ABSTRACT
In Wireless Sensor Networks (WSNs), localization is considered as one of the most significant issues 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

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 nodes 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-lateralization, 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. Lovepreet Singh et al. [7]
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:

![Figure 1. Beacon packet format](image)

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.

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.
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 $(x,y)$.

$$\begin{align*}
(x - a_1)^2 + (y - b_1)^2 &= r^2 \quad \ldots \ldots \quad (1) \\
(x - a_2)^2 + (y - b_2)^2 &= r^2 \quad \ldots \ldots \quad (2)
\end{align*}$$

![Figure 2. Basic Idea of Localization](image1)

Figure 2. Basic Idea of Localization

If all $t_i$ is chosen by using the first possible location $S$ and $S'$ as centers, and these beacons. However, if the sensor node has detected their location to assist other nodes in determining their location. 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. Hence, 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.

3.1 Forming Additional Anchors using MAP-M&N

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 neighbours 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 possible location.

![Figure 3. Estimated Locations](image2)

Figure 3. Estimated Locations

![Figure 4. Shadow Area](image3)

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.

3.2 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 neighbours 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. 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. 

4. EXPERIMENTAL RESULTS

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

Table 1 Simulation Parameters

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of Mobile Anchors</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>No. of Sensor Nodes</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Execution Time</td>
<td>200 seconds</td>
</tr>
<tr>
<td>4</td>
<td>Area of the Sensing Field</td>
<td>1000 × 1000 m²</td>
</tr>
<tr>
<td>5</td>
<td>Routing Protocol</td>
<td>AODV</td>
</tr>
<tr>
<td>6</td>
<td>Number of Iterations</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>Transmission Range</td>
<td>200 metres</td>
</tr>
<tr>
<td>8</td>
<td>MAC Protocol used</td>
<td>IEEE 802.11</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>No of Nodes</th>
<th>MAP-M&amp;N</th>
<th>MAP-M&amp;N with Tabu Search</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>520.77</td>
<td>130.05</td>
</tr>
<tr>
<td>20</td>
<td>630.70</td>
<td>174.84</td>
</tr>
<tr>
<td>30</td>
<td>587.75</td>
<td>301.17</td>
</tr>
<tr>
<td>40</td>
<td>578.72</td>
<td>140.82</td>
</tr>
<tr>
<td>50</td>
<td>600.89</td>
<td>183.49</td>
</tr>
<tr>
<td>60</td>
<td>596.02</td>
<td>199.83</td>
</tr>
<tr>
<td>70</td>
<td>553.74</td>
<td>140.04</td>
</tr>
<tr>
<td>80</td>
<td>484.08</td>
<td>104.60</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Simulation time (in Seconds)</th>
<th>No. of localized sensor Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>86</td>
</tr>
<tr>
<td>200</td>
<td>95</td>
</tr>
<tr>
<td>300</td>
<td>95</td>
</tr>
<tr>
<td>400</td>
<td>95</td>
</tr>
<tr>
<td>500</td>
<td>95</td>
</tr>
</tbody>
</table>

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).
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).

### 6. REFERENCES


