Localization Algorithm for Mobile Sensor Nodes Using 3D Space in Wireless Sensor Network

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Abstract-On the problem of wireless sensor network localization; few true three-dimensional (3D) methods have been developed to satisfy the practical needs. In this work we proposed range-based 3D localization algorithm that is accurate, anchor-free, scalable and physical position available. A novel combination of distance and direction measurement techniques introduced to estimate ranges between neighbours. Based on this information local coordinate systems are constructed and then converged to form a global network wide coordinate system ,which finally leads to nodes' absolute positions. Simulation results have shown that our algorithm achieves good trade-off between localization percentage and precision.

Keywords: *Localization algorithm, 3D Centroid.*

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I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of numerous nodes, which have several modules, including receiver and transmitter. Generally, WSNs have many advantages due to its low cost and low power dissipation. WSNs have been applied to many fields such as environment monitoring, battlefield surveillance, medical monitoring, etc . As a vital part of WSNs, localization has been concentrated increasingly. Localization algorithms can be categorized into two classes: ranging-based algorithms and ranging-free algorithms. Ranging-free localization algorithms require high performance hardware. The ranging-free localization algorithms include centroid algorithms, DV-Hop algorithms, Amorphous, APIT algorithms etc. Among them, centroid algorithm and DV-Hop algorithm are widely used. Ranging based localization algorithms are based on Time of Arrival/Time Difference of Arrival (TOA TDOA), Received Signal Strength (RSS), and Angle Of Arrival (AOA). Among them, RSS is widely used because of its simple implementation. Some wireless communication modules, which can provide RSS value directly, are embedded in sensor nodes .In this paper, centroid algorithm and RSS are combined together to estimate the position of unknown nodes' in 2D and 3D. Static nodes referred to anchors are involved to get the RSS value from unknown nodes and improved weighted centroid algorithm is applied to estimate the most possible position. A distance thresholding has been proposed to improve the accuracy of positioning.[1]

II. LOCALIZATION

To determine the physical coordinates of a group of sensor nodes in a wireless sensor network (WSN) .Due to application context, use of GPS is unrealistic, therefore, sensors need to self-organize a coordinate system. To report data that is geographically meaningful Services such as routing rely on location information; geographic routing protocols; context-based routing protocols, location-aware services. In general, almost all the sensor network localization algorithms share three main phases.

A. DISTANCE ESTIMATION

The distance estimation phase involves measurement techniques to estimate the relative distance between the nodes.

B. POSITION COMPUTATION

The Position computation consists of algorithms to calculate the coordinates of the unknown node with respect to the known anchor nodes or other neighboring nodes.

C.LOCALIZATION ALGHORITHM

The localization algorithm, in general, determines how the information concerning distances and positions, is manipulated in order to allow most or all of the nodes of a WSN to estimate their position. Optimally the localization algorithm may involve algorithms to reduce the errors and refine the node positions.Localization has been concentrated increasingly. Localization has been concentrated increasingly. Localization algorithms can be categorized into two classes:[2]

1) Range-based algorithms and

2) Range-free algorithms.

1 Ranging Algorithm based on:

- Received Signal Strength(RSS)
- Time Difference of Arrival (TDOA),
- Time of Arrival(TOA)

- Angle Of Arrival (AOA)
- Received Signal Strength

RSS is defined as the power measured by a received signal strength indicator (RSSI) by the receiver. RSS is the squared magnitude of the radio signal strength. We can consider the RSS of low frequency, RF or other signals. Wireless sensors nodes communicate with neighbouring sensors, so the signal strength of the radio can be calculated by each receiver during normal data communication without requiring additional bandwidth or energy requirements. The power of the receiving radio signals can be calculated by measuring the voltage: P = -51.3 x RSSI - 49.2[dBm].Noise is the standard deviation V of all RSS values that may be observed at a particular distance in a given environment. Even with adjacent stationary sensor nodes, RSS will vary to some degree due to noise. The noise affecting the RSS is not constant; it varies with time as well as environmental conditions. Finally, radio signals can vary significantly in both transmission strength and receptivity, particularly in cheap, low-power radio devices. The RSS directly varies with the inverse power of distance. The attenuation rate is the rate D at which radio signal strength decreases over distance's α d- generally, if α = 2 then radio signal strength drops by 3dB every time distance doubles. Generally α > 2 for highly noisy environments. This linear attenuation rate means that the difference between the radio signal strength varies according to the predefined rate for example; difference between 1 meter and 2 meter is similar to the difference between 10 meter and 20 meter i.e. exactly 3dB. Moreover, a constant level of noise can result in increasing error rates when signal strength is used to estimate, distance.The received signal strength (RSS) method uses the relationship of radio frequency signal as a function of distance. From this relationship a mathematical propagation model can be derived. From detailed studies of the RF signal propagation characteristics, the main disadvantage of this method is that the propagation characteristics of radio signals can vary with changes in the surrounding environment temperature, humidity, pressure, areas such as: rural, urban. It also suffers multipath effect (weather changes, urban, rural and indoor, outdoor settings) until a direct line of site the RSS detection is somewhat difficult.[2]

- **Time Difference Of Arrival(TDOA)**

There is a category of localization algorithms utilizing TDOA measurements of the transmitter's signal at a number of receivers with known location formation to estimate the location of the transmitter.

- **Time Of Arrival:-**

Time of arrival (ToA, also time of flight) is the amount of time a signal takes to propagate from transmitter to receiver. Because the signal propagation rate is constant and known (ignoring differences in mediums) the travel time of a signal can be used to directly calculate distance. Multiple measurements can be combined with trilateration to find a location. This is the technique used by GPS. Systems which use ToA, generally require a complicated synchronization mechanism to maintain a reliable source of time for sensors (though this can be avoided in carefully designed systems by using repeaters to establish coupling. Time of arrival measurements are also most accurate when the signal has distinct time-dependent features on the scale of interest—for example, when it is composed of short pulses of known duration—but Fourier Transform theory shows that in order to change amplitude or phase on a short time scale, a signal must use a broad bandwidth. For example, to create a pulse of about 1 ns duration, roughly sufficient to identify location to within 0.3 m (1 foot), a bandwidth of roughly 1 GHz is required. In many regions of the radio spectrum, emission over such a broad bandwidth is not allowed by the relevant regulatory authorities, in order to avoid interference with other narrowband users of the spectrum. In the United States, unlicensed transmission is allowed in several bands, such as the 902-928 MHz and 2.4-2.483 GHz Industrial, Scientific, and Medical ISM bands, but high-power transmission cannot extend outside of these bands. However, several jurisdictions now allow ultra wideband transmission over GHz or multi-GHz bandwidths, with constraints on transmitted power to minimize interference with other spectrum users.[2]

- Angel Of Arrival

Angle of arrival (AoA) is the angle from which a signal arrives at a receiver. AoA is usually determined by measuring the time difference of arrival (TDOA) between multiple antennas in a sensor array. In other receivers, it is determined by an array of highly directional sensors the angle can be determined by which sensor received the signal. AoA is usually used with triangulation to find the location relative to two anchor transmitters. The angle of arrival (AOA) at a receiving station can be determined by the use of a directional antenna, or by differential time of arrival at an array of antennas with known location.AOA information may be combined with distance estimates from the techniques previously described to establish the location of a transmitter or back scattered. Alternatively, the AOA at two receiving stations of known location establishes the position of the transmitter. The use of multiple receivers to locate a transmitter is known as multilateration.[5]

2. Range-free algorithms:

Ranging-free localization algorithms require high performance hardware. The range-free localization algorithms include

- Centroid algorithms,
- DV-Hop algorithms,

- APIT algorithms etc.

- Centroid Algorithm:-

In mathematics and physics, the centroid or geometric center of a two-dimensional region is, informally, the point at which a cardboard cut-out of the region could be perfectly balanced on the tip of a pencil(assuming uniform density and a uniform gravitational field). Formally, the centroid of a plane figure or two-dimensional shape is the arithmetic mean ("average") position of all the points in the shape. The definition extends to any object in *n*-dimensional space: its centroid is the mean position of all the points in all of the coordinate directions. While in geometry the term barycentre is a synonym for "centroid", in physics "barycentre" may also mean the physical centre of mass or the centre of gravity, depending on the context. The centre of mass (and centre of gravity in a uniform gravitational field) is the arithmetic mean of all points weighted by the local density or specific weight. If a physical object has uniform density, then its centre of mass is the same as the centroid of its shape. The geometric centroid of a convex object always lies in the object. A non-convex object might have a centroid that is outside the figure itself. The centroid of a ring or a bowl, for example, lies in the object's central void. If the centroid is defined, it is a fixed point of all isometrics in its symmetry group. In particular, the geometric centroid of an object lies in the intersection of all its hyper planes of symmetry. The centroid of many figures (regular polygon, regular polyhedron, cylinder, rectangle, rhombus, circle, sphere, ellipse, ellipsoid, super ellipse, super ellipsoid, etc.) can be determined by this principle alone .In particular, the centroid of a parallelogram is the meeting point of its two diagonals. This is not true for other quadrilaterals. For the same reason, the centroid of an object with translational symmetry is undefined (or lies outside the enclosing space), because a translation has no fixed point.[5]

- DV-HOP Algorithm:-

One of widely used range-free algorithms, is DV-HOP, in which the real distance between unknown node and anchor nodes is replaced by the product of average one-hop distance and the minimal hop number from the unknown node to some specific anchor node, and then the unknown node's position can be inferred through triangulation algorithm or maximum likelihood estimators (MLE) But the traditional DV-HOP has two drawbacks replacing the real distance between the nodes with the hops introduces certain errors to the computation range-free DV-HOP algorithm does not need any additional range modules (cost-effective), and is little affected by environmental factor (in compassion with range-based localization algorithms). These characteristics make them suitable to WSNs of simple node, low cost and large scale. But, one drawback in traditional DV-HOP algorithm lies in that in first step, the beacons issued by anchor nodes will flood into the whole networks. The great communications overhead will consume huge power, which, greatly limit the network's lifetime.[5]

- **APIT Algorithm :-**

In this section, we describe our novel area-based range-free localization scheme, which we call APIT. APIT requires a heterogeneous network of sensing devices where a small percentage of these devices (percentages vary depending on network and node density) are equipped with high-powered transmitters and location information obtained via GPS or some other mechanism. We refer to these location-equipped devices as **anchors**. Using beacons from these anchors, APIT employs a novel approach to perform location estimation by isolating the environment into triangular regions between beaconing nodes . A node's presence inside or outside of these triangular regions allows a node to narrow down the area in which it can potentially reside. By utilizing combinations of anchor positions, the diameter of the estimated area in which a node resides can be reduced, to provide a good location estimate. The APIT algorithm can be broken down into four steps: 1)Beacon exchange, 2) PIT Testing, 3) APIT aggregation and 4) COG calculation. These steps are performed at individual nodes in a purely distributed fashion.[5]

III. PROPOSED ALGORITHM

Steps for calculation of 3-D location:

- The whole area is divided into grids. The interspacing between the grids is less than the range of the anchor nodes.
- A beacon node covers a block of cubes that are within its radio range. The cube size is such that it covers the largest area in the sphere formed by the radio range.
- The distance between the un-localized sensor node and the beacon nodes is calculated using different RSS techniques.
- A list is maintained by each un-localized node that contains the number of beacon nodes and the distance form each beacon node.
- The common cubical intersection areas of all the beacon nodes is found reducing the location possibilities
- The common intersection area gives the bounded βvalues (max, min).The bounded values specifies the maximum and minimum values of co-ordinates. The nodes position should be within this rectangular region.
- Check whether the beacon nodes are forming a plane i.e. they are not on same line
- Calculate the location (x, y, z) of un-localized nodes taking the distances into account
- Check the whether the calculated values within bounding region. All the values outside the region are

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discarded.Change the status of newly localized node to new beacon nodes for further calculation of Other node[2].

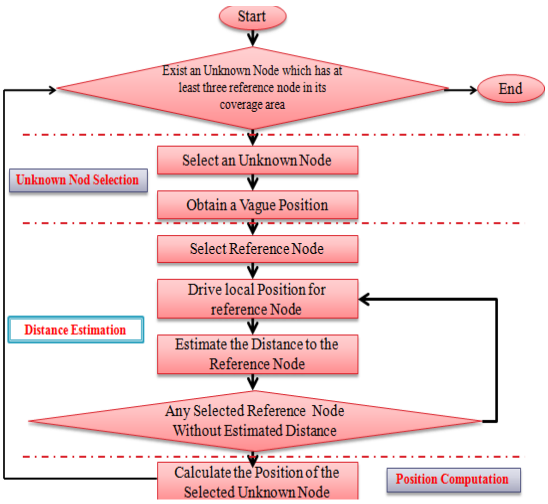


Figure.1.Flowchart of Proposed Algorithm

3.1 The Bounded Area (Ranged Free Approach) is explained below:-

Intersection Of Bounding Boxes, Shaded Region is the Common bounded region..Each Cube representing bounding area can be represented by max& min value of coordinates.

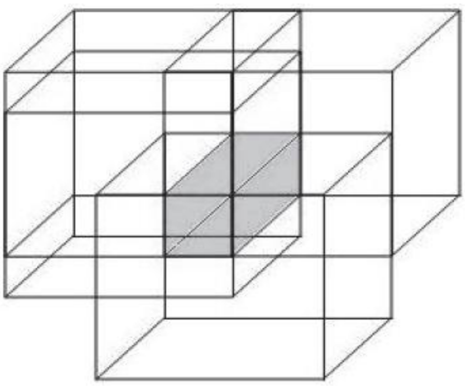


Figure.2. Intersection Of Bounding Boxes

The radio range covered by beacon node P(X,Y,Z) varies between (Xmin,Ymin,Zmin) and (Xmax,Ymax,Zmax) represents bounded β of the range.

Where,,Xmin=X-R

Xmax= X+R

Ymin=Y-R Ymax= Y+R

Zmin=Z-R Zmax= Z+R

R represent average of beacon node.[6]

3.3Calculating from known distances (Range-Based):

The method uses the distance information between the un-localized node and the beacon nodes. All the beacon nodes are considered to lie on same plane, w.r.t of these beacon nodes localization is determined. A set of three anchor nodes are selected at a time. However in the real life environmental conditions where there is interference noise the measuring and calculating errors might change the distance little bit. As a result P is considered lying within the same plane if it satisfies the constraint. Here at three anchor node Are required to calculate the location of unknown sensor node. $(x-xi)^2+(y-yi)^2+(z-zi)^2 = pi^2$ where , i= 1,2,3

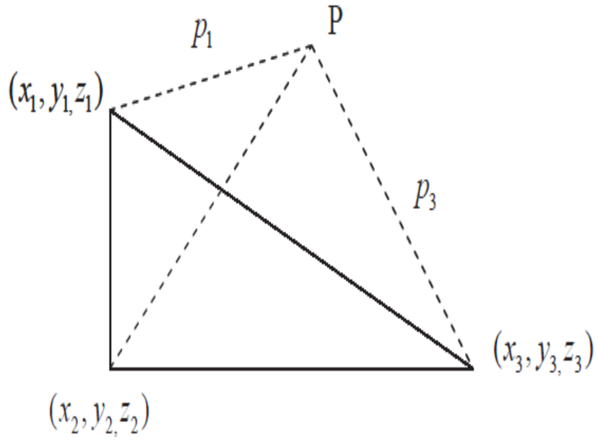


Figure.3.Coordinate Plane X,Y,Z

$(x-x_1)^2+(y-y_1)^2+(z-z_1)^2- p_1^2= 0$.......1
$(x-x_2)^2+(y-y_2)^2+(z-z_2)^2-p_2^2=0$......2
$(x-x_3)^2+(y-y_3)^2+(z-z_3)^2-p_3^2=0$......3

Solving the above equations mathematically. For the variable Z we get multiple value. By using the bounded cube the proper value of x,y,z can be selected so that it satisfies:

$\beta=\beta_1/\beta_2/\beta_3$

The β cube is calculated using the intersected cubical rectangle of beacon nodes

$[Xnew_{min},Ynew_{min},Znew_{min}] \leq P[X,Y,Z] \leq [Xnew_{max},Ynew_{max},Znew_{max}]$

Now substituting the value of z in the other given equations we can derive values Of (X,Y,Z),

$(x-x_n)^2+(y-y_n)^2+(z-z_n)^2-d_n^2=0$,Where (x_n,y_n,z_n) corresponds the location of sensor .[2]

IV. SIMULATION RESULT

Performance Analysis

$$\textbf{Performance success} = 100 - \frac{\sum di}{N-n} * 100$$

Where, di= deviation between actual node and estimated node.

N= Total no. of node.

n= no. of Nodes per layer.

Error Analysis

$$D_{error} = \sqrt{(Xa-Xc)^2+(Ya-Yc)^2+(Za-Zc)^2}$$

Xa,Ya,Za = Actual Sensor Node.

Xc,Yc,Zc= Estimated Sensor Node

Further simulation can done by:-

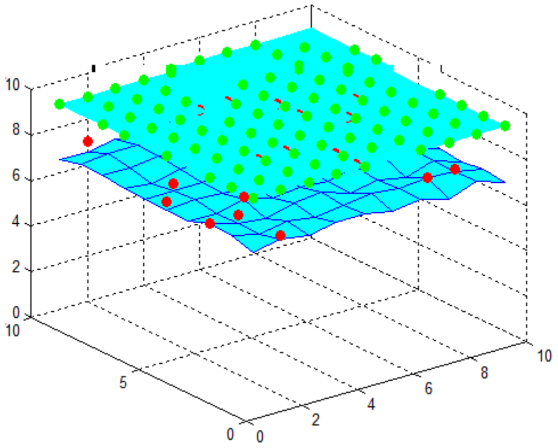
1.Scalability.

2. Radio Range.

3 Effect of Noise.

4 Distance between Layers.

SCALABILITY



Layers Defining the Anchor node and Sensor Node with estimated Distance of nodes..

V. CONCLUSION

From the simulation we can see that the first layer anchor layer is first placed then, we place second layer sensor layer ,then we take x- coordinate and y- coordinate randomly of the Anchor node and Sensor node and take z- coordinate of anchor node constant and take z- coordinate randomly of sensor node .Then each sensor node will find anchor node distance And we get the three different anchor node with three diff distance ..

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