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A Survey of Localization Methods and Techniques in Wireless Sensor Networks

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Abstract

Today, wireless sensor networks has become a key technology for different types of "smart environments", and an intense research effort is currently ongoing to enable the application of wireless sensor networks for a wide range of industrial problems. Localization is important when there is an uncertainty of the exact location of some fixed or mobile devices. This paper provides different techniques used for localization of mobile node in wireless sensor network. This study can help to learn about efficient methods for localization in wireless sensor network.

Keywords

Localization, WSN, DV-Hop Algorithm, Position Estimation

Introduction

A Wireless Sensor Network (WSN) is formed by hundreds of small, low-cost nodes which have limitations in memory, energy, and processing capacity. In this type of networks, one of the main problems is to locate each node. Recent advances in wireless communications and electronics have enabled the development of low-cost, low-power and multi-functional sensors that are small in size and communicate in short distances. Cheap, smart sensors, networked through wireless links and deployed in large numbers, provide unprecedented opportunities for monitoring and controlling homes, cities, and the environment. In addition, networked sensors have a broad spectrum of applications in the defense area, generating new capabilities for reconnaissance and surveillance as well as other Tactical applications. Self-localization capability is a highly desirable characteristic of wireless sensor networks. In environmental monitoring applications such as bush fire surveillance, water quality monitoring and precision agriculture, the measurement data are meaningless without knowing the location from where the data are obtained.

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Moreover, location estimation may enable a myriad of applications such as inventory management, transport, intrusion detection, road traffic monitoring, health monitoring, reconnaissance and surveillance [1].

Localization

Localization is one of the key techniques in wireless sensor network. The location estimation methods can be classified into Target / source localization and node self-localization. In target localization, we mainly introduce the energy-based method. Then we investigate the node self-localization methods. Since the widespread adoption of the wireless sensor network, the localization methods are different in various applications. And there are several challenges in some special scenarios. In this paper, we present a comprehensive survey of these challenges: localization in non-line-of-sight, node selection criteria for localization in energy-constrained network, scheduling the sensor node to optimize the tradeoff between localization performance and energy consumption, cooperative node localization, and localization algorithm in heterogeneous network. Finally, we introduce the evaluation criteria for localization in wireless sensor network. The process of estimating the unknown node position within the network is referred to as node self-localization. And WSN is composed of a large number of inexpensive nodes that are densely deployed in a region of interests to measure certain phenomenon. The primary objective is to determine the location of the target[1].

Review of Existing Localization Methods and Techniques

1. Received Signal Strength Indicator: RSSI enable you to estimate the space between two nodes depending on the strength in the signal received by another node. As depicted in Fig. 1, a sender node sends a signal using a determined strength that fades as being the signal propagates. The higher the distance towards receiver node, the lesser the signal strength when it arrives at that node. Theoretically, the signal strength is inversely proportional to squared distance, along with a known radio propagation model may be used to convert the signal strength into distance. However, in solid-world environments, this indicator is extremely influenced by noises, obstacles, and also the type of antenna, so that it is difficult to model mathematically. In these instances it's quite common to generate a system calibration , where values of RSSI and distances are evaluated ahead of time within a controlled environment. This method, such as the others, has both positives and negatives. The principle advantage is its cheap, because most receivers are capable [2].

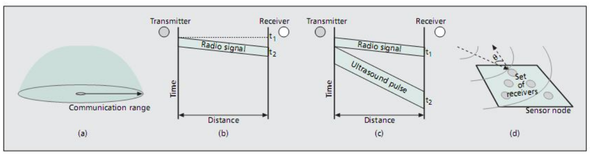

Figure 1: Received Signal Strength Indicator Method [2]

2. Distance / Angle Estimation: Distance/angle estimation consists in identifying the length or angle between two nodes. Such estimates constitute a crucial portion of localization systems, as they are utilized by the two position computation and localization algorithm components. Different methods enable you to estimate such information. Many of these methods have become accurate, but with higher costs (with regard to hardware, energy, and processor resources), while other people are less accurate but already available on most sensor nodes. From the following sections some of the main methods used by localization systems to estimate distances/angles are going to be studied. These techniques include received signal strength indication (RSSI), arrival time/time difference of arrival (ToA/TDoA), angle of arrival (AoA), and communication range [2].

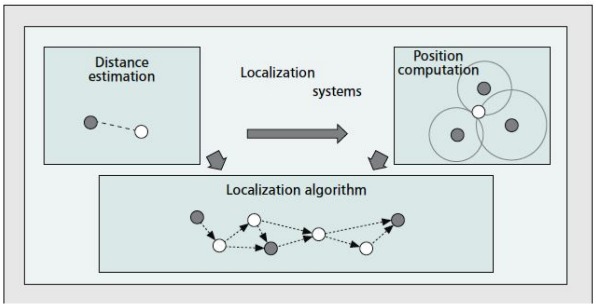

Figure 2: Division of localization systems into three distinct components. [2]

3. Time [Difference] of Arrival: Different methods make an effort to estimate distances between two nodes using time based measures By far the most simple and easy intuitive is ToA . In this case the distance between two nodes is directly proportional towards time the signal takes to propagate from place to another. That way, when a signal was sent at time t1 and reached the receiver node sometimes t2, the space between sender and receiver is d = sr(t2 – t1), where sr would be the propagation speed in the radio signal (light speed), and t1 and t2 would be the times when the signal was sent and received (Fig. 2b). This type of estimation requires precisely synchronized nodes plus the time where the signal leaves the node need to be inside packet that is certainly sent.

   TDoA will be based upon:

   1. The difference inside times where an individual signal from a single node finds three or maybe more nodes.

   2. The visible difference within the times when multiple signals at a single node reach another node.

4. Angle-of-arrival measurements: The angle-of-arrival measurement techniques can be further split into two subclasses: those using the receiver antenna's amplitude response the ones utilizing the receiver antenna's phase response. Beam forming may be the name provided to using anisotropy inside the reception pattern of an antenna, and it's also the premise of merely one category of AOA measurement techniques. The measurement unit could be of small size in comparison with the wavelength on the signals. One can suppose the beam of the receiver antenna is

rotated electronically or mechanically, plus the direction corresponding towards the maximum signal strength is taken as the direction in the transmitter. Relevant parameters include the sensitivity on the receiver along with the beam width. A technical problem to be faced and overcome arises in the event the transmitted signal has varying signal strength. The receiver cannot differentiate the signal strength variation as a result of varying amplitude from the transmitted signal as well as the signal strength variation due to the anisotropy from the reception pattern. One approach to handling the problem is try using a second non-rotating and Omni-directional antenna on the receiver. By normalizing the signal strength received with the rotating anisotropic antenna according to the signal strength received because of the non-rotating Omni-directional antenna, the impact of varying signal strength is usually largely removed. Fig. 1 shows an antenna variety of N antenna elements. The adjacent antenna elements are separated by way of uniform distance d [1]. The space between a transmitter far through the antenna array as well as the ith antenna element may be approximated by

$$R_i = R_0 - id \cos \theta$$

where R**0** is the distance between the transmitter and the 0^{th} antenna element and θ is the bearing of the transmitter with respect to the antenna array [4].

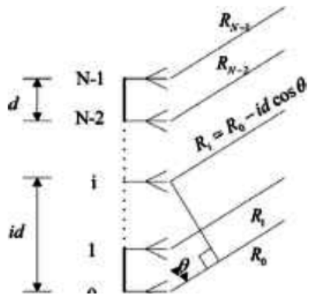

Figure 3. Angle-of-arrival measurements[4]

Recursive Position Estimation: In RPE nodes estimate their positions based on a number of initial beacon nodes (e.g., 5 percent on the nodes) only using local information. Localization information increases iteratively as newly settled nodes become reference nodes. The RPE algorithm might be put into four phases, as depicted in Fig. 5. Within the first phase a node determines its reference nodes. Within the second phase the node estimates its distance about bat roosting reference nodes using, one example is, RSSI. In the third phase the node computes its position using trilateration (to become settled node). From the final phase the node becomes a reference node by broadcasting its newly estimated position to its neighbors. Every time a node becomes a reference, it might assist other nodes in computing their positions besides.

An advantage of this algorithm is usually that the volume of reference nodes increases quickly, so that most the nodes can compute their position. But it has the issue with propagating localization errors. The inaccurate position estimation of one node can be employed by other nodes to estimate their positions, increasing this inaccuracy. Furthermore, a node must have a minimum of three reference neighbors so that you can compute its position [2].

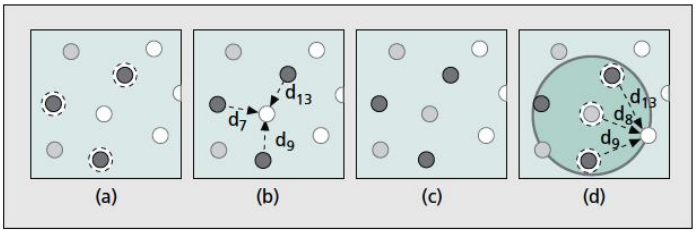

Figure 4: Example and phases of RPE [2]

5. A Tracking Scenario: We use the following tracking scenario to create out key CSIP issues. To be a target X moves from left to right through the sensor field, numerous activities are initiated from the network, as shown in Figure 4.
   a) Discovery: Node A detects X and initializes tracking.
   b) Query processing: An individual query Q enters the network and it is routed toward areas of interest—in this case, the region around node a. It must be noted that other forms of queries, such as long running queries that dwell in a network a duration of time, may also be possible.
   c) Collaborative processing: Node a estimates the prospective location, possibly with the aid of neighboring nodes. The position estimation may be accomplished by way of a triangulation or even a least-squares computation more than a list of sensor measurements. More generally, the estimate can be obtained having a statistical method for example Bayesian estimation, which is detailed in.
   d) Communication: Because target X moves, node a may hand off a primary estimate on the target location to node b, b to c, and so on.
   e) One of many key problems here's to pick out the next node among a's 1-hop neighbors. An undesirable selection of b may cause the network to reduce the target or incur unnecessary communication overhead. The communication of internet data could be inseparable from data aggregation and processing and may ought to be jointly optimized with processing.
   f) Reporting: Node d or f may summarize track data and send it to the querying node. Assume that another target, Y, enters the region around the same time.

The network have to handle multiple tasks so as to track both targets simultaneously. Once the two targets move near each other, the problem of properly associating a measurement to some target track, the so-called data association problem, has to be addressed. Furthermore, collaborative sensor groups, as defined earlier, must be selected carefully since multiple groups might need to a similar physical hardware.

This tracking scenario raises quite a few fundamental informatics issues in distributed information discovery, representation, communication, storage, and querying:

a) In collaborative processing, the down sides of target detection, localization, tracking, and sensor tasking and control
b) In networking, the issues of knowledge naming, aggregation, and routing
c) In databases, the problems of information abstraction and query optimization
d) In human-computer interface, the issues of knowledge browsing, search, and visualization
e) In infrastructure services, the difficulties of network initialization and discovery, serious amounts of location services, fault management, and security [5].

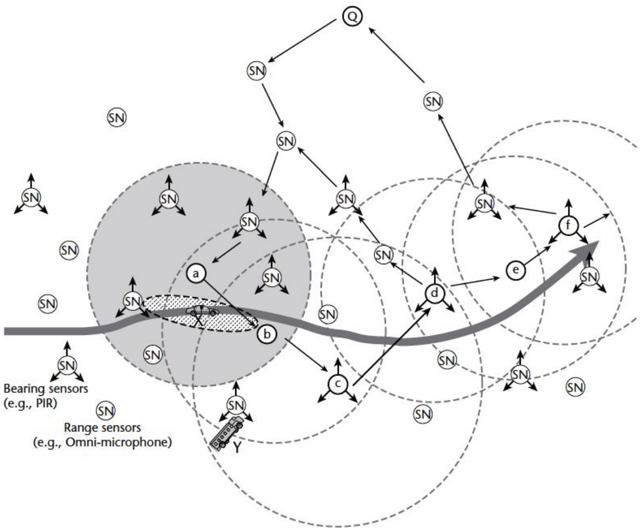

Figure 5: A tracking scenario, showing two moving targets, X and Y, in a field of sensors. Large dashed circles represent the range of radio communication for each node [5].

6. Localization With A Mobile Beacon: The usage of mobile beacons to support the nodes of your WSN in estimating their positions. A mobile beacon is often a node that may be aware of its position (e.g., furnished with a GPS receiver) and has to be able to move the sensor field. This beacon is usually a human operator, an unmanned vehicle, a private jet, or a robot. It operation was uncomplicated. In the event the nodes are deployed, the mobile beacon travels throughout the sensor field broadcasting messages that incorporate its current coordinates. Each time a free node receives a lot more than three messages through the mobile beacon it computes its position, using a probabilistic approach, good received coordinates and RSSI distance estimations. Figure 6 illustrates this scenario and three possible trajectories with the mobile beacon. The communication cost for that WSN is null, since no nodes (except the mobile beacon) ought to send any packets. An advantage in this algorithm is position estimations are computed in line with the same node (mobile beacon), thus keeping the mean localization error low and preventing the propagation with this error. Also, this algorithm avoids the application of nodes designed with GPS, except the mobile beacon. Then again, in this particular technique a sensor node can estimate its position only when the mobile beacon passes near this

node, which can require a long time depending on such factors as the sized the sensor field, the beacon's mobility capacity, and the node's trajectory. Also, the mobile beacon may never pass near some nodes, as a consequence of either the trajectory or a issue with the mobile beacon [2,9].

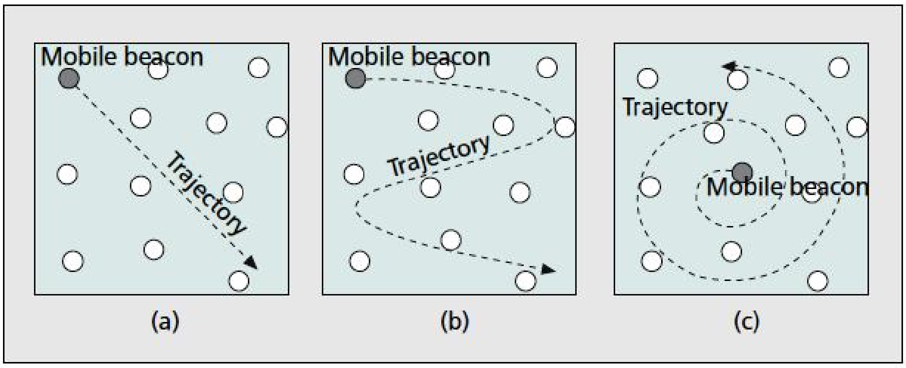

Figure 6: Operation and possible trajectories of a mobile beacon [2]

7. Linear-regression based traffic analysis: The attacker starts observing the incoming data transmission around the base station and analyzes it to estimate the direction in the data bank. However, this estimation is not straightforward because the observed transmission paths aren't linear or constant due to the multi-hop data routing along with the randomness introduced inside the secure routing protocols, including the random H hops in phantom routing. To deal with this challenge, we apply the linear-regression to find the best fit line representing the position of the sensors within the transmission path to get a single data packet, as observed through the attacker. Because the packets are forwarded towards and sent to the camp station, we force each regression curve to pass through the camp station. The regression lines are used to estimate the direction in the incoming traffic which supports us in inferring the direction in the data source. Ideally, without any spatial randomness introduced in the routing path, walking down the regression line would reveal the location of the source.

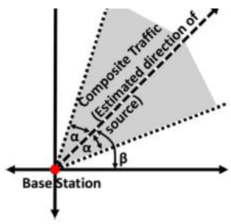

Fig. 2. α-angle anonymity.

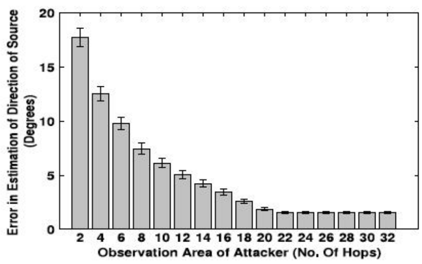

Figure 7: Error in estimated direction of source [6]

8. Communication Range: In some instances, really the only information available to estimate a distance is the communication selection of the sensor nodes. When a node receives a data packet from another node, then this distance between these nodes is between zero and also the maximum communication range. Usually, techniques designed to use this method of distance estimation don't require an accurate distance, but only an interval. To have one distance (instead of an interval), you can select one point on the interval, just like the middle point, for instance. Within this last case, the most error with this estimation will likely be one-half the communication range.

This process of distance estimation has got the good thing about being essentially the most basic and while using the lowest cost. No extra hardware is essential, nor is extra computation necessary to estimate a distance. Conversely, a mistake of half the communication range per distance estimation is just not viable for localization systems. Consider, for instance, a communication variety of 100 m. In such cases, the big mistake of the method can be about 50 m for every distance estimation [7].

9. The Global Positioning System (GPS): The GPS can be a system consists of 24 satellites in operation that orbit round the earth. Each satellite circles planet earth for a height of 20.200 km and makes two complete rotations every single day. The orbits were defined in a fashion that in each region of the world we could "see" at least four satellites above. A GPS receiver has the capacity to obtain information constantly sent through the satellites, estimate its distance to four or five known satellites using ToA, and, finally, compute its position using tri-lateration. Once these procedures are executed, the receiver will be able to inform its latitude, longitude, and altitude. One of the solutions for that localization overuse injury in WSN would be to equip all the sensor nodes using a GPS receiver. One of the primary advantages are the relatively small (2–15 m, with regards to the receiver) and precise localization error, because all nodes can have an identical error. However, this solution has many disadvantages: (a) The cost and sized the sensor nodes, are increased, (b) it wouldn't use travellers have the no satellite visible (e.g., indoor scenarios, under water, under climatic conditions, mars exploration), and (c) the other hardware consumes energy. Due to these disadvantages, using the GPS is frequently restricted to a part of the nodes (e.g., beacon nodes) [7].

10. Generic Approach: In the known localization algorithms specifically proposed for sensor networks, we selected a few approaches that fulfill the simple requirements for self-organization, robustness, and energy-efficiency:

a) Ad-hoc positioning
b) N-hop multilateration
c) Robust positioning

Another approaches can lead you to a central processing element (e.g., convex optimization by Doherty et al.. [9]), count on a infrastructure (e.g., GPS-less by

Bulusu et alibi. [6]), or induce excessive communication (e.g., GPS-free by Capkun et alibi. [8]). These selected algorithms are fully distributed and use local broadcast for communication with immediate neighbors. This last feature lets them be executed before any multihop routing is place, hence, they could support efficient location-based routing schemes like GAF [7].

Even though the three algorithms were developed independently, we found they share one common structure. We were capable of identify this generic, three-phase approach 1 for determining the consumer node positions:

1. Determine the distances between unknowns and anchor nodes.
2. Derive for each node a position looking at the anchor distances.
3. Refine the node positions using information about the number (distance) to, and positions of, neighboring nodes.

10. Localization Algorithm: The localization algorithm would be the main portion of a localization system. This component determines what sort of information of distances and positions are going to be manipulated as a way to allow most or every one of the nodes from the WSN to estimate their positions [7].
    a) The localization algorithms can be classified into some categories:
    b) Distributed or Centralized Position Computation
    c) With or With no Infrastructure
    d) Relative or Absolute Positioning
    e) Indoor or Outdoor Scenarios
    f) One Hop or Multi Hop
    g) Mean Error and Consistence
    h) Communication Cost
    i) Quantity of Settled Nodes
    j) Number of Beacon Nodes
    k) Network Density
    l) Network Scale
    m) Quantity of Beacon Nodes
    n) GPS Accuracy

Some proposed localization algorithms will likely be studied and analyzed. These algorithms are: Ad Hoc Positioning System, Recursive Position Estimation, and Localization using a Mobile Beacon, Global Positioning System, as well as the Cricket Location Support System. Thereafter, some general comments will be made regarding this component and it is methods [7].

11. DV-Hop algorithm: The precision of the node localization algorithm relies on the power of beacon nodes in wireless sensor network. But the expense of beacon nodes is high as 100 times the price tag on normal nodes. For reducing localization cost, we propose a radio sensor network nodes localization algorithm according to mobile beacon and DV-Hop. Through the foundation DV-Hop localization algorithm, allow a moving beacon node to advance and broadcast its position home elevators the pre-arranged path as a way to form multiple virtual beacons. Those unknown nodes record the hop count of each virtual beacon, and use the weighted processing to calculate the normal hop

distance as well as the distance between every virtual beacon. Finally it utilizes three border measurements to calculate the venue information of unknown nodes to get accurate localization for nodes. Since one mobile beacon is adopted, the price as well as the complexity of network tend to be reduced which prove the practicability of the method. DV-Hop algorithm can calculate the unknown node's location and that is distant from beacons. Plus it does not need extra information. However, how much errors can differ using the difference of bending degree. Because one unknown node can only get hop count through one path it the common single hop distance to calculate its very own location, that leads for the large error [10].

12. Improved DV-Hop Algorithm: The improved algorithm combines DV-Hop and Mobile Anchor Node Localization Algorithm and also introduces weighting the answer to calculate distance of each average hop in order to avoid the challenge of collinear and selectively calculate coordinates of unknown nodes. This will help to finish localization of more unknown nodes and further increase localization coverage rate. Meanwhile it keeps fine positional accuracy [10].

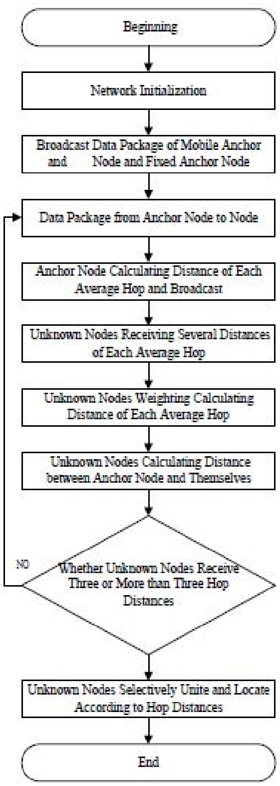

Figure 8: Achievement Flowchart the Improved DV-Hop Algorithm [10].

Description of Improved Algorithm: First stage: Exchanging stage of distance vector. This stage may be split up into two standalone parts: part one is similar to DV-Hop Algorithm. Unknown nodes use distance vector routing mechanism to lead each node of network to acquire minimum hop count and coordinate of every anchor node. In the second part, mobile anchor node traverses the whole area along Scan Model. At the moment it is going to broadcast one information package to its neighbour nodes another regular period.

Second stage: Calculation of adjusted value and broadcast stage. Calculating traditional DV-Hop Algorithm and analyzing its disadvantages, it truly is known that using average hop distance to estimate straight-line distance between nodes brings about error. Greater hops between anchor node and them, the larger error becomes.

Your third stage: estimating information of positional nodes. Aiming at Scan motion route, its greatest disadvantage is always that unknown nodes may receive distances between nodes and mobile anchor nodes from several components of collimation. In order to overcome the condition, distances between unknown nodes and anchor nodes should be united after which it coordinate of unknown node is going to be calculated [10].

13. DV-Distance Algorithm: A lot of us work today on networks and the majority people didn't have a very chance to operate in the network design. We a little while think that let's say we got the opportunity to work on the designing part than which protocol do you want to choose to implement within the network. So within this condition you should be ready before selecting the best routing protocol. Every routing protocol possesses its own advantages and drawbacks. There's no such best or perfect routing protocol. But to match want you organization it is possible to find the protocol that suits yours company essentially the most [9].

14. DV-Hop and DV-distance Propagation Methods: DV-Hop and DV-distance are incredibly much like 1 another from the sense that both use classical distance vector exchange to propagate the gap information. "DV-Hop" works as follow: Every node including anchor keeps a table with entries of fXi,Yi,hig. Each entry corresponds for the coordinates of anchor (Xi,Yi) and the hop count away from the anchor (hi). In the event the localization process starts, the tables are empty for ordinary sensors as there was one entry in each anchor which corresponds for the anchor itself. Packets bearing the related location information plus the hop count (initialized as zero) are provided by each anchor. Upon receiving the packet, node stores the coordinates with the anchors and compares the hop count field from the packet (incremented by one) with that on the table. Should the incremented hop count field with the packet is smaller, the significance from the table is updated and packets while using updated hop count field are forwarded to other one-hop neighbours. Otherwise, the packet is discarded. Eventually all nodes will know the positions of all anchors. Furthermore, the hop count fields in the table reflect the hop count of shortest path from the corresponding anchors After an anchor i has collected the coordinates of other anchors, it calculates the correction factor ci to look for the average hop size [10].

$$c_i = \frac{\sum \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}}{\sum h_{ij}}$$

Conclusion

As discussed above, we have studied some methods and techniques for localization used in Wireless Sensor Networks.

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