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A Review on Artificial Intelligence Based Relay Node Localization of Wireless Sensor Network

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Abstract –**Wireless sensor networks (WSNs) are quickly becoming an integral part of our daily life. WSN is widely used in national defense, military, environmental monitoring, traffic management, medical and health care, manufacturing etc. In this Paper we discussed Artificial Intelligence based localization along with it the algorithms for wireless sensor network. We will be shortly discussing about the routing techniques and comparing the results between the localization algorithms. Specifically, we are examining their performance and accordingly check the accuracy of wireless sensor network. We co-jointly discussed the advancement that can be made to get a better accuracy results.**

This paper gives an overview of different approach of node localization discovery in wireless sensor networks. Various overviews of the schemes proposed by different authors for the improvement of localization in WSN are also highlighted.

Keywords –**Wireless Sensor Network, Deployment, peer-to-peer network, TOA, AOA, RSS, Localization.**

I. Introduction

A wireless sensor network (WSN) is basically a distributed sensor network to monitor the physical or environmental conditions, which includes the parameters like temperature, pressure, etc. and accordingly pass these data to a main location through the network [1]. Localization of sensor nodes and localization of events occurred are the basic functions of WSN. Drastic advances in RF and MEMS IC design have made possible the use of large networks of wireless sensors for a variety of new monitoring and control applications [2][3]. For example, smart structures will actively respond to earthquakes and make buildings safer; precision agriculture will reduce costs and environmental impact by watering and fertilizing only where necessary and will improve quality by monitoring storage conditions after harvesting; condition-based maintenance will direct equipment servicing exactly when and where it is needed based on data from wireless sensors; traffic monitoring systems will better control stoplights and inform motorists of alternate routes in the case of traffic jams; and environmental monitoring networks will sense air, water, and soil quality and identify the source of pollutants in real time. According to positioning mechanism, WSN localization algorithm can be categorized into two classes: Range based localization algorithm and Range-free (non-ranging based) localization algorithm [4]. Range-based location algorithm is got by measuring the adjacent section. There isn't distance and angle information in Range-free localization algorithm, so classic algorithms are: time of arrival (TOA) ranging method, time difference location method (TDOA), the received signal strength indicator (RSSI) ranging method, etc. Range-free localization algorithm can be used for node localization without distance and angle information, only according to information such as network connectivity, classic algorithms include: centroid, DV-Hop (distance vector-hop) algorithms.

II. Wireless Sensor Network

A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions the output of the sensor is generally an electrical signal that is transmitted to a controller for further processing. Wireless sensor network is a set of large number of sensors which monitor environmental conditions. Such sensors are combined with data processing and communication equipment [5] Sensor Nodes are limited in energy and its bandwidth. These limitations causes many challenges to the design of sensor network such as sensor network do not have global addressing scheme hence only IP addressing cannot serve the purpose of routing and also the sensor nodes generates the same or redundant data during the data traffic generation. Hence some significant routing algorithm is required for wireless sensor network. Wireless Sensor Networks (WSNs) use tiny, inexpensive sensor nodes with several peculiarities: They have very low processing power and radio ranges, permit very low energy consumption and perform limited and specific monitoring and sensing functions. Several such wireless sensors in a neighbourhood self-organize and form a WSN. Information based on sensed data can be used in agriculture and livestock, assisted driving or even in providing security at home or in public places [6]. A central requirement from both the technological and commercial standpoint is to provide adequate security capabilities. Fulfilling privacy and security requirements in an appropriate architecture for WSNs offering primitive services are essential for user acceptance.

III. Evaluation of Sensor Networks

Sensor network development was initiated by the United States during the Cold War. A network of acoustic sensors was placed at strategic locations on the bottom of the ocean to detect and track Soviet submarines. This system of acoustic sensors was called the Sound Surveillance System (SOSUS). Human operators played an important role in these systems. The sensor network was wired network that did not have the energy bandwidth constraints of wireless system. Modern research on sensor networks started around 1980 with the Distributed Sensor Networks (DSN) program at the Defence Advanced Research Projects Agency (DARPA) [5]. These included acoustic sensors communication (a high-level protocols that link processes working on a common application in a resource-sharing network), processing techniques, algorithms (including self-location algorithms for sensors), and distributed software (dynamically modifiable distributed systems and language design) [6].

Recent advances in computing and communication have caused a significant shift in sensor network research and brought it closer to achieving the original vision. Small and inexpensive sensors based upon micro-electro-mechanical system (MEMS) Routing in Wireless Sensor Networks technology, wireless networking, and inexpensive low-power processors allow the deployment of wireless ad hoc networks for various applications [7]. Thus, the program developed with new networking techniques is suitable for highly dynamic ad hoc environments.

Table 1: Evaluation of sensor nodes

	1980's-1990's	2000-2009	2010-2016
Manufacturer	Custom Contractor	Commercial: Crossbow Technology Inc., Sensoria Corp., Ember Corp	Dust Inc. and others
Size	Large shoe box and up	Pack of cards to small shoe box	Dust particles
Weight	Kilograms	Grams	Negligible
Node Architecture	Separate sensing, processing and communication	Integrated sensing, processing and communication	Integrated sensing, processing and communication
Topology	Point-to-point, star	Client-server, peer to-peer	Peer-to-peer
Power Supply Lifetime	Large batteries; hours days and longer	AA batteries; days to weeks.	Solar; months to years
Deployment	Vehicle-placed on air-dropped single sensors	Hand-placed	Embedded, sprinkled, left behind

IV. Routing Techniques

All algorithms assume a set of input data that must be transformed in order to obtain an estimate of the position. However, they are not all in terms of robustness. Some, in their standard form, expect accurate data and fail when reality information is provided to them because they typically contain an error. we will first look at the tools that make the assumption of accurate data and then those that take into account the presence of errors in the measurements [11] [12].

A. Trilateration

This method relies on the knowledge of the distances separating the target from different reference points and the spatial coordinates of these anchors [12].

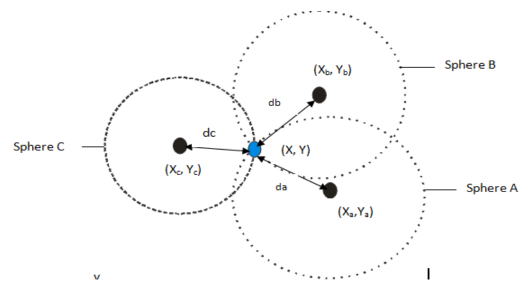

Figure 1: Trilateration

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Where,

Probable position of mobile
Anchor node

Let three beacons B1, B2 and B3, M be the mobile node that we wish to locate. The execution of the distance measurement protocol produced the triplet. (d_1,d_2,d_3) and the data exchanges allowed the mobile to know the positions of the beacons. Equations (1) and (2) describe the relationship between B1, B2 and M [13].

$$(x-x_1)^2+(x-y_1)^2=d_1^2 \quad (1)$$

$$(x-x_2)^2+(x-y_2)^2=d_2^2 \quad (2)$$

The position sought is therefore at the intersection of the circles $C_1(B_1,d_1)$ and $C_2(B_2,d_2)$. In the general case, C_1 and C_2 meet at two distinct points M and M'. Thanks to the data of the anchor B_3, one of these two candidates can be retained as the position of the mobile.

B. Triangulation

The angle of incidence of the signal emitted by the mobile can be used to regain its position [14] [15]. Consider two beacons $B_1(x_1,y_1)$ and $B_2(x_2,y_2)$ within range of the mobile M(x,y). Each has the material means of measuring the angle at which it receives the signal of M. Let α and β be the two angles.

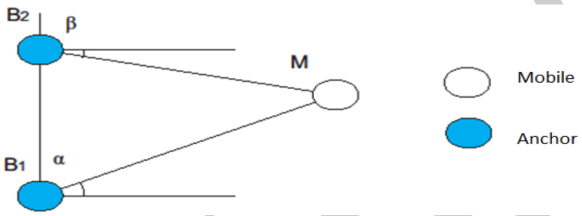

Figure 2: Angle of incidence and position

The point M is found at the intersection of the straight lines passing through the pairs (B_1,M) and (B_2, M) .By defining a new reference point whose origin is B_1 and where (B_1,B_2) coincides with the ordinate axis, the approximation of the equations of the lines leads to the expression of the position of M.

$$M\left(\frac{y_2}{\tan\alpha+\tan\beta};\frac{y_2\tan\alpha}{\tan\alpha+\tan\beta}\right) \quad (3)$$

C. Multilateration

Multilateration uses the difference between the arrival instants of the signal or TDOA to calculate the position. Here the mobile is in radio contact with beacons B_i (x_i,y_i), i=1….4. The mobile transmits a message and the instant of arrival of a message at the station i is denoted t_i [16] [17]. Since the anchors are synchronized, the difference between these instants can be used to create the system of equations where c is the propagation speed, x_i and Y_i the positions of the nodes B_i and e_i the distance between the node B_i and a station chosen as a time reference. In Figure 3 B_1 plays this role.

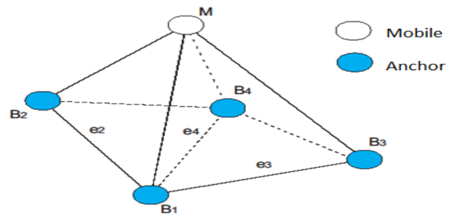

Figure 3: Multilateration

$$0=c(t_2-t_4)-\frac{e_2^2}{ct_2}+\frac{e_4^2}{ct_4}+2x\left(\frac{x_2}{ct_2}-\frac{x_4}{ct_4}\right)+2y\left(\frac{y_2}{ct_2}-\frac{y_4}{ct_4}\right)+2z\left(\frac{z_2}{ct_2}-\frac{z_4}{ct_4}\right) \quad (4)$$

$$0=c(t_2-t_3)-\frac{e_2^2}{ct_2}+\frac{e_3^2}{ct_3}+2x\left(\frac{x_2}{ct_2}-\frac{x_3}{ct_3}\right)+2y\left(\frac{y_2}{ct_2}-\frac{y_3}{ct_3}\right)+2z\left(\frac{z_2}{ct_2}-\frac{z_3}{ct_3}\right) \quad (5)$$

$$0=c(t_3-t_4)-\frac{e_3^2}{ct_3}+\frac{e_4^2}{ct_4}+2x\left(\frac{x_3}{ct_3}-\frac{x_4}{ct_4}\right)+2y\left(\frac{y_3}{ct_3}-\frac{y_4}{ct_4}\right)+2z\left(\frac{z_3}{ct_3}-\frac{z_4}{ct_4}\right) \quad (6)$$

Starting from a geometric relationship between the nodes, the methods presented above make it possible to calculate the position of a moving object in the (2D) plane. The addition of a beacon or an additional measuring device would enrich the system and give a spatial (3D) position.

D. Least Squares Estimator

One of the critical aspects of localization is the response time of the system. Indeed, if the calculation is long enough for the mobile to have moved again, the information obtained will generally be perceived as of very poor quality. In the case of the particulate filter, if the number of particles must be high, it involves a relatively long processing time depending on the hardware platform used. The size of the cloud can be reduced by the implementation of restrictions on the possible displacements through mapping of the environment [18] [19].

V. Recent Adaptations of Algorithms to Localization by Wireless Sensor Network

This section depicts how the different algorithms that had been investigated are implemented today in sensor networks. Other tools will also be introduced at this time and their relationship to the algorithms of the

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previous section highlighted. We will classify these propositions according to the families of location and the information exploited in each case.

A. Range-based Methods

As indicated above, the set of locating solutions exploiting the measurement of a characteristic, typically of the radio signal, is referred to as a range-based. In the context of wireless sensor networks, time and power data are most often used because they are relatively easy to access. In the paragraphs of this sub-section, to describe some implementations representative of the existing one.

Flight Time: Temporal information is commonly used to estimate the distance $\hat{d}$ between the mobile and the beacons. Since the positions of the latter are known, several channels make it possible to calculate the coordinates of the mobile [20]. The iterative execution of this algorithm requires a centralized implementation but also a starting point of the computation or seed close to the real solution.

$$F(x) = \sum_{i=1}^{N} \alpha_i^2 f_i^2(x)$$

$$f_i(x,y) = C\Delta_{t_i} - \sqrt{(x-x_i)^2 + (y-y_i)^2} \quad (7)$$

It has two parts: distance measurement and positioning.

RSSI and Power Received: Nearest Neighbour is based on a measurement database that serves as a reference during the online phase. The correct position is that corresponding to the point of the space of the RSSI whose Euclidean distance with the measured values is minimal. An adjustment is made to calculate the distance between the differences. BI makes it possible to choose the most probable position knowing the current values. The adaptation of this method to the proposition requires the use of an observation vector o linked to a position l. The vector o_k will have the form (AP pair identifier, RSSI difference for the AP pair). The relationship between these values and the position occupied during the measurement during the offline phase will lead to Equation 1. Starting from this, the probability of being at a position lk knowing the current capture is given by Equation 2. Recovering the true position then amounts to maximizing this probability as a function of l_k [21].

$$\Pr(o|l_k) = \prod_{1\leq i<j\leq m} \Pr\left[d\left(AP_i, AP_j\right) | AP_i \times AP_j, l_k\right] \quad (8)$$

$$P_r\left(l_k|o^*\right) = \frac{P_r\left(o^*|l_k\right)P_r(l_k)}{\sum_{k=1}^{n} P_r\left(o^*|l_k\right)P_r(l_k)} \quad (9)$$

The experience with access points, a laptop and a smartphone showed the positive impact of the proposal on existing methods.

B. Range-Free Methods

Like range-based techniques, range-free methods have an arsenal of algorithms to calculate the position from simple deductions [22].

Approximate Point in Triangulation (APIT): The APIT method is based on the Point-In- Triangulation test. This test allows a node to determine whether or not it is within a certain triangle. In its mathematical version, the test stipulates that any displacement of a moving object located inside the triangle corresponds to its approximation / distance from at least one of the vertices of the triangle.[23][24] If it approaches / moves away from all the vertices at the same time, the moving object is outside the triangle .

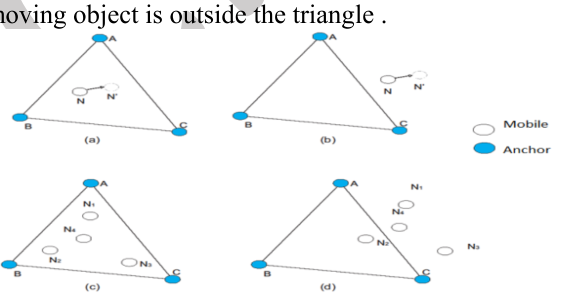

Figure 4: Geometric and network formulations of the APIT algorithm

This test is adapted to a network using the relations between the neighbouring mobiles of the node of interest and the anchors. Since the motion of the node is not necessarily a parameter controlled by the location application, the distances between the neighbours and the vertices are used to emulate the displacements.[26] Thus, if all the neighbours of a node N are closer than N of at least one of the vertices, N is inside the triangle. This approximate version of the PIT is sensitive to node placement.

Centroid

Centroid's starting assumptions include isotropic spherical propagation and an identical range for all stations.

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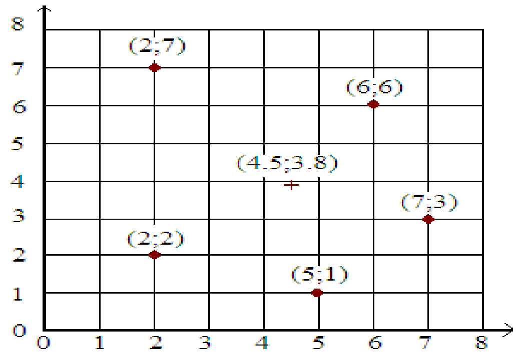

Figure 5: Example of localization with centroid

The method is based on a grid of reference nodes emitting beacons at a T interval without collision. According to a locally computed metric of connectivity and a threshold tresh, the mobile decides to take account of a subset of detected tags. The factors of this characteristic are: $N_{recv}(i,t)$: the number of beacons emitted by the beacon i and received during the time t and $N_{sent}(i,t)$: the number of beacons emitted by the beacon i during the time t [25].

$$CM_i = \frac{N_{recv}(i,t)}{N_{sent}(i,t)} \times 100 \quad (10)$$

The coordinates of the selected beacons are used to calculate the center of gravity of the zone, which the node considers to be its own. In fig., a centroid embodiment is illustrated with only the selected beacons represented by a dot. The estimated position is represented by a cross [26] [27].
Validation by a prototype in an outdoor environment involved four beacons placed at the corners of a 10m×10m square and resulted in an average error of 2m.

VI. Future Research Needs and Conclusion

As the coin has two faced so based on our research and analysis some more development will give a better result. Ultimately, actual localization performance will depend on many things, including the localization algorithm used, the size and density of the network, the quantity of prior coordinate information, the measurement method chosen, and the accuracies possible from those measurements in the environment of interest . However, based on the characteristics of the variance bounds presented in the section on limits on localization covariance, we can make some broad generalizations. It appears that TOA measurements will be most useful in low-density.
sensor networks, since they are not as sensitive to increases in interdevice distances as RSS and AOA. Both AOA and TOA are typically able to achieve higher accuracy than RSS; however, that accuracy can come with higher device costs. Because of their scaling characteristics, localization based on RSS and AOA measurements can, without sacrificing much accuracy, avoid taking measurements on longer-distance links; instead, they focus on those links between nearest neighbours. RSS measurements will allow accurate localization in dense networks, and will be very attractive due to their low cost to system designers.

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