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A Study on Scan Trajectory Based Effective Localization Method Using Mobile Anchor in Wireless Sensor Networks

Abstract: A Wireless Sensor Network (WSN) is a collection of different nodes working together in a networked fashion in an ordered way. For many applications, sensor location in wireless sensor networks (WSN) is crucial. It is expensive to equip each sensor node with a GPS receiver. Numerous methods, including range-based and range-free methods, have been put forth in the past to determine the locations of sensor nodes that are randomly distributed. The majority of them make use of unique nodes known as anchor nodes, which are thought to be aware of their own positions. These anchor nodes supply the information that other sensors use to calculate their locations. Massive numbers of sensor nodes are used in wireless sensor networks (WSNs) to gather data about the immediate environment. However, this data is useless until the precise location of the data collection points is known. Sensor node localization in wireless sensor networks (WSNs) is important for a number of applications. The current research study develops a path planning technique to apply mobile anchors to the localization systems that are currently in use. The two mobile anchors supported by the effective trajectories, or effective SCAN, is the focus of the proposed research project. To localise the sensor node and transmit data, this method involves setting the mobile anchors to move in the opposite direction. The advantages of this dual movable anchor are demonstrated by the research study in terms of decreased localization time, localization error, and other factors.

Keywords: Localization; mobile anchor node;wireless sensor networks; Average detection accuracy; Localization error

I. INTRODUCTION

The basic structure of a wireless sensor network (WSN) is a randomly distributed autonomous sensor node. Using a WSN is completed for the purpose of surveillance or environment monitoring. Environmental elements including temperature, weather, and vibration from nature, as well as noise and sound navigation, can all be studied using WSN. Additional such causes include earth pressure, the occurrence of chemical or rock explosions, and the production of smoke or pollutants. By embracing the network situation, WSN serves as a sender of detected data to the remote control station.

For a wide range of fields where intimate communications with the outside world are required, wireless sensor networks (WSNs) are indispensable. The recent developments in the fields of digital electronics, wireless communications, embedded systems, MEMS (micro electro mechanical systems), and digital signal processing make them noteworthy. Numerous applications, including those related to intelligent buildings, environmental management, machine monitoring, precision agriculture, health care and medicine, wildfire detection, logistics, and telematics, are made possible by WSNs. It is mostly employed for tracking and monitoring. It is employed, for instance, in machine monitoring, environmental monitoring, animal tracking, and animal tracking. Numerous sensors with detecting, processing, controlling, power subsystem, and communication components make up WSNs. Every node is made up of a power supply, memory, a transceiver, sensors, and a microcontroller. Modern WSNs are bi-directional, which improves both the fuel control in nuclear reactors and the activity control in sensors. WSNs have become more prevalent in a variety of industries as a result of technological advancements and the growth of scientific and technological operations. Predicting the occurrence of natural disasters such as tsunamis, identifying fire in the surrounding area, and closely monitoring national boundaries during military operations are among the main subjects of study. Modernising home necessities, automating industrial processes, and providing health care for the elderly are other related disciplines. A wireless sensor network's general operation is shown in Fig. 1, where sensor nodes actively detect and send information to the control station. The WSNs are based on nodes that are connected in a neighbouring pattern and range in size

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from hundreds to thousands. By means of the multi-hop communication system, every one of these nodes is cooperatively linked to a single control station.

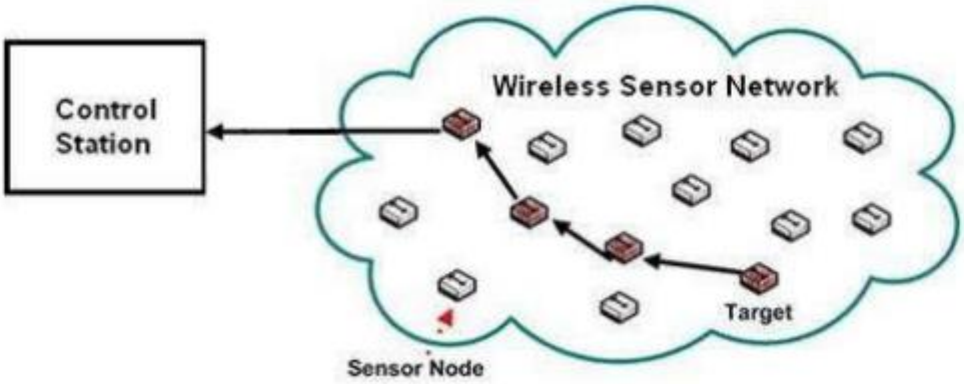

Fig. 1: Generic wireless sensor network

In order to better understand the synchronisation required in sensor to actor and actor to actor modes, Akyildiz and Kasimoglu [1] made an effort. The limitations and difficulties associated with this kind of cooperation were further discussed in the study. Additionally, the difficulties in communication and the fundamental parts of the sensor nodes that are part of the WSN are described. For many important applications, pure random deployment is a typical and fundamental WSN topology. These applications could be for a simple star network, an updated multi-hop wireless mesh network, or wildfire detection. The method of data propagation through flooding or routing is made possible by the hops that are supported in sensor node designs.

The standard architecture of a single sensor node includes essential elements like a transceiver for communication with the control station or other nearby nodes. It uses a micro-controller to facilitate computation. In addition, an analogue to digital converter (ADC) is used to activate the interface with the actuators, battery, and sensors. To trace the sensor node, these parts are incorporated into a mobile anchor node coupled with a position identification device. Additionally, there is a mobilise unit that transfers the node to other areas that are applicable or specified. The components that could easily fit in different sizes of sensor nodes, such as a shoebox or a tiny grain found in the dust. The block diagram of a generic sensor node with its components is shown in Fig.2.

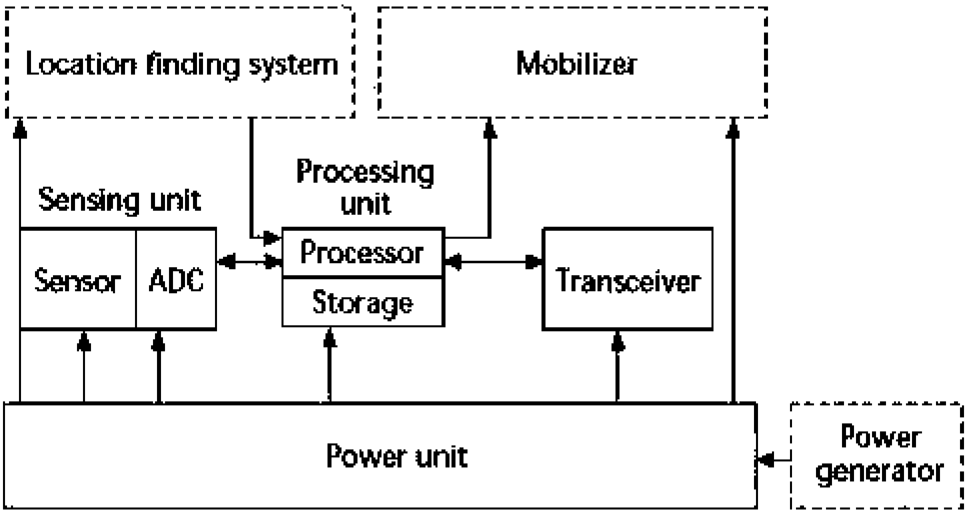

Fig.2: Block diagram of generic sensor node

The requirements and functional features which are often connected have an impact on the cost of designing sensor nodes. Constraints concerning the characteristics may be equivalent to those pertaining to the size and cost of the sensor nodes. As a result, there will be adjustments or requested limitations regarding memory size, processing speed, communication bandwidth and energy consumption.

A. *LOCALIZATION IN WSN*

A field is a physically distributed quantity with a variable value throughout space. A magnetic quantity spanning a region of space, temperature, light, pressure, or another physical quantity could be the physical quantity. A field is a vector or scalar that is connected to a physical quantity. Every point in the region has a temperature value defined by a temperature field. The locations of hot spots could be relevant information in a temperature sensing problem. In many wireless sensor network applications, knowing the precise position of the data is crucial. The node is capable of determining its own position through the use of a method known as self-localization technology. The provision of the position stamp, object tracking, quality of coverage assessment, cluster creation, and routing ease all depend on location information.The next method for localization is the Global Positioning System (GPS). However, because to its expense, it is not feasible to integrate the GPS into every node. Furthermore, it is not suitable for use indoors or in areas with a lot of leaves or mountains. Thus, some of the nodes referred to as "landmarks," "anchor nodes," or "seed nodes" are outfitted with GPS. Other nodes use the landmark as a guide and employ a variety of methods to pinpoint its location.

In WSN systems used for military boundary detection, sensor node dispersion is typically completed at random. It was demonstrated by Amundson and Koutsoukos [2] that during such deployments, the sensor nodes are unable to sense the precise or entire geographical locations. The assessment of the physical existence of sensor nodes within WSNs is the simplest definition of localization. It should be mentioned that position data is crucial for detecting the presence of events in a wireless sensor network. The possibility of routing is enabled when each sensor node's position is determined. This can prolong the life of sensor nodes within the WSN and lessen the burden on the network. Sensor nodes are often placed using their own physical and/or demo graphical locations in the sensing field. Such a physical location is considered to be the coordinates or location of every sensor node in a wireless sensor network. An altitude, latitude, or longitude representation of the sensed surroundings or locations can be used to represent this location.

In reality, sensor nodes can easily determine their exact location thanks to Global Positioning System (GPS) satellites and receivers. However, using GPS satellites and receivers to locate sensor nodes dispersedly comes at a high expense. Moreover, GPS devices draw a significant amount of power from the sensor node battery, which shortens the nodes' lifespan.

An anchor node is typically defined as having hardware that can self-position. The work of enabling uninformed sensor nodes to determine their precise locations is completed by an anchor node. Nonetheless, in certain indoor spaces, the lack of Line of Sight (LoS) prevents the sensor nodes from accessing GPS. Finding each sensor node's physical coordinates presents an alternate method of solving this kind of limitation. Therefore, the localization algorithm is useful in this endeavour, allowing a small number of anchor nodes to obtain their own GPS location data. In the absence of this, other location-aware sensor units relay the messages. When obtaining location data from location-aware nodes, the majority of sensor nodes employ radio communication protocols.

When using specific localization strategies, like range-free methods, the connection between the anchor nodes and the sensor nodes is extremely important. This is due to the fact that the beacon signals sent out by the anchor nodes greatly aid the sensor nodes in pinpointing their precise location. As a result, the exchange is known as an anchor-sensor exchange. The actual job of a sensor network is to gather valuable and comprehensible data from the sensing region. By using either inter-sensor communication or multi-hop communication, such derived information is transmitted to the control station for further actions.

II RELEATED WORK

Jiang [3] suggested a unique localization method in which the position of unknown nodes is determined by their proximity to anchor nodes. When the distance between unknown nodes and anchor nodes is greater than the node's communication radius, a novel method was employed to approximate it in order to minimise error during localization. In addition, a self-adapting evolutionary algorithm is suggested to determine the nodes' similar positions; this results in a significantly smaller localization error than the conventional approach.
A novel fingerprint technique based on logical inferences and the Received Signal Strength Indicator (RSSI) was proposed by Yetkin and Gungor [4]. Here, a confined area was partitioned into 1-by-1-meter cells. To create a radio map, the RSSI features of every cell were entered into a database. Using logical techniques, the anchor nodes' RSSIs that were received from the base station were compared in real time with the radio map. The target localization in this approach was done using mathematics. A two-phase resilient localization

approach based on the consistency of beacons in a grid was suggested by Wei Zhag [5]. A voting mechanism based on the grid's beacon consistency is employed in the initial phase to weed out some of the dubious nodes. A two-hop Collaborative Multilateral Localization Algorithm (CMLA) was investigated by Zhang and Hong Pei [6]. The implementation of this algorithm was done using event-driven approaches. Additionally, a new method is introduced that may be used to evaluation the spaces between two hop nodes, localise unknown nodes using anchor nodes within two hops, and compute unidentified node coordinates using minimal range error estimates. Any unknown node was localised by anchors and localised nodes within two hops if it could not be localised by two hop anchors nodes. A WSN localization technique based on the plant growth simulation algorithm (PGSA) was put into practice by Tang [7]. The growth mechanism of plant phototropism is characterised by this algorithm, which is a bionic random algorithm. According to simulation studies, this approach (PGSA) is more suited for large-scale environments since it is straightforward, has quick convergence, and is robust.Oguejifor [8] developed a localization method that makes use of an RSSI trilateration technique. Additionally assessed was the accuracy of the system position estimation. Xiajoun Zhu [9] looked at two potential solutions derived from preexisting concepts. One presupposes that nodes can communicate with one another only when they are in transmission range, while the other assumes that nodes that are closer to one another record higher RSSI. In practical application, neither of the possible methods performs well. A fuzzy logic-based restriction system was presented by Rama and Parvadha [10] and is appropriate for portable remote sensor hubs in wild, noisy environments. The component frameworks processed the hub region as a zone. The signal intensity is sorted into imprecision-encoding bins. Multidimensional scaling is a method that Priti and Tyagi [11] suggested. It computes the position of nodes that are within each other's communication range. This analysis method solves the problem of recreation by determining the relative positions of nodes with enough accuracy for the majority of applications. A localization method with excellent location estimation accuracy and minimal cost was created by Victor and Ramalakshmi [12]. The system located sensor nodes by using the spatiotemporal characteristics of well-controlled network events, in this example, light. The system's two main functions were to detect various network events and expand the sensor field's area by adding more nodes. Using trilateration, Nirmala [13] presented a novel method for localising every sensor node in the network. A novel technique based on radial distance modulation was put out by Baihua and Guoli [14] to locate and identify moving objects from top view angles. The advantages of this technology include non-contactness, compact computing, good robustness, easy configuration, and the ability to extract information directly from the movement and spatial location features of the moving item. After modulating and encoding the perception region of sensors, it is able to locate the moving object with basic information.

Parmar and Mehta [15] address improving underwater WSN energy efficiency and present a cross-layer technique. Because there is not enough sunshine in the underwater environment, changing the batteries is more difficult. Nonetheless, managing electricity on land is simple due to the ease with which batteries can be changed, and even changing a node is simple because it is not as costly as changing an underwater sensor node. Moreover, terrestrial wireless sensor networks can make use of solar electricity. Furthermore, compared to terrestrial WSN, a greater communication range is required. After taking into account each of these concerns, the (CL-VBF) technique is presented. Because of this method, power management along the MAC layer can be achieved via the routing layer. A cross-layer approach was suggested by Li et al. [16] to manage communication and data collection in a wireless sensor network used by unmanned aerial vehicles (UAVs). A procedure known as A-O Aloha (Adaptive-Opportunistic Aloha) is suggested in order to ensure efficiency. The cross layer, energy consumption [17], successful sensors, and transmission efficiency are all necessary for the protocol to function. A method that is dependent on priority is designed to create greater equality in the construction of sensors, and it allows for flexible modification of precedence. Optrix is a cross-layer, energy-efficient routing system that was introduced Shareef et al. [18]. Convex formulation was employed in the protocol to extend the network's lifetime.Additionally, a different approach known as Optrix-BW is put forth, which makes use of bandwidth constraints and convex formulation to allow the channel conditions to be taken into account during routing. With respect to this metric, it indicates that Optrix-BW can manage congestion. 91% of the ideal answer is obtained when this Optrix is used in TinyOS. Furthermore, a routing controller mechanism that enables this modification is described. A routing technique called CL-RS, or Reliable Cross Layer Routing technique, was developed by Kusumamba and Kumar [19] to balance energy in WSNs. It achieves a long lifetime through the controlled use of limited energy. Both the network layer and the MAC layer are considered. These layers identify optimisation difficulties, and appropriate solutions are provided to minimise energy consumption and maximise network longevity. The joint optimisation design can be formulated as a linear programming problem.

III METHODOLOGY AND INSTRUMENTATION

A. *Path Planning Techniques*

Within the localization strategy domain, common basic path planning methods including SCAN, DOUBLE SCAN are investigated in the present study.

B. *SCAN*

According to Koutsonikolas et al. [20], the SCAN technique operates by having the mobile beacon go along a single dimension, such as the x- or y-axis. The trajectory can give the network consistent coverage, and the method is straightforward and quick to use. The movement of the mobile landmark along a given dimension is depicted in Fig. 3. The mobile landmark is seen moving along the y-axis in this picture, and the resolution of the trajectory is determined by the separation between two consecutive segments of the trajectory, or the y-axis's parallel.

The resolution should be at most 2R when the sensors' communication range is taken into account as R. This presumption guarantees that every sensor will receive beacons. SCAN further makes sure that, depending on a correctly chosen resolution, every node receives beacons from the mobile landmark. Notwithstanding these benefits, collinearity of beacons is a significant disadvantage of SCAN. If the resolution is greater than the transmission range, many nodes will only be able to receive beacons from one line segment and one direction. This leads to the inability to derive a reasonable estimate along the x-axis.

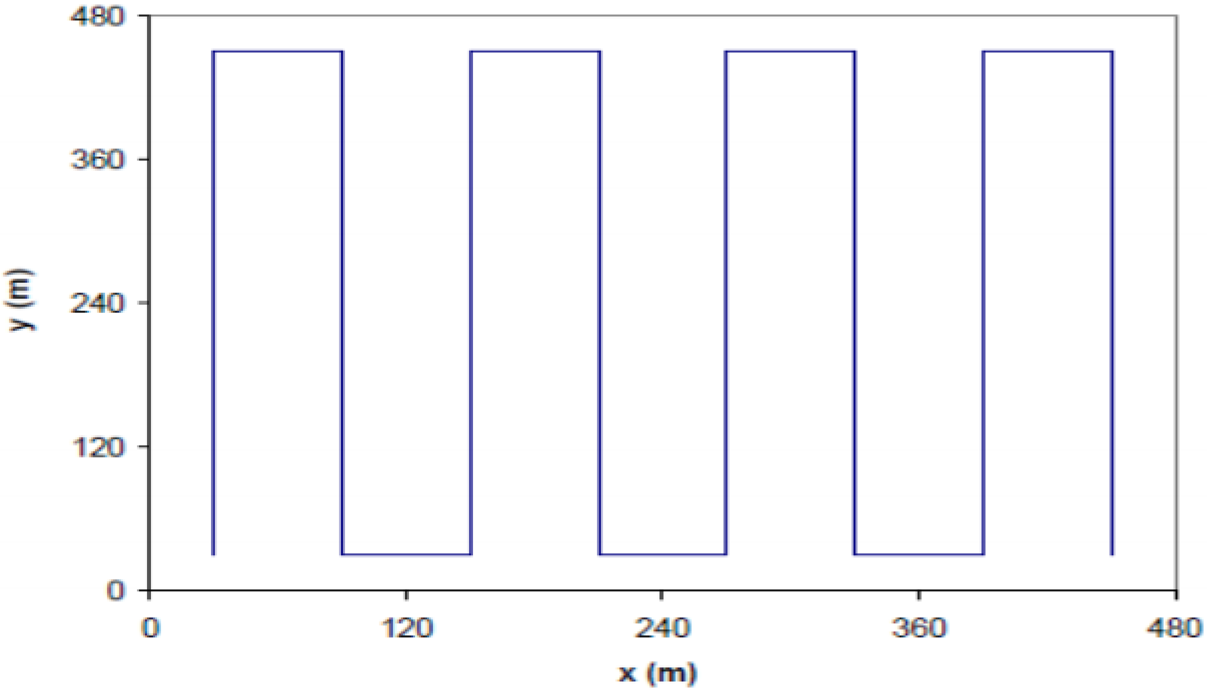

Fig.3:SCAN Trajectory

C. *Double Scan*

Making the network undergo scanning in both directions, or DOUBLE SCAN (Koutsonikolas et al. [20]), is another visible way to address the collinearity issue with SCAN, as illustrated in Fig.4. However, in contrast to the straightforward scan, this method expects the movable landmark to travel twice as far for the same resolution. It is evident from Fig.4 that the mobile landmark maintains a constant distance travelled for every trajectory. This demonstrates how well DOUBLE SCAN performs at double the resolution of SCAN.

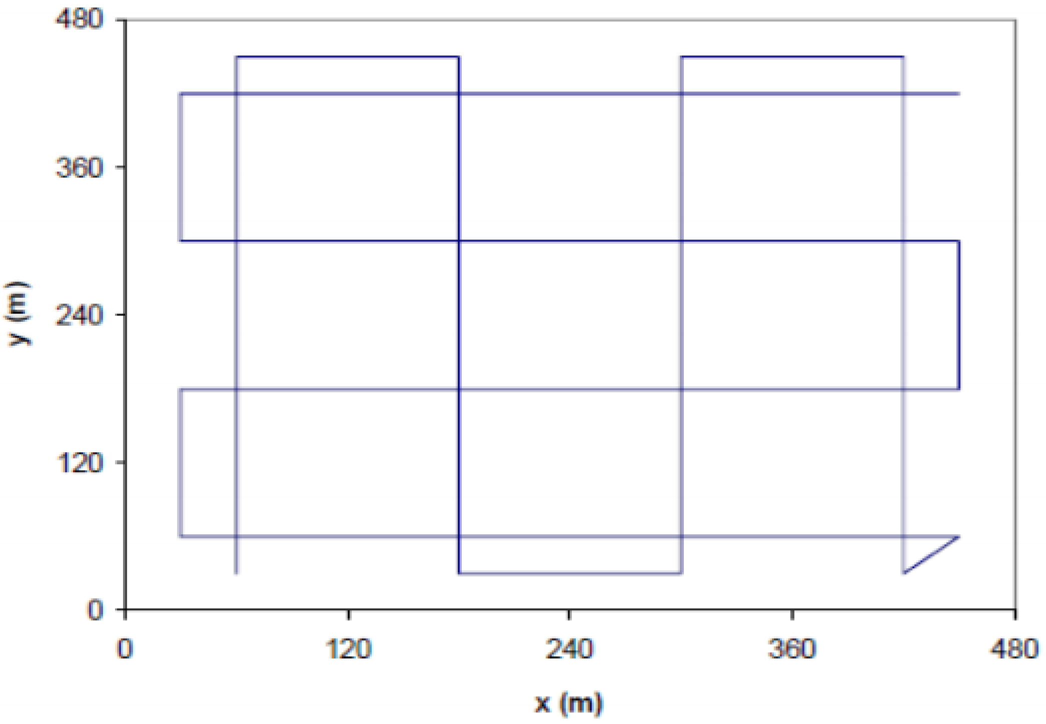

Fig.4: DOUBLE SCAN Trajectory

D. *Analysis of Efficient Scan with Dual Mobile Anchors*

Wireless Sensor Networks, with a focus on communication, have been a promising area of study in recent decades. This is due to its broader and more promising range of applications, which include tracking military operations in remote areas, monitoring medical procedures, detecting wildfires, and using acoustics for detection. The significance of these applications lies in their ability to update collected data with locally sent information. Each node is endorsed by an anchor node, which serves as an advanced level of location for the actual positions of sensor nodes instead of the GPS. The expensive nodes are replaced by mobile anchor nodes, which also substantially enclose the sensor location.

As was previously observed, the range free technique relies heavily on the beacon messages and hop count to determine the distance between each sensor network node. But because of their complexity, the mobile anchor nodes are inaccurate even though they are inexpensive. Therefore, the goal of the current study is to improve accuracy through the use of a dual anchor node. Because it is designed to move in tandem with other sensor nodes to facilitate their localization, the suggested dual anchor node operates under a range-free approach. A single movable anchor node that has been specially designed for location identification is typically used in localization algorithms. This node has been further modified to sense and receive data. This study explores the use of a mechanism involving two mobile anchors based on these concepts. Improved SCAN are extra trajectories fitted to these anchors. This method involves localising the sensor nodes by means of two mobile anchors that are configured to move in both directions. These anchors also serve as a source for the transfer of sensed data. The ability of these two mobile anchors to achieve optimal localization at shorter time intervals is the application's standout feature.

E. *Proposed Dual Mobile Anchor Nodes*

Fig. 5 shows the single anchor node that is intended to be used in the proposed work to locate static sensor nodes. Moreover, the SCAN route design method is used to allow the anchor node to be mobile.In this study, the dual anchor node in SCAN trajectory is used to identify the position of every static sensor in the designated sensing field.

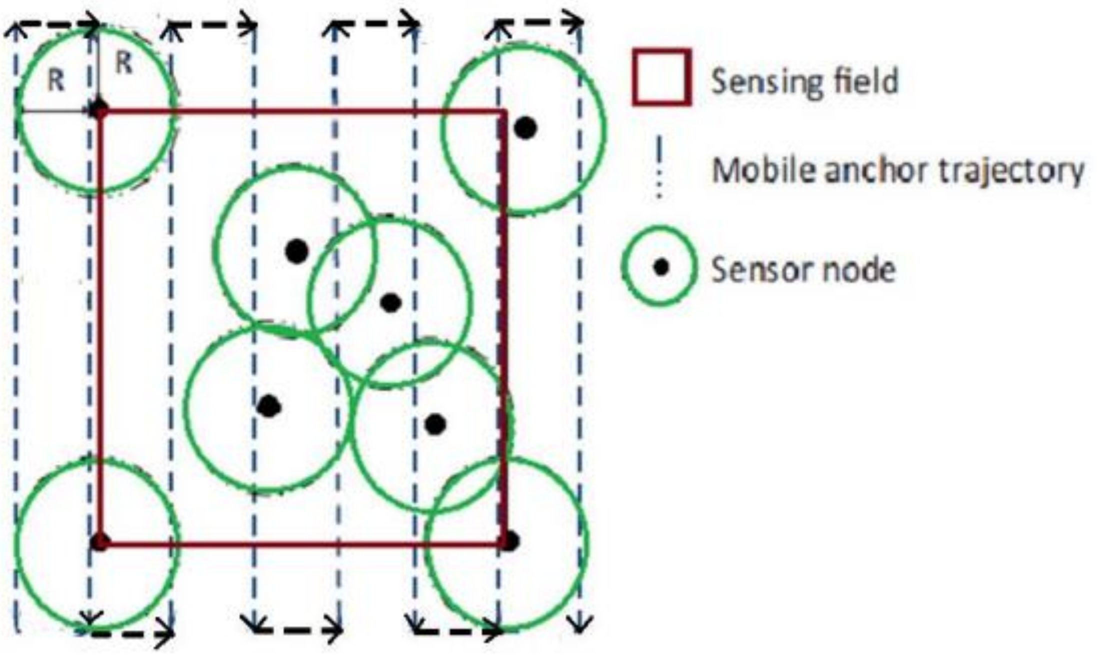

Fig. 5: Single Anchor Node Trajectory

The configuration of these two mobile anchor nodes travelling in opposing directions is shown in Fig. 6. Even though they are designed to proceed in different directions, they have the same communication range and travel speed. It should also be highlighted that these two anchors do not collide when they travel, adopting separate paths. Every sensor node is typically localised in the forward direction of these two anchor nodes when they move for the first time. They only send the sensed data to the base station when they are moving, regardless of which way they are moving. This makes it possible to continuously monitor the sensor field. Additionally, this type of monitoring has the potential to produce a high data transfer rate between these nodes and the base station.

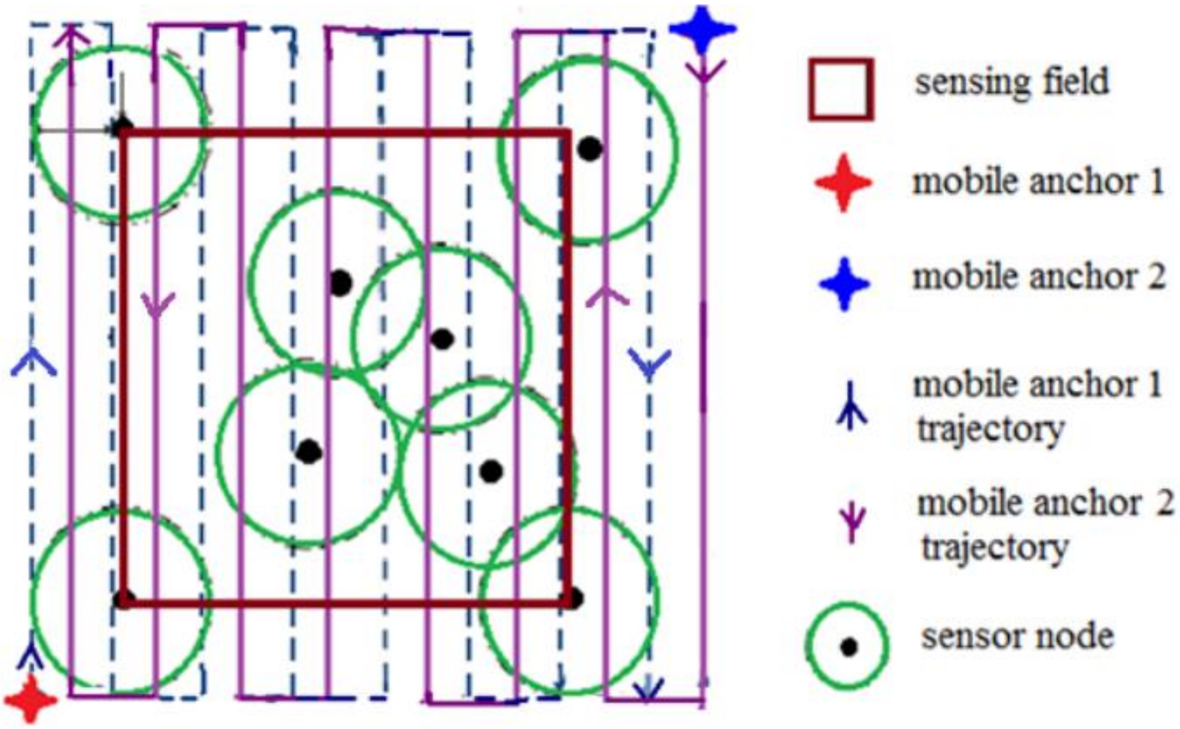

Fig.6:Proposed Dual Anchor Node Trajectories

IV RESULTS

A number of simulations using the ns-2 network simulator were used to assess the effectiveness of the suggested Dual mobile anchor nodes concept. With the assistance of two mobile anchor nodes, a fixed square sensing area measuring 100 m by 100 m was randomly distributed among the 100 sensor nodes that made up the simulation environment. Two anchor nodes, one in the left bottom corner (Red) and the other in the right top corner (Blue), are present in the sensing field. As previously said, they intend to travel against the path planning by avoiding any collisions. Additionally, anchor nodes are programmed to move under the SCAN process in order to locate each static sensor node. Based on the enhanced path planning method, it has been discovered that the mobile nodes traverse the whole sensing field during simulations. The dual anchor nodes and the single mobile anchor node were put through a comparative performance evaluation. Three evaluation measures, including accuracy, localization time, and localization success rate, have been used for this purpose.

A. *Accuracy*

The accuracy of estimated positions is measured using the average localization error. This makes it possible to calculate the difference between a sensor node's precise location and its predicted position in order to get the average localization error. The procedure used to formulate the localization error is shown in equation (1).

$$\text{error }(i) = \sqrt{(x_{ei} - x_i)^2 + (y_{ei} - y_i)^2} \qquad \text{“1”}$$

where the values of A xei and B eii represent the mean of the predicted coordinates of the unidentified sensor Si. Assume that the estimated coordinates of unknown sensor Si with respect to mobile anchor node a are $xeia$ and $yeia$. Likewise, suppose that $xe\boldsymbol{U}b$ and $yeib$ represent the approximate coordinates of an unknown sensor Si in relation to the mobile anchor node b. Equation (2) thus gives the average of the predicted coordinates of the unknown sensor Si.

$$x_{ei} = \frac{x_{eia}+x_{eib}}{2} \text{ and } y_{ei} = \frac{y_{eia}+y_{eib}}{2} \qquad \text{“2”}$$

This results in the average localization error, Le, which is given in equation (3), being derived.

$$L_e = \frac{\sum_{i=1}^{n} \text{error }(i)}{n} \qquad \text{“3”}$$

Where n is the number of unidentified sensors present in the field of sensing.

B. *Localization Time*

It is the amount of time needed to estimate where an unknown sensor is located within the sensing field. The following equation (4) is used to get the average localization time Lt.

$$L_t = \frac{\sum_{i=1}^{m} (t_{loc(i)} - t_{rec(i)})}{m} \qquad \text{“4”}$$

were trec(i) is the time it took to receive the first beacon message, tloc(i) is the total number of localised nodes, and m is the total number of localised nodes.

C. *Localization Success*

The success ratio between the number of successful nodes (m) and the total number of unknown nodes (n) in the sensor is used to measure the localization success. Equation (5) provides the calculation of the localization success (Ls).

$$L_s = \frac{m}{n} \qquad \text{“5”}$$

V DISCUSSION

The description of the localization time in the preceding context applies to the stationary sensor nodes. The localised sensor nodes in the sensing field with respect to the single and dual mobile anchor nodes in the specified trajectory are referred to by this time duration. Consequently, Fig.7 shows the net time duration for each of the 100 static sensor nodes in the sensing field.The mobile anchor node travels the 100 m × 100 m sensing field in a proportionately longer amount of time (v=10 m/s). The results showed that using two mobile anchors reduced the amount of time needed in comparison to using just one.

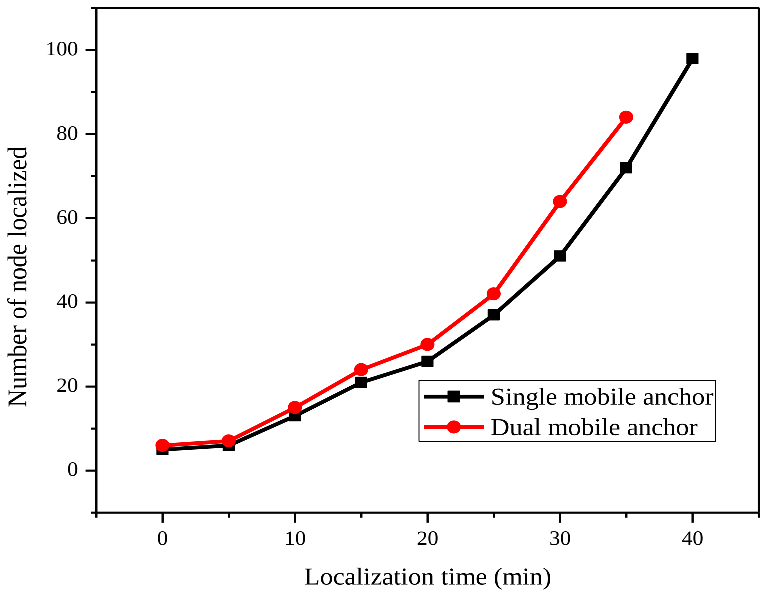

Fig. 7: Comparison of single and dual mobile anchor in SCAN trajectory

The average localization time for single and dual movable anchor nodes is shown in Fig.8 for a better understanding. A variation in the resolution range ratio led to the evolution of the average localization time. It is commonly known that the term "localization time" refers to the amount of time that is computed to locate an unknown sensor in the sensing field following the receipt of the initial beacon transmission.

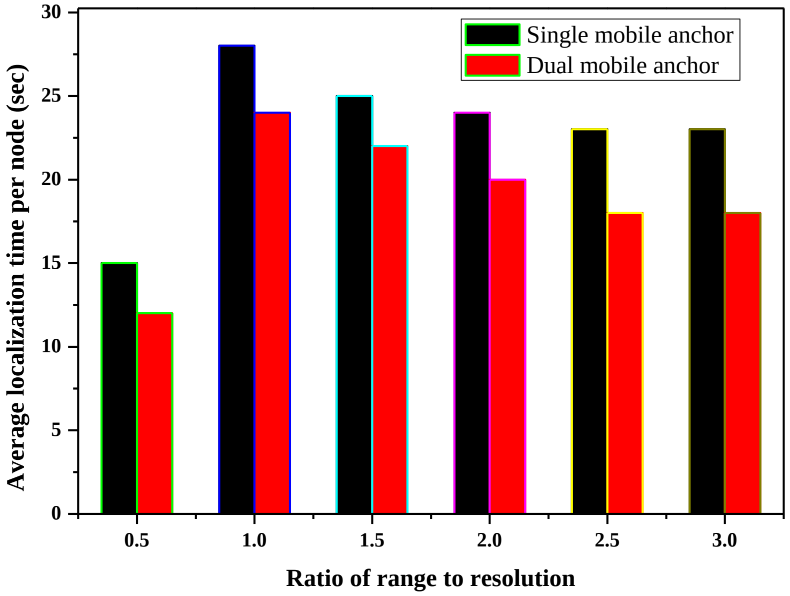

Fig.8:Localization time of single and dual mobile anchor in SCANtrajectory

Similarly, Fig.9 shows the comparative localization success rate that is determined for single and dual movable anchors, arriving at different ratios of resolution ranges. The success of localization is determined by the ratio between the total number of sensor nodes positioned in the sensing field and the number of successfully localised sensor nodes. There has been a marginal improvement in the success rate of localization.

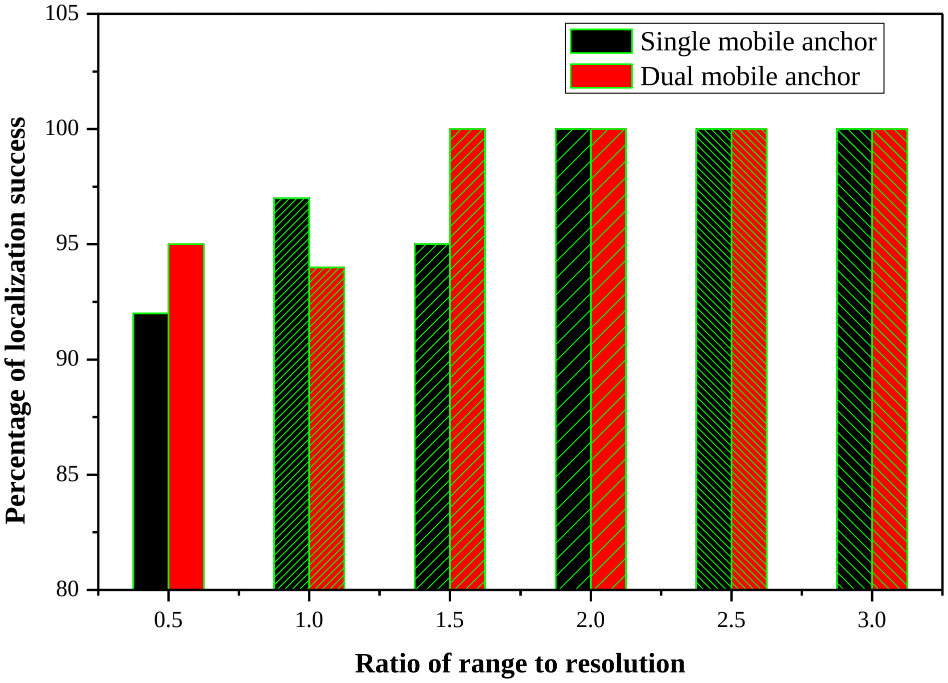

Fig. 9:Localization success of single and dual mobile anchor in SCAN trajectory

Fig.10 shows the average localization error for both single and dual mobile anchors with respect to the scan trajectory. Therefore, using two mobile anchors clearly reduces the amount of localization mistake. These results demonstrate how using two mobile anchors improves localization accuracy. Therefore, three comparative metrics are used to demonstrate the superiority of this dual mobile anchor.

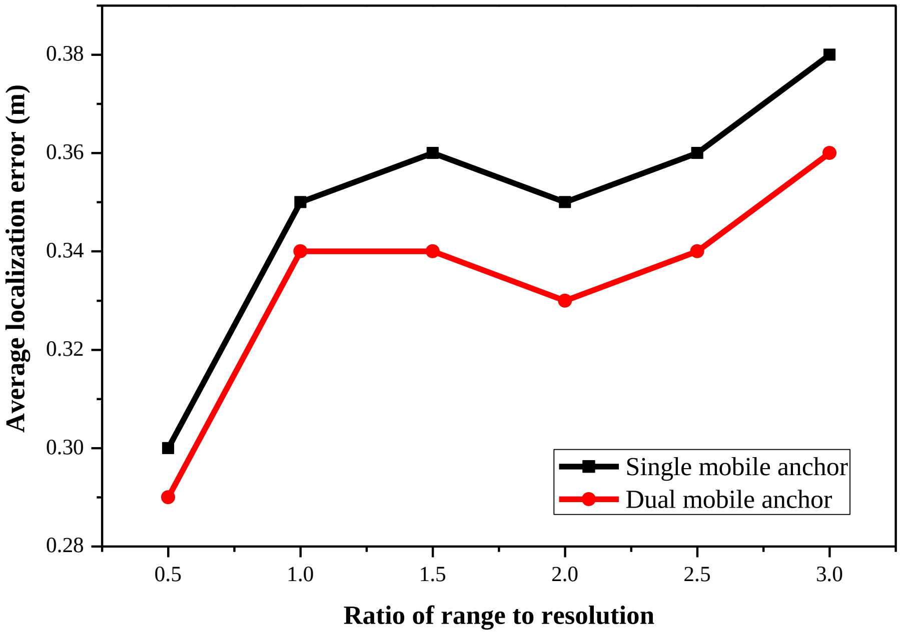

Fig. 10:Average Localization error of single and dual mobile anchor in SCAN trajectory

VI WSN APPLICATIONS

Area monitoring is one of the many uses of wireless sensor networks, and it has a special place. Deploying WSN over a designated territory comprising environmental phenomena is the process of area monitoring. Earth pressure, ground vibration, smoke emission, and the average temperature are all measured or tracked under this method. Sensor nodes are used in the monitoring of military surveillance under patrolling to identify enemy intrusions. When used in a typical setting, sensor nodes are configured to use geo-fencing to keep an eye out for any oil or gas pipelines. Wearable and implantable applications are the two types of sensor node use in the medical field. Of the two, wearable technology is intended for the body's exterior surfaces, whereas implanted technology is utilised to treat the body within. A thorough and highly accurate assessment of the WSN localization scheme was published by Chehri et al. [21]. This technique made it possible to identify tools like blast-hole drilling machines and bulldozers. The same method is used to locate mining activities under regular or emergency circumstances. The architecture created by Tacconi et al. [22] allowed mobile nodes to keep an eye on the numerous wireless sensor networks used in the intelligent transportation process. Tan and colleagues [23] investigated the potential for employing wireless sensor networks to identify collaboration targets.Future uses of wireless multimedia sensor and actor networks were discussed by Kantarci and Mouftah [24]. The study focuses on the energy-generating fields under the power grid, particularly solar panel installation, hydropower, nuclear power, fossil fuel-oriented power plants, wind energy, and solar power plants. Ramesh [25] looked into a particular wireless sensor network's promising concept for spotting unplanned land slide.

Certain uses of WSNs are very beneficial to the medical industry. The detection of landslides via WSN is a complex and difficult operation. The network's sensor nodes are capable of identifying changes in soil parameters before and during sliding. The data sent to the sensor nodes can be used to gather preliminary information about potential landslides. This can shield additional slide and stop human casualties or animal deterioration. WSNs are used to monitor the chemical characteristics of water to ensure its quality. Water in dams, reservoirs, ponds, rivers, lakes, groundwater, and even the oceans can all be observed in this way [26]. The dispersed wireless sensor nodes are perfect for accurately assessing the state of the water in these areas.

VII CONCLUSION

With respect to the percentage of sensor nodes that successfully locate themselves, the suggested path planning scheme performs better than the alternative systems. These results highlight the need to continue looking into path planning strategies for practically all mobile anchor-based localization schemes. Additionally, it has been demonstrated that effective WCL has the advantages of less complexity, less prior knowledge, and less power usage. According to the findings, using the suggested path planning method has been shown to reduce the range of localization error. In terms of localization success rate, the suggested path planning approach also performs better in practice than alternative schemes. It follows that these benefits make it possible to expand the path planning scheme to include all schemes under the mobile anchor approach. The study focuses on the suggested dual movable anchors with the effective SCAN efficient trajectory. Furthermore, there is evidence that shows improved performance in terms of localization accuracy, localization error, and localization success percentages when using two mobile anchors. Many applications involving wireless sensor networks require the location information from whence the data have been obtained. Consequently, the location of sensor nodes determines how well WSNs operate.

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