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Comparitive Analysis of DV-hop and APIT Localization Techniques in WSN

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Abstract

New advancements in wireless sensor networks (WSNs) make it a significant technology in research and academic community. Because of its ad-hoc and minimum infrastructure nature, it has gained lot of attention by researchers in past few years. In WSN, sensor nodes are small sized with limited energy processors which have most important task in WSN. They gather data, process it and further send it to the destination. In many applications like rescue operations, military tracking, environment monitoring etc. it is required that location of sensors must be known else the information collected gets no meaning. So, many localization algorithms are introduced in WSN which meet the resource, hardware, cost and energy constraints of WSN. Range free localization techniques are best suited for these requirements of network. DV-HOP and APIT range free techniques have gained attention in most of research efforts. So,in this paper ,performance of these techniques is evaluated on the basis of accuracy obtained while implementeing them in WSN . Detail analysis of localization error is done by considering different network parameters effecting it directly. Further structured deployment of anchors is proposed that gave more reliable results.

***Keywords**: Localization, DV-HOP localization Algorithm, APIT Localization algorithm, Localization error*

1. Introduction

Recent advancements in semiconductors, communication [10] and networking technologies are driving pervasive deployment of large scale wireless sensor networks (WSNs). Due to availability of tiny, cheap and smart sensors and appropriate RF circuitry for data transmission, WSN has become one of the most promising technologies [3]. WSN is formed using very small but capable sensors that sense, gather and transmit the information to a large network of such sensors. There are pronounced applications of WSN, like providing faster warnings from disasters, fine-spun observations of the surrounding environment, performing more efficient agriculture, all with important economic significance. Similarly, applications in battle field surveillance, healthcare or habitat and structural monitoring help to increase our daily welfare. Localization is one of the most important key techniques in WSN because the location knowledge of sensors is helpful in most of the applications i.e. for coverage, placement, routing, location service, target tracking, and rescue. Hence, location evaluation is a demanding technical challenge for researchers and academic community [9]. So, it is highly desirable to design cost effective, scalable, efficient and reliable localization mechanisms for WSNs. These sensor node localization schemes [8] have different features used for different applications. Localization methods are broadly categorized into two categories: Range based and Range free localization techniques [11]. Range based techniques [4] use range measurements like received signal strength [12], angle of arrival and time of arrival for location estimation whereas Range free methods omit the use of range measurement techniques, instead network topology and connectivity information is used to find the

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location of sensors placed in the network. Therefore,range free techniques overpower the range based techniques in terms of lesser power consumption, low cost, no extra hardware, less installation and computational complexity [5]. In return,these features of Range free techniques have attracted a lot of research efforts in recent years. In this paper we have implemented DV-HOP[1],[2] and APIT[7][6] using MATLAB^{TM} .The results are being analysed for various network parameters under random and uniform placement strategy of sensor nodes in the network for DV-HOP and APIT individually in sections 3and 4 respectively. After achieving best suitable network parameters for both the techniques, comparison is further extended by proposing a structured deployment strategy of anchors .Using second and third order error analysis tools ,the detail analysis is reported in section 5. Analysis based conclusion is drawn in section 6.

2. Simulation Methodology and Environment

Among the main range free localization techniques-Centroid,DV-HOP,APIT and MDS-MAP. DV-HOP is one of the techniques that brought a dramatic change in the fashion of localization by considering multi hop sensor nodes in the network after a simple centroid technique. APIT,then considered area based approach in localization of sensors in WSN with much improvement in reliability of technique. So, these two techniques are yet to be explored by researchers.we have implemented these techniques in MATLAB^{TM}.Simulations are done assuming certain parameters and setup environment as shown below in table 1:

Table 1. Simulation Setup

S.no.	Parameters	Specifications
1.	Area	100x100 square area
2.	Sensor nodes	static
3.	Total nodes	100
4.	Anchor nodes	8
5.	Unknown nodes	92
6.	Placement strategies of Anchor nodes	Random, Uniform ,Square Regular
7.	Radio Ranges	25-50m
8.	Simulations done	300

As shown in table 1, area of 100x100 sq.units is taken and the total of 100 sensor nodes of which 8 are anchor nods and 92 are unknown nodes are deployed in a way that they are connected to each other to form a network.

2.1. Network Scenarios

Deployment strategy of these sensor nodes are varied to form 3 types of scenarios-Random deployment, Uniform deployment, Square Regular deployment.

2.1.1. Random Deployment*:* Unknown sensor nodes are distributed in random fashion and also the anchors are placed randomly as shown in figure 1 below.

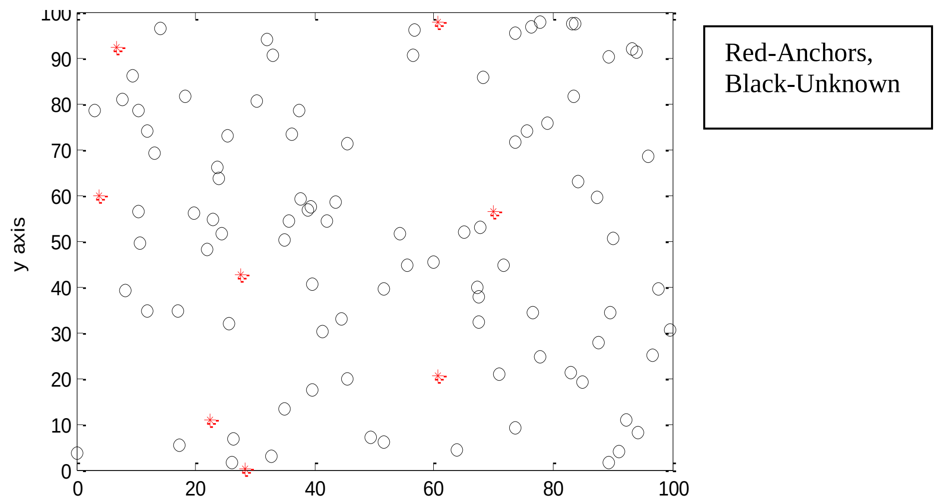

Figure 1. Random Placement Model

2.1.2. Uniform Deployment*:* Unknown nodes and anchor nodes are deployed randomly but the whole area is divided into grids to place the sensors at equal distances. This is shown in the Figure 2 below:

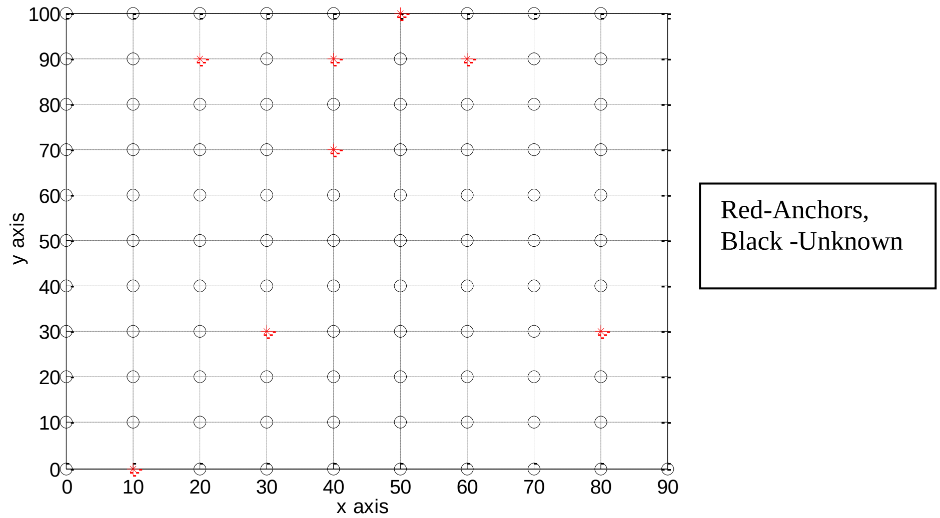

Figure 2. Uniform Placement Model

2.1.3. Square Regular Deployment*:* Unknown nodes are placed randomly at the corners of grids and the anchors are placed in concentric squares to form a regular network as shown in Figure 3.

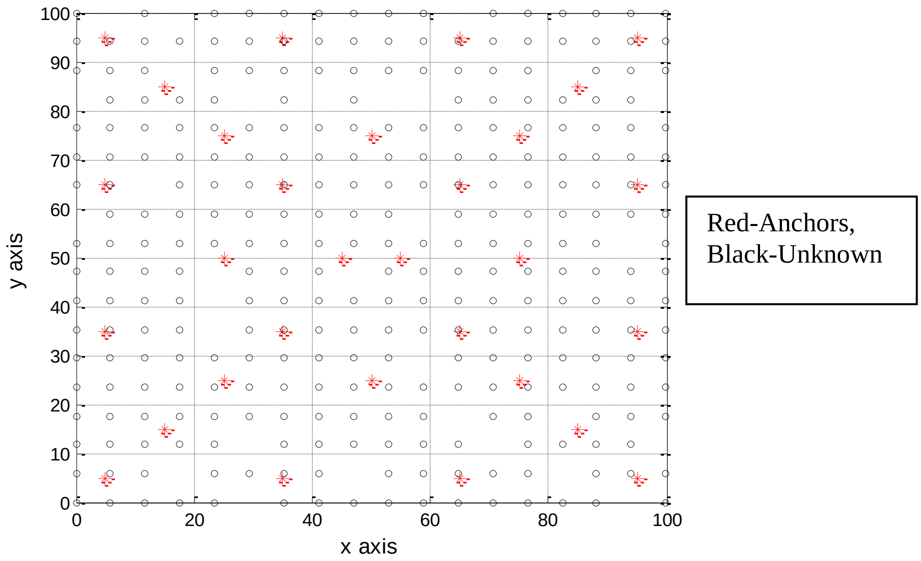

Figure 3. Square Regular Placement Model

For the presented deployment strategies, DV-HOP and APIT localization methods are implemented in the software.

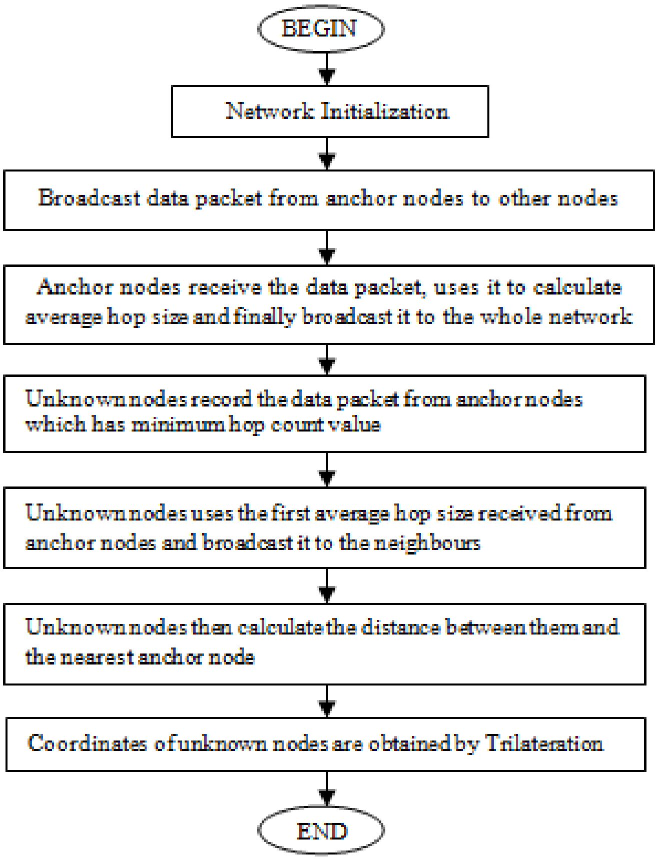

Figure 4. Flow Chart of DV-HOP Localization

Figure 4 shows the working of DV-HOP that after the network is initialised, the packets of information about the nodes are broadcasted to all nodes and then DVHOP algorithm is performed by calculating hop counts.

Working of APIT is shown in the Figure 5 that neighbour information is calculated using RSS values and then test of triangulation is done to locate the nodes shown below:

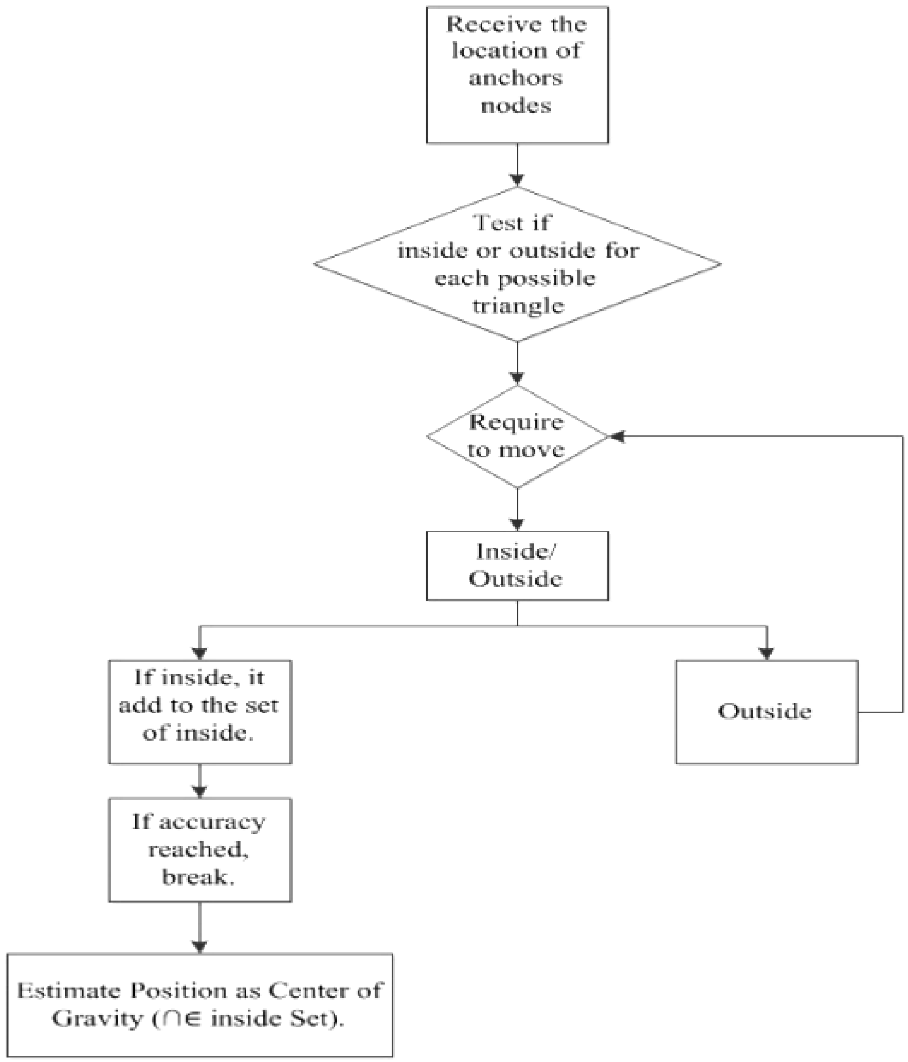

Figure 5. Flow Chart of APIT Algorithm

2.2. Network Parameters

In our experiments, we study several system-wide parameters that directly affect estimation error in the above two range-free localization algorithms. A description of these parameters follows:

2.2.3 Node Density (ND): Node density is defined as average number of nodes per node radio area.total number of nodes in the network are varied from 100 to 500.

2.2.4. Anchors Heard (AH): Average number of anchors heard by a node and used during estimation. More the anchors, better will be the accuracy. But number of anchors varies directly with the cost of network. Number of anchors are varied from 8 to 20 in our trials.

2.2.5. Anchor to Node Range Ratio (ANR): The average distance an anchor beacon travels divided by the average distance a regular node signal travels. When this value equals one, the anchor and nodes have the same average radio range. The larger this value, the fewer anchors required to maintain a desired AH value. We have taken value of this ratio from 1 to 5.

2.3. Performance Parameters

The main purpose of these experiments is to find the ideal solution for localization error. Performance of DV-HOP localization technique is evaluated on the basis of localization error for location of unknown nodes.

Localization error is the difference between actual location of unknown nodes and calculated location of these nodes. Therefore, localization error is determined by Euclidean distance between actual and calculated values and is given by:

$$E_r = \sqrt{\left(x - x'\right)^2 + \left(y - y'\right)^2} \tag{1}$$

Where (x, y) = actual coordinates of unknown nodes and (x', y') =calculated coordinates of unknown nodes.

Detail analysis of error is done using first and second order of error statistical tools considering different deployment strategies of anchors in a network:

2.3.1. Mean Localization Error

Mean of Localization error is first order error statistical tool. It is given by:

$$\overline{E_r} = \frac{\sum E_r}{n} \tag{2}$$

Where E_r is Localization Error of each unknown node that is calculated using Eq. (1) and n is number of unknown nodes.

2.3.2. Cumulative Distribution Function (cdf): Cdf of a real valued random variable X is given by

$$F_X x = P(X \leq x) \tag{3}$$

Where, P (X≤x) represents the probability that the random variable X takes a value less than or equal to x. CDF of localization error is first order error statistical tool. It is used to know the probability of occurrence of mean error at each simulation under the graph. Here, we have evaluated CDF of all placement strategies to get the information of spread of mean error for a specified deployment strategy. Lesser the slope of curve lesser the spread hence more will be the efficiency of localization.

2.3.3. Dispersion of Error: The localization error for each node location estimation deviates from its mean value. The amount of variation is calculated through standard deviation. It is given by:

$$S.D. = \sqrt{\frac{1}{n-1}\sum_{r=1}^{n}\left(E_r - \overline{E_r}\right)^2} \tag{4}$$

Where, Er is error at each node localization, $\overline{E_r}$ is mean error at each simulation and n is number of simulations. Standard deviation is a measure used to quantify amount of variation or dispersion of error values.

3. Performance Analysis of DV-HOP Technique

DV-HOP is implemented in two placement models: Random placement and uniform placement model.

Results for random placement and uniform placement by varying different network parameters are as shown below:

3.1. Varying ANR

From the Figure 6 and table 2, we observe that localization accuracy in random placement as well as in uniform placement doesn't show a fixed trend in response to variation in ANR but ANR=1 has the lowest value of all. So, in DV-Hop algorithm, the physical radio range of anchors is the same as that of target unknown nodes.So, the ANR is set to the distance an anchor beacon can propagate in units of node radio range (R).

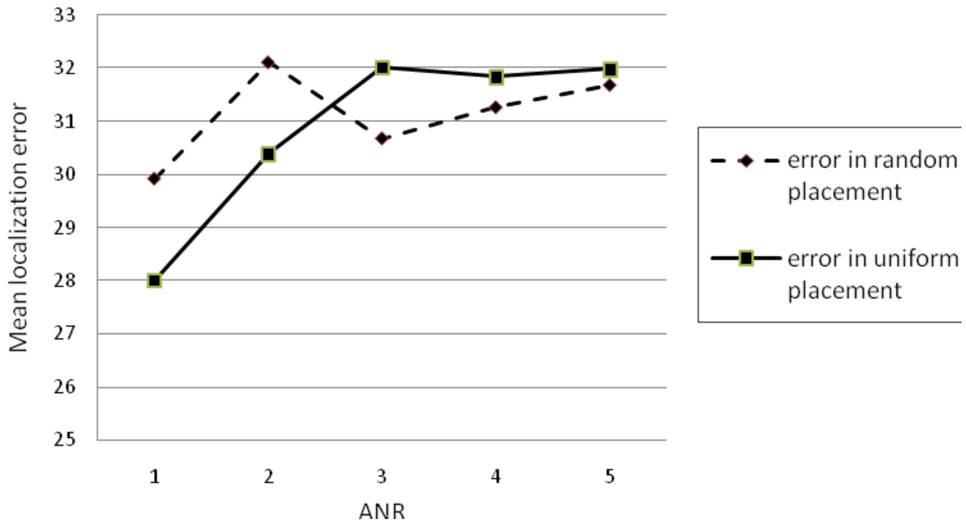

Figure 6. Comparison of Error by Varying ANR under Random and Uniform placement

Table 2. Error v/s ANR Values

ANR	Error in random placement	Error in uniform placement
1	29.92	28.02
2	32.12	30.39
3	30.68	32.01
4	31.27	31.83
5	31.69	31.98

3.2. Varying Anchors

The Figure 7 below shows that increasing the percentage of anchors improves the performance of localization but we have certain limits on the number of anchors in the network. More the anchors, more will be the hardware requirement and the energy consumed in the network and also more will be the cost of the network. So,in random placement we chose to have 10% anchor percentage in the sensor network. For this , radio range of 30-35 proved to be the best option with lower mean localization error as shown in the Figure 7 and table 3.

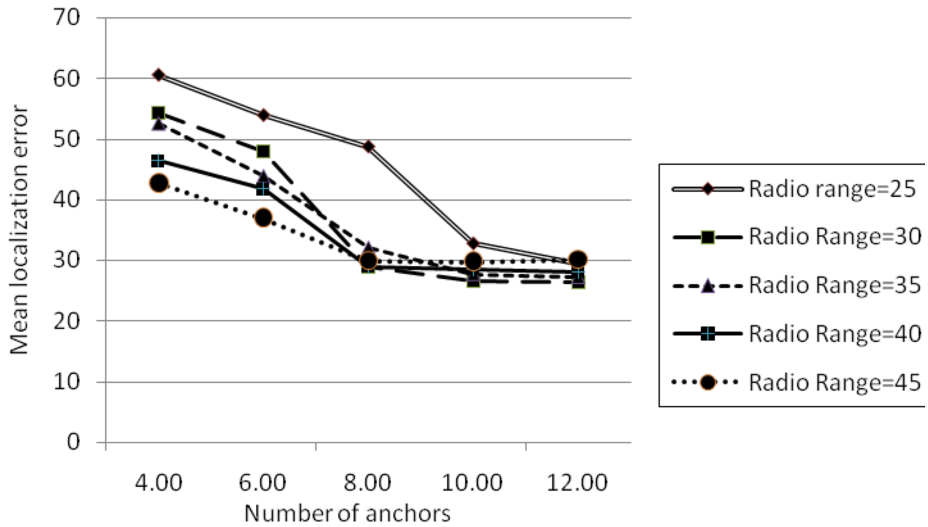

Figure 7. Mean Error by Varying Anchors at Different Radio Ranges (Random)

Table 3. Mean Error for Variation in Number of Anchors (Random)

Number of Anchors	Radio range=25	Radio Range=30	Radio Range=35	Radio Range=40	Radio Range=45
4	60.48	54.33	52.55	46.39	42.7
6	53.87	47.97	43.86	41.76	36.89
8	48.6988	28.9953	32.0553	29.0012	29.8454
10	32.7831	26.6071	27.7247	28.5666	29.7172
12	29.3798	26.3687	27.2341	28.1102	30.0974

Further, in uniform placement model shown in Figure 8, localization error showed a decrease in value compared to random. But the trend of change in error hence the accuracy was the same as in random placement. Table 4 showed the details of the error achieved during variation in the number of anchors. From the Figure 8 ,we observe that uniform placement is more reliable than random when 10% anchors are chosen in the network. Above 10% anchors ,error is little lesser but other important constraints of hardware,energy consumed and the cost of network cannot be neglected.

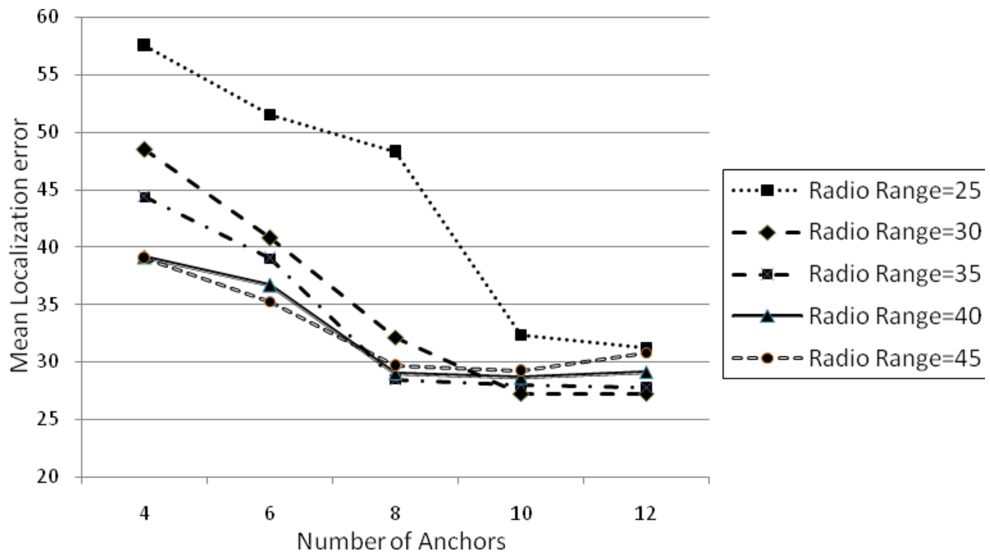

Figure 8. Mean Error by Varying Anchors using Uniform Placement

Table 4. Mean Error v/s Anchors at different Radio Ranges

Number of anchors	Radio Range=25	Radio Range=30	Radio Range=35	Radio Range=40	Radio Range=45
4	57.47	48.44	44.33	39.09	38.98
6	51.53	40.75	38.98	36.64	35.23
8	48.23	32.16	28.49	29.03	29.63
10	32.33	27.22	27.98	28.64	29.19
12	31.23	27.23	27.81	29.12	30.82

3.3. Varying Total Number of Nodes

Figure 9 shows the result of increasing node density in the network. More the sensor nodes in the network, lesser will be the communication range of sensors required. Also, results become more reliable. But above 300 nodes, error starts increasing due to interference between nodes.

Table 5. Mean Error v/s Total Nodes at Different Radio Ranges(Random Placement)

Radio Range	Total nodes=100	Total nodes=200	Total nodes=300	Total nodes=400	Total nodes=500
12	87.887	85.667	44.675	45.3456	28.985
15	50.3342	44.887	31.6846	26.98	26.6728
20	38.9987	29.7048	27.6424	28.5842	29.8181
25	28.9909	27.3317	28.9782	31.0427	32.51981
30	28.8801	28.8068	29.8672	33.1481	33.2284
35	27.7787	30.3086	33.0082	34.4759	35.421
40	31.2234	32.0382	34.0828	35.9696	35.92
45	32.7782	33.085	35.1975	37.887	38

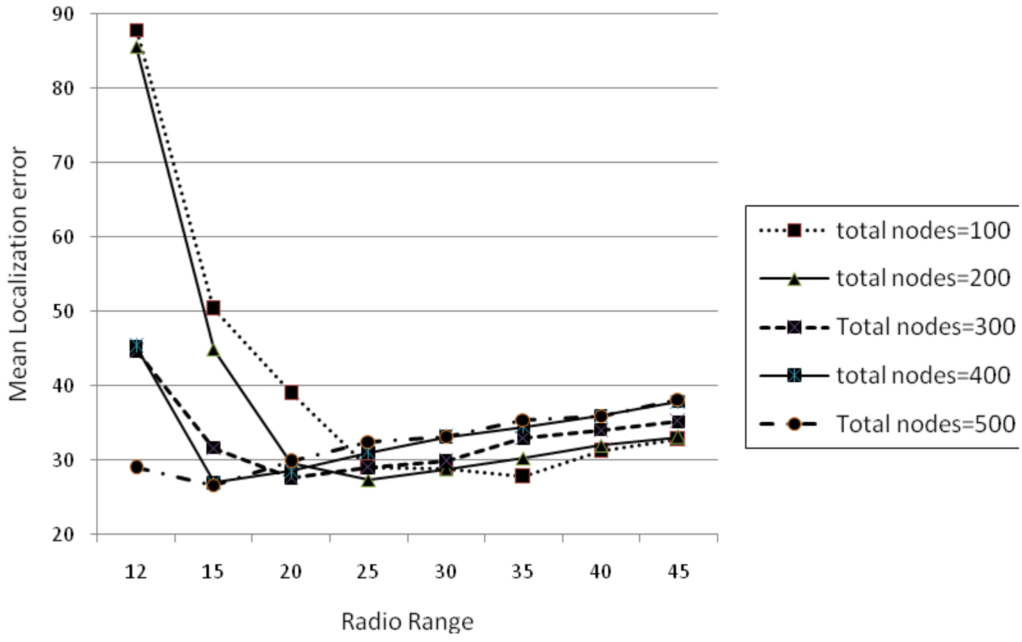

Figure 9. Mean Error varying Total Nodes (random placement)

Figure 10 shows the result of increasing total number of nodes in the network under uniform placement model.We can clearly understand that uniform model performed better than random by producing lesser error in the same conditions of network.

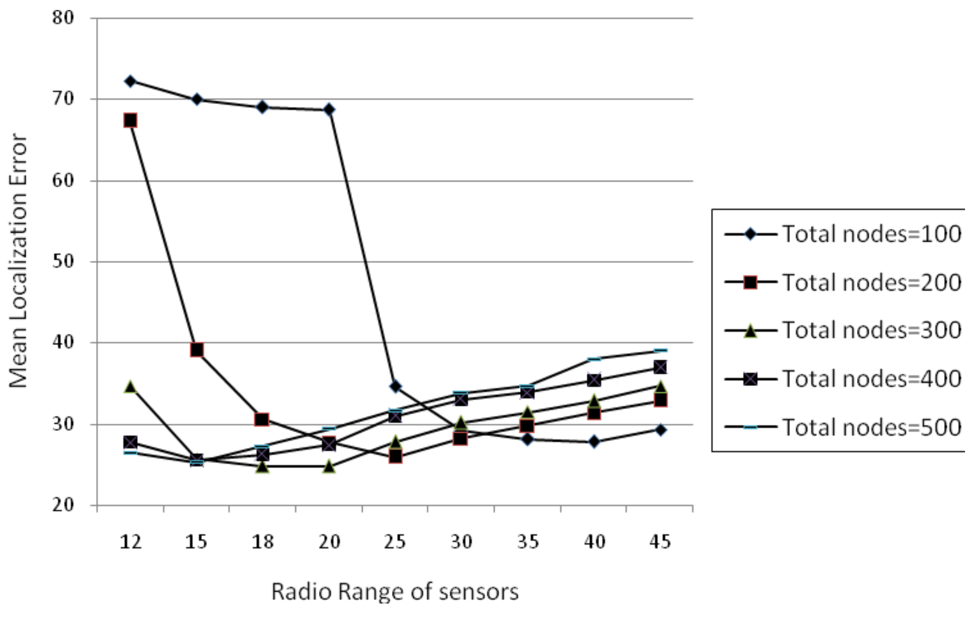

Figure 10. Mean Error Varying Total Nodes(uniform placement)

Table 6. Mean Error Varying Total Nodes (uniform placement)

Radio range	Total nodes=100	Total nodes=200	Total nodes=300	Total nodes=400	Total nodes=500
12	72.262	67.242	34.6724	27.7369	26.4417
15	69.9987	38.9826	25.6394	25.5456	25.2821
18	68.9908	30.5343	24.7925	26.2466	27.2532
20	68.6668	27.6957	24.8256	27.403	29.3555
25	34.5719	25.8963	27.7928	30.9395	31.6948
30	29.1206	28.2301	30.1838	32.9838	33.7979
35	28.0855	29.7911	31.4662	33.876	34.6542
40	27.8125	31.3574	32.8282	35.3643	37.9876
45	29.266	32.8695	34.6755	36.9879	39.0065

So, we conclude that DV-HOP performs better in uniform placement model with 10% anchors in the network i.e. 30 anchors and 300 total nodes gives a reliable DV-HOP localization system as shown in figure 10 and table 6.
Cummulative distributive function is used as first order error analysis tool.

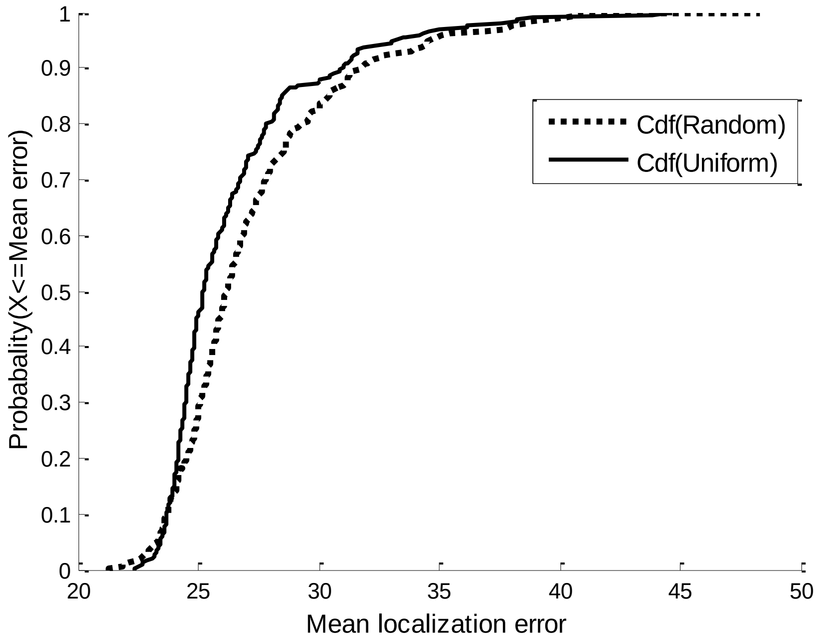

Figure 11. Cdf Graph between Errors for Random and Uniform Placement

Figure 11 shows that cdf graph of uniform placement reaches its maximum value prior to random one. This shows that uniform placement has less uncertainity. Thus, making localization system more reliable.

4. Performance Analysis of APIT Technique

APIT technique is also implemented using two placement models: Random and Uniform

ANR values variation, anchors and node density of the network affect the localization as is shown below in our experiments:

4.1. Varying ANR

Figure 12 and table 7 shows that as anchor to node radio range ratio increases from 1 to 3,the error decreases but from ANR=4, it started increasing again.So, ANR=3 is suitable for all the scenarios considered further.

Table 7. Mean Error Varying ANR(Random and Uniform)

ANR	Mean Error (Random)	Mean Error (uniform)
1	44.76	40.23
2	38.29	37.28
3	32.01	31.17
4	34.99	32.91
5	36.19	34.81

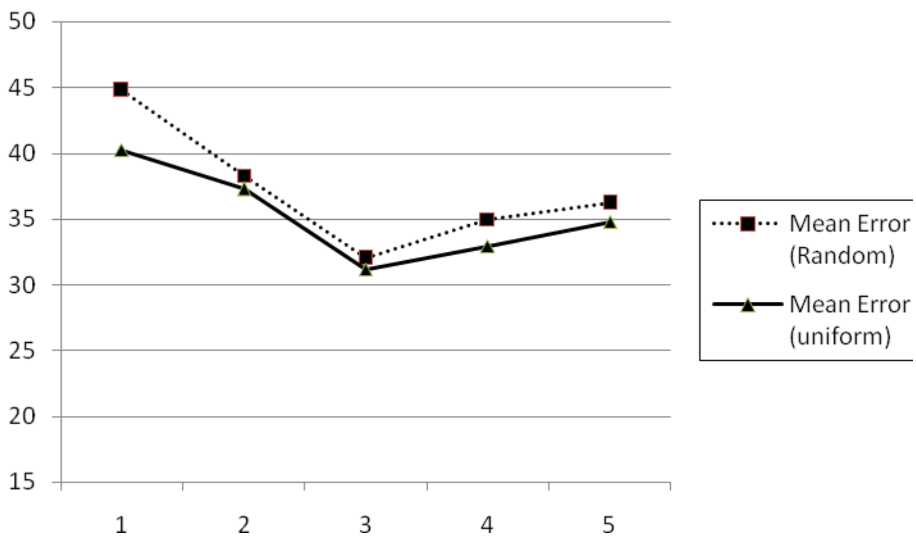

Figure. 12 Mean Error Varying ANR

3.2. Varying Number of Anchors

In Figure 13, we observe that in APIT, the mean localization error decreases with large difference as the anchors in the network are increased gradually.in random placement of nodes in the network APIT has shown better performance than DV-HOP as radio range range required by anchors and nodes respectively is very less .So, we finalise 10% anchors in the network to give desired results as shown in figure 13 and table 8.

Table 8. Mean Error v/s Anchors (random)

Node-anchor Radio Range	Anchors=4	Anchors=6	Anchors=8	Anchors=10	Anchors=12
4,12	52.26	40.39	36.43	29.52	28.92
5,15	42.19	37.17	30.01	28.71	29.59
6,18	38.9	34.52	33.01	32.68	31.96
8,24	38.29	34.71	35.15	33.37	34.01
10,30	36.61	33.44	35.3	34.32	35.87

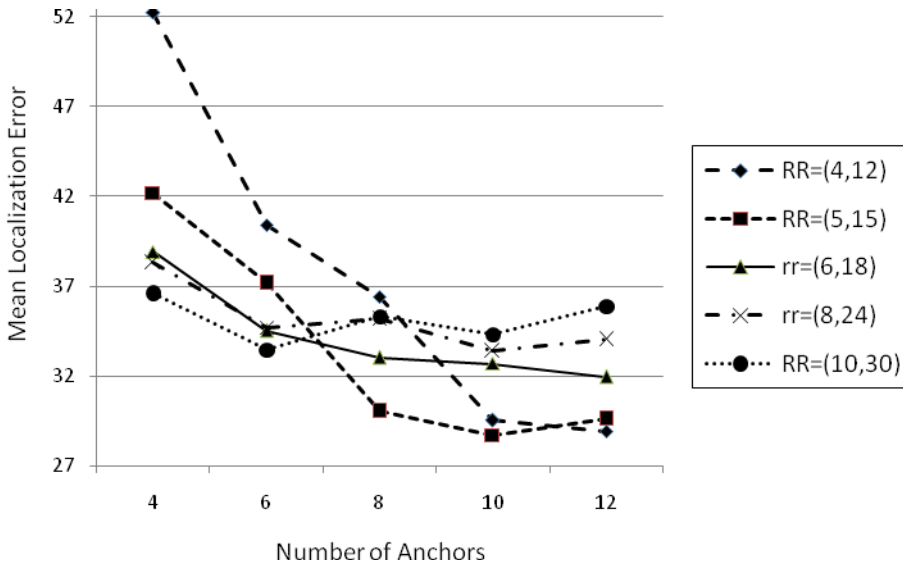

Figure 13. Mean Error Varying Anchors(random)

In uniform placement as shown in figure 14, variation in anchors quantity largely affects the the accuracy of network.As we increase the anchors, error is decreased. After 10% anchors , the decrease in the error i.e. increase in accuracy is not large enough to ignore hardware ,energy consumption increase due to increase in the number of anchor.So, 10% anchors gave desired results in the network under uniform placement.

Table 9. Mean Localization Error v/s Anchors (Uniform)

Node-Anchor Radio Range	Anchors=4	Anchors=6	Anchors=8	Anchors=10	Anchors=12
4,12	50.45	39.34	30.02	29.35	29.01
5,15	35.21	33.34	28.95	27.62	27.09
6,18	38.01	35.74	33.38	32.26	30.63
8,24	38.9	35.74	34.07	34.66	31.56
10,30	41.2	37.9	35.21	34.19	34.63

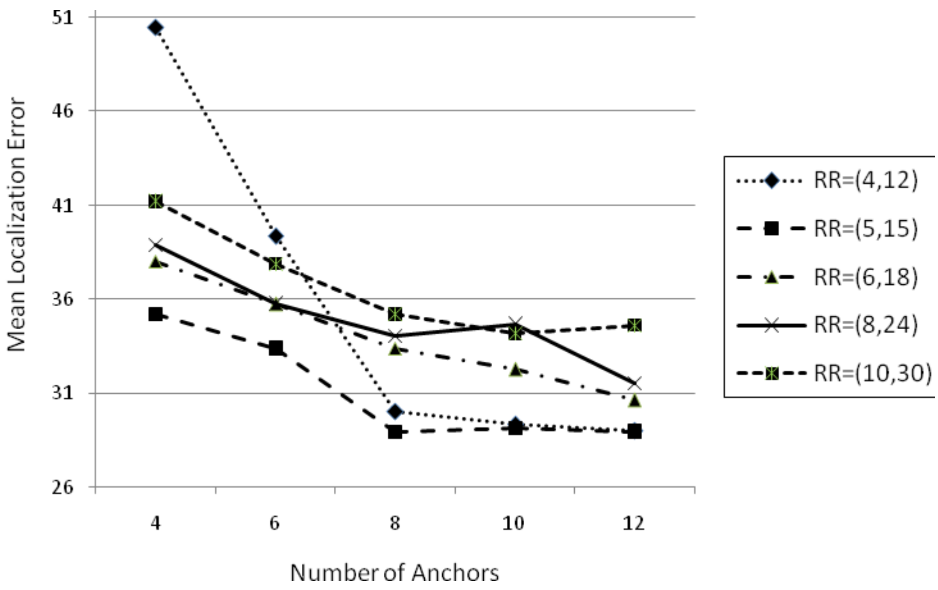

Figure 14. Mean Error Varying Anchors(uniform)

3.3. Varying Total Number of Nodes

Figure 15 depicts that higher sensor node density in the network results in lesser localization error. Hence, reliability on network increases if the network is denser. But this trend follows an increasing graph above 300 nodes in 100x100 square area of network. In Random placement, mean error shows the increasing trend at higher ardio ranges as it can settle with lesser error at low radio ranges when the network is dense as shown in table 9.

Table 9. Mean Error v/s Total Nodes

Node-Anchor radio range	Total nodes=100	Total nodes=200	Total nodes=300	Total nodes=400	Total nodes=500
3,9	39.92	36.93	22.99	17.47	15.11
4,12	37.15	22.07	22.87	24.35	28.9
5,15	28.91	31.89	33.92	33.98	42.71
6,18	32.78	35.52	37.9	39.82	47.3
8,24	34.09	35.99	38.38	40.34	47.55
10,30	37.89	36.95	42.37	48.57	49.17

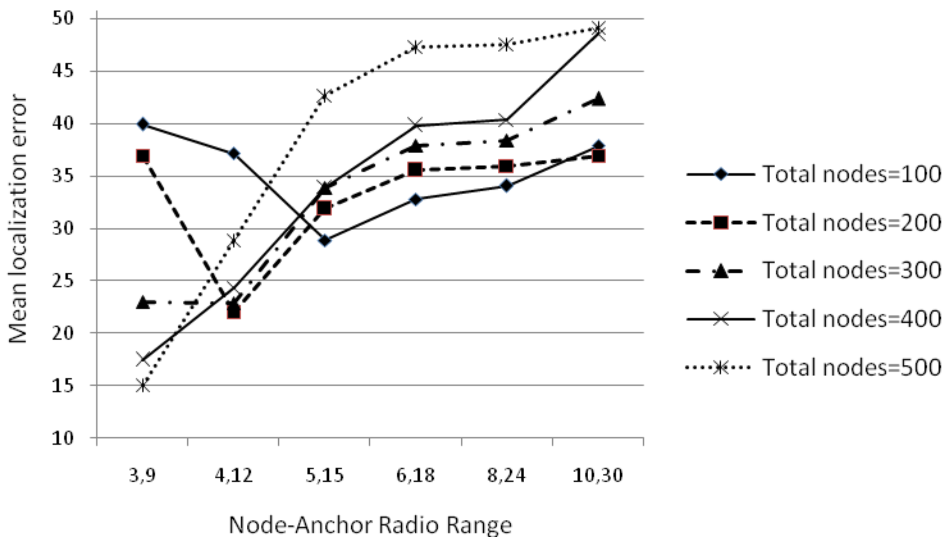

Figure 15. Mean Error Varying Total Nodes (random)

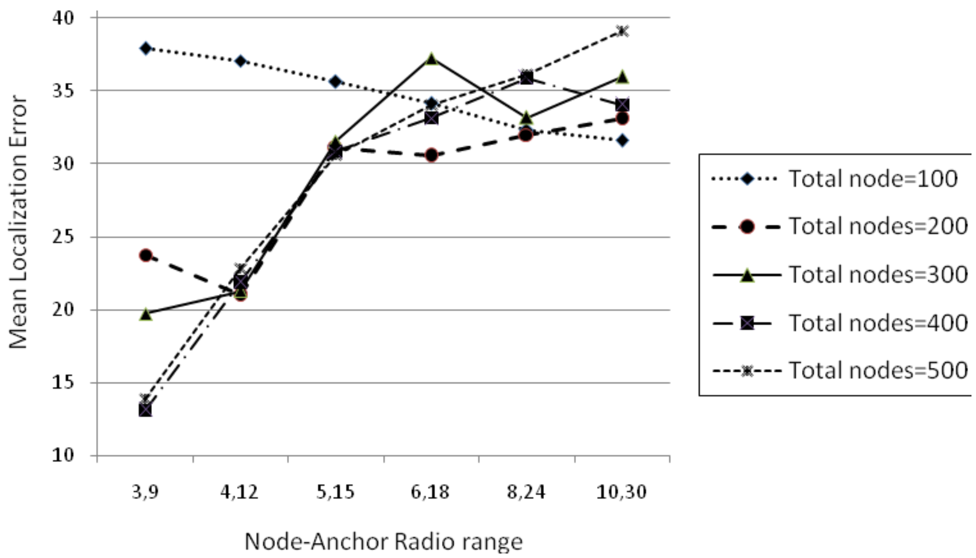

Figure 16. Mean Error Varying Total Nodes(uniform)

Table 12. Mean Error Varying Total Nodes(uniform)

Node-Anchor radio range	Total nodes=100	Total nodes=200	Total nodes=300	Total nodes=400	Total nodes=500
3,9	37.89	23.77	19.75	13.13	13.91
4,12	37.09	21	21.29	21.89	22.82
5,15	35.61	31.06	31.57	30.86	30.6
6,18	34.12	30.55	37.25	33.15	34.02
8,24	32.3	32	33.18	35.88	36.12
10,30	31.61	33.09	35.96	34.04	39.14

In uniform placement model shown in Figure 11 and table 10, the accuracy of network is significantly increased with increase in the total nodes placed in the network. Due to increase in error at 400 and 500 nodes ,we chose a network with uniform placement and 300 total nodes of which 30 are anchors as desired network for APIT to work properly as shown in Figure 11below.

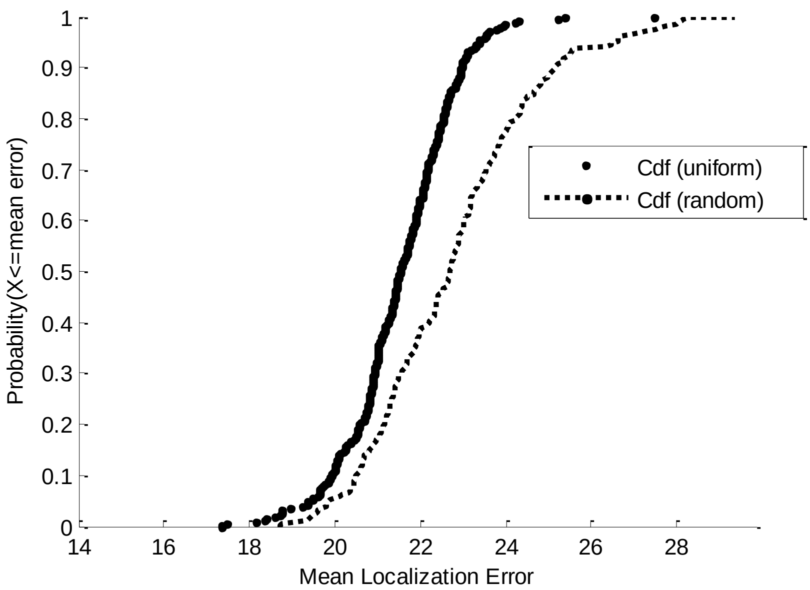

Figure 17. APIT Cdf (Random v/s Uniform)

From the Figure 12 above,it is clear that uniform placement error has very less slope.this means that APIT uniform is better than random.

5. Performance Comparison of DV-HOP and APIT Localization Algorithms

In the above sections, we have done detail analysis of APIT and DV-HOP localization system. Individually both the schemes satisfy to almost same network scenario.So, we will compare both the schemes on the basis of their best scenarios chosen i.e. uniform placement, 300 total nodes and 30 anchors.

We propose a regular placement of anchors to get better results. The observation is explained below:

DV-HOP produces localization error of 22.34 in the network of 300 nodes and 30 anchors and used radio range of 13 units whereas APIT gave error of 21.03 with node-anchor radio range of just (4-12) units. To approve our results, we will further use first order and second order statistical tools to anlyse the localization error.

Figure 18 compares DV-HOP and APIT accuracy by using Cdf of error .We observe that APIT reaches the maximum value at very early stage as compared to DV-HOP.This means that uncertainity of error in APIT is lesser than DV-HOP making it more reliable system than DV-HOP.

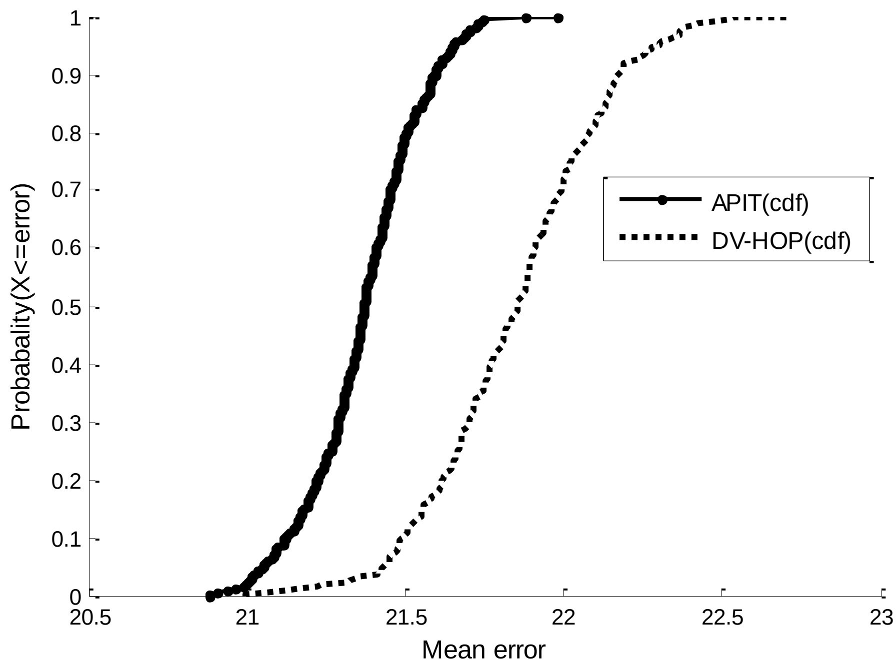

Figure 18.Cdf Comparison of APIT and DV-HOP (regular placement)

Further standard deviation is second order error analytical tool used to check the dispersion of error. More the dispersion more will be the unreliability. So, graph with lesser dispersion is better i.e APIT is better than DV-HOP as shown in Figure 19.

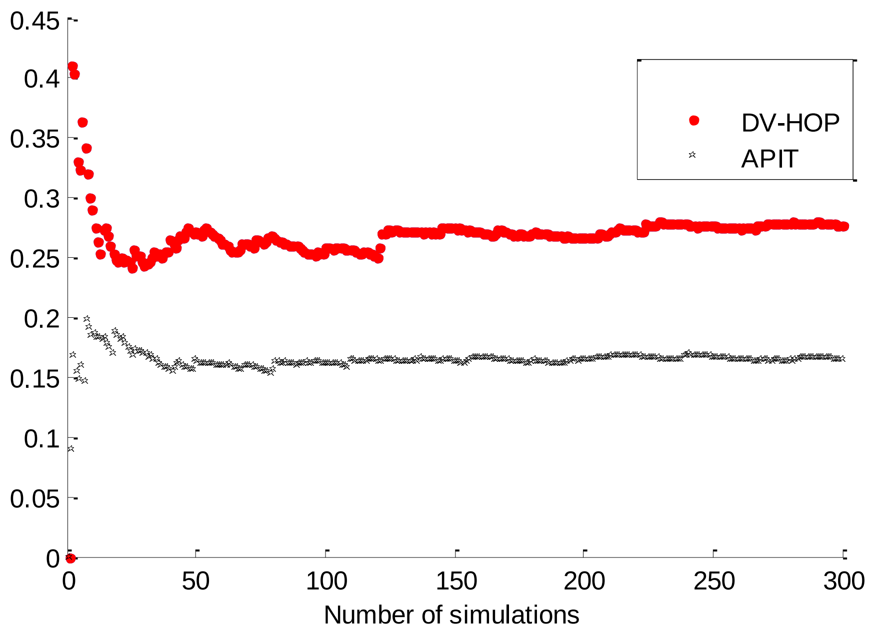

Figure 19. Standard deviation of DV-HOP v/s APIT

6. Conclusion

In this paper ,results and analysis of implementation of DV-HOP and APIT localization techniques have been shown under different scenarios by considering several network parameters.We have concluded that uniform placement of nodes gave better results than random placement.Further, we proposed square regular placement of anchors so that they are at the reach of all nodes. We observe a large improvement in the performance of both the techniques. Finally APIT showed better performance than DV-HOP in the structured deployment of anchors in the network on the basis of accuracy obtained during localization..

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