Localization System for Wireless Sensor Networks

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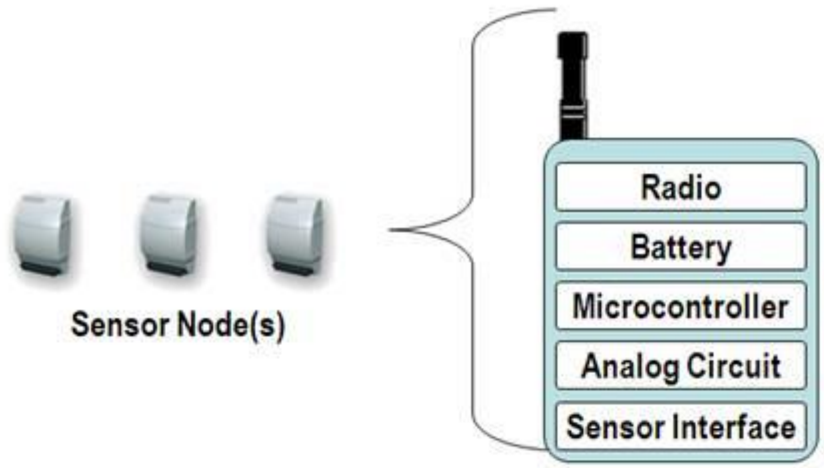
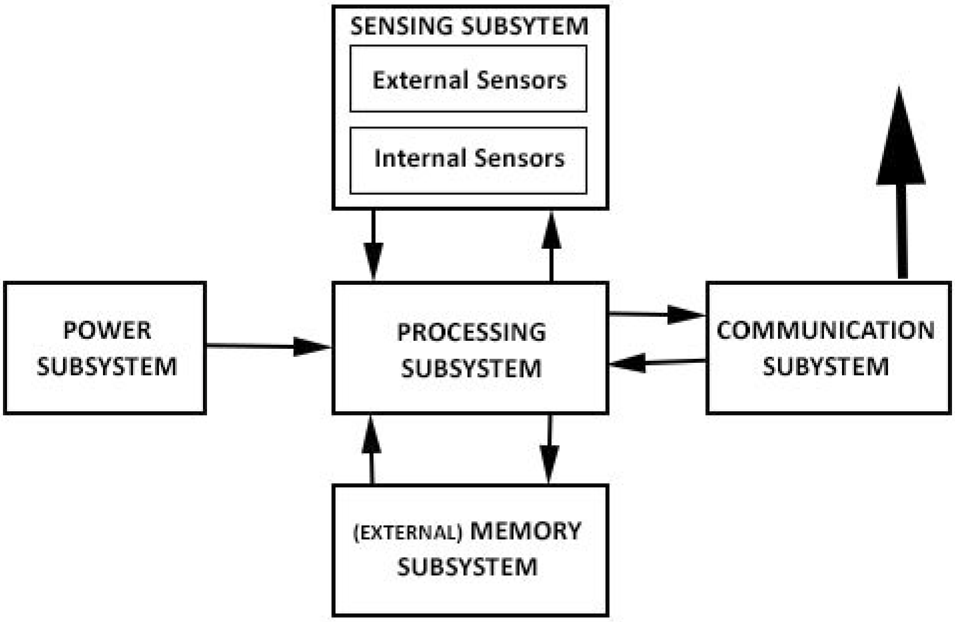
Abstract— Sensors are frequently being used for monitoring different phenomena of environment, Military, Health, Industry, Automobiles etc., and the information derived from sensed data are being used for making important decisions which directly affects humans and at times human life. This sensed data can only be of use if we know the exact position of the sensor node. This is not always easy as in many real life scenario, the deployment is random and in hostile conditions. Further, replacing a dead or damaged node is not an option in many circumstances. Many different approaches have been proposed by research community for localization information of a node deployed in a target area. In this work, an attempt has been made to review most promising localization methods proposed so far in comparative manner.

Keywords— Localization, Mobility, Sensor Networks, Beacon node, Trilateration, Multilateration

INTRODUCTION :

is a **wireless network** consisting of spatially distributed autonomous devices using **sensors** to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides **wireless** connectivity back to the wired world and distributed nodes (see Figure 1).





Architecture of wireless sensor node:

System(MEMS)[1] sensors are used to measure temperature, pressure, humidity, acceleration and chemical changes. IEEE802.15.4 defines two types of sensor nodes-a) full functional device(FDD) which uses the complete protocol set and b) reduced functional device(RFD) which uses reduced or minimum protocol set.

Generally the FDD nodes act as co-coordinator of the system in the network system. Wireless sensor network is thought to be composed of n sensor nodes with some predefined communication capabilities distributed over two dimensional area. Each node has communication range r. For simplicity we consider symmetric communication link i.e. for two nodes say, u and v, u is in communication range of v if and only if v is in communication range of u. With this regard the WSN network can be represented as Euclidean graph G=(V,E), where:

1. V = {v1, v2, ..., vn} is the set of sensor node,s.

2.< Vi, Vj> ∈ E if v i reaches v j; that is, the distance between vi and vj is less than r. w(e) ≤ r is the weight of edge e =w<i, j, the distance between vi and vj.>

Localization is the process of determining the location information of a node in the network system. . In lots of WSN application requirements like node addressing, geographical routing, node density determination, object tracking, node management, management of correlated data location information of node becomes a crucial point. Thus localization becomes a key technology for WSN development and operation.

Some terms can be used to designate the state of a node:

Definition 1 (Unknown Nodes — U): These are the free nodes which do not have their location information. The main goal of the localization system is to find out the position information of Unknown nodes.

Definition 2 (Settled Nodes — S): These are the nodes which were previously unknown nodes and after computing localization algorithms have got their position information. The error and inaccuracy in measurement are the key parameters which determine the quality of the localization system.

Definition 3 (Beacon Nodes — B): These are also known as anchor node-having pre-determined position information either by manual placement or by use of GPS device.

The localization problem can then be defined as follows.

Definition 4 (Localization Problem): A system of sensor node deployed randomly having some nodes with known position Bi(xi,yi) and unknown node u1,u2,……un. To find out position of node ui and transforming it to settled node S or making them beacon node for further computations

CLASSIFICATION OF LOCALIZATION SYSTEM :

Localization approaches are classified into two groups- Range based and Range free approaches.

Range based: approaches- This system depends on calculation of point to point range measurement. These methods aim to calculate the exact position of the sensor nodes. The devices used by these methods are expensive and more energy consuming. The most promising methods are- GPS, RSSI, AoA, TODA, Active Echo, TOA etc.

Range free :approaches- These methods compute relative or approximate position of sensor nodes. It does not require expensive hardware support for localization hence it is cost effective and low energy consuming but less accurate. Range free methods are classified into following groups depending upon basis of classification-

Based on anchor node- Beacon node required- diffusion, bounding box, gradient, APIT, centroid etc.

Beacon node not required- MDS-MAP, Relaxation based, co-ordinate stiching Based on connectivity- Proximity information – APIT, convex, centroid. Network connectivity- Dv-hop, MDS-MAP, Amorphous

LOCALIZATION ALGORITHMS:

GPS:

which stands for **Global Positioning System**, is a radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world.

RSSI:

RSSI is usually invisible to a user of a receiving device. However, because signal strength can vary greatly and affect functionality in wireless networking, IEEE 802.11 devices often make the measurement available to users.

RSSI is often done in the intermediate frequency (IF) stage before the IF amplifier. In zero-IF systems, it is done in the baseband signal chain, before the baseband amplifier. RSSI output is often a DC analog level. It can also be sampled by an internal ADC and the resulting codes available directly or via peripheral or internal processor bus.

TOA:Time of Arrival (ToA): To obtain range information using ToA, the sig-nal propagation time from souce to destination is measured. A GPS is the most basic example that uses ToA. To use ToA for range estimation,a system needs to be synchronous, which necessitates use of expensive hardware for precise clock synchronization with the satellite.

speed of wavelength and time of signals travelling between

anchor node and blind node is measured to estimate the location of blind node. TOA is a highly precise method. The distance to the source can be calculated as follow:
S = (T 2–T1) Vp (2)Where T1 is the time at which signal is sent, Vp is the signal
propagation speed in the medium and T2 is the time of arrival
TDoA (Time Difference of Arrival) Anchor node sends signal and waits for some time, t delay. Blind node receives these signals at time t sound. Blind node uses this time information for calculating the distance between anchor node and itself using the following equation D = (Sradio -Ssound)*(tsound -tradio -tdelay) There are many conceptions used in localization. Node Localization is approximated over communication between anchor nodes and blind nodes. Location is estimated through distance estimation and angle estimation.

Trilateration and Multilateration:

Trilateration is the most important technique to compute the position of nodes. The unknown node determines its distance from any three non-collinear reference nodes using one of distance estimation method and computes its position as the intersection point of N circles drawn taking reference nodes as centers and the distance between reference nodes. If the position of the reference nodes be (x1,y1), (x2,y2) and (x3,y3), to (xn,yn) and corresponding distances from unknown node be d1,d2 and d3,dn, we can compute position(x, y) of unknown node with the equations $(x - x_i)^2 + (y - y_i)^2 = d_i^2$, for i=1,2,3...n However in real world scenario the distance estimation suffers from errors and the computed position result in infinite set of solution instead of only one point.

In case, where large numbers of reference nodes are available, multilateration is used to compute the position of the node. However if the distance estimation suffers from error the corresponding position estimation do not produce a single point solution but In this case an over- determined system of equations must be solved. These systems of equations do not produce a single solution. With n reference point and also taking error in consideration, which makes $d_i = d_i - \varepsilon$, and corresponding equation becomes $(x - x_i)^2 + (y - y_i)^2 = d^2 - e$, where ε is an independent normal random variable with zero mean. By subtracting last equation the system can be linearized into $Ax \approx b$. This linear system can easily be solved using standard methods. The number of floating point operations

needed to compute a position depends on the method used to solve the system of equations. In
the case of the least square method, $(m + n/3)n^2$
Ad Hoc Positioning System

In Dv-Hop APS the beacon nodes start the:

propagation of their position information Working as an extension of the distance vector algorithm, all nodes receive the position information of all beacon nodes as well as the number
of hops to these beacons. When a beacon node receives the position information of the other
beacon nodes, it has enough information to compute the average size of one hop based on its own position, the position of the other beacon nodes,and the number of hops between them

This last value is then flooded in a controlled way into the network as a correction factor. When an unknown node receives a correction, it is able to convert its distance to the beacon nodes from number of hops to meters The complexity of message exchange in this algorithm is driven by the total number of beacon and normal nodes,which is O(n*(m+ 1)), where n

is the number of nodes and m is the number of beacon nodes. An advantage of the APS is that its localization algorithm requires a low number of beacon nodes in order to work. However, the way distances are propagated, especially in Dv-Hop and Dv-Distance, as well as the way these distances are converted from hops to meters in Dv-Hop,result in erroneous position computation, which increases the final localization error of the system.

SDP:

Kernel-based learning algorithms work by embedding the data into a Euclidean space, and then searching for linear relations among the embedded data points. The embedding is performed implicitly, by specifying the inner products between each pair of points in the embedding space. This information is contained in the so-called kernel matrix, a symmetric and positive semidefinite matrix that encodes the relative positions of all points. Specifying this matrix amounts to specifying the geometry of the embedding space and inducing a notion of similarity in the input space---classical model selection problems in machine learning. In this paper we show how the kernel matrix can be learned from data via semidefinite programming (SDP) techniques. When applied to a kernel matrix associated with both training and test data this gives a powerful transductive algorithm---using the labeled part of the data one can learn an embedding also for the unlabeled part. The similarity between test points is inferred from training points and their labels. Importantly, these learning problems are convex, so we obtain a method for learning both the model class and the function without local minima. Furthermore, this approach leads directly to a convex method for learning the 2-norm soft margin parameter in support vector machines, solving an important open problem.

MDS-MAP:

We propose an approach that uses connectivity information - who is within communications range of whom - to derive the locations of nodes in a network. The approach can take advantage of additional information, such as estimated distances between neighbors or known positions for certain anchor nodes, if it is available. It is based on multidimensional scaling (MDS), an efficient data analysis technique that takes $O(n^3)$ time for a network of n nodes. Unlike previous approaches, MDS takes full advantage of connectivity or distance information between nodes that have yet to be localized. Two methods are presented: a simple method that builds a global map using MDS and a more complicated one that builds small local maps and then patches them together to form a global map. Furthermore, least-squares optimization can be incorporated into the methods to further improve the solutions at the expense of additional computation. Through simulation studies on uniform as well as irregular networks, we show that the methods achieve more accurate solutions than previous methods, especially when there are few anchor nodes. They can even yield good relative maps when no anchor nodes are available.

LLE [22]:

In this algorithm the local connectivity information is assumed to be high-dimensional data at each node in such a way that it resembles that each node obtain a snap-shot of the map (where each node occupies one dimension). After getting high dimensional data from each node a search algorithm is run to find the neighbourhood of all nodes. After that a LS fitting problem is solved by eigenvalue decomposition [23] to find location of all nodes. Considering local estimates this algorithm is less complex than MDS but for regular shapes it is inferior to that.

Bounding Box: The bounding box [12] method uses squares -instead of circles as in trilateration to bound the possible positions of a node. An example of this method is depicted in Fig. For each reference node i, a bounding box is defined as a square with its centre at the position of this node (xi , y i), with sides of size 2d i (where d is the estimated distance) and with coordinates (x i -d i , y i - d i) and (x i + d i , y i + di). The intersection of all bounding boxes can be easily computed without any need for floating point operations by taking the maximum of the low coordinates and the minimum of the high coordinates of all bounding boxes. This is the shaded rectangle in Fig.. The final position of the unknown node is then computed as the center of the intersection of all bounding boxes.

Despite the final error of this method, which is greater than trilateration, computing the intersection of squares uses fewer processor resources than computing the intersection of circles.

Centroid:

In this method position of node is computed as the centroid of its neighbor position. It only requires the radio connectivity between the node and averaging the position of the neighboring nodes position of unknown node is computed. Let the position of the neighboring n nodes are(x1,y1),(x2,y2)……(xn,yn) the position of node will be X0=(x1+x2+…..xn)/n and y0=(y1+y2+…..yn)/n. Centroid localization algorithm uses the centroid coordinate of the selected beacon nodes as the estimated coordinates of the unknown nodes. This algorithm requires a small amount of computation cost. However, it is bad in localization accuracy.

Recursive Position Estimation:

In this approach [16] a set of beacon nodes (usually 5 percent of total nodes) are deployed with other nodes. The unknown nodes estimate their position using beacon nodes and become reference nodes. In this way the number of reference node or beacon node increases significantly and soon all unknown nodes find their position information. This algorithm is divided into four phases- 1. A node determines its reference nodes. 2. Node estimates its distance from reference node using any of distance estimation methods like AoA, TDOA, and RSSI etc. 3. Node computes its position using trilateration or multilateration. 4. Node broadcasts its estimated position information and becomes a reference node.

As soon as a node becomes reference node, it assists other nodes to find their position. In this way the number of reference node increases rapidly and hence all nodes estimate their position quickly. But there is a drawback of this method, that once error in encountered in the measurements it propagates throughout the network causing more inaccuracy in localization of the system

Localization with a Mobile Beacon:

Some of the recent research works in literature proposed solution based on mobile beacon [21] to assist the nodes to estimate their location information. Mobile beacon knows its position and able to move in certain known direction and up to some distances. This beacon can be robot, some vehicle or human beings. The unknown nodes get three or more signals from the same source from different places and compute its position using simple trilateration or multilateration.

The communication cost is small as there is not much communication overheads since only one beacon node broad-cast its position information. And rest of nodes estimate its position based on packet it receive from the mobile beacon.

This method is elegant in the sense that error propagation is low but there is overhead of time in localization procedure as unless mobile beacon passes nearby an unknown node it cannot estimate its position.

IV.FINAL REMARK AND FUTURE PROSPECTS:

The Localization strategy depends on the application type and the environmental condition of the area. In most of the cases we require only the approximation in measurements and some cases we need exact position of the sensor node. The application where only approximate result is required we follow range free localization methods while for exactness we follow range based calculation. There is no any method has been developed till date which can be applicable in all scenarios. Different methods have been devised for different application condition like indoor, outdoor, undersea and space etc. Localization system for extreme space, device setup for RSSI based calculation and calibrations, prolonging the battery life , smart dust, smart home, indoor localization, undersea localization are the open research issues on which most of the work is going on these days.

CONCLUSION:

In this paper we have briefly provided the introduction to wireless sensor networks. We have briefly explained the most important algorithms developed so far providing their merits and demerits. There is not any general rule or general method of localization which suits in all scenarios. In this paper we have provided different algorithms with proper specification of its usefulness in certain scenario. The necessity of different solution for different environment and also higher number of possible application of WSNs motivated the research and study of new solution for localization system.

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