International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.3, Issue.4, Jul - Aug. 2013 pp-1958-1964 ISSN: 2249-6645

Performance Analysis of DV-Hop Localization Using Voronoi Approach

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ABSTRACT : *Localization that is to be aware of position of the node in the network is an essential issue in wireless sensor network (WSN). Localization algorithm in WSN can be divided into rangebased and range-free algorithm. In this paper, we present the analysis of DV-Hop using Voronoi diagrams in order to scale a DV-Hop localization algorithm while maintaining or even reducing its localization error. With this we tried to analyze the efficiency of the DV-Hop localization algorithm by changing various parameters.We show how the proposed algorithm can scale in different aspects such as communication and processing costs when increasing the number of nodes and beacons.*

Keywords: *Localization, DV-Hop, Range free algorithms, WSN*

I. INTRODUCTION

Wireless Sensor Network is composed of large number of low cost sensor nodes which are limited in power, computational capacity and memory. Sensor nodes are capable of sensing and communicating with each other. The WSN can deploy these low cost sensors in variety of different settings. WSN can supply many applications, such as weather sensing, environment monitoring, building and structure monitoring, military sensing. Localization is to determine the location and it coordinates of the sensor nodes that are deployed randomly in the sensor network. It is the important issue in location dependent applications of WSN. Global Positioning System GPS is straightforward solution to this problem but due to its large equipment and high cost it is not feasible [1]. Localization algorithms in WSN are divided into range based and range free algorithms. Range based algorithm finds the location of the sensor node using point to point distances [2] for this it requires hardware support but provide more accurate localization result than range free approaches. It includes algorithms such as Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA), and Received Signal Strength Indicator (RSSI) [3]. Whereas range free algorithm depends on connectivity and hop information such as Centroid, APIT, Amorphous, DV-Hop, etc. It provides low accuracy, but it is preferred over range based because it is easier to implement with less hardware which is suitable for low power, low cost WSN.

DV-Hop [4] range free localization algorithm finds the distance using hop information and then calculates the location. This algorithm is simple, feasible, provides high coverage quality, and is useful and does not require localization devices. The other important advantage of DV-Hop is the fact that it does not depend on measurement error. But the position accuracy obtained through this algorithm is low. In this paper we analyze DV-Hop approach of range free localization algorithm by varying different parameters. A DV-Hop localization system works by transforming the distance to all beacons (nodes that know their position) from hops to units of length measurement (e.g., meters, feet) using the average size of a hop as a correction factor. A typical example of this technique is the Ad Hoc Positioning System (APS) [5]. Some of the advantages of the DV-Hop technique are: first, it is suitable for sparse networks; second,it is immune to RSSI inaccuracies; and third, it requires a small number of beacons. However, the DV-Hop technique has also a few disadvantages: first, it has a large communication cost of O(bn) — where b is the number of beacons and n the number of nodes — that compromises the algorithm scalability; and second, by mapping hops into distance units, the DV-Hop technique introduces errors that are propagated to the computation of a node location.. The rest of this paper is organized as follows. Section II presents the DV-Hop algorithm. In section III The Distributed Voronoi Localization System – DV-Loc and simulation results are shown in section IV and localization performances are discussed. Finally, we present our conclusions and future scope in Section V.

II. PROBLEM STATEMENT

In this work, we consider a WSN as composed of n nodes, with a communication range of r units, and distributed in a two-dimensional squared sensor field Q = [0, s] × [0, s]. For the sake of simplification, we consider symmetric communication links, i.e., for any two nodes u and v, u reaches v ifand only if, v reaches u. Thus, we represent the network by a graph G = (V,E) with the following properties:

- V = {v1, v2. . . vn} is the set of sensor nodes;
- {i, j} ∈ E iff vi reaches vj , i.e., the distance between vi and vj is less than r;
- ω(e) ≤ r is the weight of edge e = {i, j}, i.e., the distance between vi and vj .

In an Euclidean graph, each node has a coordinate (xi, yi) ∈ R2 in a 2-dimensional space, which represents the location of the node i in Q. For the sake of simplicity, we will only consider two dimensions in this work, but the methods here explained can be easily extended to provide position information in three dimensions.

Some terms can be used to designate the current state of a node:

(Unknown Nodes – U): Also known as free or dumb nodes, these are the nodes of the network that do not know their position. The position estimation of these nodes is the main goal of the localization systems.

(Settled Nodes – S): These nodes are initially unknown nodes, but manage to estimate their positions by using a localization system. The number of settled nodes and the estimated position error of these nodes are the main parameters of the quality of a localization system.

(Beacon Nodes – B): These nodes, also known as landmarks or anchors, do not need the localization system to estimate their physical positions. Their position is obtained by manual placement or by external means such as a GPS. These nodes form the base for most localization systems for WSNs.

The localization problem can then be stated as follows.

Given a network that uses a multi-hop communication represented by a graph G = (V,E), and a set of beacon nodes B and their positions (xb, yb), for all b ∈ B, we want to find the position (xu, yu) of as many unknown nodes u ∈ U as possible, transforming these unknown nodes into settled nodes.

In a DV-Hop localization system, as proposed by Niculescu and Nath in APS [5], the beacon nodes start by propagating their position information (Fig. 1(a)). Working as an extension of the distance vector algorithm, all nodes receive the position information from every beacon as well as the number of hops to these beacons. When a beacon node receives a position information from the other beacon nodes, it has enough information to compute the average size of one hop based on its own position, the position of the other beacon nodes, and the number of hops among them (Fig. 1(b)). This last value is then flooded in a controlled manner into the network as a correction factor. When an unknown node receives the correction, it is able to convert its distance to the beacon nodes from hops to units of length measurement (Fig. 1(c)). The complexity of message exchange of this algorithm is determined by the total number of beacon and regular nodes, which is O(n(b + 1)), where n is the number of nodes and b is the number of beacon nodes.

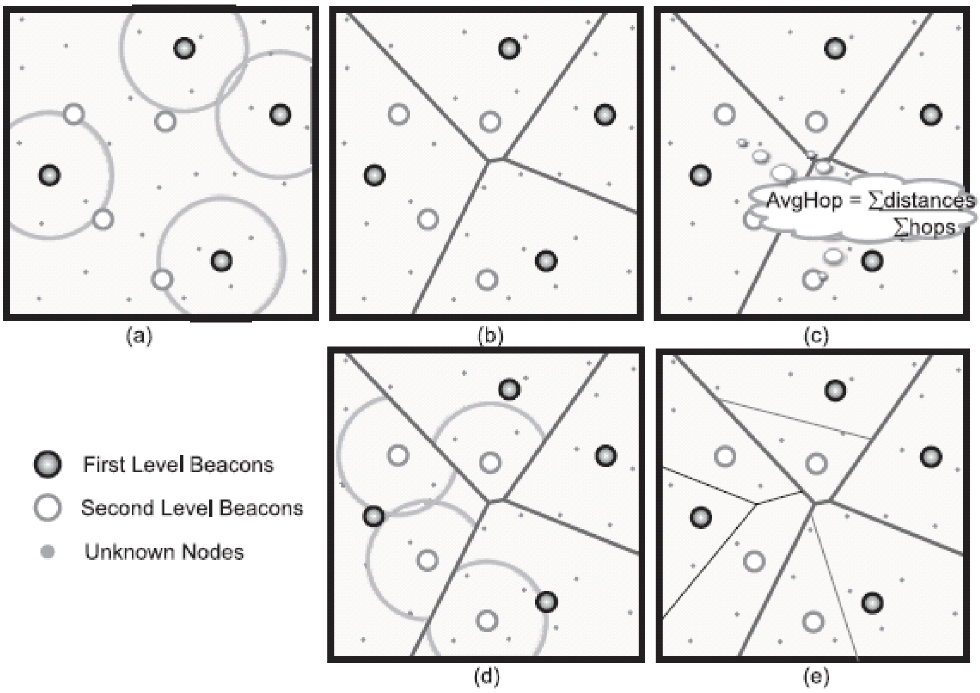


Figure 1: Example and phases of the DV-Loc algorithm

III. THE DISTRIBUTED VORONOI LOCALIZATION SYSTEM – DV-LOC

As mentioned in the previous section (1) the complexity of message exchange in the APS DV-Hop algorithm limits its applicability. In this section, Here propose and explain the Distributed Voronoi Localization (DV-Loc), a new DV-Hop localization solution[6].

A. The Localization Algorithm

The main idea of DV-Loc is to use the Voronoi diagram to limit the scope of the flooding in a DV-Hop localization system. DV-Loc is a scalable solution that uses the Voronoi cell of a node to limit the region when computing its position in order to reduce its localization error.

Algorithm 1 shows the pseudo-code of the DV-Loc algorithm. Initially, b beacon nodes (set B) are deployed in the sensor field with the u unknown nodes (set U). These beacon nodes are previously divided into levels. For example, four beacons are first level beacons, other four beacons are second level, other eight or less are third level, and so on. It is important to note that besides we are considering the use of four nodes as the first level beacon nodes, any other number greater than three could be used. The same applies to the other levels. The DV-Loc works in four steps:

1) The four beacon nodes of the first level start the algorithm by flooding its position information. Each node that forwards the packets saves the position and the number of hops to each one of the beacon nodes—Fig. 1
2) Upon receiving the packets, the nodes are capable of building a Voronoi diagram based on the position information of the first level beacon nodes — Fig. 1(b).Each node is also capable of estimating the Voronoi cell it belongs to; based on the number of hops (the beacon with the lowest number of hops is the cell of a node).When the distance towards two or

more beacons are the same, the node can use the sum of the RSSI as a tiebreaker The beacons of second level compute the average size of a hop (like in the APS algorithm) based on the position information of the first level beacon nodes—Fig. 1(c) Steps are repeated for the beacons of the other levels with a few differences:

3) When no beacon packet is received after a timeout, a node transforms the distances to the beacon nodes from hops to distance units based on the average size of a hop received by one or more beacon nodes. The position is then computed by using multilateration. The node checks if the computed position is inside or outside its estimated Voronoi cell. If the computed position is outside the Voronoi cell, the node changes its computed position to the nearest point inside the Voronoi cell. This characteristic is responsible for decreasing the localization error computed by the nodes.

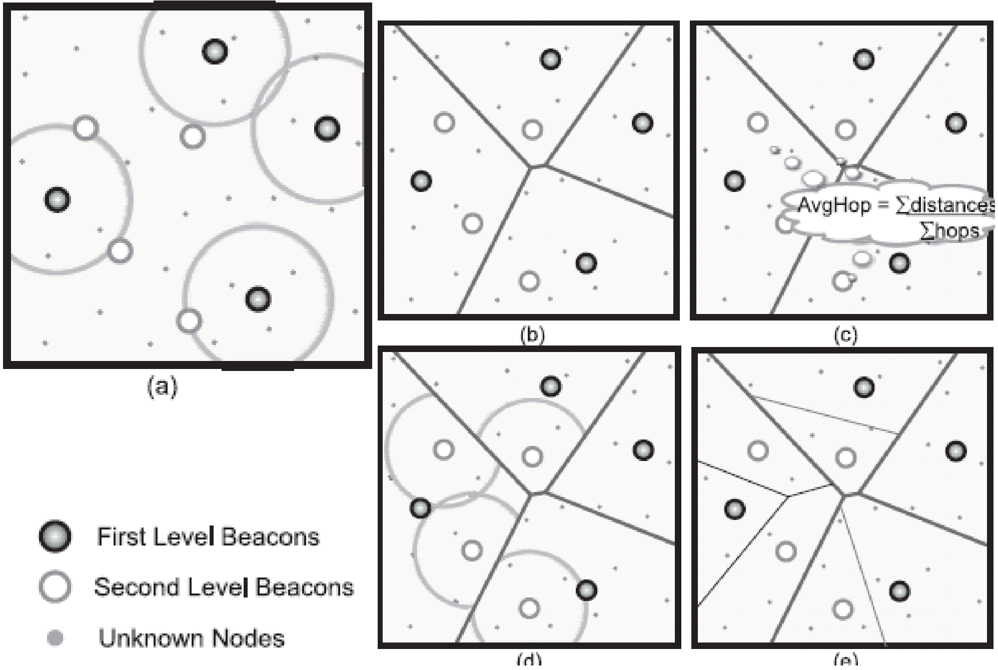
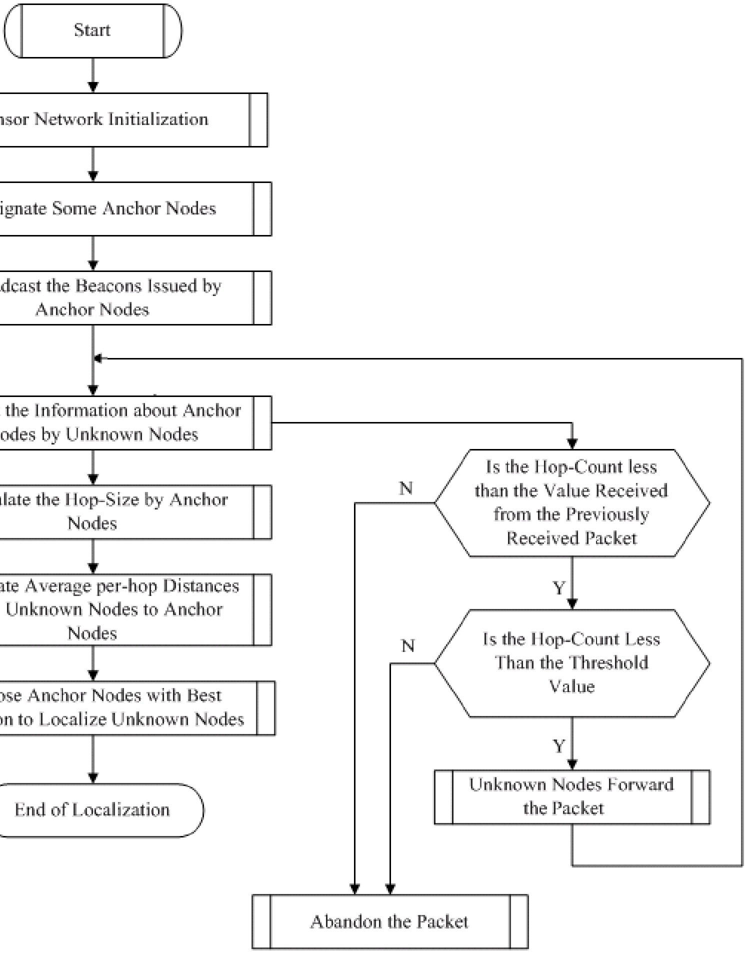


Figure 2: Example and phases of the DV-Loc algorithm

B. Flowchart of DV-Loc Algorithm.



IV. SIMULATION RESULTS

In this section, the proposed scheme, DV-Loc algorithm is evaluated and compared it with the APS algorithm, a similar DV-Hop algorithm that uses the position information of all beacons to compute its position.

The Impact of the Network Scale –

Scalability is evaluated by varying the network size from 50 to 150 nodes with a constant density of 0.03 nodes/m2.Thus, the sensor field is resized according to the number of sensor nodes. The number of beacons in both algorithms is fixed i.e. 4. The comparison of the localization error obtained by the APS algorithm and DV-Loc algorithm is shown in Fig. 6. In both the cases, localization error increases with network size, but in DV-Loc algorithm less error occurs in large networks. Number of sent packets increase when the size of network increases. As the previous section shows, localization errors can increase with the number of nodes. The first solution to this problem would be the deployment of additional beacon nodes in the network to decrease localization errors. Hence, the communication cost also increases with the number of beacons. The number of sent packets by the DV-Loc is not only smaller than in APS but it also increases with a logarithmic factor (b’ = 4+log(b−4), which shows how the DV-Loc can also scale in the number of beacons[6]. The number of correctly estimated cells increases when the number of beacons increases.

As shown in experimental results, the DV-Loc algorithm can maintain a high level of correct cell estimations even when the number of beacons and, consequently, number of cells, increases. Here n=no. of nodes.

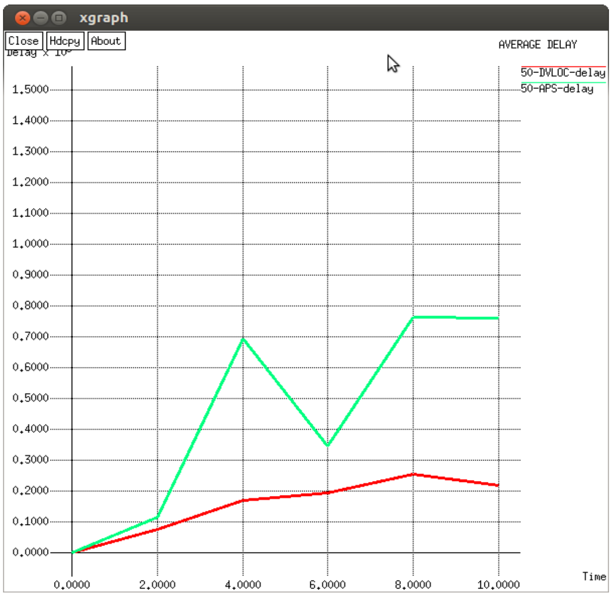


Figure 3 (a) Average Delay Graph for n=50 nodes

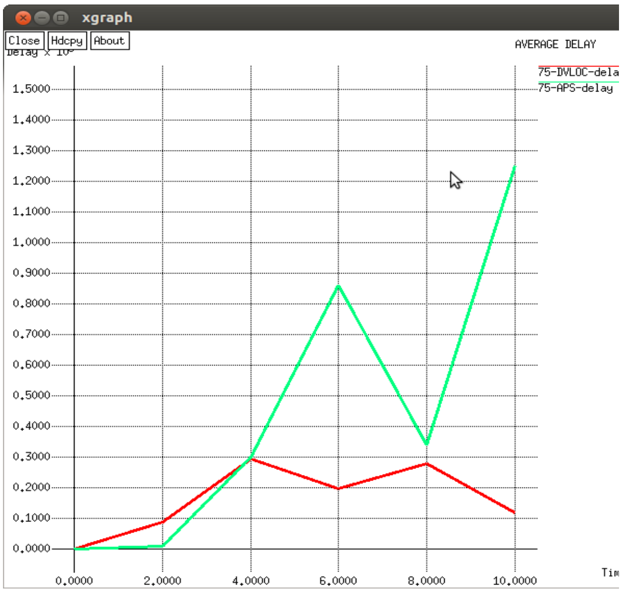


Figure 4(b)Average Delay Graph for n=75 nodes

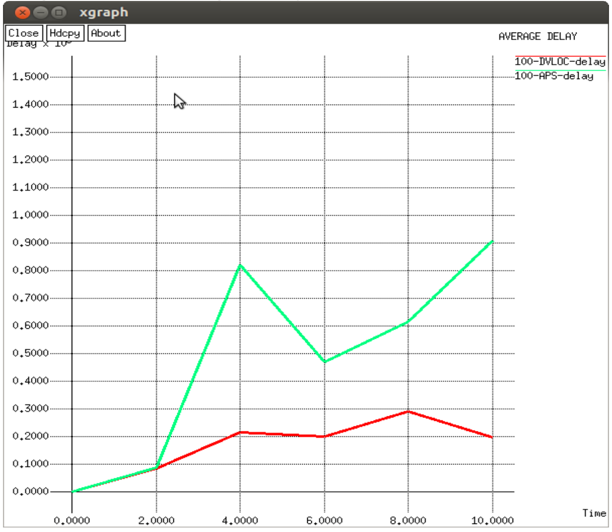


Figure 5(c) Average Delay Graph for n=100 nodes

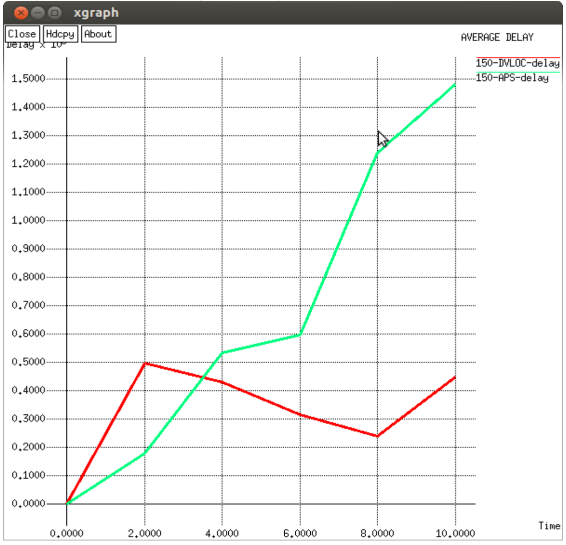


Figure 6(d) Average Delay Graph for n=150 nodes

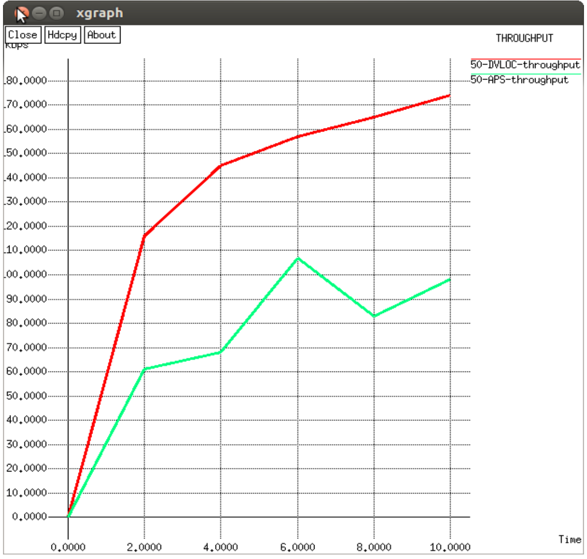


Figure 7 (a) Throughput for n=50

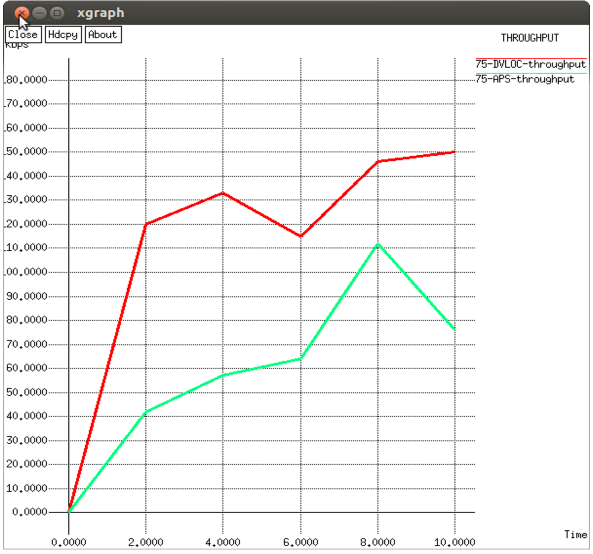


Figure 8 (b) Throughput for n=75

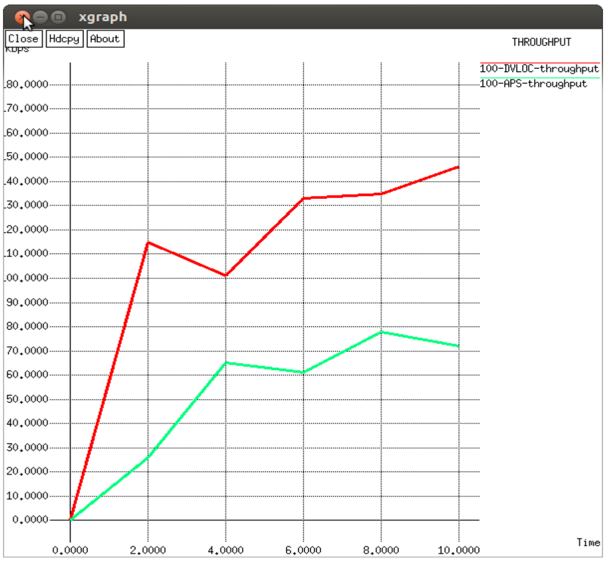


Figure 9 (c) Throughput for n=100

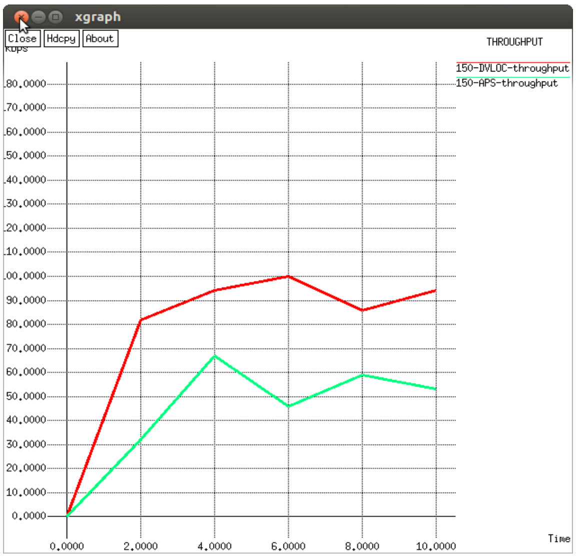


Figure 10 (d) Throughput for n=150

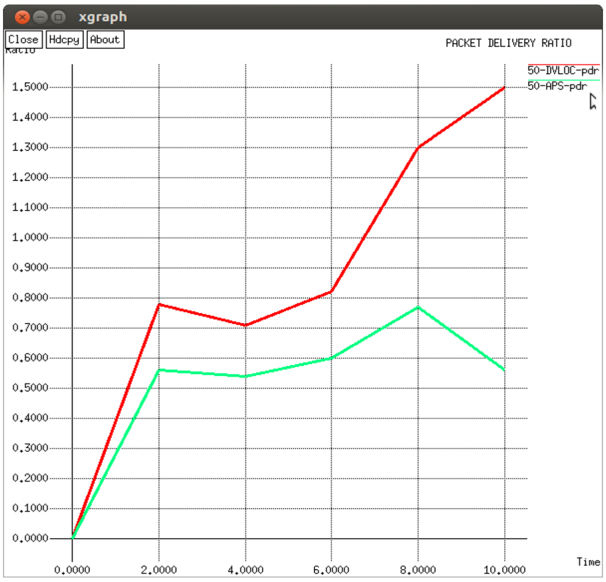


Figure 11 (a) Packet Delivery Ratio for n=50

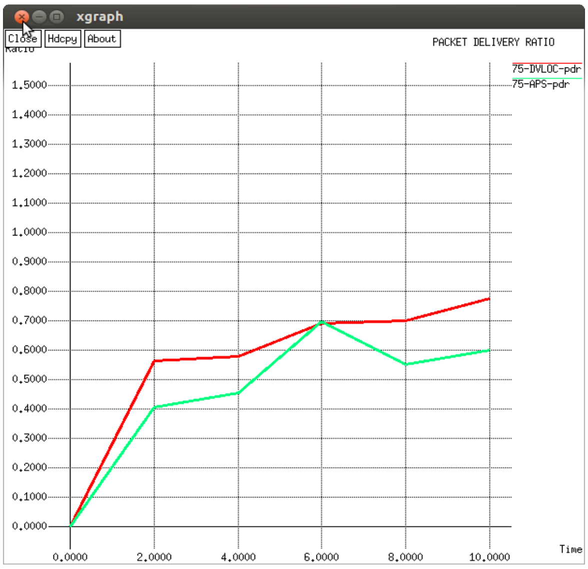


Figure 12 (b) Packet Delivery Ratio for n=75

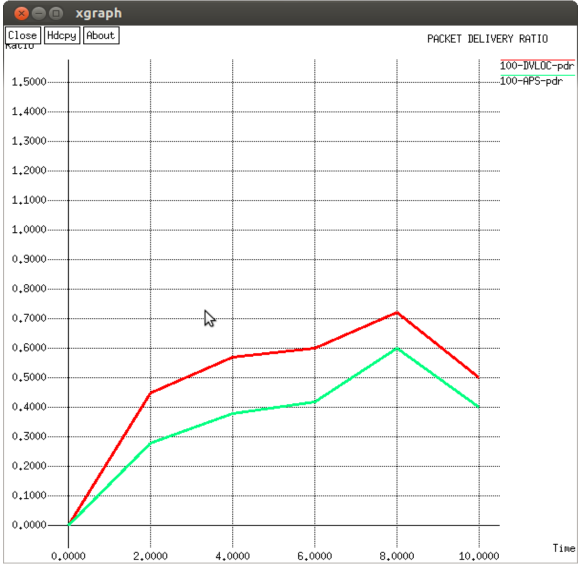


Figure 13 (c) Packet Delivery Ratio for n=100

Figure 14 (d) Packet Delivery Ratio for n=150

Figure 15(a) Localization Error for n=50

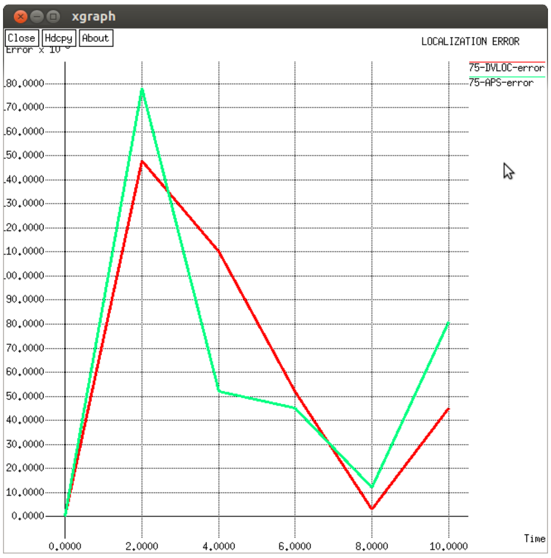


Figure 16(b) Localization Error for n=75

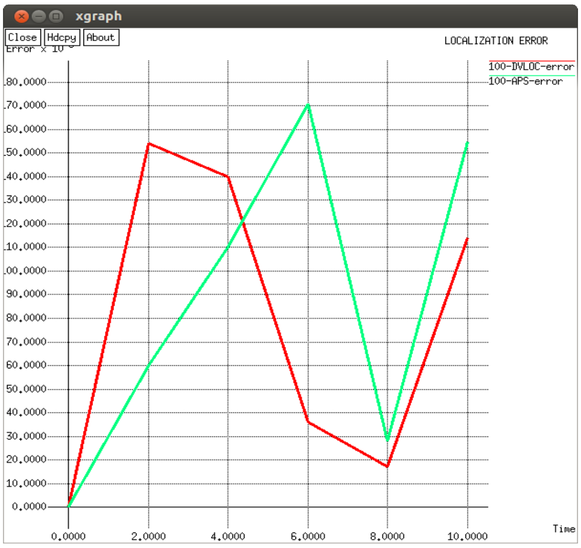


Figure 17(c) Localization Error for n=100

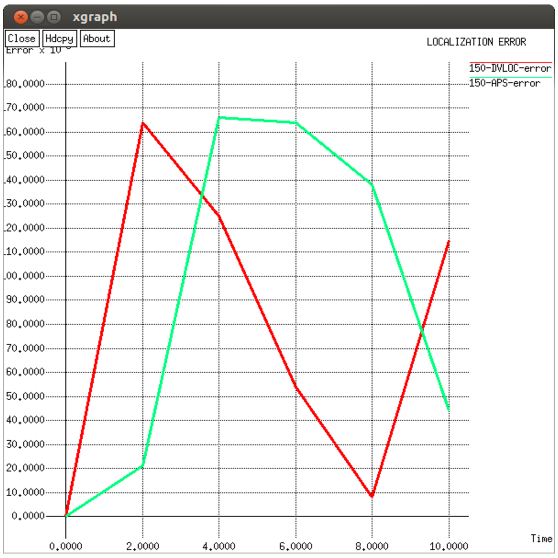


Figure 18(d) Localization Error for n=150

We can see that the best results (Fig.6) are achieved by the DV-Loc algorithm because it limits the position errors to the node's Voronoi cell. Also, to better understand and compare the error behavior of these algorithms, the localization error of both algorithms decreases as the number of beacon nodes increases.

In the DV-Loc algorithm, although the network size increases, the localization error decreases effectively as compared to APS algorithm. Finally, it is important to evaluate the number of nodes that correctly estimated their Voronoi cell, since those cells can be used not only to reduce localization errors but can also be used by routing and clustering algorithms. The DV-Loc maintains a high level of correct cell estimations even when the network size increases.

Table IV.1 Average Values for Different Parameters in APS-Algorithm

PARAMETERS	NUMBER OF NODES 'n'			
	n=50	n=75	n=100	n=150
DELAY(ms)	535.01	584.41	556.1	805.75
ERROR	0.061	0.0734	0.105	0.106
PDR	0.5516	0.462	0.339	0.0606
THROUGHPUT	83.6	70.08	60.314	51.34

Table IV.2 Average Values for Different Parameters in DV-Loc Algorithm

PARAMETERS	NUMBER OF NODES 'n'			
	n=50	n=75	n=100	n=150
DELAY(ms)	182.13	190.65	194.91	385.49
ERROR	0.038	0.0714	0.0922	0.0934
PDR	1.022	0.6640	0.598	0.4752
THROUGHPUT	151.68	132.53	99.01	91.18

As noted in the above Tables IV.1 and IV.2, the delay deteriorates for number of nodes =150. Thus both the algorithms perform better for number of nodes <150 in the network

V. CONCLUSION

The main contribution in this paper is a distributed algorithm for localization of nodes in a wireless ad hoc communication network and its error estimation. There are many possible improvements of the algorithm. For example, an unknown node could only query some of its neighbors and use correlation coding. This would reduce communication costs but increase computations. The algorithm can also be iterated to exploit the newly obtained position estimates of unknown nodes.

In DV-Loc (Distributed Voronoi Localization) algorithm, a DV-Hop localization system takes advantage of Voronoi diagrams to produce a scalable and robust WSN localization algorithm. The proposed localization system provides a way of localizing the nodes by their Voronoi cell. This leads naturally to a novel routing algorithm capable of taking full advantage of node information and the resulted Voronoi cells can be used by clustering algorithms.

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