Tabu Search Algorithm for Localization in Wireless Sensor Network

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ABSTRACT
In Wireless Sensor Networks (WSNs), localization is considered as one of the most significant issue as it plays a critical role in many applications such as target tracking, routing etc. The main idea of localization in wireless sensor networks is that some deployed nodes with known coordinates (e.g., GPS-equipped nodes) transmit beacons with their coordinates in order to help the other nodes in the sensing field to localize themselves. Broadly there are two types of localization methods used for calculating positions namely the range-based and range-free methods. The Mobile Anchor Positioning - Mobile Anchor & Neighbour (MAP-M&N) method categorized under the range-free technique is initially applied in which the sensor nodes use the location information of beacon packets of the mobile anchor node and the location packets of neighbouring nodes to improve the accuracy in localization of the sensor nodes. In this work, the proposed Meta-Heuristic Optimization Algorithm named Tabu Search is used along with MAP-M&N to further improve the accuracy in positioning of the sensor nodes. An analysis on Average localization error and comparison between these two approaches namely, MAP-M&N and MAP-M&N with Tabu Search have been done.

Keywords
Wireless Sensor Networks, GPS, Localization, beacon packets, MAP-M&N, Meta-Heuristic, Tabu Search.

1. INTRODUCTION
A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions such as climate prediction, analysis of sane, atmospheric pressure, etc. and it passes their data by using network to the desired location. The current networks are bidirectional, also these networks have the enabling capacity to control sensor activities. The enhancement of wireless sensor networks was motivated by military applications such as security in battlefield,and also used in many industrialized and consumer applications, such as industrial procedures,screening and control,health monitoring etc. Henceforth, opposing to classical networks, WSNs are useful only if sensor nodes are aware of the environment surrounding them.Each sensor could only monitor its region and proceed to send the collected data to the sink node. However, the conceivable efficiency of WSNs lies in its ability to correlate the collected data in time and in space [1].

1.1 Localization
The locational information plays a vital role in coverage, deployment purpose, routing information, locational service, target tracking and rescue operations in wireless sensor networks. The localization information is important where there is an ambiguity about some positioning. If the sensor network is used for observing the temperature in a building, it is obvious to know the accurate location of each node [2,3]. On the adverse, if the sensor network is used for observing the climatic condition in a remote forest, sensor nodes may be spread out in the location by airplane and the respective location of most sensors may be unknown. A localization algorithm can use all the available localization information from the motes to compute all the positions. Nodes are deployed with a Global Positioning System (GPS), but this is a costly solution in terms of volume, money and power consumption.For this purpose many localization protocols are proposed [4]. Localization in wireless sensor networks is performed by following these 3 steps:

1. Distance estimation - This phase involves measurement techniques to estimate the relative distance between the nodes [4].

2. Position computation - It consists of algorithms to calculate the coordinates of the unknown node with respect to the location of known anchor nodes or other neighboring nodes. Triangulation, multi-lateration, and proximity are some techniques that are used for sensing location.It uses the geometric properties of triangles to calculate node locations. Triangulation are classified into lateration and angulation. lateration is calculated using distance measurements and angulation is calculated using angle information.2-dimension method is to calculate the node location using lateration ,distance information from 3 reference points is required and using angulation,2 angle measurements and 1 distance information is required [5].

3. Localization algorithms - It determines how the information concerning distances and positions are manipulated, in order to allow most of the nodes of WSN to estimate their position. Optimally the localization algorithms may involve algorithms to reduce the errors.In this paper, range free localization algorithm namely MAP-M&N and meta-heuristic algorithm Tabu Search was proposed along with MAP-M&N and the average error in localization was analyzed using these algorithms.

2. RELATED WORK

2.1 Range-based Localization method
Nabil Ali Alrejeh et al. [6] have proposed the range-based and range-free localization techniques. These techniques estimate, point-to-point, the distance between each pair of nodes. With this information and using techniques, such as multilateration, triangulation or other methods, the absolute position of the non-anchor nodes can be estimated. Lovepreetsingh et al. [7]

described on range-based localization techniques such as Received Signal Strength Indication (RSSI), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA). New algorithms continue to appear based on these classical methods for the improvement of accuracy, for example, based on AoA, based on ToA and based on TDoA. Other authors propose new range-based algorithms that uses a likelihood calculation for determining the distance.

Received Signal Strength Indication: It requires no additional hardware, and are unlikely to significantly impact local power consumption, sensor size and thus cost.

Time Difference of Arrival: There is a category of localization algorithms utilizing TDoA measurements of the transmitter's signal at a number of receivers with known location information to estimate the location of the transmitter.

Time of Arrival: In this technique cross-correlation method is used to estimate the location of the sensor node.

Angle of Arrival: The beam of the receiver antenna is rotated electronically or mechanically and the direction corresponding to the maximum signal strength is taken as the direction of the transmitter. Relevant parameters are the sensitivity of the receiver and the beam width.

In general, the range-based methods offer good accuracy, but additional hardware is often needed. Therefore, the weight, the cost and the power consumption of the node devices increase and make these techniques unsuitable for the proposed application. RSSI range-based techniques are an exception to this because most of the current transceivers provide this measurement by default. However, RSSI techniques are very sensitive to noise and interferences. The RSSI techniques require calibration and a model of the environment. Moreover, the calibration could change according to the environmental conditions. The determination of how to improve the accuracy of the RSSI techniques is an important research area.

2.2 Range-free Localization method

W.-H.Liao et al. [8] described about the range-free localization techniques. In range-free localization methods, neighborhood information such as node connectivity and hop count is used to determine the nodes location. Additional hardwares are not required for range-free methods. They generally work well when networks are dense. By nature, sparse networks contain less connectivity information and it is more difficult to localize accurately. These algorithms required to interact with each other i.e. in the communication range of each other. Their locations are estimated by using ideal radio range of sensors. Range-free techniques are most cost-effective because they do not require sensors to be equipped with any special hardware but use less information than range-based.

In these algorithms, the position of the non-anchor nodes are obtained from the exchange of beacon packets among the nodes (anchor and non-anchor nodes).

Beacons contain different information such as

Radio coverage membership: An anchor node detects whether a non-anchor node is in its radio coverage. Using this information, the system can estimate the non-anchor nodes position. The intersection coverage areas of every anchor are determined.

Number of hops to an anchor-node: If there is no connectivity with an anchor node, a non-anchor node can estimate its position knowing the number of hops to every anchor node. For example, consider that Node A is at a distance of two hops to first anchor node, three hops to second anchor node and two hops to third anchor node. According to this information and considering the mean distance between the nodes, the absolute position can be calculated by applying algorithms, such as triangulation. The most common range-free localization techniques are Centroid Algorithm [9], Distance Vector Hop (DV-Hop) method [10], Approximate Point-In Triangulation Test (APIT) Algorithm [11] , etc.

3. PROPOSED METHODOLOGY

The proposed methodology is based on initially applying Mobile Anchor Positioning with Mobile Anchor & Neighbour (MAP-M&N) algorithm and then combining MAP-M&N with Meta-Heuristic algorithm [12] named Tabu Search optimization algorithm for localization.

Mobile Anchor Positioning

The nodes are disseminated in the sensing field. Here number of sensor nodes used are 80 and number of mobile anchor nodes used are 3.So the sensor nodes of the number having 81,82,83 are considered as anchor nodes.The Anchors move throughout the field according to the movement file created in simulator. As they move they broadcast their positions periodically through the beacon packets, at fixed time interval, to all the nodes which are at a hearing distance from it. The beacon packet which was broadcasted by anchor node consists of its id and location of the anchor node. The format of beacon packet is as shown in Figure 1 below:

2 octets	2	6	6	2	0-2312	4
Frame control	Duration	Address	BSSID	Sequence control	Frame body	FCS

MAC Header

Figure 1. Beacon packet format

Since the anchor node has mobility, the location of the anchor node is updated periodically.The anchors traverse around the field with a specific speed and their directions are set to change for every 10 seconds. Visitor list is being maintained by every sensor node in the field. It has the location information that is being extracted from the beacon packets. It collects enough information from the packets sent by mobile beacons before estimating its position. After collecting enough beacon packets, the first and the last beacon packets of the node in the visitor list are selected. The beacon points are considered as an approximate endpoint on the sensor node's communication circle. This is assumed to be the two extremes of a node's communication range. These points are considered to be the center points and two circles are drawn. The intersection points of the two circles are the two possible locations of the sensor node. Given the two centers and the radius, the intersection points are calculated.

CASE 1: If the distance between radius of the two circle is greater than the sum of radius, then the circles have no intersection points.

CASE 2: If the distance between radius of the two circle is less than the difference of the two radius, then one circle is within another and there are no solutions.

CASE 3: If the distance is zero then circles are coincident and there are infinite solutions.

The intersection is calculated, for the rest of the cases. For example, in Figure 2, the centers of two circles A and B are (a_1, b_1) and (a_2, b_2) respectively. The radii of both the circles are r. The two intersection points of the circles can be calculated by simple algebraic calculation using the position (x,y).

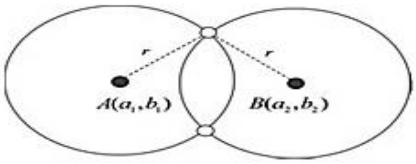

Figure 2. Basic Idea of Localization

$$(\boldsymbol{x} - \boldsymbol{a_1})^2 + (\boldsymbol{y} - \boldsymbol{b_1})^2 = \boldsymbol{r^2} \ldots \ldots . . (\mathbf{1})$$

$$(\boldsymbol{x} - \boldsymbol{a_2})^2 + (\boldsymbol{y} - \boldsymbol{b_2})^2 = \boldsymbol{r^2} \ldots \ldots . . (\mathbf{2})$$

POSSIBLE LOCATION OF SENSOR NODES

BEACON POINT

BEACON PACKETS

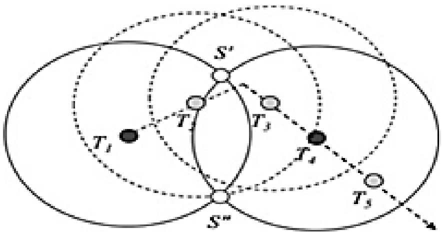

Figure 3. Estimated Locations

Figure 3 depicts the coordinates of two intersection points which are the two solutions for the estimated locations.The visitor list is searched after identifying the two possible positions i.e. the intersection points. If a node could hear around its range there is a possibility of a beacon point to be situated at a distance r from one of the two possible location. Thus there is one point in the list, whose distance from one possible location is less than r, and the distance from other possible location is greater than r, then the location of the sensor node is chosen by using the first possible location. Assume R as the communication range of mobile anchor. After receiving enough beacon packets from the mobile anchor in its range the MAP-M maintains the visitor list. By using the information from the visitor list approximate location of the sensor node is calculated. Let the visitor list of a sensor node S consists of various location information represented as $\{T_1, T_2 \ldots . . T_n\}$. The beacon points are the two extreme points i.e., $T_1$and T_n. Two circles with radius R and centers T_1 and T_n are constructed. S′ and S″ are the two intersection points of two circles. If there is any T_i (2 ≤ i ≤ n-1), such that the distance between Ti and S′ is less than R and that between T_i and S″ is greater than R, then finally the location of the sensor node is S′. This is because of the fact that the sensor node should lie inside the communication range of the mobile anchor to receive the beacon packets. Hence, the distance between the sensor node S and beacon packet T_i should be less than R. There is an area named as the shadow region, as shown in Figure 4. If all of the Beacon points lie inside this shadow region, then the location of the sensor node cannot be identified as the shadow region comes under the range of both the intersection points. This can be explained by drawing two circles with S' and S" as centers and the shadow region is the intersection of the two circles. Hence in order to obtain the location of the sensor node there is a need that at least one of the beacon packets in the visitor list must lie outside the shadow region.

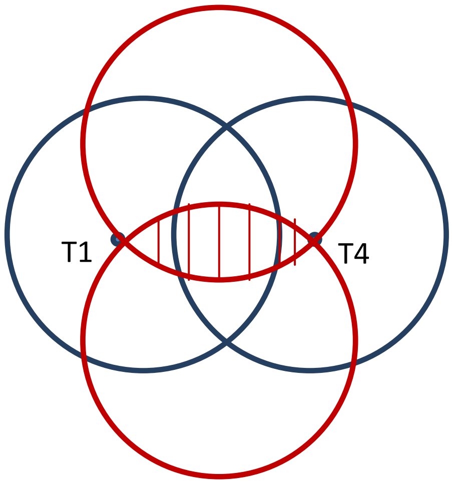

Figure 4. Shadow Area

Hence, it is not possible to determine the location of the sensor node S using the available beacon packets, thus the node is made to wait until it gets further beacon packets. If no further beacons are obtained then a single position of sensor node S cannot be obtained. The node will have two positions. To overcome this problem the method of Tabu Search [13] is being adopted.

3.1 Forming Additional Anchors using MAP-M&N

The location estimation done for sensors using MAP-M method gives positions for few sensors and for the others it gives two positions and hence it is the responsibility of MAP-M&N to produce outputs with a single position for each sensor. It is possible for the sensor nodes that have already determined their location to assist other nodes in determining their locations. As soon as the location is identified, the localized nodes start acting like anchors. They embed their calculated location inside the packet and then broadcast the beacons. Nodes which are at its hearing range and waiting for additional beacons to finalize their location can make use of these beacons. However, if the sensor node has determined its location, then it simply discards the packet. This method can reduce the cost of movement of the mobile anchor.

3.2 Tabu Search Algorithm

The localization steps followed by using Tabu Search Algorithm are that it takes the results of Mobile Anchor Positioning as its input. The results of MAP, giving the approximate solution of the location of each sensor at each specified time instance is given as the input to the post optimization method. At any iteration it has to find a new solution by making local movements over the current solution. The possible solution of a node which was predicted by MAP algorithm is maintained in a tabu list. The average distance of neighbour nodes of the corresponding nodes are calculated. The difference between the location and the average distance of the node are calculated. If the solution is less than the average value then that value is considered as a best solution. The “next solution" is the best among all (or a subset of) possible solutions in the neighborhood $N(\sigma)$ in order to carry out the exploration process, the recently visited solutions are avoided. Tabu list is maintained. Therefore once a solution is visited, the movement from which it was obtained is considered as tabu. $N(\sigma)$ will be changing along the exploration, so in a certain sense dynamic neighborhood is compared to the previous local search algorithms where $N(\sigma)$ remains static. Typically there are two kinds of tabu lists, a long term memory and short term memory. Long term memory maintains the history through all the exploration process as a whole and a short term memory is to keep the most recently visited tabu movements. A movement with a tabu status (tabu movement) is avoided to be applied, unless it satisfies certain aspiration criteria. This aims to avoid falling into local optima. Tabu list size is fixed before the hand each element of the list belongs to it for a number of iterations bounded by given maximum and minimum values. Repeat the iterations until the stopping criteria is met.

The first one has to do with the Tabu Search as a whole (when the algorithm finishes). Number of iterations = 100. Then the best solution is obtained from the tabu list. If the same solution gets repeated continuously for three to four iterations, then the algorithm is stopped.

4. EXPERIMENTAL RESULTS

The simulation parameters followed in NS2 simulator for result analysis are as shown below in Table 1:

Table 1 Simulation Parameters

S.No	Parameters	Value
1	No. of Mobile Anchors	3
2	No. of Sensor Nodes	80
3	Execution Time	200 seconds
4	Area of the Sensing Field	1000 × 1000 m^2
5	Routing Protocol	AODV
6	Number of Iterations	100
7	Transmission Range	200 metres
8	MAC Protocol used	IEEE 802.11

4.1 Comparison of accuracy obtained from MAP-M&N and MAP-M&N with Tabu Search

The root mean square error (RMSE) was calculated using the formula,

$$RMSE=\sqrt{\frac{\sum_{i=1}^{n}(x_{act(i)}-x_{obt(i)})^2+(y_{act(i)}-y_{obt(i)})^2}{N}}$$

Where,

$x_{act(i)}$,$y_{act(i)}$ - Actual x and y coordinates of sensor nodes

$x_{obt(i)}$, $y_{obt(i)}$- Obtained values of x and y coordinates of sensor nodes

N- Total number of localized nodes

Table 2 RMSE for MAP-M&N and MAP-M&N with Tabu Search Algorithm

No of Nodes	MAP-M&N	MAP-M&N with Tabu Search
10	520.77	130.05
20	630.70	174.84
30	587.75	301.17
40	578.72	140.82
50	600.89	183.49
60	596.02	199.83
70	553.74	140.04
80	484.08	104.60

4.2 Analysis of varied execution time

The results were obtained for the simulation time of 500 seconds, which produced the percentage of localized nodes to be approximately 95%. But if the simulation time was decreased, the percentage of localized nodes are most probably the same. This is because of the considerable amount of time that was needed to visit all the areas in the field. This result is displayed in Table 3 as shown below:

Table 3 Analysis of varied execution time

Simulation time (in Seconds)	No. of localized sensor Nodes
100	86
200	95
300	95
400	95
500	95

4.3 Performance Analysis

Figure 5 shows the pictorial representation of RMSE value for MAP-M&N and MAP-M&N with Tabu Search (TS).

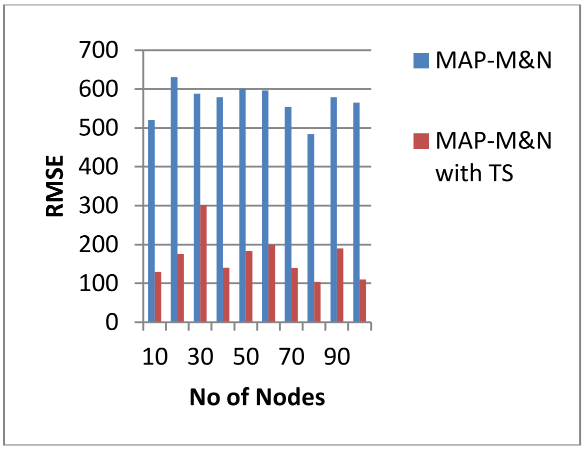

Figure 5. RMSE for MAP-M&N and MAP-M&N with TS

From this graph, it is observed that the value of Root Mean Square Error (RMSE) is drastically reduced when Tabu Search optimization algorithm is used with MAP-M&N when compared to the RMSE value that is being produced using MAP-M&N alone.

Figure 6 shows the pictorial representation of the analysis of varied execution time value performed for MAP-M&N with Tabu Search (TS) algorithm. The graph plotted in Figure 6 shows that if the simulation time was 500 seconds, then the percentage of localized nodes will be 95%. Even though the simulation time was decreased, the percentage of localized nodes remains probably the same.

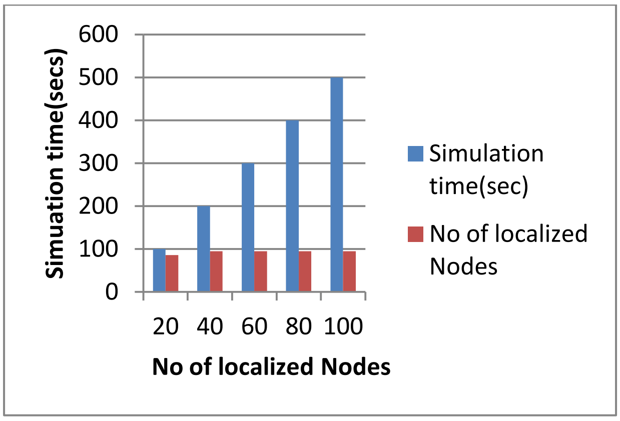

Figure 6. Analysis of varied execution time

5. CONCLUSION

Mobile Anchor Positioning uses the range-free localization method which does not involve the usage of any hardware. The percentage of localized nodes is high which proves that MAP technique is efficient for localization purpose. However, since this method does not provide fine-grained accuracy in localization, Meta-Heuristic optimization technique named Tabu-Search algorithm is applied over the results of MAP. From the experimental results of these two algorithms, Mobile anchor positioning with Tabu Search algorithm significantly brings down the RMSE based localization error by 79.5% when compared to MAP-M&N. It was also shown that if the simulation time was 500 seconds then about 95% of the sensor nodes are localized. Thus it can be concluded that the localization error was significantly reduced while using MAP-M&N with Tabu Search when compared to MAP. The future work can be done by using hybrid localization algorithm i.e Tabu Search combined with Simulated Annealing Algorithm and the localization error of this new hybrid Tabu Search algorithm can be compared with the Tabu Search algorithm (MAP-M&N with TS).

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