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Effective Obstacle Avoidance Path Planning and Maximized Network Lifetime Algorithm for Wireless Sensor Networks

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ABSTRACT

The developments in embedded systems, Very Large Scale Integration, wireless communication continue to produce tiny wireless sensors. Thousands of wireless nodes are deployed in many applications to observe, to track and to control the quantities. These are Wireless Sensor Networks (WSNs). These nodes possess limited sensing, processing and communication. WSNs are subjected to various challenges and constraints. Accurate location information is needed for various applications. Global Positioning System is a good location detecting system. But it is not possible in WSN because of its cost and coverage in indoor applications. Few nodes may be fitted with a Global Positioning System called as anchor. All the nodes perform localization using anchors. The anchor travels to give complete coverage and the path length must be lesser. The important aspect of the paper is the proposed V curve path which provides lesser path length. The proposed algorithm handles the obstacle in a proper way. Also the mobile anchor provides wireless charging for the static nodes. Therefore, this increases the network lifetime.

Keywords: *WSN, Anchor, Path planning, Obstacle avoidance, Backtracking algorithm, Wireless Charging*

INTRODUCTION

WSNs are essential for wide range of applications like precision agriculture, wildfire detection, intelligent buildings, machine surveillance and health care. Some of the applications like Cold chain monitoring implemented on a refrigerated vehicle [4] Habitat and environmental monitoring deployed [3], Health applications like ECG monitoring concentrated in [17], various Structural Health Monitoring applied in [20] , [2], and in [16]. WSN are important due to advances in embedded systems, Microelectromechanical Systems, digital electronic and wireless communications. WSNs consist of thousands of sensors with sensing, processing and controlling. Each node contains sensors, microcontroller, memory, transceiver and power supply. WSN consists of thousands of motes that capture, process, store and reveal real data to the world. So many sensor nodes like Berkeley mote, TelesB mote, IRIS mote, NI WSN mote are available. Wireless nodes are scattered over wide area for sensing and collection of data. It is useful if the locations of nodes are also known. Location information is useful to monitor and track the object, to enhance security, to provide

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energy efficient location based routing. Implementation of GPS for localization in each node is not feasible because of its cost. Non GPS based localizations are useful for WSN. Localization algorithms can be categorized as centralized and distributed. In the centralized algorithm the central node calculates the location of the node. In the distributed algorithm, every node computes its location. Further in range free algorithm utilizes seed nodes. Seed nodes broadcast control message. Other nodes receive control messages and evaluate their locations. In a range based algorithm, range information, like time of arrival (ToA), time difference of arrival (TDoA) or angle of arrival (AoA) is essential. Localization can be done with Received Signal Strength value.

RELATED WORKS

To reduce the cost of localization, single node fitted with GPS called anchors; it travels the entire network and helps the other node for localization. In anchor free localization (AFL) algorithm, they do not depend on anchors at the time it measures the distance, also at the time when it computes the node coordinates. But the accuracy is less compared to anchor based localizations. Anchor based localization algorithm provides accurate localization but anchors are additional overhead for WSN.

Researchers in [7] studied trajectories SCAN, DOUBLE SCAN and HILBERT. Among these, SCAN offers good resolution. But for larger communication range, HILBERT outperforms SCAN. Localization error is less in DOUBLE SCAN, but the cost is high. In [18], researcher presented CIRCLES and S-CURVES path plan. The sensors are uniformly arranged in the sensing area. A robot is used as an anchor to localize the nodes. It follows a predetermined path and periodically transmits the beacon messages. In [9] LMAT has been presented. The anchor travels in trilateration trajectory and transmits its location periodically. The other nodes form an equilateral triangle using messages from mobile node can and localize themselves. Researchers in paper [11], developed a mobile beacon assisted localization technique. A superior path planning, *Z*-curve has been proposed. The anchor transmits a message at the centroid, received by sensors in the same square and two more adjacent squares. All the sensor nodes collect three beacons and estimate its position. Also the Z curve algorithm tolerates the obstacles. An efficient Obstacle-Resistant Robot Deployment (ORRD) was proposed in [5], it involves node placement policy, serpentine pattern movement, obstacle avoiding method.

The region is partitioned into cells using Adaptive Cell Decomposition , and connectivity graph is plotted. Shortest global path is generated in Modified Max min Ant System algorithm. In [22] , the anchor follows a concentric circles of flexible radii, traveling in a free cell. Single obstacles Route Guided Protocol and Multiple obstacles Route Guided Protocol was developed in [6]. It reduce the route length and energy consumption for WSN.

Authors in [10] discussed the network lifetime is increased by resolving a sequence of shortest path problem. Lifetime of the node is increased by solving a number of shortest path problems. It concludes a near optimal relocation scheme for nodes. Researchers in [19] presented a novel DeteRministic dynamic bEAcon Mobility Scheduling algorithm. Depth First Traversal defines the visit sequence of robot to the sensors. It moves from one sensor to another in a manner according to RSS based measurements. Local Minimum Spanning Tree is applied to reduce the beacon visit and delay.

A synchronised mobile charging protocol has been presented in [15] to reduce the travel length and the recharging delay time. A mobile charger provides a reliable energy supply for the static nodes. When the static node’s energy consumption is different, a set of nested Travelling Salesman Problem is presented. The tour of the mobile node is based on its energy consumption and the nodes with low residual energy are involved in each round.

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The network lifetime is given by the node which first fails in the network given in [12]. The node which fails is called as critical node. The number of living nodes as a function of time defined in [14] is taken into account to know the network lifetime. The researchers in [21], described the network lifetime as a fraction of surviving nodes and as a function of time.

PATH PLANNING ALGORITHMS FOR MOBILE ANCHOR

In [1] the author proposed RWP. Due to its random movement it results in highest localization error. RWP randomly alters the Mobile Anchor's direction and the velocity. Velocity is chosen between the minimum and maximum value. RWP does not solve coverage problem and does not provide a reasonable error rate. In SCAN , the anchor travels in one direction, either along the X axis or along the Y axis. In Double SCAN algorithm, the anchor travels in both directions. It results in good accuracy but path length travelled by anchor is increased. The space filling curve, HILBERT, doesn't give assurance that each node get three beacons to construct chords for localization. Particularly border nodes receive the beacons in a single direction and their estimation will be inaccurate.

A Mobile Anchor Assisted Localization algorithm based on a Regular Hexagon proposed in [8]. In MAALRH anchor starts from the centre point and moves in hexagon shape one step. Once it reaches the hexagon's starting point, it moves out one step in the distance of the resolution and starts forming another bigger hexagon. It gives very poor results both in its localization ratio and error. The mobile anchor in MAALRH cannot able to reach the corners. So the nodes in the corner cannot able to determine their position

The researchers in [11] proposed the Z curve algorithm. The Mobile Anchor travels by forming Z-shape. The network is partitioned into three levels, and Z-shapes are connected to each other in each level. When Mobile Anchor faces an obstacle , it turns around the corner of the obstacle and goes to the obverse point of the obstacle to continue its pattern.

Proposed V curve path planning

The proposed path plan for the anchor is 'V' curve trajectory. According to this, LxL is deployment area, R is resolution of the anchor, and the path-length is given in Equation (3.1).

Path length D= $$\left\lfloor \frac{L}{R} \right\rfloor \sqrt{R^2 + L^2} \qquad (3.1)$$

The performance of the proposed Curve has been estimated by simulation network of areas like 200 m x 200m and 400m x 400m for indoor and outdoor applications. The path length travelled the mobile anchor for SCAN, Double Scan and V curve trajectories simulated in MATLAB. The length travelled by mobile anchor analysed as shown in Table 3.1.

Table 3.1Path length analysis of existing path plan with proposed path plan

ALGORITHM	L=200		L=400	
	R=30	R=40	R=80	R=100
PROPOSED V CURVE	1213.42	1019.80	2039.61	1649.24
SCAN	1733.33	1400	2800	2400
DOUBLE SCAN	1873.33	1520	3040	2600

The graph has been drawn for the network area 200m x 200m and mobile anchor range 30m and 40m for existing and proposed path planning algorithm as shown in Figure 3.1.

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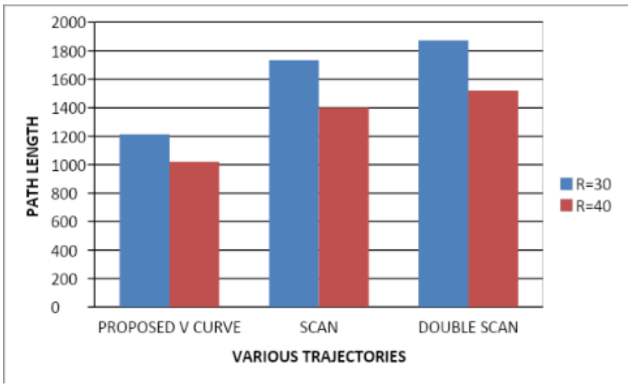

Figure 3.1 Path length analysis of existing path plan with proposed path plan (200m x 200m)

Also the graph is drawn for the network area 400m x 400m, mobile anchor range 80m and 100m for existing and proposed path planning algorithm as shown in Figure 3.2.

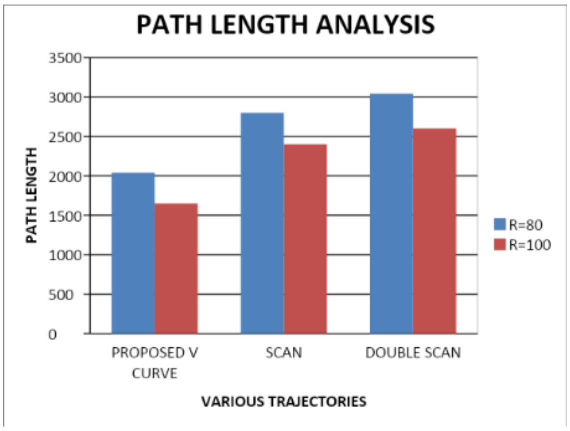

Figure 3.2 Path length analysis of existing path plan with proposed path plan (400m x 400m)

The path length of the proposed V curve trajectory is less than that of the existing SCAN and Double SCAN. Here the main focus is on path planning of mobile anchors to reduce path length for improved coverage and enhance network lifetime.

OBSTACLE AVOIDANCE USING BACK TRACKING ALGORITHM

The V curve is applied with the backtracking algorithm to handle static and dynamic obstacles. Backtracking is a way of finding out various sequences of decisions, until the mobile anchor finds a way to proceed. It is a general algorithm that considers every possible combination in order to solve a problem. The program starts with the user's input. It requests the input from the user like Without obstacles, With static obstacles or With dynamic obstacles.

If the user request is 1, the program starts its execution without an obstacle. It randomly deploys 20 nodes. A mobile anchor follows the V curve. Since there is no obstacle, it continues the path, it reaches the destination.

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If the user request is 2, the program starts its execution with a static obstacle. It randomly deploys 20 nodes and a static obstacle. The mobile node travels in a V curve. If it finds the obstacle by means of a sensor, it backtracks to previously successfully visited nodes and waits for random back off time. When the time expires it continues its path. Because of a static obstacle it cannot able to proceed the predetermined path. So it goes to the previously visited node , takes a one hop and continues its walk.

If the user request is 3, the program starts with a dynamic obstacle. It randomly deploys 20 static nodes and a dynamic obstacle. The obstacle is supposed to move in a random manner. The mobile anchor travels in a V curve. If it detects the obstacle, it backtracks to previously successfully visited nodes and waits for random back off time. In the meanwhile if it is a dynamic obstacle, it may have moved to another place. When the time expires it again continues its travel. Since it is a dynamic obstacle , it may be moved, so the mobile anchor continues the same V curve path.

Using the data, the graph was drawn, by taking visit order along the X axis and time taken to meet the static node by the anchor along Y axis as in Figure 4.1.

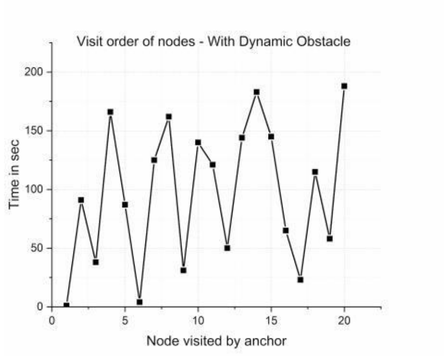

Figure 4.1 Visit order of the nodes– With Dynamic Obstacle

The comparison for coverage of static nodes by the anchor is depicted in Figure 4.2. In case 2 complete coverage is not possible because of static obstacles. So it is not possible to cover the network. In the case 3, the mobile anchor will wait for back off time for the obstacle to move. So it gives complete coverage but with a small time delay.

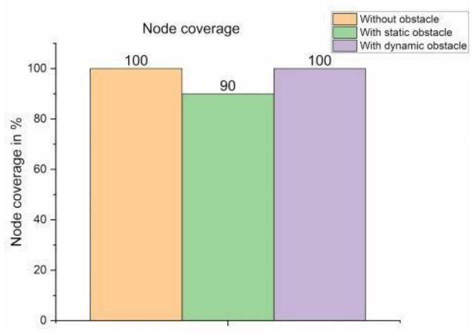

Figure 4.2 Comparison of Node Coverage of with and without obstacles

The comparison chart for time taken by mobile anchor to reach the destination for all the cases has been given in Figure 4.3. It is clear, with static obstacles, the anchor reaches the destination quickly since it does not cover the entire network and With dynamic obstacles, the mobile anchor takes extra time to reach destination.

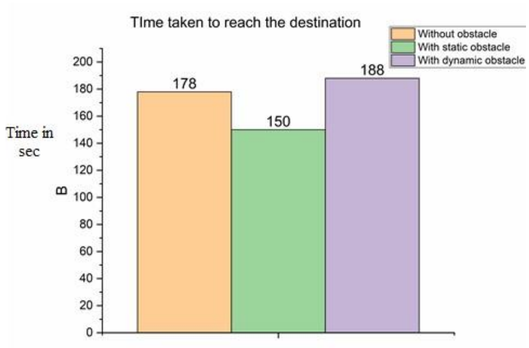

Figure 4.3 Comparison of Time taken by mobile anchor to reach the destination

Finally the visit order for all cases is compared in Figure 4.4. It is clear that the anchor reaches destination speedily in the case 2.

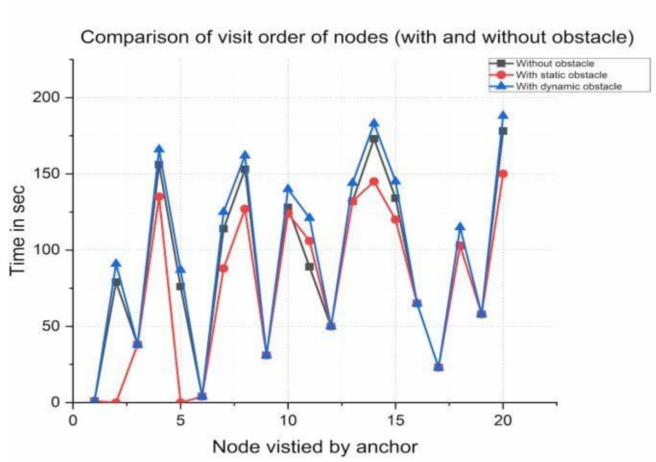

Figure 4.4 Comparison of Visit order of static nodes with and without obstacles

WIRELESS CHARGING OF MOBILE ANCHOR:

This part deals with the charge remaining in static node and to recharge the static node. The mobile beacon moves in the network in V curve, the unknown sensor receives the messages and computes its location. The mobile node notes down the charge in static node. If it is less than 40%, it recharges the static node to 80%. It repeats the procedure till it reaches the destination. Sensing range is selected depending on the indoor and outdoor applications. For indoor, range of the sensing node is 30 to 40m and for outdoor it is 75 to 100m. The parameters like area, number of nodes also varied along with sensing range. Python Program was executed for all the parameters. The program execution starts with the mobile node's sensing range. Users can assign values for R. Initial value can be assigned by typing 'Y' else for default 'N'.

At stating each node will be charged to a level. It has been used for calculation and communication. It may be wasted because of collision, over hearing and idle listening. The mobile anchor used for localization receives the neighbourhood node's beacon messages and calculates the energy of the node. If its value is less than 40% , it recharges the node. After

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assigning the mobile anchor's sensing range and initial charge values, the mobile anchor starts its V curve. For various parameters, the simulations have been done and the results, comparison graphs have been drawn.

The comparison is between the visit order of static nodes by mobile anchor with and without charging static nodes. The mobile anchor sensing range is taken as 80m. From the simulation output, mobile data.txt file, the time taken by mobile anchor to meet static node is tabulated and the graph drawn as depicted in Figure 5.1.

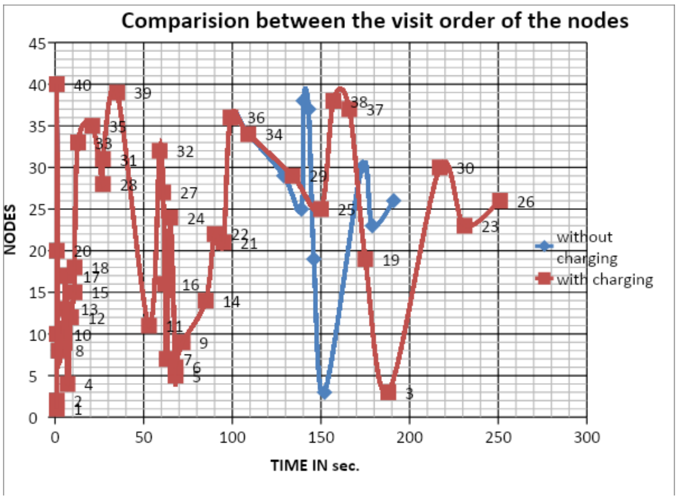

Figure 5.1 Visit order of static node (R=80m)

The comparison is also done for the network's lifetime. For example sensing nodes range 80m with and without charging the static node is taken. The number of nodes alive in the particular time is counted from the simulation - dying time of static node. The result is tabulated and graph is drawn as depicted in Figure 5.2.

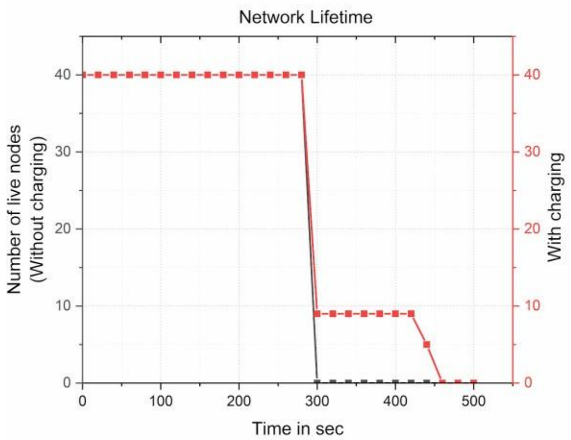

Figure 5.2 Comparison of Network Lifetime (R=80m)

From the graph Figure 5.2, it is evident that the network's lifetime has been increased from 300 sec to 460 sec.

CONCLUSION

In the proposed method, the path length of the mobile anchor is reduced by implementing the V curve path. From the simulation , it can be concluded that the V curve path is an efficient algorithm for localization as it reduces path length. Proposed V curve path length has been compared with Scan and Double Scan. Z curve algorithm proposed by [11] travels longer distances than the Circles, Scan, double Scan and Hilbert algorithms. Based on literature survey the SCAN and Double SCAN are observed to be performing better and hence they have been considered for performance comparison in this paper. The results show that it is overwhelming than the existing algorithms like SCAN and DOUBLE SCAN.

To handle the obstacles on the path of mobile anchor, a backtracking algorithm is used. To prolong the lifetime of the network, a wireless charging of static nodes is done by the mobile anchor.

The outcomes of the research work are as follows:

- Indoor environment: Network area 200m x 200m and the sensing range 30m or 40m , V curve path length is 1213.42m and 1019.80m respectively.
- Outdoor environment: Network area 400m x 400m and the sensing range 80m or 100m, V curve path length is 2039.61m and 1649.24m respectively.
- The network coverage for static obstacle : 90% and for dynamic obstacle 100%
- The network lifetime is increased from 240 to 360 sec for the sensing range 30m, from 300 sec to 460 sec for the sensing range 80m and from 340 sec to 500 sec for the range 100m.

The parameters like path length, obstacle handling and wireless recharging are considered for proposed V curve trajectory. Simulation results prove that for the same number of nodes and same network size, the path length is lesser than the traditional algorithm. It also handles the static obstacles with some time delay. Finally, it recharges the static nodes in the network, which in turn avoid the unattended node and also prolong the lifetime of the network. Overall, the proposed research work is well suited for indoor and outdoor localization, tracking and Wireless Rechargeable Sensor Networks (WRSN).

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