.

When communication radius increases for a fixed number of unknown nodes and anchor nodes, network connectivity increases. Consequently, the number of neighboring anchor nodes per unknown node increases and the neighboring nodes will use TOA algorithm. Therefore, the location error of the algorithm decreases with the increasing in the communication range. The results show that TOADV algorithm gives better location accuracy for each value of communication radius when compared with other algorithms.

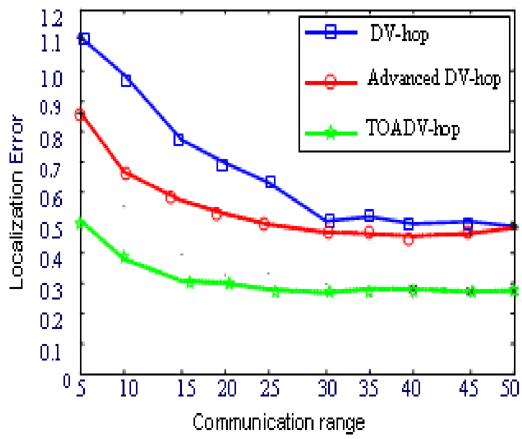

Figure 6: Communication range versus localization error

Evaluation of Consumed Energy: Fig. 7 shows the time in seconds taken to localize an unknown node. As the number of total nodes and ratio of anchor nodes increase, the time required to localize an unknown node increases. In DV-hop and Advanced DV-hop as the number of total nodes and anchor nodes increase, the localization time increases rapidly, whereas in TOADV algorithm, the time required for localization increases gradually. On increasing the total nodes or ratio of anchor nodes in the network, the node density (average number of nodes per node radio area) increases, as a result average number of neighbors of each node increases. Therefore, each unknown node obtains information from more number of neighbor nodes; it takes more time to estimate the location. As shown in Fig. 7, TOADV algorithm takes lesser time for localization of an unknown node than DV-hop and advanced DV-hop. In DV-hop, the network overhead is on the anchors therefore by increasing the number of anchors, the consumed energy has a significant increase compared to the TOADV this point is shown in Fig. 7.

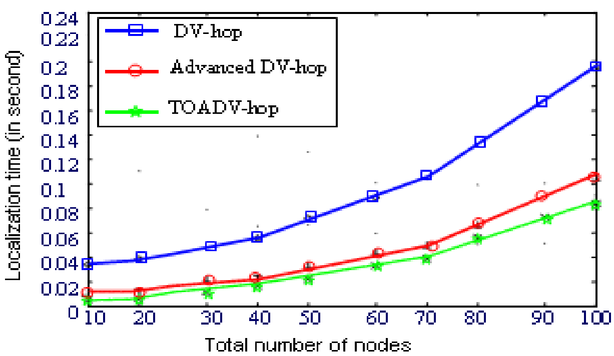

Figure 7: Ratio of anchor nodes versus localization time

The network Overhead: is the number of sent or received packets by total nodes, in Advanced DV-hop anchors distribute their localization message and AHL message to the entire network and all nodes will receive it but in TOADV, neighboring nodes doesn't need to send or receive the AHL messages which decreases the overhead in the network. Fig. 8 shows the number of messages taken to localize an unknown node.

As the number of total nodes and ratio of anchor nodes increase, the number of messages increases for every algorithm. In DV-hop and Advanced DV-hop as the number of total nodes and anchor nodes increases, number of messages rapidly increases, whereas in TOADV algorithm, the number of messages required for localization increases gradually, on increasing the total nodes or ratio of anchor nodes in the network this is because the node density increases, the average number of neighbors of each anchor node increases. Therefore, each unknown node will use TOA algorithm to estimate the location, therefore TOADV will take lesser number of messages for localization of an unknown node than DV-hop and advanced DV-hop.

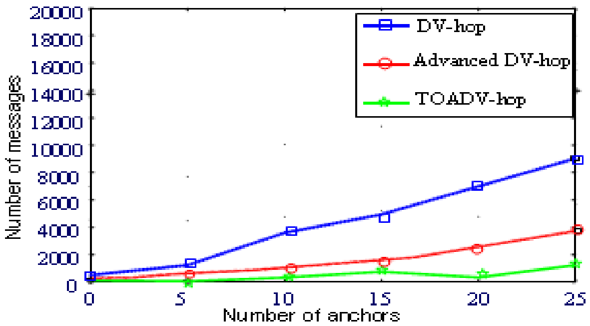

Figure 8: Total number of nodes versus Number of messages.

5. Conclusion

Both the precision and the cost of localization are important criterions to evaluate the localizing algorithms based on previous localizing algorithm, in this paper, we have proposed an algorithm that integrates TOA and advanced DV-hop. The new TOADV algorithm makes the unknown node which is one hop distance from anchors to calculate its distance from neighbor anchors using TOA method instead of advanced DV-hop method. By this way, the estimate error in network is reduced. The experimental results proved the validity of our method. The limitation of the algorithm is that only neighbors of anchor can update. So how to precisely localize more nodes and increase the localization accuracy of the whole network further are our future objectives.

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