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A Comparison of Distributed Range Free Localization Algorithms in Wireless Sensor Networks

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Abstract

Background/Objective: In most of the applications of WSN from traffic monitoring to military applications via surveillance location of the node is the prime concern. Various localization algorithms are there for the position estimation but their capabilities are varying from one another in the context of the deployment mode, accuracy in location determination and complexity. Hence this paper focuses on the comparative analysis of various range free localization algorithms under distributed environment. **Methods/Statistical Analysis:** Algorithms such as APIT, DV-Hop, MDS-MAP, Centroid, Grid Scan, Bounding Box and Amorphous are tested in MATLAB under various parameters and results are then compared. **Findings:** Main parameter for the comparison is the localization error. Simulation results emphasis on the algorithms suitability with respect to the parameters in hand. From the results it is evident that with the increase of the number of nodes the localization error value decreases and also by increasing the range value the same impact is seen on the error value. MDS-MAP is the best approach of localization in both of the scenarios either by increasing the node amount or by increasing the range value.

Keyword: Bounding Box, Centroid, Distance Vector, Grid Scan, Localization, Range Free

1. Introduction

Wireless Sensor Network (WSN) is one of the latest areas to work on as its applications are there in environment monitoring, habitat monitoring, military and defense to disaster management. No area is left where we can't find any application and relevance to WSN. In most of the stated applications the nodes need to collect the position of interest and this has to be done with full precision otherwise there will be abnormalities in the final results. This makes the localization algorithms in to the picture. For the successful completion of event in WSN the accuracy in location determination is the prime concern. Hence the suitability of a particular localization algorithm is based on the accuracy in providing the exact location values. So there is need of analysis of various localization algorithms in order to choose the best out of them.

Localization algorithms are categories on the basis of the location determination mechanism in to two classes: Range based localization[1] and Range free[2] localization. Range based uses the distance information and angle values to compute the position of unknown[3] nodes with the help of various techniques like Received Signal Strength (RSS), Angle Of Arrival (AOA) and Time Difference Of Arrival (TDOA) whereas Range free techniques are not taken in to account the distance and angle information in order to compute[4] the unknown node position . Although the accuracy of range based techniques is more as compared to range free techniques as the use of GPS in range based makes the calculations more accurate one but the cost and the special hardware requirements turns more in the favor of range free localization techniques and this makes them most favorable. This paper focuses on the range free localization algo-

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rithms under distributed environment as in centralized the robustness of the algorithm is compromised in case of central node failure. As a result this research paper focus is on distributed range free localization algorithms. In this paper seven classical localization algorithms: APIT, DV-Hop, MDS-MAP, Centroid, Grid Scan, Bounding Box and Amorphous are analyzed on the basis of simulation results in MATLAB. Various localization algorithms are compared and tested on the same parameters like range value, localization error and connectivity so that better inference can be gain for the algorithms and it helps in selecting a particular algorithm for specific application based on their parameters.

2. Algorithms Introductions

Localization is the process of determining the position of unknown node based on the known node position by some mechanism or logic integrated in the algorithm. This section provide an overview of the various localization algorithms stated above for understanding the process of location determination of unknown node.

2.1 Centroid Localization Algorithm

In this approach the anchor nodes broadcast a beacon signal to all the nodes in the network and when the signal that is received from the unknown nodes exceeds a particular threshold value or received after a particular time the process stops . Location of unknown node[1] is computed as the polygon of centroid. Implementation of the algorithm is very simple but having one deficiency is that accuracy of the algorithm is based on higher density of the anchor nodes.

2.2 Amorphous Localization Algorithm

This algorithm[5] is the enhancement of the DV-Hop algorithm to large extent as it assumes that the network connectivity value is already known to the nodes in order to find the average hop distance. Then the average hop distance is multiplied with the minimum hop count value to compute the position of the unknown node[1].This algorithm also suffers from the high node density requirements for better accuracy.

2.3 DV-Hop Localization Algorithm

This algorithm[6] consists of three steps in position determination like in the first step[4] each anchor node broadcast a beacon signal in the containing its location and hop count value initialize to zero. After wards each nodes maintains the data about the minimum hop count value per anchor along with the signals it receives. Beacons with higher value are to be ignored. In the second step the distance between the unknown node and anchor node is estimated using the maximum likelihood estimation or some another method. Then in the last step the actual distance is calculated as the multiplication of average hop size and the hop[7] count value.

2.4 APIT Localization Algorith

This algorithm[8] taken in to the consideration the intersection of the triangle with respect to each node as a polygon and then determining the smaller area including the unknown node and then again considering the position of centroid as the position of unknown node. Disadvantage of this technique some nodes to be equipped with high power transmitters to obtain the information.

2.5 Bounding Box Localization Algorithm

This algorithm[9] takes the square as the communication area for a particular node with range as the radius and twice the range value as the length of the side of square. Position of the unknown node[1] is taken as the intersection of the three squares or the centroid of the rectangular region.

2.6 MDS- MAP Localization Algorithm

This algorithm first calculates the distance matrix that serves as the input to multi dimension scaling .Basically this distance is the shortest distance between every pair of nodes. After wards the relative map is to be calculated based on the inputs of first step. At last relative map is converting to absolute map using minimum number of anchor nodes. Advantage of this approach is to generate relative map in spite of no anchors nodes.

2.7 Grid Scan Localization Algorithm

In this algorithm first of all each anchor node collects the information about all the anchors that are at a distance of 2 hops from it and this information is named as 2 hop flooding . After wards the estimated region is calculated as the overlapping region of all circum rectangles whose length and breadth is two times the range value of anchor node. At last the grid points are find out and validated and tested based on the distance from the anchor nodes.

3. Simulation and Analysis of Algorithms

Performance of the localization algorithms based on large number of factors and network parameters like the model and the deployment strategy which is further classified in to random, regular or square random. Number of anchor nodes and radio range[10] can be the parameters for the comparison of various algorithms. Apart from this density of nodes and connectivity can also be considered for the analysis of algorithms. Thus localization error estimation needs to consider there all parameters for better contrast among the range free algorithms.

It is assumed that sensor network composed of 300 nodes deployed randomly in a given environment of 1000 m* 1000 m with 0.2 GPS error. Communication range is taken as 200 m in this scenario. Deployment of nodes is done in square random fashion with regular model in hand. The position of the nodes is generated in random fashion in each iteration of the algorithm for all different localization approaches as mentioned in the paper. Figure 1 is a distribution of the nodes in case of DV Hop localization algorithm, Figure 2 represents the position of nodes in case of APIT, and moreover other figures would be around same for other algorithms representing the position of beacon and unknown nodes in the given environment mentioned above. In the Figure 1 red* represents

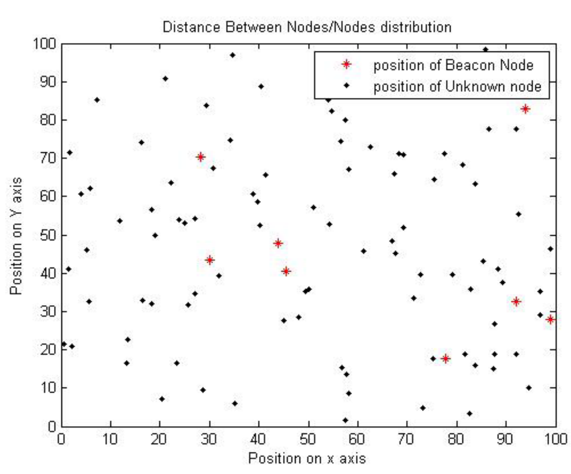

Figure 1. Node distribution in DV hop.

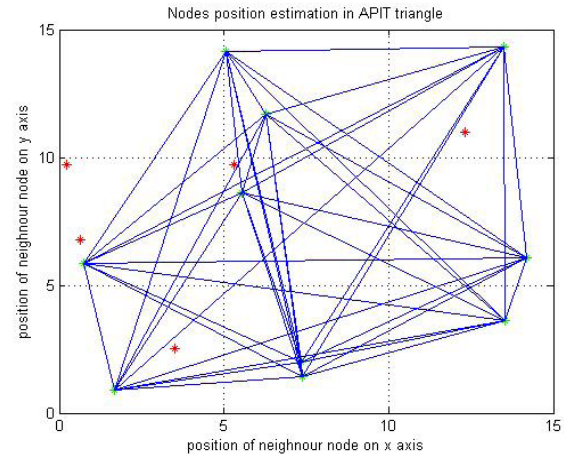

Figure 2. Node distribution in APIT.

the position of beacon nodes and black rectangle represents the position of unknown nodes. While in Figure 2 red* represents position of unknown node and green* represents the position of known node. By implementing the various algorithms, percentage in localization error is being calculated with respect to changing the number of nodes for all seven algorithms as mentioned in Figure 3 and 4 respectively for Centroid and DV Hop localization.

Average Network connectivity value for Amorphous in case of changing the number of nodes from 50 to 300 is 18.66 and keeping the number of nodes fixed i.e. 200 and varying the communication range from 50 to 200 is 8.38. Same results while applying on others algorithms turn out as, in case of APIT is 18.13 while changing the nodes and 8.53 while the node amount is fixed and range is vary. For Bounding Box it is 18.431 and 8.594 respectively, 17.69 and 8.72 for Centroid and 18.47 and 8.55 for DV Hop, moreover 18.35 and 8.28 for Grid Scan, 18.58 and 8.49 in case of MDS-MAP.

By implementing the various algorithms, localization error is being calculated with respect to changing the number of nodes and the range[11] value under different iterations for all seven algorithms as mentioned in Figure 5 and 6.

In Figure 5 the x coordinate represents the value of nodes starting from 50 to to 300 with the increment of 50 nodes in each step and y axis represents the value of localization error with respect to nodes value for all the algorithms as mentioned above. Figure 6 represents the range value in the x axis varying from 50 to 200 and localization error in terms of y axis but by keeping the number of nodes fixed i.e. 200 for different algorithms.

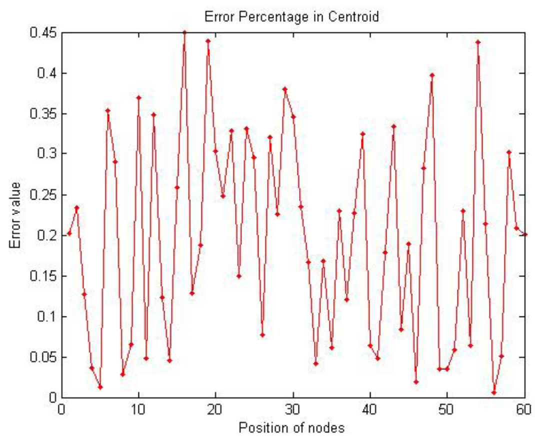

Figure 3. Localization error in Centroid .

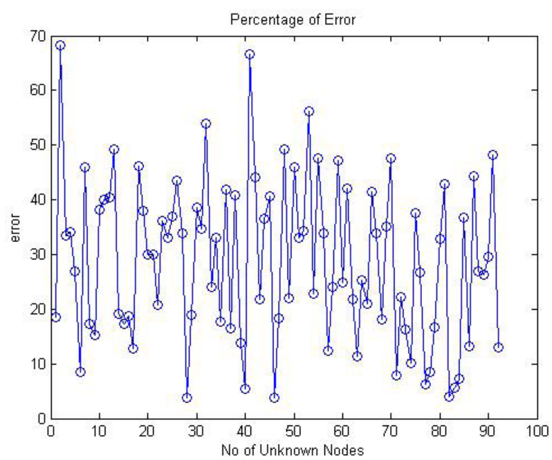

Figure 4. Localization error in DV Hop.

From the Figure 5 it is concluded that localization error is maximum for the DV Hop and Bounding Box in the beginning when the number of nodes are around 50 and as the number of nodes are increasing localization error in decreasing and it is minimum in case of MDS-MAP and maximum for the Centroid approach. It is evident from the results that as the number of nodes are increasing the error value decreasing to some extent as more nodes are available for the computation of the position of unknown node.

Also from the Figure 6 it is evident that even if the range value is increased for the various localization algorithms their error value reduces to large extent as more number of nodes will be available for the computation of unknown position very precisely. Like from Figure 6 it is concluded that error is maximum in case of Grid Scan in the beginning when the range value is 50 and later when

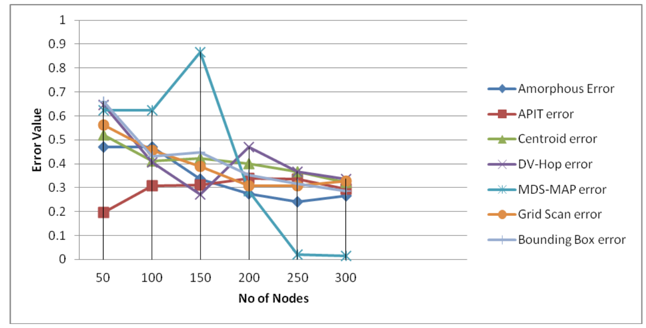

Figure 5. Localization error with respect to number of nodes for various localization algorithms.

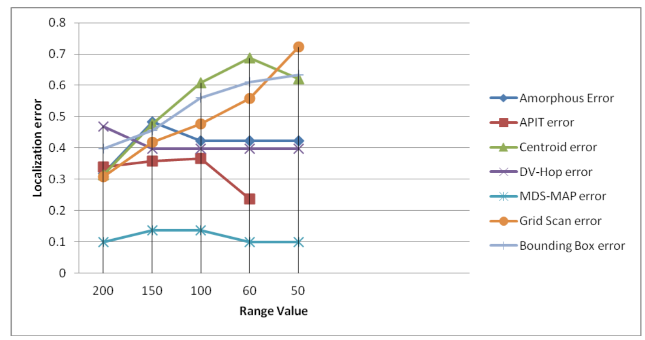

Figure 6. Localization error with respect to number of nodes for various localization algorithms.

the range is reach up to 200 the value of error is reduce drastically. So increasing the value of range definitely will reduce the value of localization error for almost all algorithms in spite of DV Hop where the error value increases after the range value of 150. It is concluded that MDS-MAP is the best approach for the better localization in the given scenario.

4. Conclusion

Localization is one of the prime concerns for various event sensitive applications. Simulation of various algorithms is being done under various parameters like the node amount and the range value with respect to the localization error value. From the results it is evident that with the increase of the number of nodes the localization error value decreases and also by increasing the range value the same impact is seen on the error value. MDS-MAP is the best approach of localization in both of the scenarios either by increasing the node amount or by increasing the range value. But in case of DV Hop and amorphous algorithm the change in the error is quite less both of the schemes are based on average hop distance. So node density can be one of the major issues that can affect the accuracy of localization algorithm as ultimately it links with the network lifetime of the network. Moreover future work will be on distributed localization algorithms in three dimensional spaces with security aspect added to it and also by employing the Meta heuristics[12] approach for better localization.

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