Localization of Sensor Nodes using Mobile Anchor Nodes

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***Abstract*—Wireless Sensor Networks (WSNs) consist of spatially distributed wireless sensor nodes. Each sensor node cooperate with each other to monitor and collect data pertaining to physical or environmental conditions such as temperature, pressure, motion, sound, and other phenomena. Localization is an essential issue in wireless sensor networks because many applications require the sensor nodes to know their locations with a high degree of precision, to determine where a given node is physically located in a wireless sensor network (WSN). Various localization methods which based on mobile anchor nodes have been proposed for assisting the sensor nodes to determine their locations. However, none of these methods attempt to optimize the trajectory of the mobile anchor node. The proposed method presents the use of a mobile anchor in localization and a path planning scheme for the mobile anchors, which ensures that the trajectory of the mobile anchor node minimizes the localization error and guarantees that all of the sensor nodes can determine their locations .As an addition to the proposed scheme, I tried to add two mobile anchors, that helps to reduce time constraints in larger networks and provides localization in quicker time. The obstacle-resistant trajectory is also proposed for anchor nodes to handle the obstacles in the sensing field.**

***Index Terms*—Wireless Sensor Network; Sensor Nodes; Mobile anchor nodes; Received signal strength; Network Simulator2**.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consist of hundreds or thousands of sensor nodes and a small number of data collection devices. The sensor nodes have the form of low cost, low-power, small-size devices, and are designed to carry out a range of sensing applications, including environmental monitoring, military surveillance, fire detection, animal tracking, and so on. The sensor nodes gather the information of interest locally and then forward the sensed information over a wireless medium to a remote data collection device (sink), where it is fused and analyzed in order to determine the global status of the sensed area. In many WSN applications, the sensor nodes are required to know their locations with a high degree of precision, such as tracking of goods, forest fire detection, and etc. For example, in forest fire tracking, the moving perimeter of the fire can only be traced if the locations of the sensors are accurately known. Accordingly, many sensor localization methods have been proposed for WSNs. Broadly speaking, these methods can be categorized as either range-based or range-free. In range-based schemes, the sensor locations are calculated from the node-to-node distances or inter-node angles. Conversely, in range-free schemes, the sensor locations are determined by radio connectivity constraint. Range based schemes are typically more accurate than range-free schemes. However, they require the use of infrared, X-ray or ultrasound techniques to calculate the inter-node distance and/or angle, and are therefore both more complex and more expensive than range-free schemes. As a result, range-free localization schemes tend to be preferred for large-scale WSN applications. Most localization mechanisms use fixed anchors. However, if all of the nodes within the network have the ability to determine their locations, a large number of fixed anchors are required. Thus, several methods have been proposed for reducing the anchor deployment cost by utilizing GPS-enabled mobile anchors, which navigate the sensing field and issue periodic beacon messages advertising their current coordinates. However, the problem of deriving the optimal trajectories of the mobile anchors in the sensing field has attracted relatively little attention. Although several anchor movement strategies have been proposed for WSNs], they are all based on some specific localization algorithms (or trilateration), and thus their compatibility with other localization methods is not guaranteed.

II. RELATED WORK

One of the critical issues in WSN research is to determine the physical positions of nodes. This is because the sensed data are meaningful to most applications only when they are labeled with geographical position information. Position information is essential to many location-aware sensor network communication protocols, such as packet routing and sensing coverage. It has been a challenging task to design a practical algorithm for node localization given the constraints that are imposed on sensors, including limited power, low cost, etc. There are several sensor localization methods have been proposed for WSNs. They are explained below.

2.1 **Sensor Localization:** Sensor network localization algorithms estimate the locations of sensors with initially known location information by using knowledge of the absolute positions of a few sensors and inter-sensor measurements such as distance and bearing measurements. Sensors with known location information are called anchors and their locations can be obtained by using a global positioning system (GPS), or by installing anchors at points with known coordinates. Many sensor localization methods have been proposed for WSNs. Broadly speaking, these methods can be categorized as either range-based or range-free. Range based schemes are used to estimate range information which represents physical distance or the relative angle between nodes. Methods such as Time of Arrival (TOA) and Time Difference of Arrival (TDOA) compute the transmission time of wireless signal to obtain the distance information. Angle of Arrival (AOA) method estimates the direction of propagation of wireless signal by using an antenna array. The angle-of-arrival measurement techniques can be further divided into two subclasses: those making use of the receiver antennas amplitude response and those making use of the receiver antennas phase response.

2.2 **Mobile Anchor Path Planning:** In Path planning of mobile landmarks for localization in wireless sensor networks, by Koutsonikolas et al. proposed three path planning schemes for the mobile anchor node in the localization scheme presented by Sichitiu and Ramadurai in Localization of wireless sensor networks with a mobile beacon, namely SCAN,DOUBLE SCAN and HILBERT. Huang and Zaruba in Static path planning for mobile beacons to localize sensor networks, presented two further path planning schemes designated as CIRCLES and S-CURVES, respectively, for avoiding the collinearity problem inherent in the localization method presented in Localization of wireless sensor networks with a mobile beacon.

SCAN: SCAN is a simple and easily implemented trajectory. The mobile landmark traverses the network area along one dimension, the mobile landmark travels along the y axis, and the distance between two successive segments of the trajectory, parallel to the y axis, defines the resolution of the trajectory. If the communication range of the sensors is R, the resolution should be at most 2R, to make sure that all the sensors will be able to receive beacons. SCAN has the advantage of offering uniform coverage to the whole network, and it ensures that all nodes will be able to receive beacons from the mobile landmark under a properly selected resolution. Moreover, uniformity keeps the maximum error low. SCAN has one important drawback collinearity of beacons. For large resolution, many nodes will receive beacons only from one line segment and one direction, which will create uncertainty and prevent them from obtaining a good estimate along the x axis.

DOUBLE SCAN: Another straightforward way to overcome the collinearity problem of SCAN is to scan the network along both directions. In this case, the mobile landmark first traverses the whole network, scanning along the y axis, as in the previous case, and all the nodes obtain a good estimate for their y coordinate. Then the mobile landmark performs a second scanning along the x axis, giving the nodes the possibility to eliminate the uncertainty for their x coordinates. The problem with this method is that it requires the mobile landmark to travel doubled distance, compared to the simple scan, for the same resolution., we selected to keep the distance traveled by the mobile landmark similar for all trajectories, hence DOUBLE SCAN is performed with a double resolution compared to SCAN.

HILBERT: A HILBERT space-filling curve creates a linear ordering of points in a higher dimensional space that preserves the physical adjacency of the points. Algorithms based on bit manipulation, finite-state diagrams and recursive construction exist to generate HILBERT curves. A level-n HILBERT curve divides the 2-dimensional space into 4n square cells and connects the centers of those cells using 4n line segments, each of length equal to the length of the side of a square cell. If the mobile landmark moves on a HILBERT curve, the sensors to be localized will have the chance to receive non-collinear beacons and obtain a good estimate for their positions. A HILBERT curve has also a potential drawback compared to SCAN or DOUBLE SCAN. Since this curve always connects the centers of two successive square cells, the mobile landmark will never move on the border of the deployment area. Thus sensors near the border will possibly receive beacons only from one direction and their estimates will not be accurate.

CIRCLES: In CIRCLES, the mobile anchor follows a sequence of concentric circular trajectories centered at the center point of the deployment area. Circles can only guarantee that all four sides of sensing field is covered. It has largest distance construct.

S-CURVES: In S-CURVES, the anchor follows an S-shaped curve rather than a simple straight line as in the SCAN method. The results showed that given a trajectory resolution much larger than the radio range, both schemes cope effectively with the collinearity problem and provide a significantly better localization accuracy and coverage than previous solutions. Han et al. introduced a path planning scheme for a Mobile anchor node based on the trilateration localization Scheme in Path planning using a mobile anchor node based on trilateration in wireless sensor networks. The anchor node moves according to an equilateral triangle trajectory and broadcasts its current position information in the sensing area. After receiving three position information, each sensor node can estimate itself location based on trilateration calculation. The distance between the sensor node and the anchor node can be measured based on Received Signal Strength (RSS). The main advantage of the triangle trajectory is to solve the collinearity problem of the trilateration method.

Limitations of Existing Path Planning Schemes: As described, various path planning schemes have been proposed for the single mobile anchor used in the localization method presented. However, these schemes cannot be directly applied to the localization method proposed. For example, SCAN cannot guarantee that the length of each chord exceeds a certain threshold. Similarly, the use of DOUBLE SCAN increases the beacon overhead due to the generation of redundant beacon points. Meanwhile, HILBERT cannot guarantee that every sensor node will obtain the three or more beacon points required to construct two chords of the communication circle. CIRCLES can only guarantee that the four corners of the sensing field are covered by expanding the diameter of the concentric circles. As a result, the path length is extended, and the energy consumption is increased. Finally, in S-CURVES, the trajectory of the mobile anchor cannot guarantee that each sensor node can construct two valid chords.

III. Proposed Method

A single mobile anchor node moves randomly through the sensing field broadcasting periodic beacon messages containing its current coordinates. The locations of the individual sensor nodes are determined by exploiting the fact that the perpendicular bisector of a chord of a circle passes through the center of the circle. It is assumed that the communication range over which a sensor node can detect broadcasts from the mobile anchor node is bounded by a circle and the sensor node is located at the center of this circle. As the anchor node moves through the sensing field, it broadcasts its coordinates periodically, and each sensor node chooses appropriate locations of the anchor node (called beacon points) to form chords of its communication circle. Once three beacon points (i.e. two chords) have been constructed, the sensor node determines it location by calculating the intersection point of the two perpendicular bisectors of the chords (see Figure 3.1). The project provides a computationally straightforward means of determining the sensor locations. However, the accuracy of the localization results is dependent on the length of the chords. In realistic environments, the selected beacon points may not be exact on the communication circle. When the length of the chord is too short, the probability of unsuccessful localization will increase rapidly (see Figure 3.1). The length of each chord should exceed a certain threshold in order to minimize the localization error.

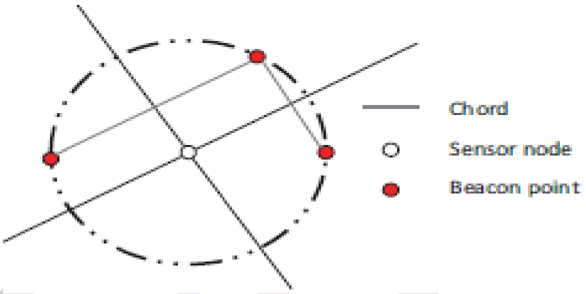

Fig 3.1 Localization Concept

3.1 Mobile Anchor Path Planning Scheme

If three beacon points are obtained on the communication circle of a sensor node, it follows that the mobile anchor node must pass through the circle on at least two occasions. In the path planning scheme proposed in this study, the distance between two successive vertical segments of the anchor trajectory (i.e. the resolution of the anchor trajectory) is specified as R-X, where R is the communication radius of the mobile anchor node and X is set in the range 0<X <R/3 . This is because if X is bigger than R/3, R - X will be smaller than 2R/3. Hence, the distance between four successive vertical segments is less than the diameter of the communication circle (i.e. 2R). As a result, the mobile anchor node will pass through the circle more than three times. In other words, increasing the value of X may incur redundant beacon points. Conversely, decreasing the value of X may cause the chord length to fall below the minimum threshold value. Thus, in practice, a careful choice of X is required. To determine the positions of the sensor nodes close to the boundary of the sensing field, the dimensions of the field are virtually extended by a distance of R on each side, as shown in Fig.3.1. By extending the sensing field, and choosing an appropriate value of X, the proposed path planning scheme ensures that the mobile anchor node passes through the circle of each sensor node either two or three times. As shown in Fig.3.1, the total path length D is given as

$$D = (L+2R)([(L + 2R)/ (R -X)] + 1)+(R-X)(L + 2R)/ (R - X). \quad (1)$$

As shown, the path length D comprises two components, namely a vertical path component and a horizontal path component. The vertical path component comprises [(L+2R)/ (R-X)]+ 1 segments of length L + 2R, while the horizontal path component comprises (L+2R)/(R-X) segments of length R -X. Assume that the sensor node chooses only those beacon points located on a vertical segment of the trajectory by comparing the coordinates of the received beacon messages to accomplish the localization process. Therefore the proposed path planning scheme guarantees the following conditions: (a) the length of the two chords generated by the three beacon points exceeds 2R/3; and (b) all of the sensor nodes in the sensing field can estimate their locations.

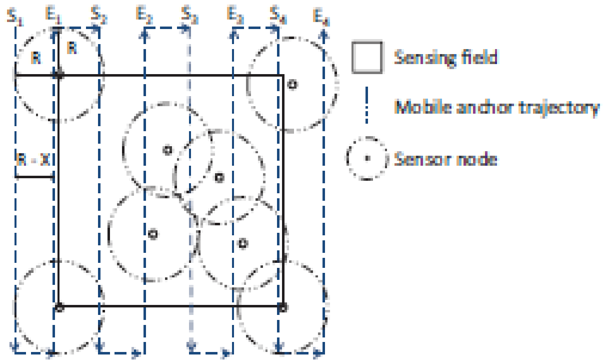

Fig 3.2 Proposed Mobile Anchor trajectory

3.2 Multiple Anchors Extension

In the literature, the existing anchor movement strategies use a single mobile anchor node for localization. The proposed path planning is extended to supported by multiple mobile anchor nodes. As indicated, the beacon collision at sensor nodes can occur if there are multiple anchor nodes moving in the sensing field. With the proposed path planning, anchor nodes should not move along successive vertical segments of the proposed trajectory. Because of the distance between two successive vertical segments R' = R – X < R, the beacon collision problem happens when a sensor node is within the overlap area of the broadcast coverage of two anchor nodes. In other words, the distance between two anchor nodes should be larger than R. In the scenario of multiple anchor nodes, the distance between two anchor nodes is specified as 2R'. Assuming that the sensor field has a length L' and the anchor trajectory has a resolution R', the number of required anchor nodes (n) in the field is equal to n = (L'/2R') + 1. As shown in Fig 3.2, each anchor node Ai is able to move simultaneously following with a U-type trajectory from Si to Ei where i = 1, . . . , n. The total path length of the trajectories of all anchor nodes is given as

$$D_{multiple} = (L')[(L'/R') + 1]+(R')(L'/2R') + 1 \quad (2)$$

where Dmultiple¡ Dproposed. On the other hand, assuming that the moving speed of the anchor node is v, the execution time of the localization process based on the single mobile anchor node (Tsingle) is equal to Dproposed/v. With the scenario of multiple anchor nodes, the execution time for localization can be reduced to about Tsingle/n. In addition, faster moving speeds of the anchor nodes also decrease the execution time for localization.

3.3 Obstacle-Resistant Trajectory

In a realistic environment, obstacles may appear in the sensing field and thus obstruct the radio connectivity between the anchor node and the sensor nodes. In the localization algorithm, the obstacle problem has been carefully handled by using the enhanced beacon point selection mechanism. In the enhanced selection mechanism, the sensor node based on the idea of concentric circles to choose the beacon points with similar RSS for localization. However, based on the proposed path planning, the obstacle can block the trajectory of the anchor node. Thus, sensor nodes may not receive enough beacon points for estimating their positions. For instance, in Fig 3.3, the sensor node S only recognizes two beacon points, B1 and B2, because path P2 of the mobile anchor node is obstructed by the obstacle.

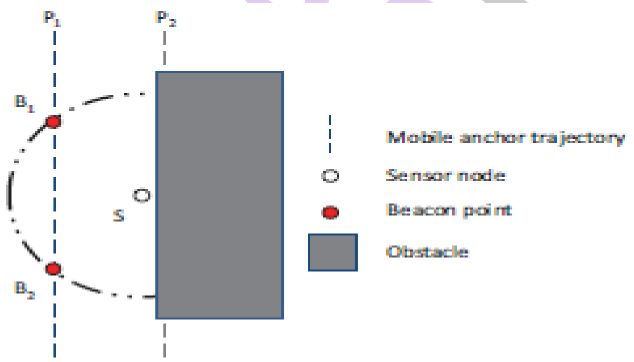

Fig 3.3 Impact of Obstacle in the Mobile Anchor trajectory

The obstacle-resistant trajectory of the anchor node is introduced in Fig 3.4. When the anchor node moving along the proposed trajectory discovers an obstacle, the anchor node detours around the obstacle toward the right-hand direction. After detouring, the anchor node returns to the original proposed trajectory. However, the obstacle-resistant trajectory may cause that sensor nodes obtain beacon points which are not on the circle. The localization performance will be degraded due to incorrect beacon points. As shown in Fig 3.4, the sensor node S gets four beacon points, B1, B2, B'3, and B'4, based on the obstacle resistant trajectory. Due to the obstacle, S cannot obtain the correct beacon points (B3 and B4). To solve the problem, once the anchor node contacts with the obstacle within a beacon distance (e.g., E in Fig 3.4.), the anchor node broadcasts the beacon messages with a detour flag to notify sensor nodes of detouring around the obstacle. If the anchor node moves away from the obstacle (e.g., O in Figure 3.4), the anchor node starts broadcasting the normal beacon messages again. The sensor nodes do not select the beacon messages with the detour flag as the beacon point. Therefore, S determines onlyB1 and B2 as its beacon points. Based on our observations, two cases (i.e., the sensor node only has two beacon points) are required to deal with when using the obstacle-resistant trajectory. Because the sensor node needs at least three beacon points to measure its own position, one more virtual beacon point is generated for sensor nodes position determination. In the first case (see Fig 3.3.), the sensor node identifies two beacon points (B1 and B2) from the same vertical segment of the anchor nodes trajectory.

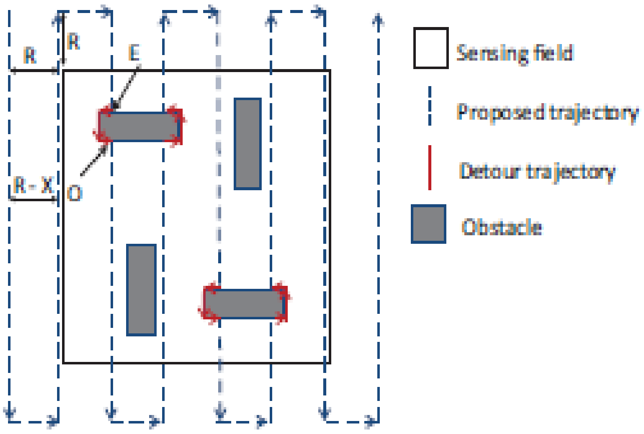

Fig 3.4 Obstacle resistant trajectory of mobile anchor node.

With the obstacle location (e.g., l) in the beacon messages at B1 and B2, the sensor node knows that the obstacle is located on the left side of the anchors trajectory. Therefore, the virtual beacon points, B'1(x'1, y'1) and B'2 (x'2 , y'2), are calculated as shown above Note that M1 and M2 are the beacon positions where the sensor node receiving the beacon message with the largest RSS on the vertical segments, respectively. If a sensor node obtains only two beacon points after a predefined period, the sensor node considers that it matches the first or the second case by comparing the x-axis coordinates of two beacon points. The sensor node then generates one more beacon point to estimate its location based on the virtual beacon point determination.

IV. IMPLEMENTATION ON NS2

Deploying sensors:

The experiments are performed on Network Simulator tool 2. Deploying of sensors is created as a topology with 9 number of sensor nodes.

Path planning for mobile anchors:

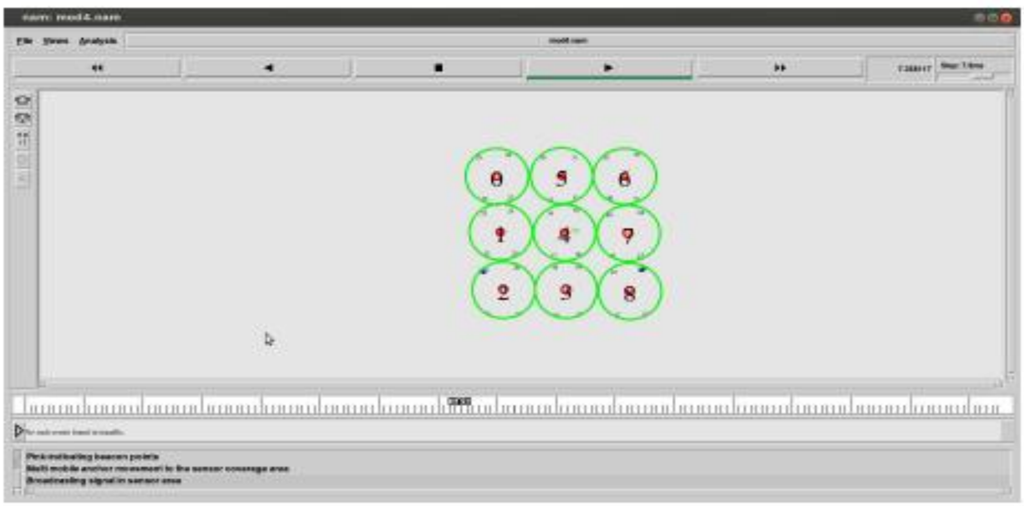

Fig: 4.1 Sensor Nodes deployment.

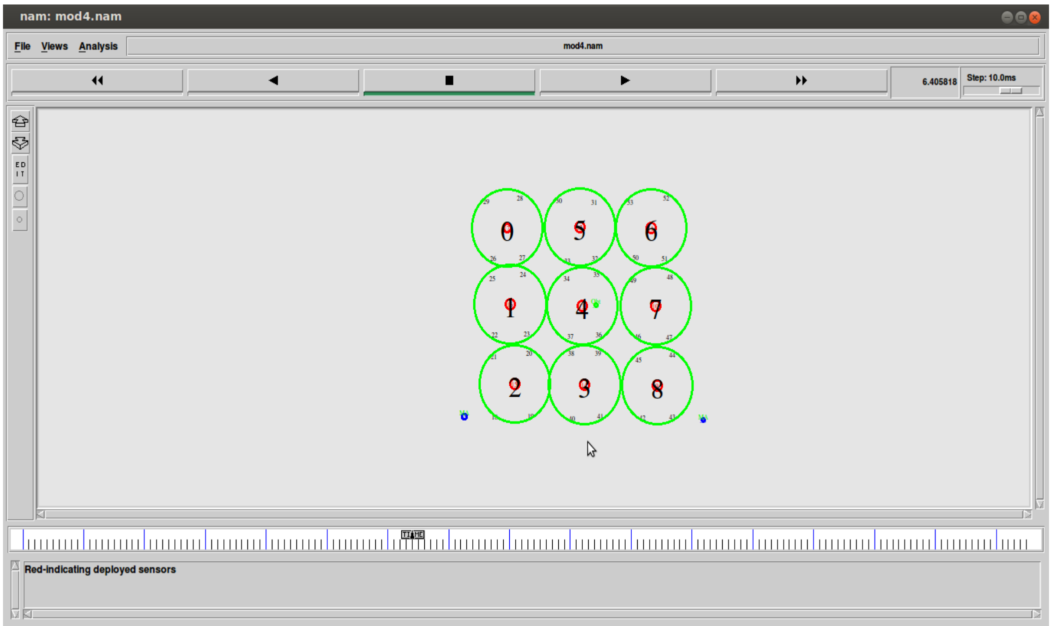

Fig 4.2 Placing Mobile Anchor Nodes

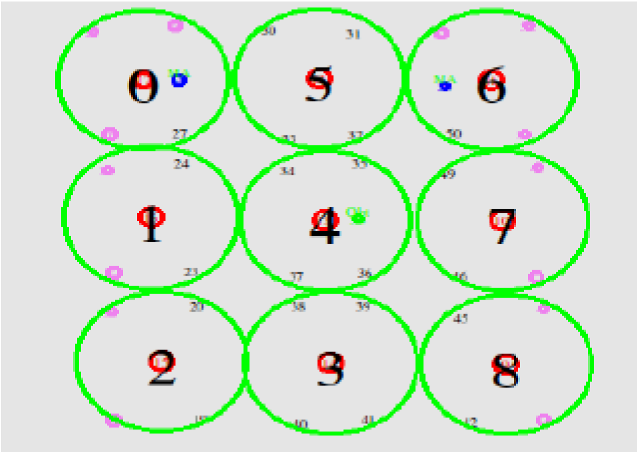

Fig 4.3 Mobile Anchor movement inside Sensing field

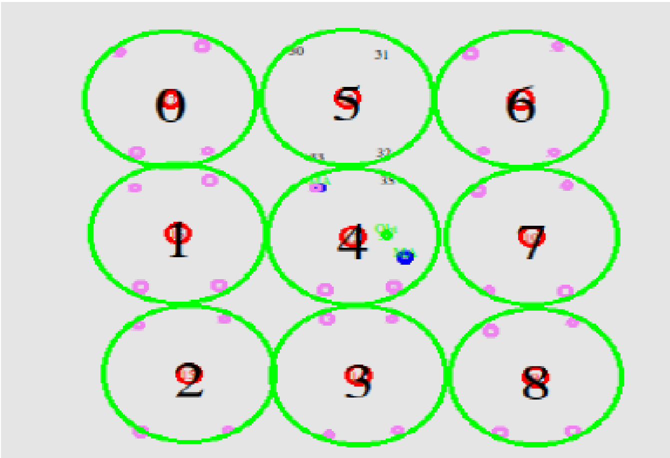

Fig 4.4 Detouring of Anchor Node due to the presence of obstacle in Anchor node trajectory

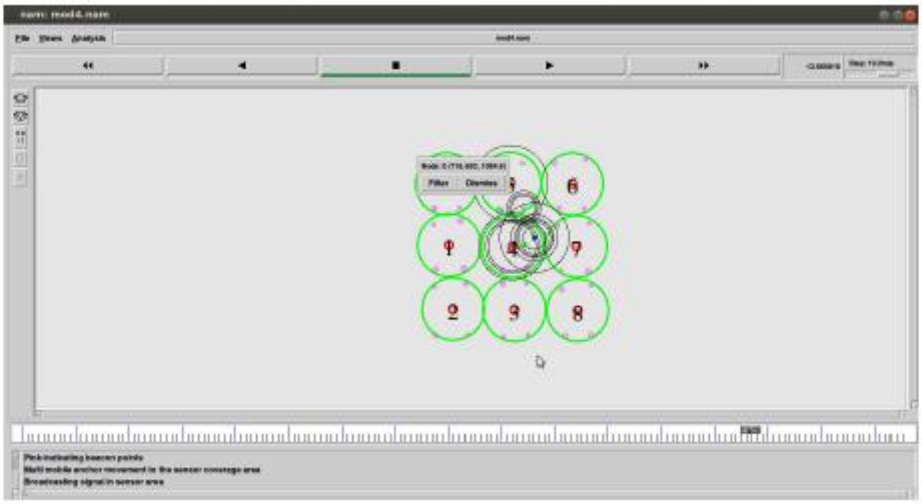

Fig 4.5 Broadcasting of beacon messages

V. CONCLUSION

This project has proposed a path planning scheme for the mobile anchor node in the localization method. The proposed approach ensures that the chords constructed by the individual sensor nodes always have a length greater than 2R/3. Thus, the short chord problem is resolved. In a large network it takes much time to find the sensors localization by using single mobile anchor. But the project proposes that path planning by extending Localization by using multiple mobile anchor nodes. For avoiding collision of beacon points the paper plans path for both the mobile anchors. Besides, the modified movement trajectory and the virtual beacon point generation scheme are presented to tolerate the obstacles in the sensing field. It has been shown that all sensor nodes can determine their locations

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