Localization of wireless sensor network

Abstract

Generation of communications networks demands, real-time localization and position-based services that are accurate, low cost, energy-efficient and reliable [26,35]. Every day, Wireless Sensor Networks (WSNs) technique can be used in many applications, such as targets tracking, natural resources realization, monitoring in difficult reachable places ….etc. In these applications, the information is collected and transferred by the sensor nodes. many applications request these sensor nodes' location information. Moreover, the location information is also necessary for geographic routing protocols and clustering [25,26]. All these mentioned above make localization algorithms important in WSNs services. Due to that, locations of sensor nodes are important for operations in WSNs.

In the simplest way localization mean identifying the location of the node. In WSN distribution of nodes will be randomly in a huge area, also to overcome high coast little number of sensors can be connected to GPS (nodes with known positions). it is important to determine the place which has an unstable environment under hard constraints. Global Positioning nodes (GPS) are not always possible GPS cannot work indoors, and power consumption is very high. Other sensor nodes estimate their distances to anchor nodes and calculate positions with multi-literation techniques. These methods provide a different level of accuracy with a small proportion of anchor nodes in WSNs [19,20]. The sensor nodes are randomly placed in unreachable positions by the vehicle robots or aircrafts to be used in many promising applications, such as health surveillance, battlefield surveillance, environmental monitoring, coverage, routing, location service, target tracking, and rescue [29].

Localization algorithms can be classified into two categories which are range free and range based. Various localization algorithms and methodologies have been proposed to deal with different problems in different applications.

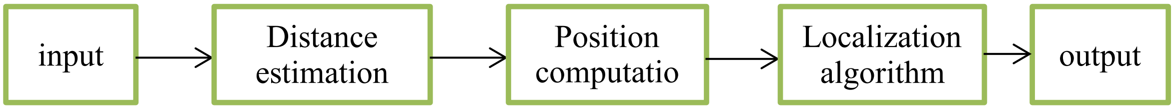
This chapter discusses the techniques used in localization and compares them to illustrate the choice of technique used in the network depend upon the application request.

Key word: WSNs, localization error, accuracy, topologies , localization applications.

1.1 Concepts and properties of localization:

1.1.1 definition of localization and requirement

Localization is a process to compute the location of the wireless sensor in the WSNs figure(1) show the steps of this process.



Figure(1):localization process.

To determine the unknown node position in a large network with random deployment, that need a reference, those references are beacons which know their position by one of two methods manually or by connect to the GPS(global position system).first method not suitable in large network, many application use GPS but beacons are little in numbers in the network.

Beacons have extra hardware to connect with GPS, increase the power dissipation. the unknown node estimates its position by beacons information around it, techniques used to locate unknown depend on the type of information between nodes .there are two localization techniques which are: rang-based or range The flow chart in figure(2) shows the sequence of the localization process.

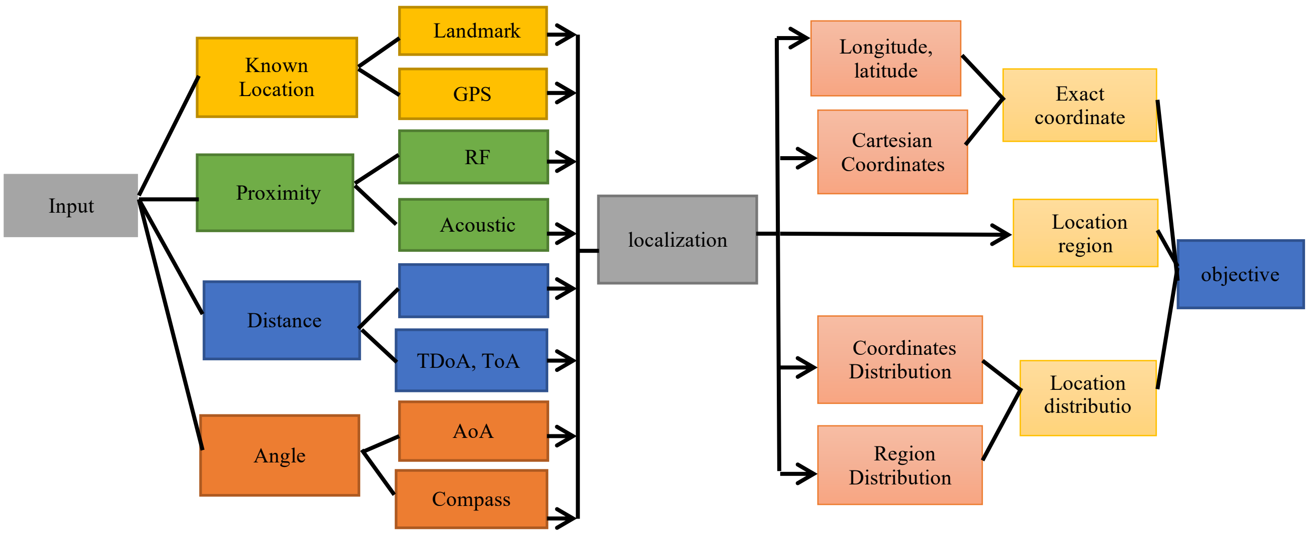
Figure (2): localization flow chart

1.1.2 taxonomy of localization in WSNs

The WSNs localization system requirements are:

- Large number of unknown position deployment sensors.
- Small number of beacons.
- Communication channel between nodes.
- Measurement localization technique.
- Localization algorithm to estimate location of unknown

The taxonomy of the localization problem shown in figure (3).



Figure(3): problem of localization.

1.2 Measurement Techniques for Localization in WSNs

Several measurement techniques are used to measure the signal exchange between nodes in WSNs as shown in figure(4).

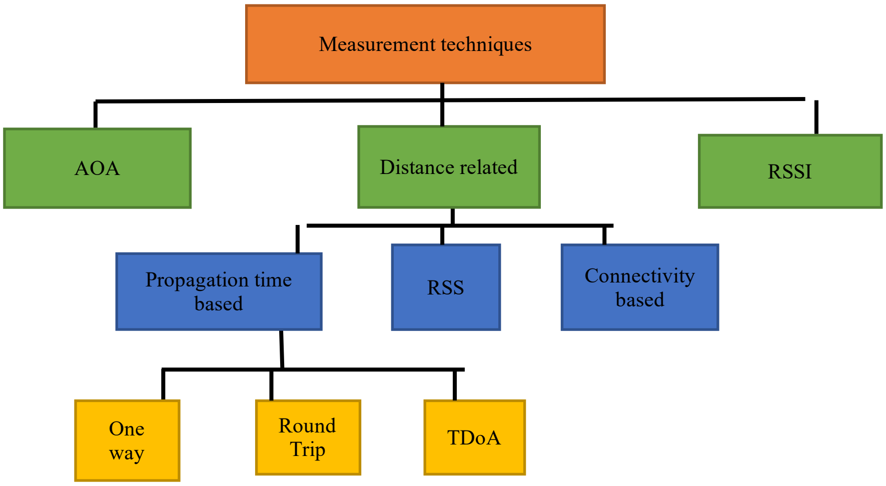
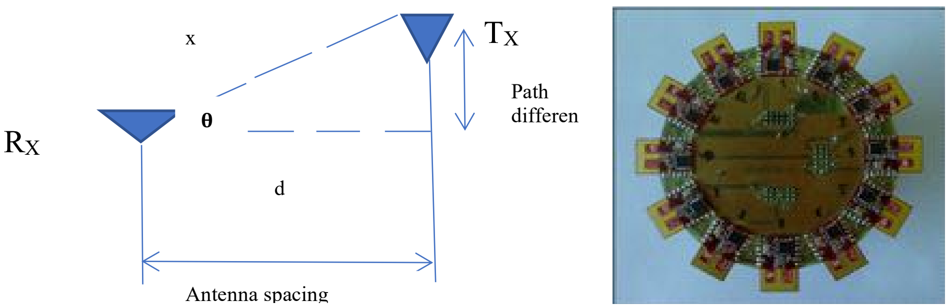


Figure (4): measurement techniques.

Measurement techniques can be classified into three categories [22]. As shown in Figure (4) .those measurements are, distance-related, Angle of Arrival (AOA), and the Radio Signal Strength (RSS) profiling techniques. we briefly discuss these techniques along with their restriction in different WSNs applications.

- **Angle of Arrival (AoA)**



a B

Figure (5): angle of arrival(AOA). a)how to measure the angle of arrival. (b) a circular array of the antenna.

Unknown node location can be estimated using the angle of two anchors signals in figure (5). These are the angles at which the beacons signals are received by the unknown nodes [2]. Unknown nodes use the triangulation method to estimate their locations [1]. The AOA measurements classified into two categories: one from the receiver antenna's amplitude response and another from the receiver antenna's phase response. nodes used this method use special type of antenna called array antenna increasing the array that increases the accuracy of position estimation but increases node hardware, and power dissipation.at least use 3 antenna array to apply the triangulation method. The localization error could be large if there is a small error in measurement. The accuracy is depended on the directionality of the antenna and measurement s.in real environment error must happen due to shadowing of multi-path noise, due to that AOA has low accuracy, and not reliable with WSNs.

1.3 Distance Related Measurement

Distance related measurements technique can be classified as propagation time measurements (one way, round trip and time difference of arrival (TDOA)), RSS based and connectivity based measurements

1.3.1. Propagation Time Measurement

The principle of propagation measurement depends on measure the time taken between receiver and transmitter, and measure the velocity by know both its easy to get distance. this type of calculation is similar to that in radar. If the sensor network is based on UWB radar systems, we can talk about UWB WSN. This type of network cans be very helpful for applications such as through wall or rubble or snow object location during security operations, etc. [13].

Propagation Time Measurement classified into three categories which are:

- **One way propagation time measurement** in this type measures the time difference between transmitted signal and received, and by knowing the velocity of signal we can determine the distance. major challenge is synchronization between transmitter and receiver .a small difference between the local times at the transmitter and the receiver will cause large error in estimating distance . to increase the accuracy of this method need to use clock synchronization in receiver and transmitter, that increase the cost and power dissipation, because that it is less attractive in WSNs.

- **Round trip propagation time measurement** measures the difference time when a signal sent by a sensor node is returned from the second sensor node to the first sensor node. In this technique, there is no demand to synchronization clock because time difference calculated at receiver .but here delay will increase because the delay achieves in the second sensor node to handle the signal, process it and send back again.

In general, the synchronization problem for both one way and round trip propagation time measurements are affected by noise, signal bandwidth, non-line-of-sight and multipath environment.

- **Time difference of arrival measurement** measures the difference of arrival time by two separate receivers, assume that both receivers are synchronized. This technique requires three receivers to uniquely locate the transmitter location. the disadvantage of this technique is synchronization which affected by noise, and multipath.

1.3.2 Received Signal Strength (RSS) Based Measurement

Received signal technique measure the strength of received signal between two nodes to estimate the distance. the relation between received signal strength and distance is normal distribution as shown in figure 1.6.

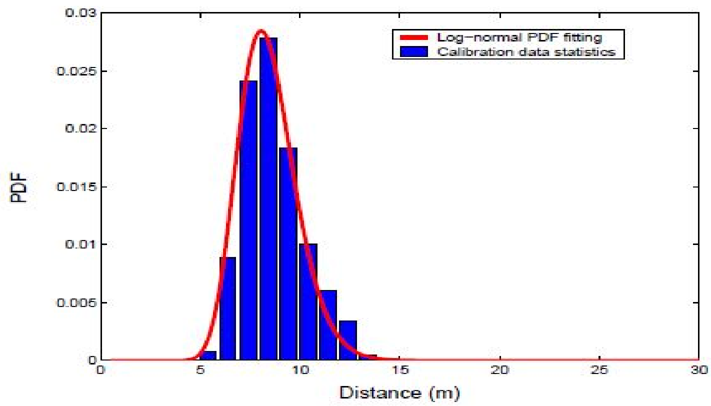


Figure (6): Log–normal distribution for the packet with rss=83db.

The relation between signal strength and distance is written as follow:

$$P_R\,(d) = P_T - P_L(d_0) - 10\eta\log\left(\frac{d}{d_0}\right) \quad (1)$$

Where $p_R(d)$ is received signal power,p_T is transmitted power and $p_l(d_0)$ is the path loss for a reference distance of d_0 and η is the path loss exponent. Given the model and the model parameters, which are known via a priori measurements, the distance between two sensor nodes can be obtained from the RSS measurements. Localization algorithm can then be execute to use this distance and estimate the position using the iteration algorithm.

1.3.3. Connectivity Based

In the Connectivity Based technique measure the connectivity between nodes, if a sensor node connects to another one which is in its range get a binary number (1), if there is no connection get (o). after that, account number of hope between connected sensor, this counting of number of hopes used to calculate distance. this method is very easy and gives small localization error .class of algorithms use this technique called rang free.

1.4 Localization techniques:

Depend on the measurement of inter-sensor distance, localization algorithms in WSNs can be classified into two categories: centralized and distributed [21] as shown in figure(7).

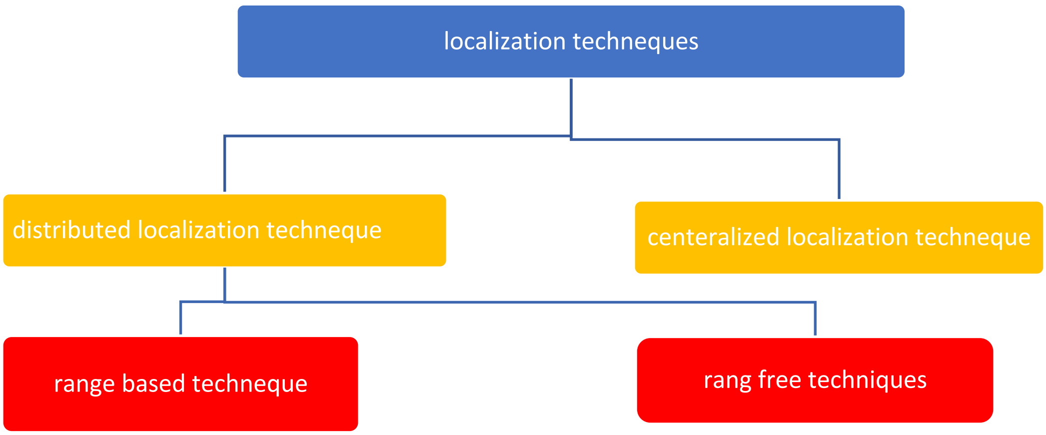


Figure (7): classification of localization in WSNs based on sensor interior.

1.4.1Centralized Localization Techniques

In a centralized localization technique, all the inter-sensor measured distances are sent to the central location where the positions of each sensor node are calculated. [4],[14].

The Base station determines the location of each node by collected data and transfer them back into the network. The collection of information performed by message rotate between nodes, hence, with the number of nodes increased in-network, centralized localization algorithms become lower energy-efficiency, longer delay, and larger network communication traffic. On another hand, it will obtain a relatively high accurate location. Common node has light calculation burden. In general, this technique is not suitable in a large network.lk. figure (8) shows the physical connection of the centralized technique.

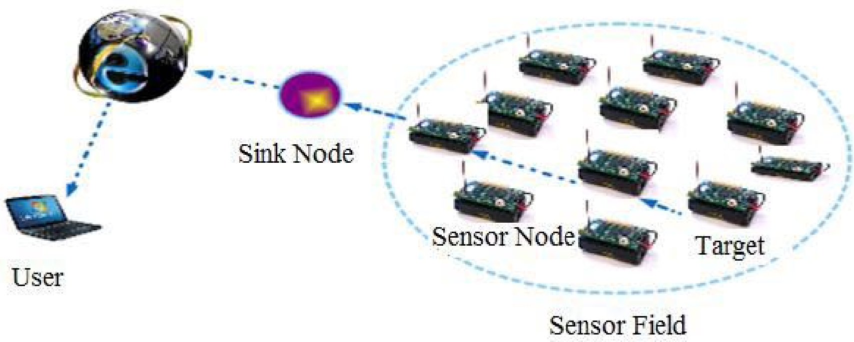


Figure (8): centralized WSNs[10].

The famous centralized localization algorithms are Multi-Dimensional Scaling-Mobile Assisted Programming (MDSMAP), Semi Definite Programming (SDP), Simulated Annealing based Localization (LBSA).

5.5.2 Distributed Localization Techniques:

In distributed localization [19], [20],[29],[18], sensor nodes perform the required computation themselves and communicate with each other to get their location in the network. Depend on range measurements, the distributed localization can be classified to range based: and range-free localization techniques. Distributed localization technique is suitable for the huge area and numerous environments, these methods give high accuracy for nods location, also low coast and power consumption due to the little number of nodes use GPS. most outdoor applications use a different type of distributed techniques. Show in figure (9).

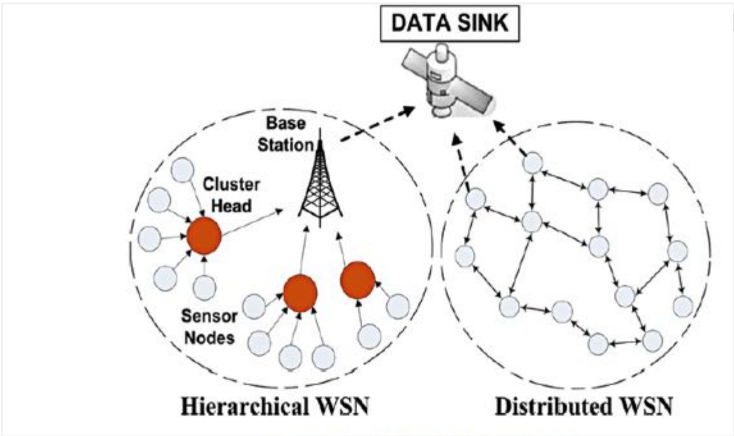


Figure (9): distributed WSNs.

The distributed technique classified into two categories which are:

1.4.3 Range Based Localization Techniques

Range-based localization employs distance estimation angle information or received signal strength Obtained by measuring techniques. Some well-known range-based algorithms are RSSI algorithm (received signal strength indicator, TOA algorithm (time of arrival) , AOA algorithm (angle of arrival), TDOA algorithm (time difference of arrival) [6],[1],[39].

1.4.4 Range free localization techniques

Range free algorithms do not require distance or orientation information between nodes for localization. Range-free algorithm provides cost-effective localization, but their results are less accurate than the range-based algorithm. Some typical range-free localization algorithms are APITA algorithm (approximate point-in triangle test), centroid, amorphous, DV-Hop (distance vector-hop) [15]. show figure (10).

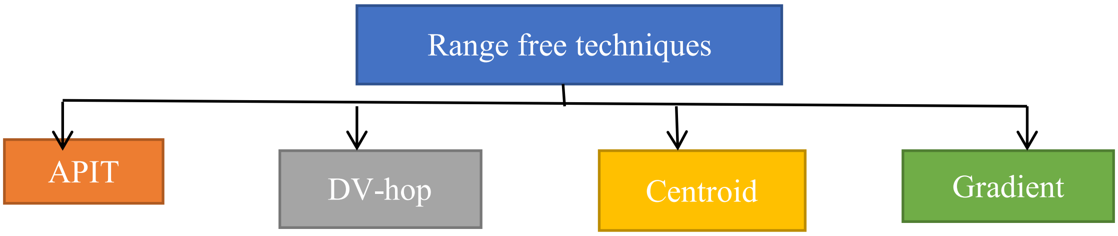
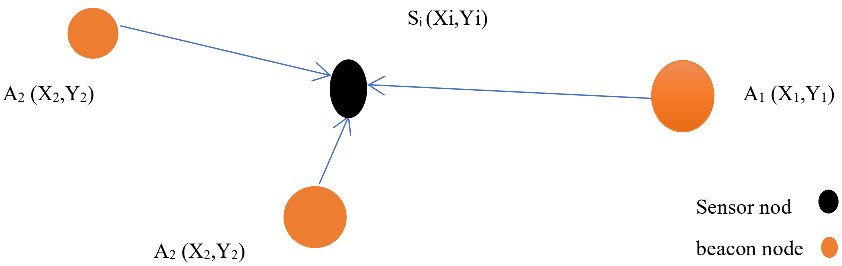


Figure (10):range free techniques.

- **Hop Count Based**

All the range-free localization techniques at most use hop count based information to Calculate the distance between connective nodes to determine the unknown position.DV-Hop and Centroid are the famous approaches of this type.

- **The centroid algorithm**
  is a classical range-free localization algorithm. After Receiving the beacon nodes, a node estimates its location using the centroid formula designed for sensor nodes that have at least three neighbor beacons nodes. As shown in figure (11).



$$S_i(x_i,y_i)=(\quad x_1+x_2+x_3\backslash 3 \quad , \quad y_1+y_2+y_3\backslash 3 \ )$$

Figure (11): Example of centroid algorithm with three anchor nodes.

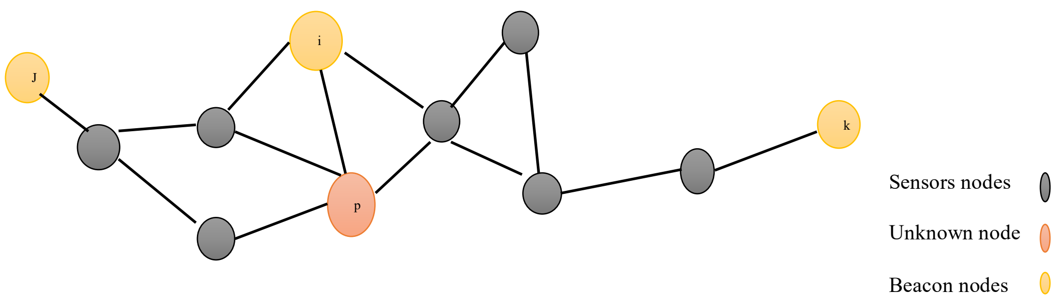
Centroid has very low communication and computation cost and can get relatively good accuracy when the distribution of anchors is uniform. However, if the distribution of anchors is not even, the estimated position found from the Centroid algorithm will be inaccurate.

- **DV-HOP**

The main idea of DV-Hop is that the nodes exchange the traditional distance vector packets so that each node has the short path and knows the coordinates of all beacons, that make the hop count-based method of DV-Hop and hop requires a small number of anchors. Then, each beacons broadcasts its average distance of each hop with data packets. When the unknown node receives the average distance of each hop, it calculates the distance to each beacon according to the recorded hop information. figure (12) shows an example of DV-HOP.

The actual distances between beacon *i* and the other two beacon *j* and *k* are *dji* and *dik* , respectively. Hop number *hij* and *hik* are 3 and 4, respectively, then beacon *i* can calculate the average distance to each hop, which is $ci = (dji + dik)/(hij + hik) = (dji + dik)/(3+4)$. Therefore, the unknown node *p* obtains the average value of each hop to beacon *i*, and calculates the distances to beacons *i, j, k* are *ci* , 3*ci* , 4*ci* respectively.

Then *p* calculates its coordinates using trilateration or maximum likelihood estimation (MLE).



Figure(12): DV-HOP example.

DV-Hop propagates distance estimation among beacon nodes represented by the number of hops throughout a WSN. beacon nodes can then estimate the average distance of each hop, with which each sensor node calculates its estimated distances to beacon nodes. By multi iteration. there are two disadvantages of DV-HOP it needs uniformly distribution and the same attenuation of signal strength in all directions. but, both disadvantages can be disappeared by modify the following metric of the algorithm.

- **average hop distance**

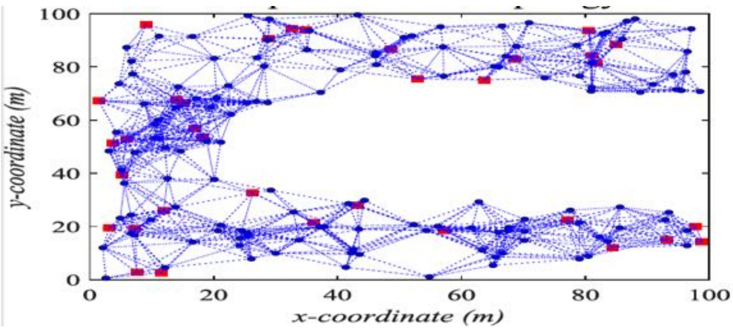
Modifying the average hop between beacons increase the accuracy of the algorithm and decreases average error. Such as [17], modified the location accuracy by improve the network average hop distance based on minimum mean square error. Many modified averages hop helpful to decrease the localization error.

Improve based on average hop distance:

In the random distribution node density and connectivity of the network, many works improve the average hop distance between beaccon nodes to modify the position estimation accuracy . it improved the location accuracy by modifying the network average hop distance based on minimum mean square error criteria as $\text{HopSize}_i^N = \frac{\sum_{j\neq i} h_j d_{ij}}{\sum_{j\neq i} h_j^2}$ where d_{ij} is the straight line distance between beacon nodes i and j, h_j is the hop segment number between beacon nodes i and j. Another algorithm calculate the error e^{ij} as $e^{ij} = d_{est}^{i,j} - d_{true}^{i,j}$,Where $d_{est}^{i,j}$ is the estimated distance between beacon nodes i and j, $d_{true}^{i,j}$ is the Euclidean distance between anchors i and j.finally ,correcting the average hop distance by $\text{HopSize}_{eff}^{i,j} = \text{HopSize}_i - \frac{e^{i,j} + e^{i,m}}{h^{i,j} + h^{i,m}}$, Where m is the closest beacon node i and HopSize_i is calculated as $\text{HopSize}_i = \frac{\sum_{j\neq i}\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j\neq i} h_{ij}}$, where (x_i, y_i) (x_j, y_j) are the coordinates of beacon nodes i and j and h_{ij} is the number of hops between anchor i and j.

- **node information and nearest beacon**

Modifying average hop in anisotropic network is increase the accuracy of localization But, these approaches are accurate insofar only when the topology is isotropic. The shortest path between two sensor nodes calculated by Euclidian distance.in isotropic WSNs it is possible, otherwise happened in an anisotropic WSNS, figure (13) shows an example of anisotropic WSNs.



C-shape anisotropic WSN.
Beacons=34 , nodes=170, node rang=20m

Figure (13): example of anisotropic WSNs topologies.

Because the modification in the algorithm use methods were suggested using the anchor node information and the relationship between the anchor node and sensor node or topological deployment shape information to improve the DV-Hop localization method. To decrease the effect of holes(obstacle shape), Shang et al. [17] suggest using only four nearest anchors, assuming that the shortest paths to the nearest anchors may be less influenced by irregularities, and this does produce good results in some cases but with a drawback of the possibility to falsely drop some good anchors which can increase the localization accuracy.

1.5.5 Analytical Geometry Based

In this method, the average hop distance evaluated theoretically by using the statistical characteristics of the network deployment. The calculated average hop distance is locally computable at each sensor node, and it has to be broadcasted to other sensor nodes.

Analytical Geometry Based dealing with anisotropic environment by two types of modification methods, to calculate the estimated distance between anchors and sensors based on whether the beacon is slightly detoured or strongly detoured from normal sensor nodes.

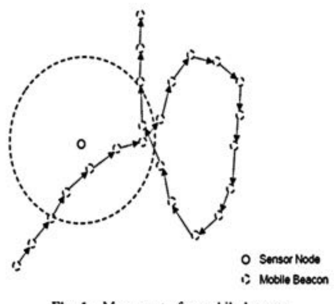
For slightly detoured beacons, it use the information from the nearest beacons (namely reference station) and this reference station must be within three or four hops away from normal sensor nodes. That means the beacons distribution density must be very high. It is one of the designed methods to decrease the strongly detoured beacons. However, no indication of how many beacons fall in the strongly detoured category because it may be impossible to accurately determine which beacon is little detoured and which are strongly detoured. Solution of this problem in [27, 24] by calculating the angle of the detoured path Between beacon and sensor nodes.

Another algorithm discusses in [3] that average hop distance and number of hops between beacons and sensor nodes are enough to calculate the accurate position of the sensor nodes. It also depends on the number of connecting nodes (which forward any data between two nodes). By using this information along with other information, the solution showed that further accuracy can be achieved.

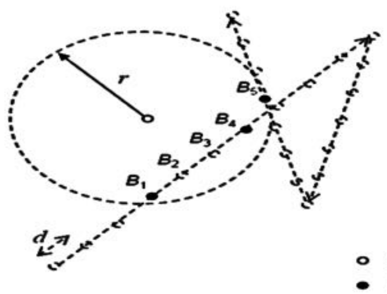
1.5.6 Mobile beacon Based

The mobile beacon navigates to the sensing field and periodically broadcasts its current location coordinate, Also the sensor node listens to the beacon messages, once the mobile beacon enters the communication range of the sensor node. Later, the sensor nodes choose three non-collinear coordinate points of the mobile beacon node and use various mechanisms to estimate position .depend on this basics several localization algorithms are designed [30,31,19,10,5].

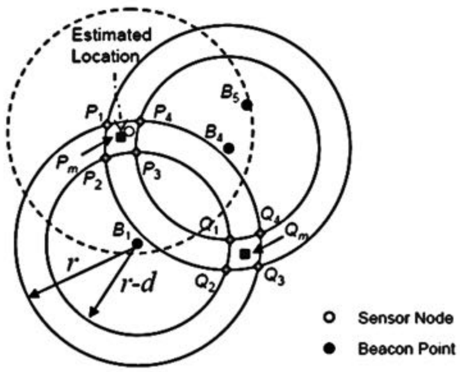
In [31] the author discusses the geometric conjecture (perpendicular bisector of the chord of a virtual circle) based range-free localization algorithm, where a mobile beacon path through a sensing area and periodically broadcasts its current location coordinates. The neighboring sensor nodes keep track of receiving and transmitted beacon coordinate points to construct a chord on its communication range. The sensor node repeats this process until it gets at least three coordinate points from the moving beacon node on its communication range. The line segments between these three selected coordinate points make two chords on their communication range. After that, the perpendicular bisector of the two cords gives the position estimates of the sensor nodes as shown in figure (14).



Mobile beacon movement



Beacons points selection

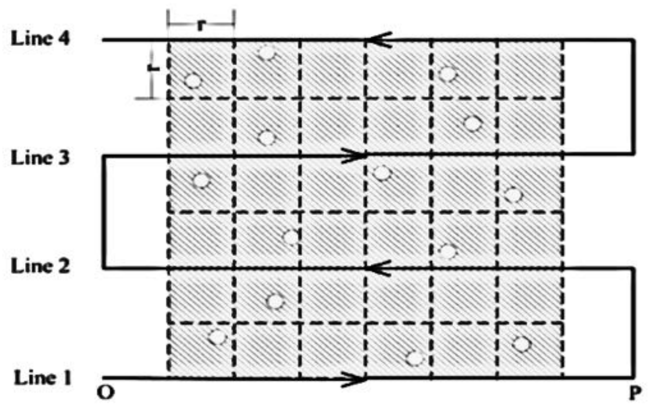


Analytical estimation location

Figure(14): steps of the analytical algorithm[31].

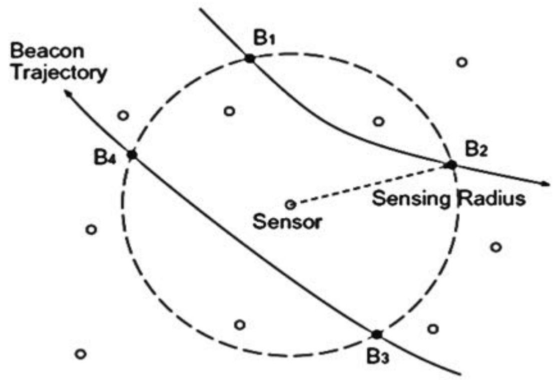
This algorithm modified in [19] geometric constraint-based localization scheme, in this scheme the selection process of the three anchor coordinate points on the communication range of the sensor node remains the same as in [31]. The steps to find the location are, first, the intersection of the selected two beacon coordinate points know the constraint area of the sensor node. This process is repeated with another two intersected points to decrease the constraint area of the sensor node. Finally, the average of all the intersection points gives the position estimates of the sensor node.

Another algorithm in [38] modifies the main algorithm in [31] the object is decreasing the constraint area by the new type of moving beacons paths create a specific type of constraint area for the sensor node. To identify the potential location of the sensor node within different constraint areas, several intersections are created within various constraint areas until the final arrival of the coordinate points before the final departure of the beacon node. Each additional intersection narrows down the potential location of the sensor node within the intersection constraint areas. However, the scheme shows high localization error when the random waypoint mobility model is used for the moving anchor node. Also, the scheme is computationally expensive because of multiple intersection computation.



Figure(15): specific beacon transceiver

Another approach [38] discuss a curve fitting method along with a mobile beacon node to calculate the location of the sensor node. In this approach, the received and transmitted coordinate points of the moving beacon nodes are saved and this is repeated as many times as the moving beacon re-enters the communication region of the sensor node. The localization begins by fitting a curve on the few selected coordinate points on communication range as shown in figure (15)and iteratively calculated through the Gauss-Newton method. The center coordinates of the fitted curve define the position of the sensor node figure (16).



Figure(16): beacon curve fitting transceivers.

Another approach in [5], where the localization begins with an approximation of the geometric arc parameters. The approximated arc parameters are used to create the chord on the virtual circle. After that, the perpendicular bisectors of the chords along with the approximated radius are used to estimate the position of the sensor node. The accuracy is increased for boundary nodes too.

Many techniques are designed so far, a common fault to all mobile beacons based Localization schemes achieve when considering the longer periodic interval of the message send by the anchor node and the irregular radio propagation pattern.

1.5.7 Hybrid Data Fusion

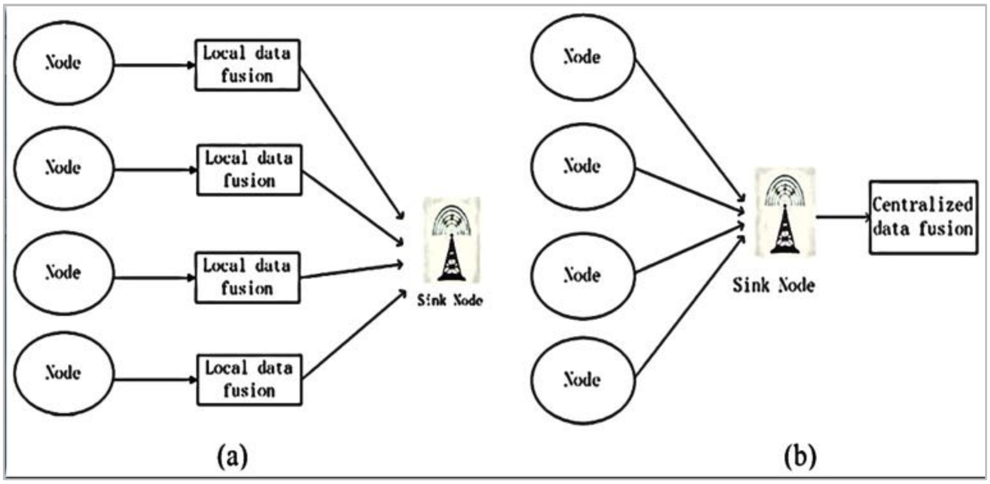
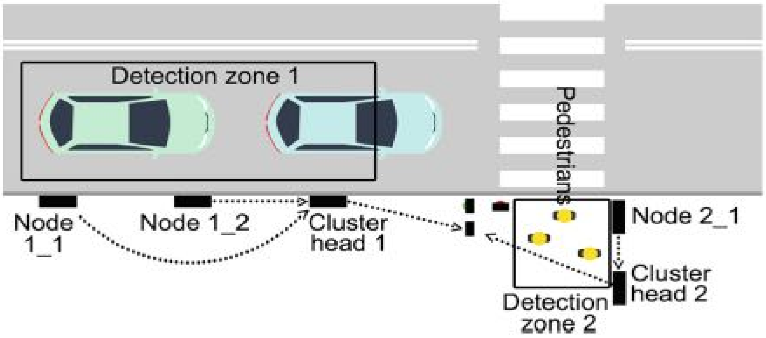


Figure (17): classification of hybrid data fusion in WSNs.

The basics of hybrid data fusion are to combine the information from different positioning systems with various physical measurement techniques to obtain low power consumption and higher accuracy as compared to other stand-alone localization techniques .today, there are two approaches, distributed and centralized as shown figure (17). Iterative positioning [27,32,33] and mutual link selection [11,41] are used with the distribution method. In iterative multiple literation, once the position is estimated for unknown nodes, this node is used as the beacon node for other unknown sensor nodes. Multiple iterations are needed to complete the localization process.

One important application is pedestrian tracking [34] show in figure (18). this hybrid technique combine inertial measurement and RSS information via a Kalman filter.



Figure(18): structure of WSN for road controlling.

Simple hybrid methods [36, 37] were based on fingerprinting RSS method or map-based method. Otherwise, another method [38] uses a channel modeling technique, where a propagation channel model gives a direct relationship between the distance of two nodes and the RSS. Then, triangulation or multi literation is used to estimate the node position from a set of distances to some known beacon nodes. This approach has minimal calibration cost. Additionally, fusion between inertial measurements and channel-based localization provides higher accuracy as compared to fingerprinting based methods.

Many applications used hybrid data fusion techniques connected to WLAN with the built-in camera on a smartphone for position estimation [7]. These applications use visual marker spree-installed on the floor for the position correction. Visual information is merged with the radio data to track a person wearing a tag using a mobile robot in indoor environments The author in [33]discuss a method to modify range-based sensors and ID sensors (i.e., infrared or ultrasound ensign sensors) using a particle filter to track people in a networked sensor environment.

Another approach is based on the fusion of video and compass data acquired by the beacon node [23]. This system calculates the beacon node location by utilize a digital comp ass (magnetometer), an image taken by a video camera and the exact location data for some geographically-located referential objects (e.g. electricity transmission towers, solitary trees, furnace chimneys, etc.) situated in the deployment area. This method, due to the low price of digital compasses, is helpful for video-based or multimedia-based WSNs, where the nodes already contain digital compasses may simply become beacon nodes or anytime the GPS receiver is not considered to be the suitable solution. Some approach modifies a hybrid localization system in WSNs, which is contained a coarse-grained localization system and fine-grained localization system. The coarse-grained localization system takes the wireless signal strength as the reference for distance and gets the harsh area as the unknown node. The fine-grained localization system is in charge of location refinement that takes an image to localize the unknown node with camera sensor nodes.

All hybrid data fusion system used to decrease localization error and power consumption of the network by combining more than one method in collecting data.

1.6 Performance evaluation Criteria for Localization in WSNs

Evaluation of WSNs is very important to construct a fit network to a specific application. the main metric are accuracy, localization, coverage, scalability, robustness, cost, scalability, Topology etc. The decision of this metric is more important than the others depend on the demand of the application this WSN designed for it .so, evaluation metric is an interested branch for researchers, users, designers.

- Researchers interested in this metric to decide which one of these metrics is more important than others, and use the fit algorithm for this application. Also, they study the relationship between this metric against each other to modify the network.
- Designers take the researcher's result and built it in the real environments with choose the available contents of this network with low cost(the type of nodes, which channel suitable for application area, configuration,……etc.).
- Users must have a good a knowledge about service get from the WSN.

1.6.1 Accuracy

Accuracy in WSNs can be defined as how much the estimated location found by the localization algorithm near to the correct position in actual. The simplest method to calculate accuracy in 2D space is to determine the summation residual error between estimated algorithm location and actual position for each node and divide over total nodes number to get the average error.as in the equation

$$E_{mne} = \frac{\sum_{i=1}^{n} \sqrt{\left(x_i - \tilde{x_i}\right)^2 + \left(y_i - \tilde{y_i}\right)^2 + \left(z_i - \tilde{z_i}\right)^2}}{n} \qquad (2)$$

Where $(x_i, y_i)$is actual node position and($\tilde{x}_i$, $\tilde{y}_i$)is the estimated position, and n number of sensor in the network. Also, the root mean square error can be used to .it is similar to the average error which given by

$$E_{rms} = max_{i=1 \ldots n} \sqrt{(x_i - \tilde{x_i})^2 + (y_i - \tilde{y_i})^2 + (z_i - \tilde{z_i})^2} \qquad (3)$$

Sometimes it's important to find the error by using distance to reflect the relative geometry of the network estimated by the localization algorithm and the relative geometry of the actual network. Which find by

$$\text{GER} = \frac{1}{n(n-1)/2} \sqrt{\sum_{i=1}^{n} \sum_{j=i+1}^{n} \left(\frac{\hat{d}_{ij} - d_{ij}}{d_{ij}}\right)^2} \qquad (4)$$

The distance error between the algorithm estimated distance ($\tilde{d}ij$) and the actual distance (dij) is normalized by the known distance (dij), calculating the error a percentage of the known distance.

To defining accuracy well that need to use relation reflects the root mean square error this error is called GDE

$$\text{GDE} = \frac{1}{R} \sqrt{\frac{\sum_{i=1}^{n} \sum_{j=i+1}^{n} \left(\frac{\hat{d}_{ij} - d_{ij}}{d_{ij}}\right)^2}{n(n-1)/2}} \qquad (5)$$

Where R is the rang of sensor node.

1.6.2 cost

Cost of a localization technique involves hardware cost, communication cost, and computation cost. Hardware Cost includes the node density, the density of beacon nodes and measurement equipment [40]. Communication cost includes two parts inter-node communication and communication between nodes and Base Station (BS) or Central Server. Centralized Localization procedure often covers communication between sensor nodes and BS, unfortunately, this communication cost consumes more energy as compared to inter-node communication or computation cost. That is why distributed algorithms are often more suitable than centralized algorithms because in distributed approach computation cost and inter-node communication is less than communication between BS and nodes.

1.6.3 Coverage

Coverage metric of WSNs can be defined as how many nodes success to identify its location by the estimated total number of network nodes. this metric dependent on:

- **number of beacons in the network**

Beacon nodes are those nodes which know their coordinates by use of additional hardware such as a GPS receiver or by manual handling. Beacon configuration has an important effect on the localization. The disadvantages of using beacon nodes are increasing hardware cost because GPS receivers are very expensive; also beacon nodes can't be used for indoor localization. The advantages of using beacon nodes are that we can easily get global coordinates which used to determine the unknown nodes location.

- **Node Density**

Many localization techniques are sensitive to node density. For example, hop-count based technique generally needs high node density so that the number of hops approximation of the distance is correct [40]. Thus, when designing the network, it is important to consider the desired technique in terms of node density.

1.6.4Topologies

Defining real placement of node by knowing its topology has an important role in WSNs accuracy. scattering node in the network can be classified into two strategies which are:

- **Regular deployment**

Sensor nodes are placed uniformly in the coverage area of the network this type reflects the actual deployment of most WSNs applications. sensor nodes in this type are scattered by aircraft .in estimation location nodes calculate the shortest path by the information from beacons and by calculating the number of hopes node can estimate its position with low error and high accuracy.

- **Irregular deployment**

based on hole size and shape inside the network area, the shape of the Irregular topologies have different known deployment which are C-shaped, S-shaped, L-shaped, O-shaped, etc. many applications use those deployment .distance between nodes depend on Euclidian distance algorithm. the main disadvantage is the detoured path between nodes because of that there is a difference between the estimated hop distance and the actual Euclidean distance is large. Individual error is accumulated and result in increasing the localization error. as show in figure1.19 path between two nodes around obstacle.

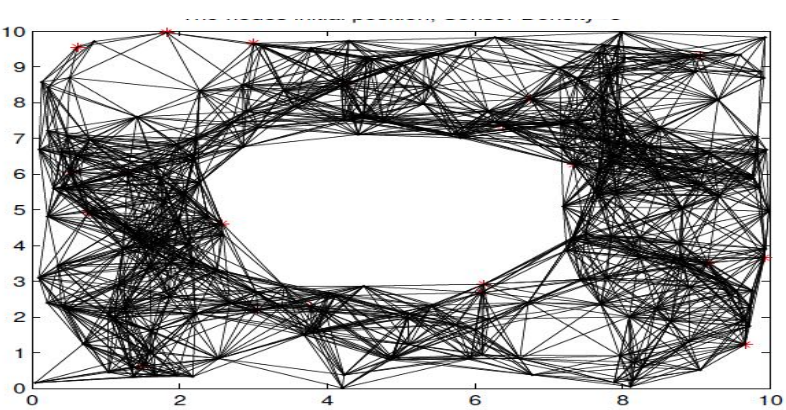


Figure (19):irregular O-shape

1.7 comparisons between centralized and distributed techniques

Centralized techniques depend on collect all information in BS due to that those techniques are high localization accuracy than distributed because in centralized base station has more overview of the network. But the main problems of centralized algorithms those are not scalable and not suitable for large scale networks, Other drawbacks of centralized techniques than distributed are their higher computational complexities, unreliability because of the low accuracy in accumulated information (waste information may happen over multi-hop) collected from multi-hop sensor nodes to the central node in WSN. On the other hand, distributed techniques are more complex in the localization algorithm and deployment of sensor nodes are difficult than localization techniques but it is scalable, less power consumption, accuracy is fair, low cost, high accuracy than centralized. In general, most application of WSNs depends on distributed localization techniques.

1. 7.1 Comparison between Range Based and Range free Localization Techniques

	Range-based	**Range free**
Coast	**more**	**less**
Level of accuracy	**High (85%-90%)**	**Low (70%-75%)**
Power consumption	**more**	**less**
deploy ability	**Hard**	**essay**
Dependency on additional hardware	**yes**	**no**
Robustness	**High**	**low**

Table (1): comparison between range free and range-based localization techniques.

5.7.2 comparison between range-based techniques

Localization algorithm	Accuracy	Hardware coast	Computation coast
Distance-based • RSSI	median	low	low
• TDoA	high	high	low
Angle based • AoA	high	High	low

Table (2): comparison between range –based techniques.

Table(2) summarized the main differences between types of range-based techniques discussed in this chapter to indicate the character of each one. the farmhouse one in the researcher is RSSI because it is low cost and suitable for many WSN application with a small localization error that increases the accuracy of it .but the decision of choosing the type of network-dependent only on the requirement of the network.

1.7.3 Comparison between Range free Localization Techniques

Technique	coast	Node density	accuracy	Overhead	scalability
APIT	low	>16	good	small	yes
DV-hop	medium	>8	good	largest	no
Multi-hope	high	>12	good	large	no
Centroid	low	>0	fair	smallest	yes
Gradient	low	>6	average	large	yes

Table (3):comparison between range free techniques.

The range-free localization techniques are the most widespread in WSNs because no need for more hardware increased in the sensor nodes .also, algorithms of these techniques based on distance between nodes that make them easy to implement and have high accuracy with low cost.

1.8 applications based on localization

Many application based on localization of WSNs, in this section make scope on the important applications which are:

1.8.1 location-based services

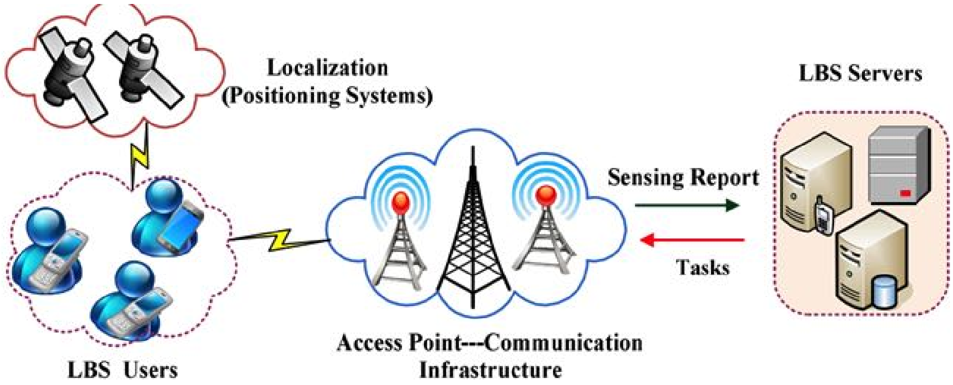


Figure (20): The common location-based service (LBS) system deployment contents: LBS servers, localization, communication networks, and mobile users.

A typical LBS application working in a centralized network, i.e., the location information collected by the mobile devices of users are reported (using wireless communication infrastructures) at a central location server for processing, as illustrated in Figure (20). As shown, the architecture of this LBS application consists of the following four parts: (a) LBS users with smartphone devices; (b) positioning services, based on localization infrastructure; (c) communication networks (channels); and (d) third-party service providers. During the normal operation of the LBS application, each user needs to report their location-based on information to the third-party LBS provider due to receive the service.

The Smartphone devices, used by LBS users, can embed different positioning systems (e.g., GPS) to know current geographic locations and other information. also, they can produce a wireless connection through communication channels (e.g., a cellular network), transmit an LBS query and then return the query result from the service providers.

*1.8.2 **Ambient assisted living (AAL) and health applications***

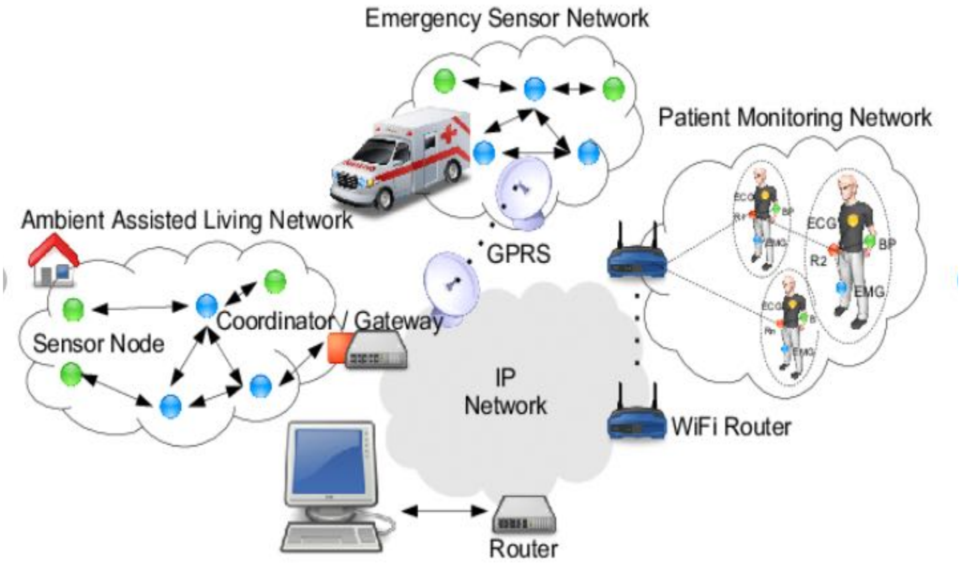


Figure (21): different healthcare examples: ambient assisted living (AAL), emergency response and patient monitoring.

The main goal of this type of application is to improve health care, The most beneficial category of this application are the elderly, patients need care in home every time, ALL help them to control their health conditions example of the indoor localization systems depend on the AAL applications are "Smart Floor Technology" to detect the presence of people and the "Passive Infrared Sensors" to notice the motion of people. some AAL use ultra-wideband (UWB) technology such as orthopedic computer-aided surgery as well as its integration with smart surgical tools such as a wireless probe for real-time bone morphing is implemented.

1.8.3 Robotics

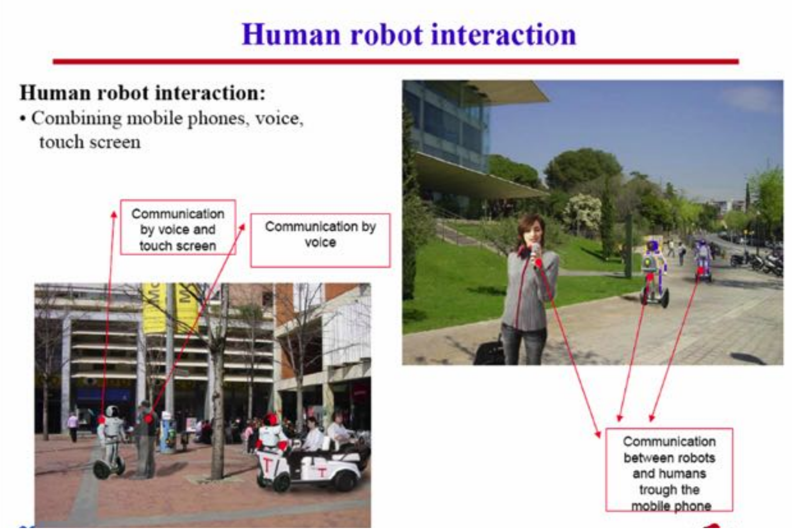


Figure (22): connection between people and robots

The application based on robotics applications based on a robot move periodically between nodes in the WSNs and the node which have a problem transmit its signal and the robotic define its position by identify the path from the nearest node information to solve the problem the main problem solved by this scenario in WSNs when the node has low power. robotic constraints can be variable like programing it to detect fire or defect samples in an industrial factory,……etc. an other example Ubiquitous Networking Robotics in Urban Settings (URUS), an example of using localization for evacuation in the emergency, where the robots tell the people to the evacuation place.

1.8.4 Cellular Networks

Connect the WSN to the cellular networks increase the accuracy of localization. All the above Applications can be combined with cellular network, every generation of cellular network improved to fit with WSNs.

1.9 Conclusion

In this chapter, we classify various localization techniques to centralized and decentralized or distributed techniques. A comparative study of localization techniques is also given with a focus on their limitations, costs, and benefits. The designer must choose the low hardware cost and high accuracy.

References:

[1] Afzal, Samira: 2012" A Review of Localization Techniques for Wireless Sensor Networks". J.Basic Appl.Sci.Res 2(8):7795---7801.
[2] A. Youssef and M. Youssef, 2007. "Ataxonomy of localization schemes for wireless sensor networks," in Proceedings of the International Conference on Wireless Networks (ICWN '07), pp. 444–450, Las Vegas, Nev , USA.
[3] Al-Karaki, J.N.; Kamal, A.E. 2004 " Routing techniques in wireless sensor networks: A survey". IEEE Wirel. Commun.2004, 11, 6–28.
[4] Cesare Alippi, Giovanni Vanini . 2006:" A RSSI-based and Calibrated Centralized Localization Technique for Wireless Sensor Networks" .In: Proceedings of Fourth IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06),Pisa, Italy.
[5] Dong, L.; Severance, F.L. March 2007 " Position estimation with moving beacons in wireless sensor networks".In Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), Kowloon,China, 11–15; pp. 2319–2323.
[6] Elnahrawy, Eiman, Li, Xiaoyan, Martin, Richard P.2004. .: "The Limits of Localization using Signal Strength": A Comparative Study. In: Proceedings of IEEE SECON, pp.406—414, California, USA.
[7] Germa, T.; Lerasle, F.; Ouadah, N.; Cadenat, V.; Devy, M. October 2009 "Vision and RFID-based person tracking in crowds from a mobile robot". In Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, St. Louis, MO, USA, 10–15; pp. 5591–5596
[8] Gang, P.; Yuanda, C.; Limin, C. 2004 " Study of Localization Schemes for Wireless Sensor Networks". J. Comput. Eng. Appl., 40, 27–29.
[9] Hu, L., Evans. 2004.:" Localization for Mobile Sensor Networks". In: Proceeding of Annual International Conference on Mobile Computing and Networking (MOBICOM).pp.45--57.
[10] http://mdpi.com/1424-8220/9/11/8399.
[11] Hadzic, S.; Bastos, J.; Rodriguez, J. Reference node selection for cooperative positioning using coalition formation games; 15–16 March 2012. In "Proceedings of the 9th Workshop on Positioning Navigation and Communication", Dresden, Germany,; pp. 105–108
[12] Hattori, K.; Kimura, R.; Nakajima, N.; Fujii, T.; Kado, Y.; Zhang, B.; Hazugawa, T.; Takadama, K. 28–29 December 2009. "Hybrid Indoor Location Estimation System Using Image Processing and WiFi Strength". In Proceedings of the International Conference on Wireless Networks and Information Systems, Shanghai, China; pp. 406–411.

[13] Ian Oppermann , HAMALAINEN, M., IINATTI, J. 2004 " UWB Theory and Applications". John Wiley & Sons, Ltd.
[14] Kannan, Anushiya A., Mao, Guoqiang, Vucetic, Branka:" Simulated Annealing based Wireless Sensor Network Localization". Journal of Computers 1(2):15--22,.
[15]Kumar S, Lobiyal D K ,2016 . "Novel DV-Hop localization algorithm for wireless sensor networks" Telecommunication Systems .PP: 1-16.
[16] Lee, S.; Kim, E.; Kim, C.; Kim, K. 2009 " Localization with a mobile beacon based on geometric constraints in wireless sensor networks". IEEE Trans. Wirel. Commun., 8, 5801–5805.
[17] Liu, K.; Yan, X.; Hu, F. China, 20–22 November 2009 "A modified DV-Hop localization algorithm for wireless sensor networks".In Proceedings of the IEEE International Conference on Intelligent Computing and Intelligent Systems,Shanghai,; Vulume 3, pp. 511–514.

[18] Liu, J., Zhang, Y., Zao, F.2006..:" Robust Distributed Node Localization with Error Management". In: Proceedings of 7th ACM International Symposium on Mobile Ad-Hoc Networking and Computing (Mobi Hoc), pp.250-261, Florence, Italy.
[19] Langendoen, K., Reijers, N., 2003. "Distributed Localization in Wireless Sensor Networks": A Quantative Comparison. Computer Networks 43(4): 499--518
[20] Moore, D., Leonard, J., Rus, Daniela, Teller, S 2004..:" Robust Distributed Network Localization with Noisy Range Measurements". In: Proceedings of the Second ACM Conference on Embedded Networked Sensor Systems (SenSys), Baltimore, MD.
[21] Mao, G.; Fidan, B. 2009. " Localization Algorithms and Strategies for Wireless Sensor Networks"; Information Science Reference-Imprint of IGI Publishing: Hershey, PA, USA.
[22] Noureddine, H.; Gresset, N.; Castelain, D.; Pyndiah, R. 4–7 April 2010" A new variant of Nonparametric Belief Propagation for self-localization". In Proceedings of the 17th International Conference on Telecommunications, Doha,Qatar; pp. 822–827.
[23] Pescaru, D.; Curiac, D. 2014 " Anchor Node Localization for Wireless Sensor Networks Using Video and Compass Information Fusion". Sensors, 14, 4211–4224.
[24] Pedersen, C.; Pedersen, T.; Fleury, B.H. 31 July–5 August 2011 "A vibrational message passing algorithm for sensor self-localization in wireless networks". In Proceedings of the IEEE International Symposium on Information Theory Proceedings,St. Petersburg, Russia; pp. 2158–2162
[25] Paul, A.K.; Sato, T. 2013" Detour Path Angular Information Based Range Free Localization in Wireless Sensor Network". J. Sens. Actuator Netwrk., 2, 25–45.
[26] R. Manzoor, 2010 "Energy efficient localization in wireless sensor networks using noisy measurements" [M.S. thesis].
[27] Pal, A. 2010: "Localization Algorithms in Wireless Sensor Networks: Current Approaches and Future Challenges". Network Protocols and Algorithms (2):45—73.
[28] Shang, Y., Ruml, W., Zhang, Y., Fromherz, M.2003.: Localization from mere Connectivity. In: "Proceedings of ACM Symposium on Mobile Ad Hoc Networking and Computing" (MobiHoc'03), Annapolis, Maryland, USA.
[29] Savarese, C., Rabaey, J.M., Langendoen, K. 2002.: "Robust Positioning Algorithms for Distributed Ad Hoc Wireless Sensor Networks". In :Proceedings of 2002 USENIX Annual Technical Conference on General Track, pp.317--327, Berkley, USA,.
[30] Singh, M.; Bhoi, S.K.; Khilar, P.M. 2017 " Geometric Constraint Based Range Free Localization Scheme for Wireless Sensor Networks". IEEE Sens. J., 17, 5350–5366.
[31] Ssu, K.F.; Ou, C.H.; Jiau, H.C. . 2005 "Localization with mobile anchor points in wireless sensor networks". IEEE Trans. Veh. Technol, 54, 1187–1197.
[32] Savic, V.; Wymeersch, H.; Penna, F.; Zazo, S. 22–27 May 2011 "Optimized edge appearance probability for cooperative localization based on tree-reweighted nonparametric belief propagation". In Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Prague, Czech Republic,; pp. 3028–3031.
[33] Schulz, D.; Fox, D.; Hightower, J. 9–15 August 2003. " PeopleTracking with Anonymous and ID-sensors Using Rao-Black wellised Particle Filters". In Proceedings of the 18th International Joint Conference on Artificial Intelligence (IJCAI'03), Acapulco, Mexico; Morgan Kaufmann Publishers Inc.: San Francisco, CA,USA; pp. 921–926.
[34] Tarrío, P.; Besada, J.A.; Casar, J.R; 9–12 July 2013 "Fusion of RSS and inertial measurements for calibration-free indoor pedestrian tracking". In Proceedings of the 16th International Conference on Information Fusion, Istanbul, Turkey; pp. 145.
[35] Wang, Jing, Gosh, R.K., Das, Sajal K. 2010 : "A Survey on Sensor Localization". J Control Theory Appl 8(1): 2--11 .
[36] Woodman, O.; Harle, R. 21–24 September 2008. "Pedestrian Localisation for Indoor

[37] Wang, H.; Lenz, H.; Szabo, A.; Bamberger, J.; Hanebeck, U.D. 22 March 2007. “WLAN-Based Pedestrian Tracking Using Particle Filters and Low-Cost MEMS Sensors”. In Proceedings of the 4thWorkshop on Positioning, Navigation and Communication, Hannover, Germany,; pp. 1–7.
[38] Xiao, B.; Chen, H.; Zhou, S. 2008” Distributed Localization Using a Moving Beacon in Wireless Sensor Networks”. IEEE Trans. Parallel Diatribe. Syst. 19, 587–600.
[39] Y. Liu, Z. Yang, X. Wang, and L. Jian, Mar. 2010 “Location, localization, and localizability,” journal of computer science and technology .
[40] Youssef, A., Youssef, M.2007..: “A Taxonomy of Localization Schemes for Wireless Sensor Networks”. In: Proceeding of International Conference on Wireless Networks (ICWN), Las Vegas, USA.
[41] Zirari, S.; Denis, B. 11–13 September 2012” Comparison of links selection criteria for mobile terminal positioning in cooperative heterogeneous networks”. In Proceedings of the 20th International Conference on Software,Telecommunications and Computer Networks, Split, Croatia; pp. 1–6.