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Option: Intelligent Systems

Wireless Sensor Networks Localization using Trilateration, Bounding Box and Harmony Search

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Abstract

Information has been constantly changing since the birth of the Internet and communications. Therefore, the issue of wireless sensor networks attracting the attention of many scholars, WSN is one of the most important topics in the field of communication. Sensors and a collection of nodes make up wireless sensor networks, which can have a huge number of nodes. The purpose of WSN is to use sensors to locate these nodes, which is critical in the field of localization. There are numerous methods and strategies for detecting the location using localization algorithms, such as the most widely used global positioning system (GPS), which saves time. This thesis gives an overview of wireless sensor networks, their components, application areas, and so on, as well as three types of localization methodes: The method of Trilateration, the method of the bounding box, and the metaheuristic method of Harmony Search. The method of Triliteration gave us excellent results, unlike the bounding box whose results were average, and this made us think about developing it by combining it with the method of Harmony Search, and from it a new hybrid method, called BBAHS 1. The results were better than the Bounding Box, then we tried to fix the defects of BBAHS 1 and developed the BBAHS 2 method, which was good in its results and excellent in terms of localization.

Keywords: wireless sensor networks, localization, WSN, nodes, GPS, localization algorithms.

Résumé

L'information est en constante évolution depuis la naissance d'Internet et des communications. Par conséquent, la question des réseaux de capteurs sans fil attirant l'attention de nombreux chercheurs, WSN est l'un des sujets les plus importants dans le domaine de la communication. Des capteurs et un ensemble de nœuds constituent des réseaux de capteurs sans fil, qui peuvent avoir un grand nombre de nœuds. Le but de WSN est d'utiliser des capteurs pour localiser ces nœuds, ce qui est critique dans le domaine de la localisation. Il existe de nombreuses méthodes et stratégies pour détecter l'emplacement à l'aide d'algorithmes de localisation, tels que le système de positionnement global (GPS) le plus utilisé, ce qui permet de gagner du temps. Ce mémoire donne un aperçu des réseaux de capteurs sans fil, de leurs composants, des domaines d'application, etc., ainsi que de trois types de méthodes de localisation : la méthode de trilatération, la méthode de la boîte englobante et la méthode métaheuristique de recherche d'harmonie. La méthode de Triliteration nous a donné d'excellents résultats, contrairement à la boîte englobante dont les résultats étaient moyens, et cela nous a fait penser à la développer en la combinant avec la méthode de Harmony Search, et à partir de là une nouvelle méthode hybride, appelée BBAHS 1. Les résultats étaient meilleurs que la boîte englobante, puis nous avons essayé de corriger les défauts de BBAHS 1 et développé la méthode BBAHS 2, qui était bonne dans ses résultats et excellente en termes de localisation.

Mots clés : réseaux de capteurs sans fil, localisation, WSN, nœuds, GPS, algorithmes de localisation.

ملخص

لقد تغيرت المعلومات باستمرار منذ ولادة الإنترنت والاتصالات. لذلك فإن موضوع شبكات الاستشعار اللاسلكية يستحوذ على اهتمام الكثير من العلماء ، وتعتبر WSN من أهم الموضوعات في مجال الاتصالات. تشكل المستشعرات ومجموعة من العقد شبكات استشعار لاسلكية ، والتي يمكن أن تحتوي على عدد كبير من العقد. الغرض من WSN هو استخدام المستشعرات لتحديد موقع هذه العقد ، وهو أمر بالغ الأهمية في مجال التوطين. هناك العديد من الطرق والاستراتيجيات لاكتشاف الموقع باستخدام خوارزميات التعريب ، مثل نظام تحديد المواقع العالمي الأكثر استخدامًا (GPS) ، والذي يوفر الوقت. تقدم هذه الرسالة نظرة عامة على شبكات المستشعرات اللاسلكية ومكوناتها ومناطق التطبيق وما إلى ذلك ، بالإضافة إلى ثلاثة أنواع من طرق التعريب: طريقة التثليث ، وطريقة المربع المحيط ، والطريقة المتعالية للبحث المتناغم. أعطتنا طريقة المثلثية نتائج ممتازة ، على عكس المربع المحيط الذي كانت نتائجه متوسطة ، وهذا جعلنا نفكر في تطويره من خلال دمجه مع طريقة Harmony Search ، ومنه طريقة هجينة جديدة تسمى BBAHS 1. النتائج كانت أفضل من المربع المحيط ، ثم حاولنا إصلاح عيوب BBAHS 1 وطورنا طريقةBBAHS 2 ، والتي كانت جيدة في نتائجها وممتازة من حيث الترجمة.

الكلمات الرئيسية شبكات الاستشعار اللاسلكية ، الموقع ، العقد ، نظام تحديد المواقع العالمي ، خوارزميات الموقع

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First of all, we thank Almighty God for making this work happen, because without God nothing would happen.

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And special thanks to all our teachers during the school years.

Without forgetting, of course, to deeply thank all those who have contributed directly or indirectly to the realization of this work.

DEDICATION

I dedicate this work

To my dear parents who supported me to all my brothers and sisters

To all my family and all my friends

Elfatmi khadra.

DEDICATION

After much stress and hardship, my university adventure has come to a conclusion. And now I'm wrapping up my graduation thesis with zeal and effort.

On this beautiful day, I devote my delight and happiness to my mother and father, the source of my pride and pride, and those who have accompanied me since the beginning of my school career.

To my friends and all those who supported me and helped me in every way they could .Thank you to all of my good friends, family members, and brothers that stood by my side and backed me up. My dear brothers, thank you and your blessings.

Baarab Fadila

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Introduction

Since ancient times and to this day, science is constantly evolving, and research does not stop in order to solve the problems and difficulties faced by the human race and the pursuit of providing a simple and easy life, free from complications, and the realization of the idea of the world as one block. Many fields have witnessed rapid development, including the electronic field and the field The medical field, the military field and the field of communications, for example, in the past, direct contact between humans was the only method adopted, after which wired communications appeared, as this stage began in conjunction with the discovery of electrical energy, then the stage of wireless communications appeared in the late nineteenth century, which paved the way for the emergence of many inventions Including radio, television, computer, satellite, and the Internet.

In the twenty-first century, wireless sensor networks appeared, which is an important way to study and interact with the physical world, as it is used to follow a specific physical or chemical phenomenon, but in the past ten years, a lot of research has been done to improve it in various aspects, such as the mechanism for determining its location. From this we ask the following question: How are wireless sensor networks localized ?

One of the most important problems faced by the wireless sensor network is the problem of estimating the location of the sensor nodes when deployed. For sensors with very low power, the size, cost and environment preclude the use of GPS receivers on the sensors,

As for the approach that we followed in this research, it included both the scientific method represented in the use of functions and mathematical calculations, as well as the descriptive approach based on the analysis of the results.

Our main goal in this thesis was to reveal the best way to locate the nodes by introducing some algorithms, understanding their working mechanisms, and extracting a new, optimal, and inexpensive algorithm.

To achieve these goals, we divided the research according to the following plan: an introduction, three chapters and a conclusion.

In the first chapter entitled "Wireless Sensor Networks" it is divided into two parts, as I mentioned in the first element a simple explanation of the sensors, while in the second section I explained wireless sensor networks with all their components and elements, and in the second chapter I mentioned a set of techniques used in the localization of sensor networks Wireless and how it works with an explanation of how to determine it and how to program it, as for the third and final chapter, in which we conducted a series of experiments and lab simulations to gain a deeper knowledge of the different settlement methods and the pros and cons of each approach. In conclusion, we mentioned the most important results that we obtained in this research.

Chapter01

Wireless Sensors Network

1.1 Introduction

Thanks to the great interest that the field of communications and information processing has received, new technologies have appeared, such as *wireless sensor networks (WSNs)* and their applications, which have become open to many areas: military, security, transport, industrial, environmental, etc., where sensors control, drive, or monitor. We cannot compare it with a wired environment because this environment allows the user to easily access data.

In this chapter, we will provide some general information about wireless sensor communication systems.

1.2 Wireless Sensor

1.2.1 Sensor node

A small device, inexpensive ,with low energy, as it relies on other resources to collect its energy. Among the main tasks it performs is to collect and process information from the environment in which it is located, and it has the ability to communicate with other nodes [1].

1.2.2 Sensor node architecture

There are usually four main components in a sensor node : Sensor unit, processing unit, communication unit, power supply.

The sensor unit consists of sensors and analog to digital converters. The sensors are responsible for measuring the physical data of the system state such as temperature, humidity, pressure. The analog signals are converted to digital by *Analog-to-Digital Converters* (*ADCs*) and then It is transferred to the processing unit responsible for processing data, which in turn contains a microcontroller linked to a small storage unit. The sensors are connected to each other through the communication unit, where there is a transmitter and receiver that includes the functions of both the transmitter and the receiver. As for its power source, it is rechargeable or non-rechargeable batteries. This is all shown in Figure1 [1].

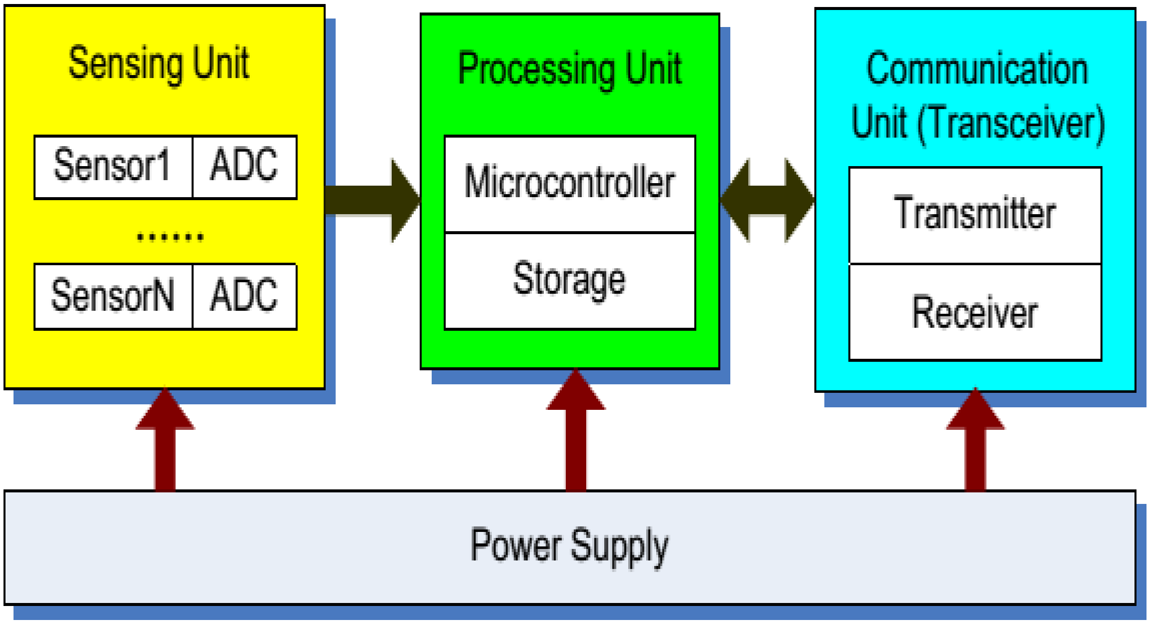


Figure 1.1: Sensor nodes architecture [1].

1.3 Wireless Sensor Networks

1.3.1 Definition of WSNs

It is a network of spatially distributed sensors connected wirelessly to cover a specific area. The key concepts of WSN are: ubiquity, wireless, mobility, smart spaces, distributed, etc. WSN is technology solutions for implementing low-cost, self-configuring networks [2].

1.3.2 WSN architecture

WSNs contain multiple components for the production and management of data and other components of a covered area network. As shown in Figure 1.2.

The components of a WSN are:

- **Gateway**

Which is as an interface between the application platform that runs on a base-station (e.g., PC) and sensor nodes in the WSNs

- **Relay Node**

  It is for extending the covered area in the same network

- **Leaf Node**

  which connects actuators and sensors ,and also called end-point device,

- **Sensor and Actuator**

  It is smart devices that measure and control environmental events [2].

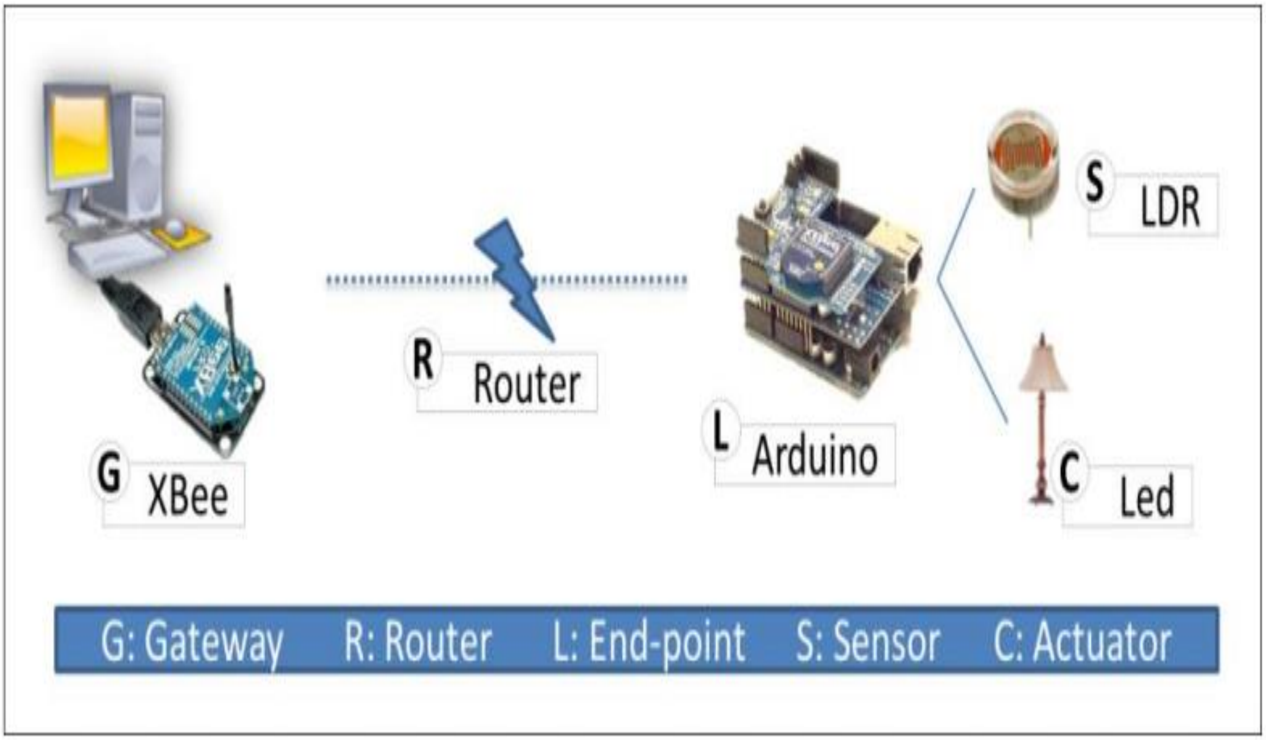


Figure 1.2: Components of WSN [2].

1.3.3 Different topologies in WSNs

Different Wireless sensor network topologies are:

1.3.3.1 Bus topology

Bus topology features one congestion of traffic and single path communication but is easy to install . However, bus networks work best with a limited number of nodes. In this topology, there is a node sends message to another node on the network sends a broadcast message onto the network that all other nodes see, but only the intended recipient actually accepts and processes the message [13].

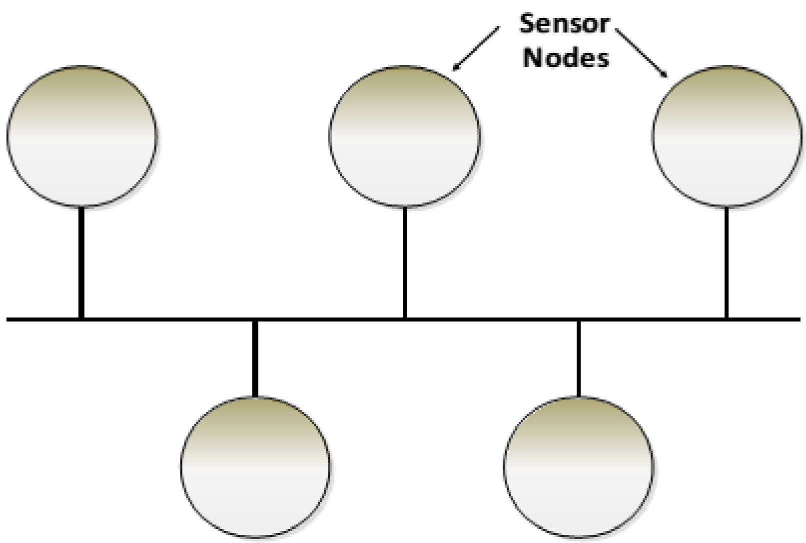


Figure 1.3: Bus topology [13].

1.3.3.2 Tree topology

The network uses the root node which is a central hub called as the main hub Connection vector A tree network can be considered as a combination of both star and peer-to-peer network topologies as shown in Figure 4. In the sensor the network path may be a single hop or multiple hop, to extract data from the environment and send it to the sink and the sensor redirects it to its father after receiving data messages from its children. It is important to find the best tree for the shortest path Maximum life and shortest delay [3].

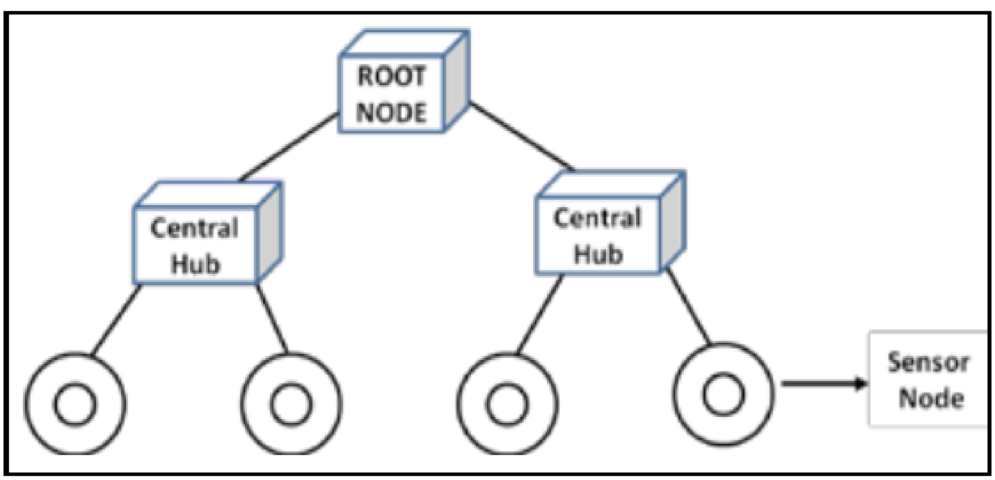


Figure 1.4: Tree topology [3].

1.3.3.3 Star topology

Are connected to a central communications hub The center of each node is a 'client' while the central axis is "Server" as shown in (Figure: 1.5) A failure in any pair of star network-hub node connection will only take down one node communication network access and not the entire network. However If the central node fails the entire network also fails and Nodes cannot communicate directly with each other [14].

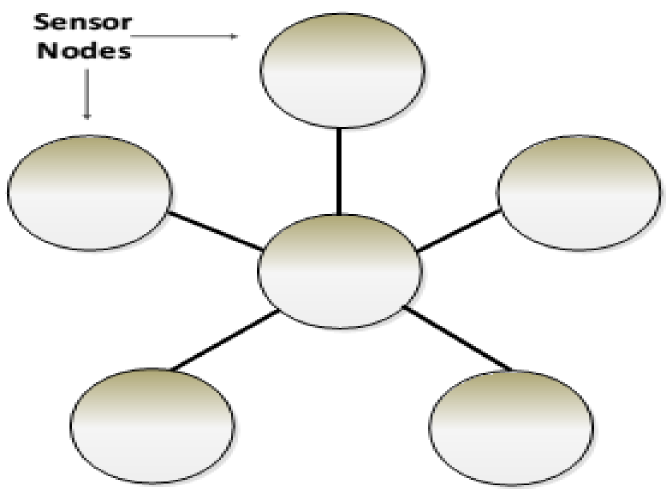


Figure 1.5: Star topology [3].

1.3.3.4 Ring topology

In a ring network, all messages are transmitted in the same direction (either “clockwise” or “counterclockwise”). Any defect in the node destroys the loop and can take down the entire network. [3]

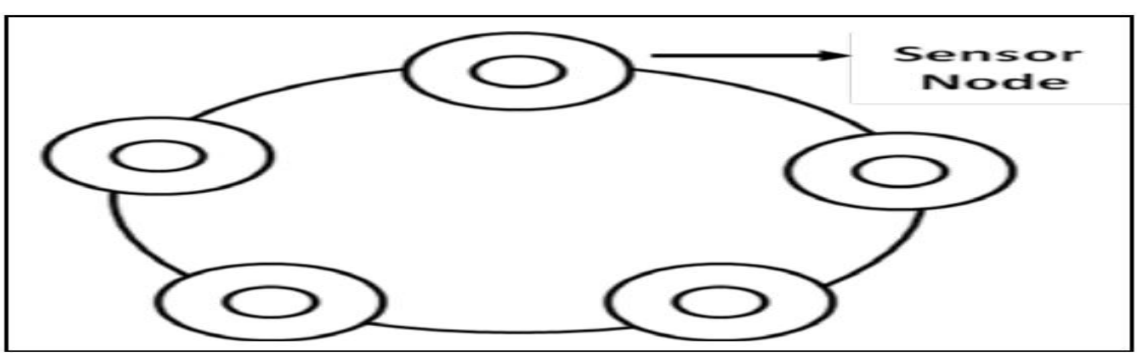


Figure 1.6: Ring topology [3].

1.3.3.5 Mesh topologies

In a mesh network , different paths are used to carry information from source to destination. A fully connected mesh network is a network in which every node is connected to every other node in the network, whereas in a partial mesh network, some nodes are indirectly connected to other nodes, meaning that there is a connection between all nodes connects [13].

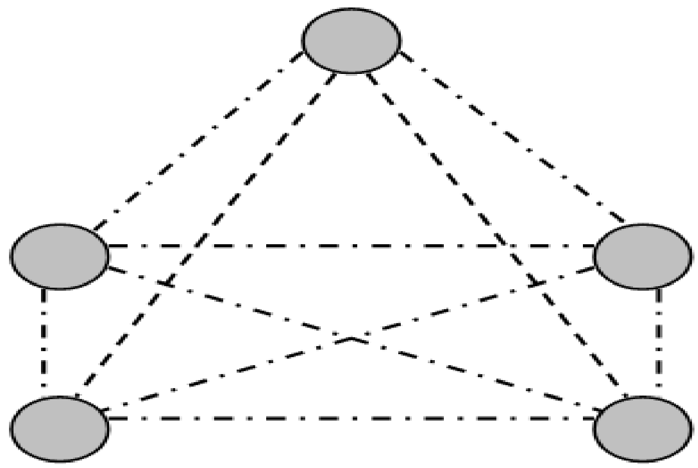


Figure 1.7: Mesh topologies [14].

1.3.3.6 Circular topology

In circular topology, there is a sink in circular sensing area and .The nodes are randomly deployed. Depending on the distance of a node from the sink and the transmission range of the nodes, data have to traverse single or multiple hops before being received by the sink as shown in (Figure1.8) [3].

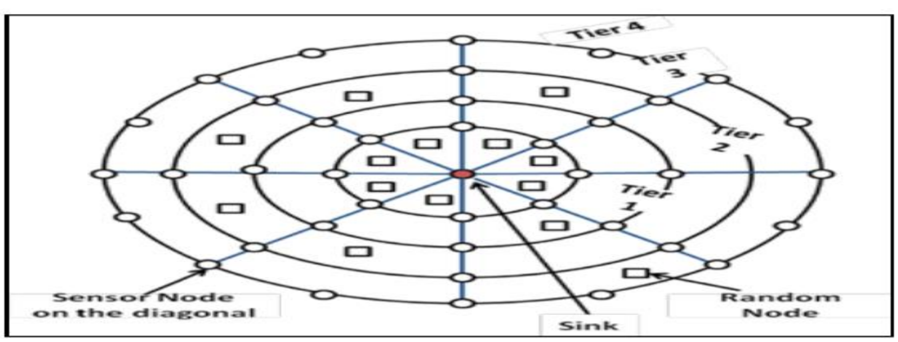


Figure 1.8: Circular topology [3].

1.3.4 Types of WSN

Five functional types: terrestrial, underground, underwater, multimedia and mobile WSNs. In the following, we will explain each type briefly and accurately:

1.3.4.1 WSN terrestrial networks

There are two ways to deploy sensor nodes on WSNs:

➢ In an unstructured WSN, a dense set of sensor nodes can be deployed , but once deployed their performance cannot be monitored. In this network, maintenance and troubleshooting is difficult because there are many nodes.

➢ In a structured WSN, it is planned in advance to deploy all or some of the sensor nodes. The advantage of an organized network is that fewer nodes can be advantageously deployed as they are placed in specific locations to provide coverage. Extensive deployment of hundreds or thousands of sensor nodes in an area requires structure maintenance in three stages:

a. Pre-publication and publication stage. Sensor nodes may be thrown into the field of deployment by placing them one by one by a robot, a human, or as a block from an aircraft.

b. Post-publication. After deployment, the architecture changes due to change in sensor nodes position, accessibility, residual strength, failures, and mission details.

c. Republish additional nodes. Additional sensor nodes can be redeployed to to replace broken nodes.

In a terrestrial WSN. Sensor nodes must deliver excellent and efficient data to the kernel. Although it is difficult to recharge the battery of sensor nodes, ground sensor nodes can be supplied with a secondary power source such as solar cells, and they can also reduce power consumption through routing eliminating data redundancy, reducing delays, short transmission range, and data aggregation within the network [7].

1.3.4.2 WSN underground

Underground WSNs used a number of sensor nodes that are used to monitor underground. Underground WSNs, which are costly in terms of maintenance, equipment and deployment, need above ground nodes in order to help them transmit information from the sensor nodes to the base. Energy is a challenge and an important concern in the ground, where once the sensor nodes are deployed underground, it becomes difficult to recharge or replace their battery, and in order to increase the life of the network, energy must be conserved by implementing an effective communication protocol [9].

1.3.4.3 Underwater Acoustic Sensor Networks (UASNs)

Thanks to the technology of UASNs, science has been able to understand environmental issues, such as the life of ocean animals. In addition, UASNs can enhance the underwater capabilities of navies as they can be used for surveillance and detection of submarines. In addition, it can help monitor oil rigs and report disasters for preventive action. Underwater acoustic sensor networks can provide early warning of earthquakes and tsunamis [11].

However, there are many challenges including [11]:

- The bandwidth of the voice channel is low, and from it we get low data rates compared to the data of terrestrial WSN networks. The solution is to add more sensor nodes
- Underwater WSNs involve very expensive sensor nodes.
- Large propagation delay due to the slow speed of sound (about 1500 m/s).
- The main problem is always the limited battery and the energy conservation issue.

1.3.4.4 Multimedia WSNs

WSN multimedia networks consist of a set of low-cost sensor nodes equipped with cameras and microphones that are connected to each other via a wireless connection. And the sound. However, she faced some challenges:

- High demand for bandwidth.
- High energy consumption.
- Providing Quality of Service (QoS).
- Data processing and compression techniques.
- Multi-layered design.

1.3.4.5 WSN Mobile Networks

Mobile WSNs are distinguished from other networks in that they can interact with the physical environment, and they have the ability to reorganize themselves in the network where they do some initial dissemination and nodes can then spread out to gather information and this information is communicated about the collected by A mobile node to another one when they are in each other's range.

The mobility characterized by these networks was useful for several reasons, including:

➢ Cost: In this type of network, fewer nodes are deployed compared to other networks; but on the other hand, the mobility feature may be expensive. Cars and attach sensors to them.

➢ Reliability: Fixed networks often use multi-hops as a model for communication between their nodes, and from it some interferences and collisions may occur when using it. For this reason, reliability is more vulnerable and the message loss rate is greater the greater the number of hops.

However, as there are advantages, there are challenges presented by mobility in WSN networks such as:

➢ Contact detection. Since communication is only possible when nodes are within transmission range of each other, it is necessary to correctly and effectively detect the presence of a mobile node.

➢ Perceived energy management for mobility. If visit times are known or can be predicted with certain accuracy, the sensor nodes can only be awake when they expect the moving object to be within their transmitting range.

➢ Navigation control. The path, speed or waiting time of the nodes must be specified in order to improve network performance [7].

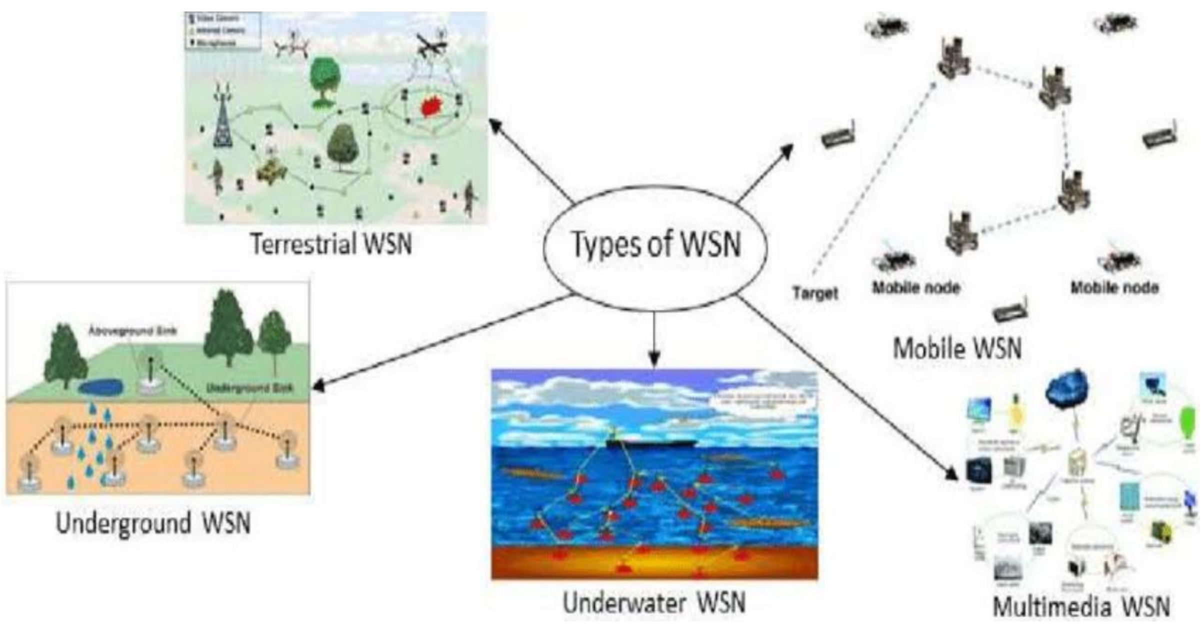


Figure 1.9: Types of WSN.

1.3.5 Characteristics of WSN

Here we have mentioned some of the characteristics of WSN:

1.3.5.1 Auto-configuration of sensor nodes

A wireless sensor network can be deployed in two different ways, either randomly using an aircraft or drones, or in a well-defined way by a human. So a sensor must have the ability to self-configure in a sensor network but also to be able to collaborate with other nodes in the network [5].

1.3.5.2 Quality of service (QoS)

In conventional computer networks, QoS means the ability of the communication system to guarantee the performance required by the application, i.e. in terms of end-to-end transmission delay, loss rate and throughput. However, QoS metrics are dependent on the adopted application due to different characteristics specific to each type of data used. With regard to WSNs, QoS is the quantity and quality of information which are extracted by the data collected on the environment where the sensors have been deployed and most importantly of all this ,data should be delivered within specific time period [10].

1.3.5.3 Communication ability

There are two ways to proceed to transmit data from a source node to a destination node We can use a transmission of long range therefore with a single hop in order to transmit data to the collection point or we have the possibility of using the multi-hop which allows to transmit to nodes neighbors and so on to the collection point. This corresponds best in view of its energy consumption [5].

1.3.5.4 Types of communication

There are different types of connections used in WSN [12]:

a. Uncast

This type of communication is used to exchange information between two nodes on the network.

b. Broadcast

The base station transmits some information to all sensor nodes of the network

c. Local gossip

This type of communication is used by nodes in the area where a sensor sends a message to its neighboring nodes within a range

d. Converge cast

Used for communications between a group of sensors and a very specific node.

e. Multicast

Allows communication between a node and a group of nodes.

1.3.5.5 Scalability and collaboration between sensors

The particularity of the wireless sensor network is that it is able to take into account and manage a very large number of nodes cooperating for the same objective. Unlike traditional wireless networks (personal, local, extended). Moreover, the collaboration of the nodes is very important in the WSN for example to avoid the treatment and redundant data transmission across the network. This kind of treatment is necessary in order to avoid a significant loss of energy and time in the context of an optimization of energy consumption throughout the network [5].

1.3.5.6 Life time of WSN

In general, the sensor nodes can be in the working (or on) or sleep (or off) state. Sleep consumes less energy. Of course, keeping the node in working condition is simplest scheduling to hold sensors if they have enough power or power offer at any time. All sensor nodes follow predefined rules for decision making in the working stage. At the end of the formation stage, nodes that If they are not elected to work, they will stop and remain asleep until the end of the round. This mechanism helps in balancing the energy consumption between the nodes to prolong Network lifetime. But it requires time synchronization of all sensor nodes [4].

1.3.6 Application domain of WSN

WSNs are varied; they are used depending on the requirements of the application and usually include some form of monitoring, tracking or control [6]:

Table 1.1: Applications of WSN [8].

Area	Applications	Requirements
Home	Home automation Gaming Entertainment	o Little to medium scalability o Indoor performance o Static nodes o No security
Environment	Physical world surveillance Emergency situation surveillance	o High scalability o Outdoor performance o High energy efficiency o Long lifetime
Military	Recognition mission Intrusion detection Criminal hunting Tracking	o High scalability o Outdoor performance o High energy efficiency o Long lifetime o High security
Automotive	For traffic decongestion For driving safety For avoiding accident areas	o High scalability o Outdoor performance o High security o High energy efficiency o Guaranteed delivery
Commerce	Conferences Meetings Extension of cellular networks	o Low scalability o Indoor performance o Long lifetime o Good speed in message

1.3.7 Functional challenges of forming WSNs

- The design and implementation of WSNs are constrained by three resources, processing, energy, and memory [7].
- Harsh environmental conditions may cause part of industrial sensor nodes to destroy such as corrosive environments, high humidity levels, vibrations, dirt . Furthermore may Sensors are exposed to radiofrequency interference [7].
- QoS requirements. A variety of applications envisaged on WSNs will have requirements. between the data reported that come from the control center is different. because the QoS provided by WSNs is different [15].
- Variable link capacity. The attainable delay in each link depends on the location and varies constantly, making the provision of quality of service a challenging task.
- Security. When creating WSNs, the designers focus on making Safety the first goal and the primary design feature to make the connection secure against outside intrusion.
- Integration with the Internet and other networks WSNs must be remotely accessible from the Internet to retrieve useful information from anywhere at any time [7].
- Sensor energy is a limited resource for data transmission.
- Localization: nodes are randomly deployed and difficult to locate and manage without infrastructure support. The localization problem involves knowing the actual location of the deployed nodes. [15].

1.4 Conclusion

In this chapter we have seen wireless networks in general and WSNs in more detail, and we have introduced wireless sensors with their characteristics and architecture. Then we studied WSNs from their structure, characteristics, classification and the difficulties they face in the environment and its fields.

In the next chapter, we will talk in more depth about WSNs and specifically the ways to localize them.

Chapter02

Localization technique for wireless sensors network

2.1Introduction

Thanks to the recent developments in sensors and wireless communication technology, low-cost and energy-efficient sensors have been developed with the aim of creating a wireless sensor network that has the ability to communicate with each other and perform some tasks such as sensing the ocean, monitoring natural phenomena, knowing the weather, and detecting forest fires.

Sensor nodes are randomly deployed in different areas and at different distances in order to know the location of the nodes in the wireless sensor network. So that their coordinates are estimated by several algorithms (Harmony search method, *Bounding* Box and Trilateration).

In this chapter, we will provide an overview of the different techniques that can be used on wireless Sensor Network WSN in order to detect location.

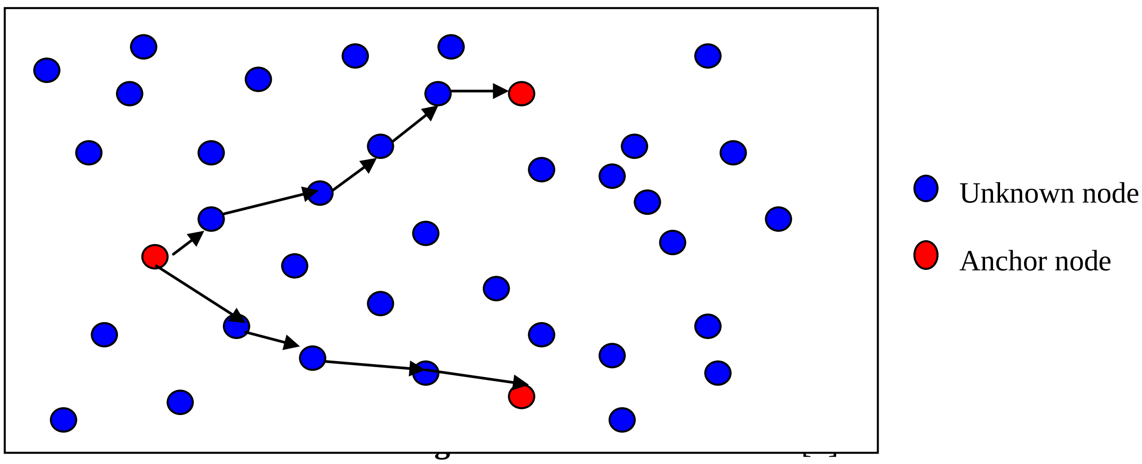


Figure 2.2: wireless Sensor Network [17].

2.2Localization Process

The purpose of localization is to know the location of nodes in the presence of the sensor according to the input data (contact information for range-free techniques, and distance or angle between the nodes for range-based techniques , the distance between the nodes). the localization process is shown in **Figure 2.3**.The flowchart of a localization process is shown in **Figure 2.4**. [18]

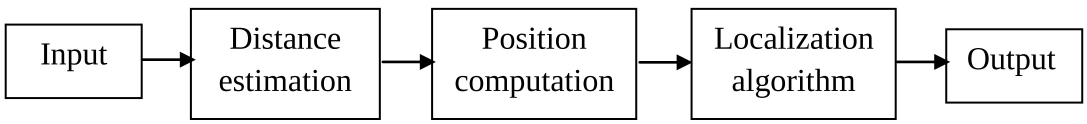


Figure 2.3: Overview of Localization Process [17]

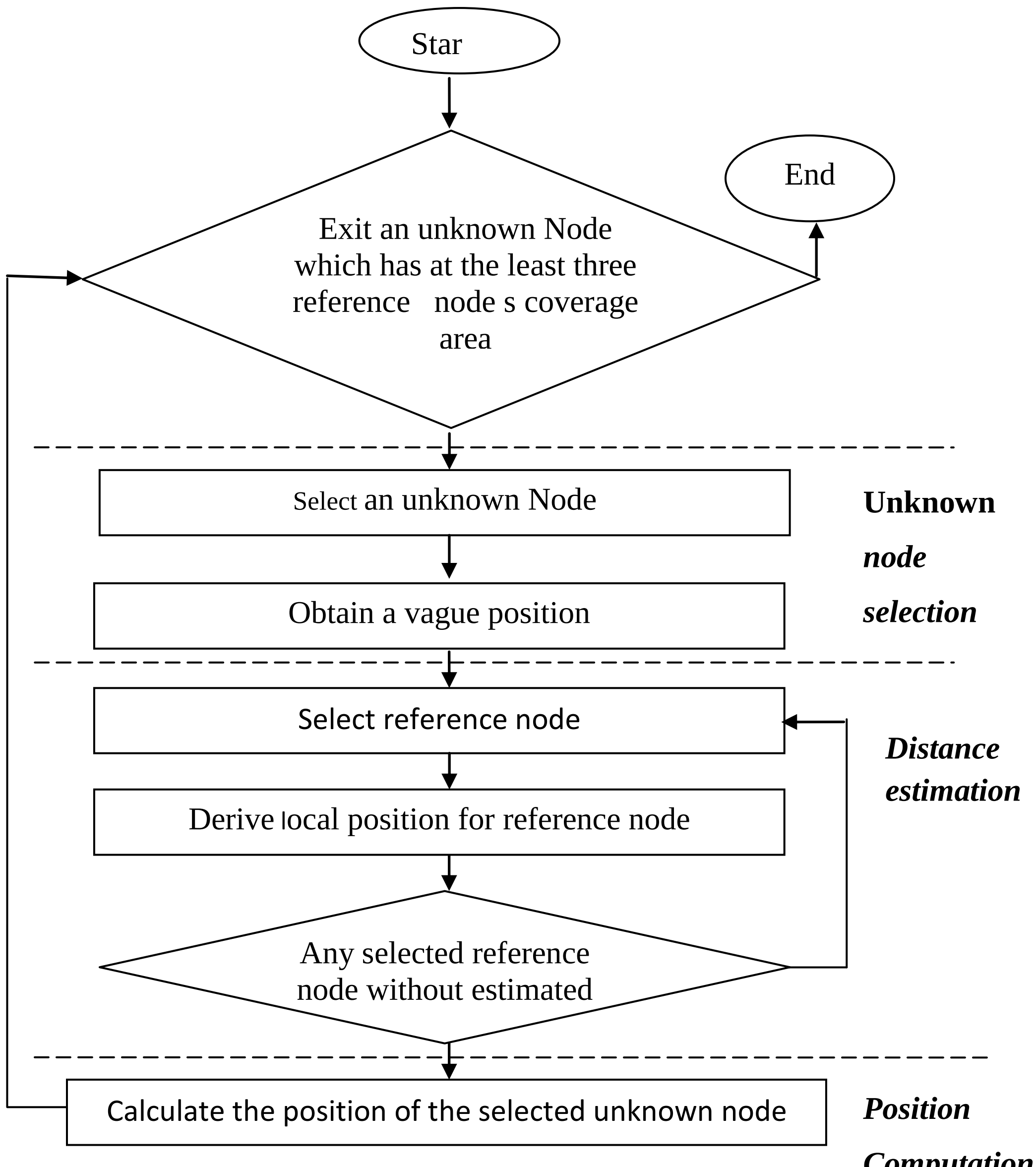


Figure 2.4: Flowchart of localization process [17].

2.3Localization Systems

There are numerous positioning systems available; we will discuss two of them:

2.3.1 The global positioning system (GPS) [19]

The *GPS (Global Positioning System)* is a satellite navigation system that consists of 24 operational satellites orbiting the planet. Every day, each satellite circles the globe at a height of 20.200 kilometers and completes two complete rotations.

A GPS receiver may receive information from the satellites on a continuous basis, estimate its distance from at least four known satellites using ToA, and then compute its location using trilateration. Following the completion of these steps, the receiver is able to provide information about its latitude, longitude, and altitude

Equipping each of the sensor nodes with a GPS receiver is one of the answers to the WSN's localization problem. Because all nodes would have a comparable mistake, one of the key advantages would be the relatively small (2–15 m, depending on the receiver) and precise localization error.

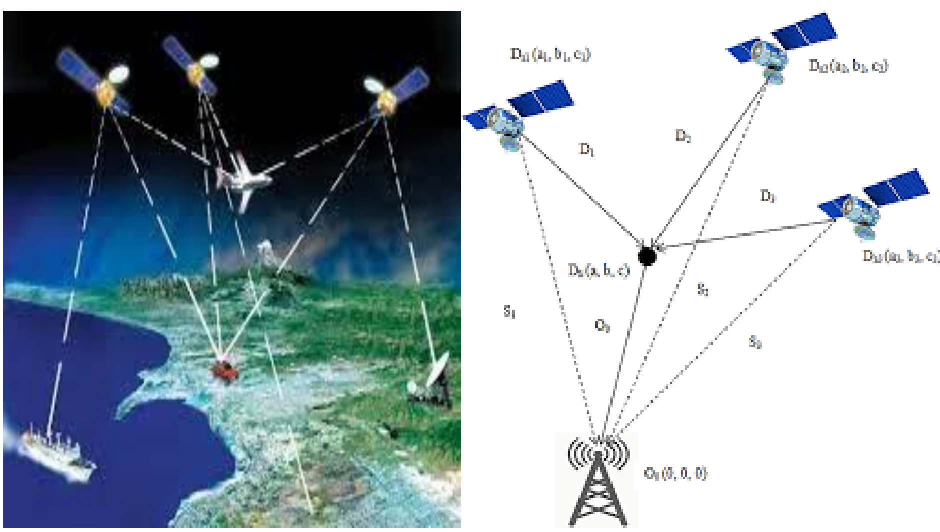


Figure 2.5: GPS system

2.3.2 GNSS system [20]

The *Global Navigation Satellite System (GNSS)* is a system that relies on the continuous transmission of signals from a constellation of satellites to GNSS users, who are usually positioned near the Earth's surface. As a result, the system is a one-way system in which GNSS users do not transmit any data to the satellites. The process of resolving a system based on knowledge of the location of visible satellites and the distance between the user receiver antenna and these satellites is known as GNSS user localization. Figure 2-1 depicts a (simplified) representation of the GNSS positioning principle.

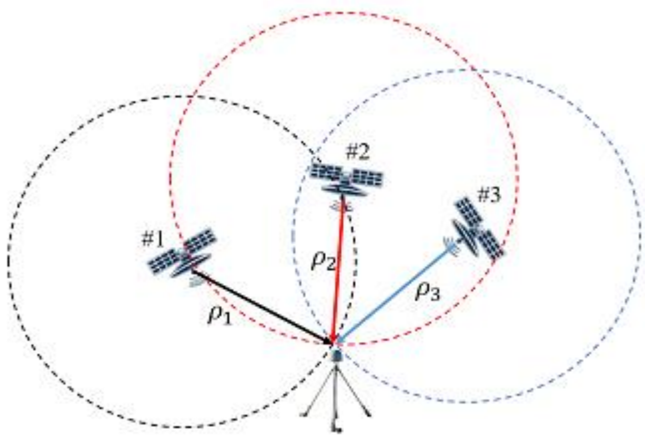


Figure 2.6: GNSS Positioning with Sphere Intersection [21]

2.4 Components of location systems **[**22]

Location systems consist of three basic components:

2.4.1 Distance estimation/angle

Distance estimation/angle calculates the distance or angle between two nodes because they are employed by both the position computation and the localization method. Such estimation is an important part of the localization systems. There are a number of algorithms that use this strategy, like:

- A signal-based method like the Received signal strength indicator (RSSI)
- Time-based methods like the Time of Arrival (ToA)
- Methods based on angles, such as Angle of Arrivals (AoA).

2.4.2 Position computation

The position computation calculates the location of nodes based on the available information about the distance. . There are a number of algorithms that use this strategy, like:

- Trilateration
- Multilateration
- Trilateratoin

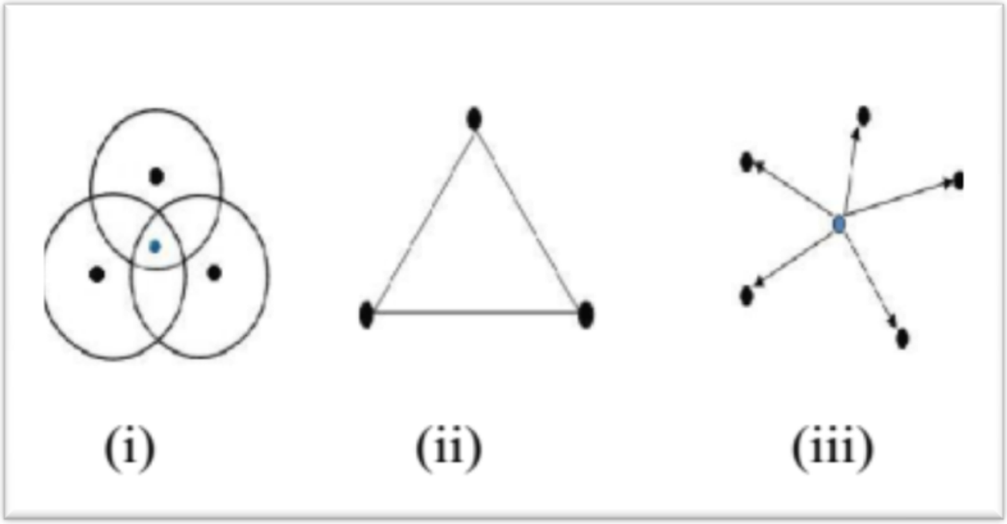


Figure 2.7: Distance combining methods (i) Trilateration (ii) Trilateratoin (iii) Multilateration [23]

2.4.3 Localization algorithm

Localization algorithms are the most important components because they determine how the given information is processed in order to find the location of all nodes in the wireless sensor network.

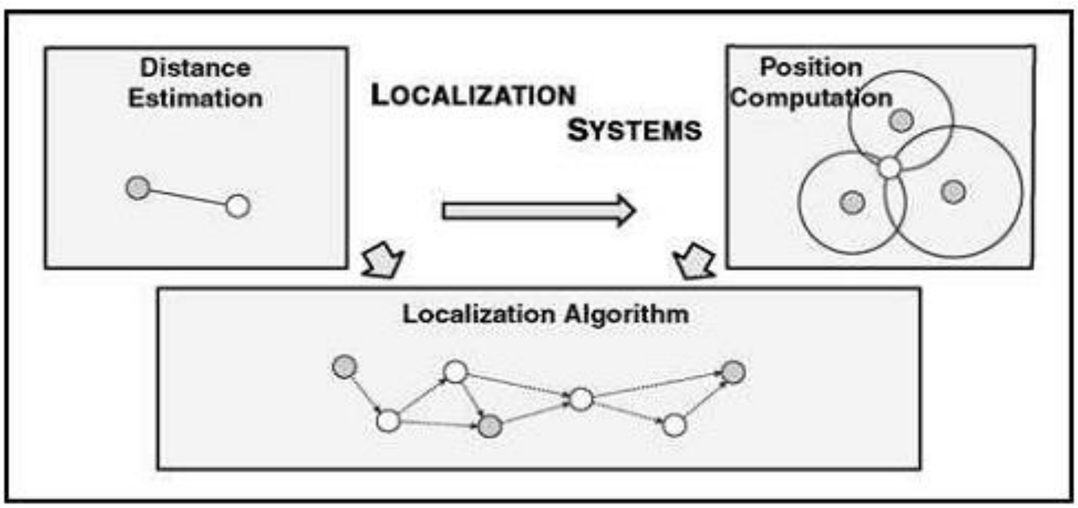


Figure 2.8: Components of location systems [24]

2.5Classification of Localization Techniques [25]

Sealing techniques are classified into two main sections, and this classification is done according to the algorithm chosen in determining the location of nodes: central and decentralization techniques, or distributed. The following format illustrates this classification:

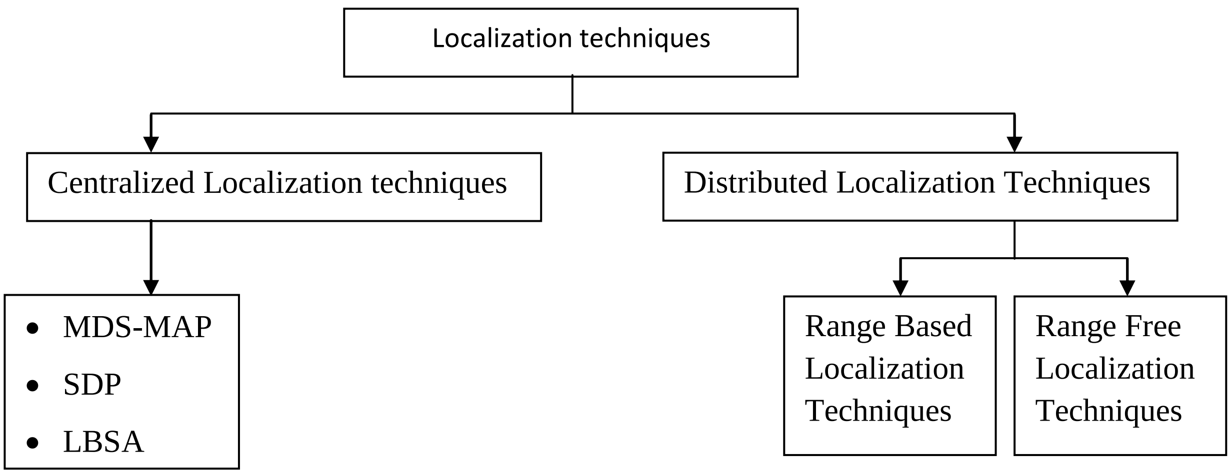


Figure 2.9: Taxonomy of localization techniques [17].

2.5.1 Centralized localization techniques

The importance of this technique is to get rid of the problem of the account in each node so that all measurements are collected at a centralized *base station (BS)* and results are forwarded to all the contracts (due to global information between these algorithms being more accurate than other triggers). But this technique's defects have been in the inability to access the data in an appropriate way as well as its being used only in small-sized networks. The centralized localization algorithms are: *Multi Dimensional Scaling-Mobile Assisted Programming (MDS-MAP)*, *Semi Definite Programming (SDP)*, and *Simulated Annealing based Localization (LBSA)* [20].

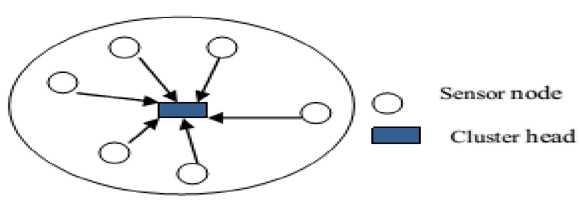


Figure 2.10: Centralized architecture [26]

2.5.2 Distributed localization technique

sensor nodes perform the required computation t and communicate with each other to get their own location in network this technique is divided into two types: range free localization technique and range based localization Techniques [26].

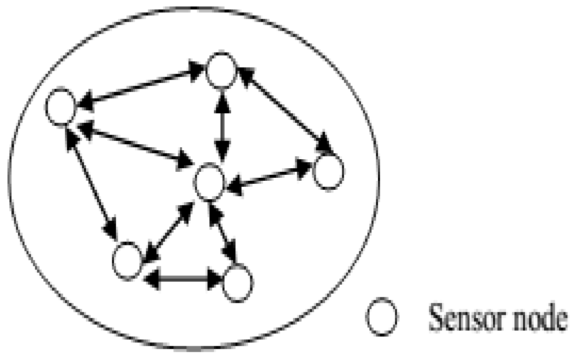


Figure 2.11: Distributed architecture [26]

Table 2.1: comparison between centralized and distributed localization techniques [29].

	centralized	**Distributed**
Cost	More	Less
Power Consumption	More	Less
Accuracy	70-75%	75-90%
Dependency on additional hardware	No	Yes
Deploy ability	Hard	Easy

- **Range based localization techniques**

This technique is based on calculating the angle or the distance between the transmitters and receiving nodes in order to locate the nodes by using geometrical principles like the Trilateration algorithm, Bounding Box algorithm, and Multitrilateration [27].

- **Range free localization techniques**

Rang free algorithms do not need to measure distance or angle information between the unknown nodes for example the DV_Hop, Multi_Hop, and APIT algorithms [28].

Table 2.2: comparison between range-based and range-free localization techniques [29].

Techniques	range based	range free
Cost	More	Less
Power Consumption	More	Less
Accuracy	85-90%	70-75%
Dependency on additional hardware	No	Yes
Deploy ability	Hard	Easy

2.6 Algorithms Used In This Research

We used two algorithms for range-based localization techniques represented by the Trilateration algorithm and Boding box algorithms. We also used a genetic algorithm represented by the Harmony search method. We will explain them below.

2.6.1 Trilateration [24]

Trilateration is the basic method for calculating the location of a particular node when that node is randomly placed somewhere. This method calculates the position by the intersection of three circles, so that the center and radius of these circles are known as shown in Figure 1.These coordinates are either recorded in advance or obtained using an external device such as a GPS.

Equations of circles with diameters d1, d2, and d3 centered at feature locations respectively as follows:

$$(\hat{x}-x_1)^2+(\hat{y}-y_1)^2=d_1^2 \Leftrightarrow \hat{x}^2+\hat{y}^2-2(\hat{x}x_1-\hat{y}y_1)^2+x_1^2+y_1^2-d_1^2=0 \quad (1)$$

$$(\hat{x}-x_2)^2+(\hat{y}-y_2)^2=d_2^2 \Leftrightarrow \hat{x}^2+\hat{y}^2-2(\hat{x}x_2-\hat{y}y_2)^2+x_2^2+y_2^2-d_2^2=0 \quad (2)$$

$$(\hat{x}-x_3)^2+(\hat{y}-y_3)^2=d_3^2 \Leftrightarrow \hat{x}^2+\hat{y}^2-2(\hat{x}x_3-\hat{y}y_3)^2+x_3^2+y_3^2-d_3^2=0 \quad (3)$$

$(\hat{x},\hat{y})$: the position of the node to be located.

(xi, yi)**:** The location of the node whose location is known.

di : The distance between the node whose location is to be determined and the node whose location is known.

By subtracting equation (3) from the first two equations we obtain:

$$\hat{x}(x_3-x_1)+\hat{y}(y_3-y_1)=\frac{1}{2}(x_3^2-x_1^2+y_3^2-y_1^2+d_1^2-d_3^2) \quad (4)$$

$$\hat{x}(x_3-x_2)+\hat{y}(y_3-y_2)=\frac{1}{2}(x_3^2-x_2^2+y_3^2-y_2^2+d_2^2-d_3^2) \quad (5)$$

The system can be defined by the system of equation (6):

$$\left.\begin{array}{l}(\hat{x}-x_1)^2+(\hat{y}-y_1)^2=d_1^2-\varepsilon \\ (\hat{x}-x_n)^2+(\hat{y}-y_n)^2=d_n^2-\varepsilon\end{array}\right\} \quad (6)$$

ε **:** is a random variable that follows the normal distribution and has a mean zero.

This system can be made linear by subtracting the last equation from the other equation of (1) to (n-1).The linear system is given by equation (7):

$$\begin{bmatrix}(x_n-x_1)(y_n-y_1)\\ \vdots \\ (x_n-x_1)(y_n-y_{n-1})\end{bmatrix}\begin{bmatrix}\hat{x}\\ \hat{y}\end{bmatrix}\approx\begin{bmatrix}x_n^2-x_1^2+y_n^2-y_1^2+d_1^2-d_n^2\\ \vdots \\ x_n^2-x_{n-1}^2+y_n^2-y_{n-1}^2+d_{n-1}^2-d_n^2\end{bmatrix} \quad (7)$$

This system can be solved with a standard method such as the minimization of the sum of quadratic errors, whose optimal solution is given by formula (8):

$$x=(A^TA)^{-1}(A^Tb) \quad (8)$$

A^T : is the transpose of matrix A and M^{-1} :is the inverse matrix of the matrix M.

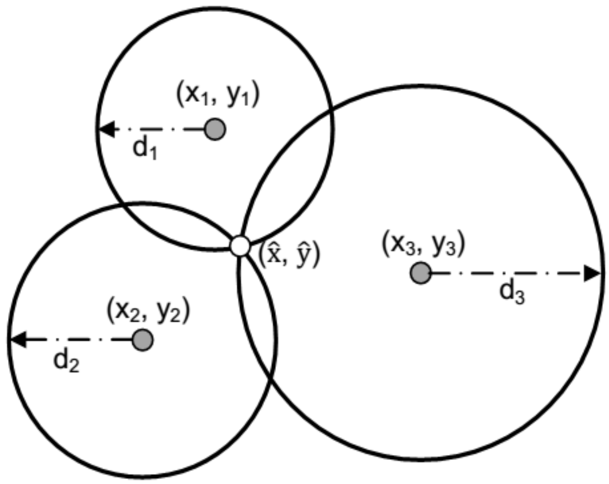


Figure 2.12: Principle of Trilateration [24].

- **Advantage and disadvantage of trilateration** [30]

Advantage

- Calculation complexity is modest, and an increased number of anchors is used (Improve the accuracy)

Disadvantage

- Especially sensitive to distance discrepancies.
- The number of anchors can only be limited (At least three anchors are necessary).

2.6.2 Boding box [19]

Instead of circles, the bounding box method use squares. Make a list of possible node locations. The bounding box (or rectangle) for each parameter I is specified as a square centered at anchors$p_i = (x_i, y_i)$, with a side length of d_i (d_i being the predicted distance to a node that has not yet been located) cross.

All bounding boxes indicate where the node could be located. Is it possible to calculate this intersection by taking the maximum of the lower coordinates and the minimum of the upper coordinates?

$$\begin{cases}(max(xi - di), max(yi - di)) \\ (min(xi + di), min(yi + di))\end{cases}$$

The final position of the node is the center of the resulting rectangle, and it is calculated as follows:

$$(\hat{x}, \hat{y}) = \left(\frac{max(xi - di) + min(xi + di)}{2}, \frac{max(yi - di) + min(yi + di)}{2}\right)$$

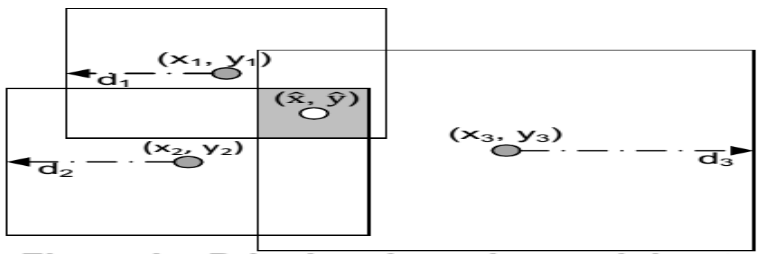


Figure 2.13: Principle of bounding box [19]

- **Advantage and disadvantage of bounding box [30]**

Advantage

- A low complexity of calculation

Disadvantage

- Error of the final position.

2.6.3 *Harmony search method*

HS is a metaheuristic optimization algorithm [31] based on the imitation of musical instrument improvisation. Each musician (= variable is a possible solution) takes (= generates) a note (= value) to determine the best sound that achieves a certain harmony (= global optimum) during music improvisation. The main goal of composing a musical piece or performance is to achieve harmony, in which the individual sounds are perceived as a whole [31].The steps of the HS algorithm are :

Step 1: entry the parameters. The parameters include the *Harmony Memory Consideration Rate (HMCR), Harmony Memory Size (HMS),* and *bandwidth (BW) , Pitch Adjustment Rate (PAR)* [33].

HMS: Harmony memory size.

HMCR: Probability of randomly selecting a harmony from the HM.

PAR: Probability of fine-tuning randomly selecting a harmony.

BW: Fine-tuning range

Step 2: Initialize the HM [30].

$$HM=\begin{bmatrix} x_1^1 & \cdots & x_j^1 & \cdots & x_{N-1}^1 & x_N^1 \\ x_1^2 & \cdots & x_j^2 & \cdots & x_{N-1}^2 & x_N^2 \\ \cdots & \vdots & \cdots & \cdots & \vdots & \cdots \\ x_1^{HMS-1} & \cdots & \cdots & \cdots & \cdots & x_N^{HMS-1} \\ x_1^{HMS} & \cdots & \cdots & \cdots & \cdots & x_N^{HMS} \end{bmatrix}$$ ……………….……………… Equation (1)

Step 3: A new solution was improvised. In this step, a new candidate solution is produced utilizing three operators, specifically harmony-memory consideration, pitch adjustment, and random selection, as shown in Equation (2) [30].

$$X_i = (x_{i,1}, x_{i,2}, \dots, x_{i,j}, \dots, x_{i,t})$$ ……………………………… Equation (2)

As shown in Equation (3), the HS calculation generates a new, previously unused solution, improving the optimal solution in the HM by improvisation [30].

$$x_{new,j} = \begin{cases} x_{new,j} & if\ rand < HMCR \\ x_{new,j} & otherwise \end{cases}$$ ……………………..………. Equation (3)

Step 4: Make a change to the HM. The fitness function is used to evaluate the final solution. If the fitness function esteem of the new solution is higher than that of the worst solution in the HM, the worst solution will be substituted by the new solution [33].

Step 5: Examine the conditions of termination. Repeat Steps 3–5 if necessary; otherwise, the algorithm finishes [32].

- **Advantage and disadvantage of harmony search method [31]**

Advantage

- Combining HA with other algorithms is strongly satisfying.
- An elevated method of getting surprising answers.

- Appropriate for many forms of optimization problems.

Disadvantage

- The primary HSA has been proposed for discrete, single-objective, and multi objective problems.
- Suffers from premature convergence.
- Possibility distribution changes with the needs of generations.

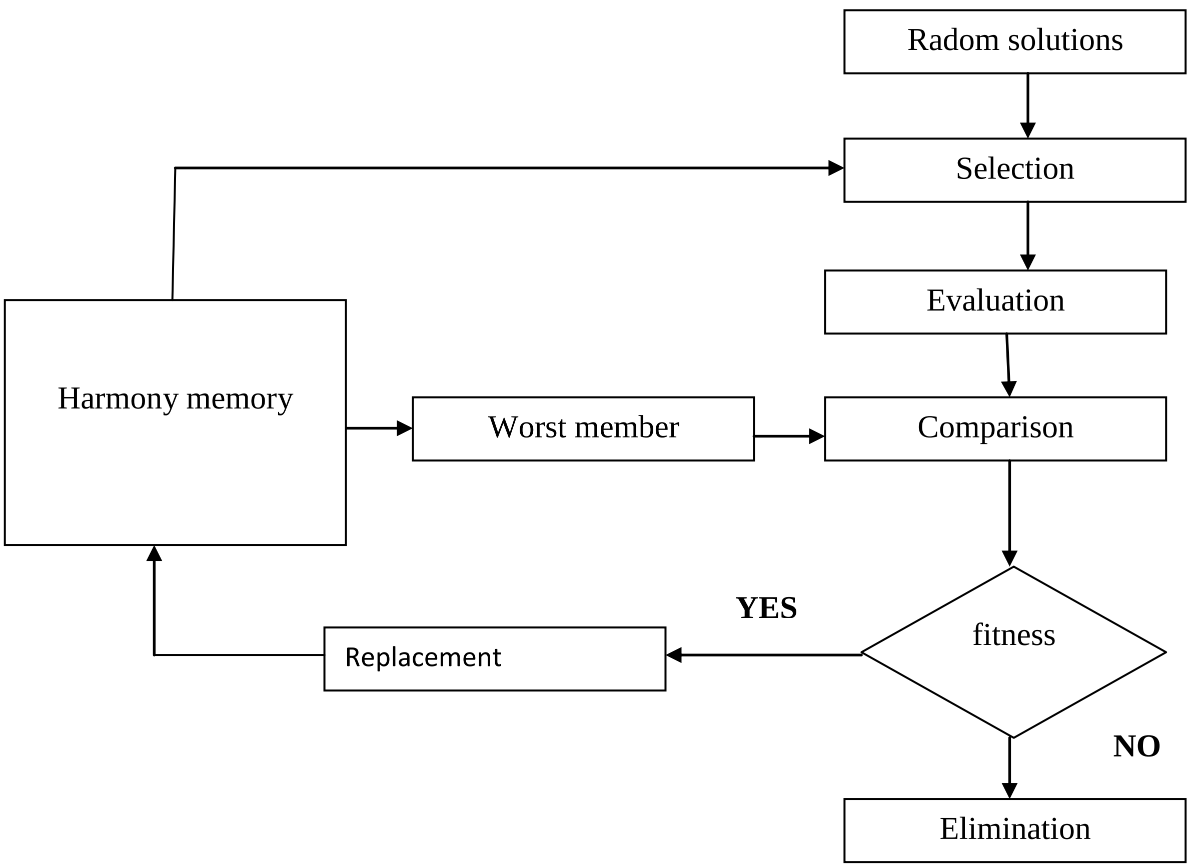


Figure 2.14: Harmony Search (HS) method. [32]

- **Harmony search method in localization**

Harmony search (HS) is a meta-heuristic search algorithm which tries to mimic the improvisation process of musicians in finding a pleasing harmony, used in optimization problems. We'll discuss how we used Harmony Search to find the contract in the section below.

We have:

$$\begin{cases} \hat{x} = \hat{x}_1, \hat{x}_2, \dots \dots \dots , \hat{x}_i, \dots \dots \dots, \hat{x}_N \\ \hat{y} = \hat{y}_1, \hat{y}_2, \dots \dots \dots , \hat{y}_i, \dots \dots \dots, \hat{y}_N \end{cases}$$

$(\hat{x}, \hat{y})$: The position of the node to be located.

We want to search the position of nodes using HS

The steps of the HS algorithm in localization are :

Step 1*:* entry the parameters. The parameters include the number of nodes N and number of iteration N_itr

Step 2*:* Initialize the random HM (nodes)

$$HM=\begin{cases} x = x_1, x_2, \dots \dots \dots , x_i, \dots \dots \dots, x_N \\ y = y_1, y_2, \dots \dots \dots , y_i, \dots \dots \dots, y_N \end{cases}$$

(x, y)**:** The location of the node whose location is known.

Step 3*:* A new solution was improvised. In this step

$$\begin{cases} x\_r = x\_r_1, x\_r_2, \dots \dots \dots , x\_r_i, \dots \dots \dots, x\_r_N \\ y\_r = y_{\_r1}, y\_r_2, \dots \dots \dots , y\_r_i, \dots \dots \dots, y\_r_N \end{cases}$$

$$x = \begin{cases} x\_r_i & if \ D\_new < D\_precedent \\ x\_r_i & otherwise \end{cases} y = \begin{cases} y\_r_i & if \ D\_new < D\_precedent \\ y\_r_i & otherwise \end{cases}$$

(x_r, y_r)**:** Random nodes

D_new : The distance between the node whose location is to be determined and the random nodes.

$D\_precedent$: The distance between the node whose location is to be determined and the random nodes.

Step 4*:* Make a change to the HM. The fitness function is used to evaluate the final solution. If the fitness function esteem of the new solution is higher than that of the worst solution in the HM, the worst solution will be substituted by the new solution.

Step 5*:* Examine the conditions of termination. Repeat Steps 3–5 if necessary; otherwise, the algorithm finishes.

2.6.4 BBAHS methods:

- An abbreviation for **B**ound **B**ox **A**nd **H**armony **S**earch .
- It's a hybrid between two algorithms :

1.Bounding Box

2.Harmony Search

We first need to determine the field of research for each node in order to reduce the error rate and we determine this by using the bounding box method, where the distance between each node and the existing anchors is calculated and the locations of the anchors are extracted whose distance is less than the value of the specified diameter, from which we extract the largest and smallest value and by means of the relationship 1 we calculate the initial positions of the points, and from In order to reduce the field, we subtract the value of the diameter from the maximum, and add the value of the diameter with the minimum, and so we get in a table about the initial values and the search field for each value

$$(\hat{x}, \hat{y}) = \left(\frac{max\,(xi - di) + min(xi + di)}{2}, \frac{max(yi - di) + min(yi + di)}{2}\right) \ldots..(1)$$

2.6.4.1BBAHS1

We use the bounding box method in both BBAHS1 and BBAHS2 in ordrer to find the field of research , but in BBAHS1 method we calculate the sum of the distances between the real locations and the sum of the distances between the initial locations we got from the bounding box method, then we subtract the value from the initial locations from the value of the real locations and keep the result and then randomly choose the location Contract and then calculate the difference again and compare this result with the previous result. If it is greater than it we keep the old locations, but if it is less, we keep the new locations of the nodes, and this process is repeated when changing the location of each node, and in the end we keep the value we got and repeat the process according to the number of iterations to be performed. We take the smallest value we get in all iterations. With the location of each node

2.6.4.2BBAHS2

In the BBAHS2 method, we choose the locations obtained by the bounding box as the initial values, then we calculate the difference between the location of each real node and the location of each node obtained by the bounding box and we keep these results, then in the second iteration we choose random locations for the nodes and calculate the difference between the real and random location of the first node We compare the result with the previous result of the first knot. If the new value is greater than the previous one, we keep the old site, and if it is the opposite, we keep the new site and do this process on all the nodes. And we repeat it in the third and fourth iterations until the specified number of iterations is reached

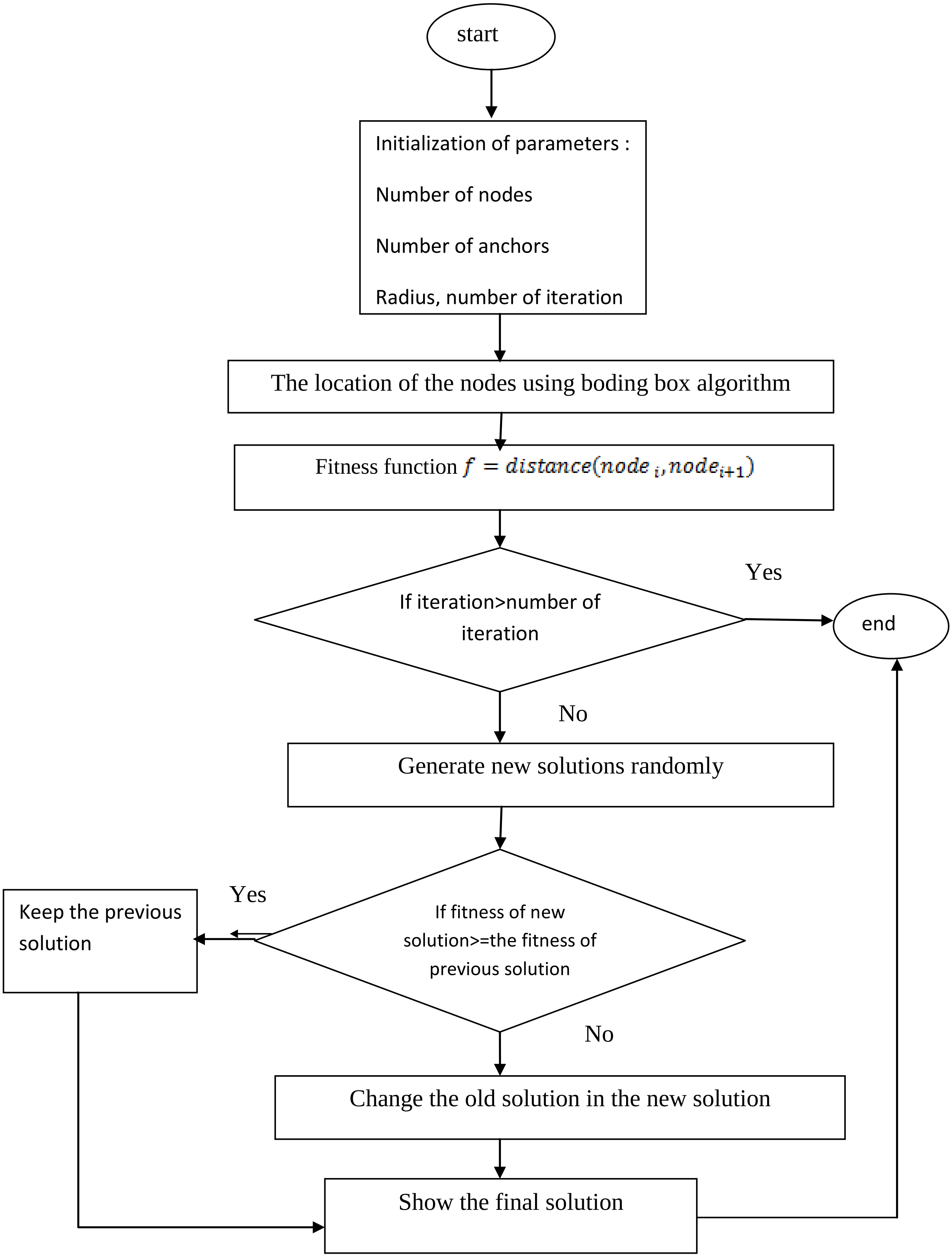


Figure 2.15: diagram of BBAHS

2.7 Issues in Localization Techniques [29]

Sensor network localization is an active research area so still has a lot of scope for research community. Some of the issues are:

- Low-cost algorithms: When designing a localization algorithm, the designer must consider the cost of hardware and deployment.
- Robust algorithms for mobile sensor networks: Because of their mobility and coverage. As a result, new algorithms must be developed to accommodate these mobile nodes.
- Accuracy: If the node position is incorrectly estimated, the accuracy of the localization is affected. When it comes to sensor localization, designers must keep in mind that precision is crucial.
- Scalability: Enlarging the monitoring area between nodes is often desired in large-scale deployments.

2.8Conclusion

The issue of localization in WSN has been very interested in the research community .in this chapter we have presented an overview of various range free localization techniques and their corresponding localization algorithms for sensor network .we also addressed the Classification of Localization Techniques (Centralized Localization Techniques, Distributed Localization Technique).

Chapter03

Implementation

3.1 Introduction

In this chapter, we will do a set of experiments on each of the following methods, the trilateratoin algorithm, the bounding box algorithm and finally the first and second BBAHS algorithm in order to evaluate the performance of each algorithm and compare the results obtained

3.2 Environment Implantation:

3.2.1 Hardware resources:

- In terms of hardware, we used a Dell laptop with a 3th generation Intel (R) Core (TM) i3-3217U CPU @ 1.80 GHz, 4.00 GB of Ram
- As for the Operating system, Windows 7 64-bits version was installed.

3.2.2 Software Resources:

Matlab 2015 (an abbreviation of "matrix laboratory") is an engineering program (and it has other fields) that analyzes and represents data by processing that data according to its database. The program was founded by two people, the first is Elif Muller and the second is Jack Little

3.3 Simulation Results:

In this section, we use the MATLAB platform to evaluate and illustrate the performance of different localization methods and then compare them with our hybrid method. First, we simulate the random method because it is considered a simple algorithm and the error in it is large, so that the error rate in other methods should not exceed the error rate of the random method, otherwise this method will have no meaning. Second, we simulate the trilateratoin method. This method depends on a number of anchors with known location, so that the greater the number of anchors, the lower the error rate. Third, we simulate the bounding square method. This method needs at least two anchors with known location. Finally, we simulate a new method. This method appeared as a result of merging the bounding box method with the meta-heuristics method, which is harmony search, where we were able to get a good method in terms of error rate, but it is not accurate in positioning, and this made us add some changes to get an excellent method in terms of the percentage of errors. In terms of positioning.

Some parameters play a major role in terms of error rate. These properties can easily be changed when performing simulations, which is why we will analyze each of them independently.

Among the most important parameters that affect the error rate: the transmission radius, anchors, sensor nodes, where we specify the transmission radius from 0 to 50, as for anchors from 1 to half the number of sensor nodes, and the number of sensor nodes from 1 to 100, all of which are distributed over Square area with a normal fixed size 50 * 50 2m.

Figure 1.1 Shows an example of a square network with N = 30 nodes and M = 10 randomly scattered binding nodes. Red stars represent unknown nodes and blue stars represent anchor nodes.

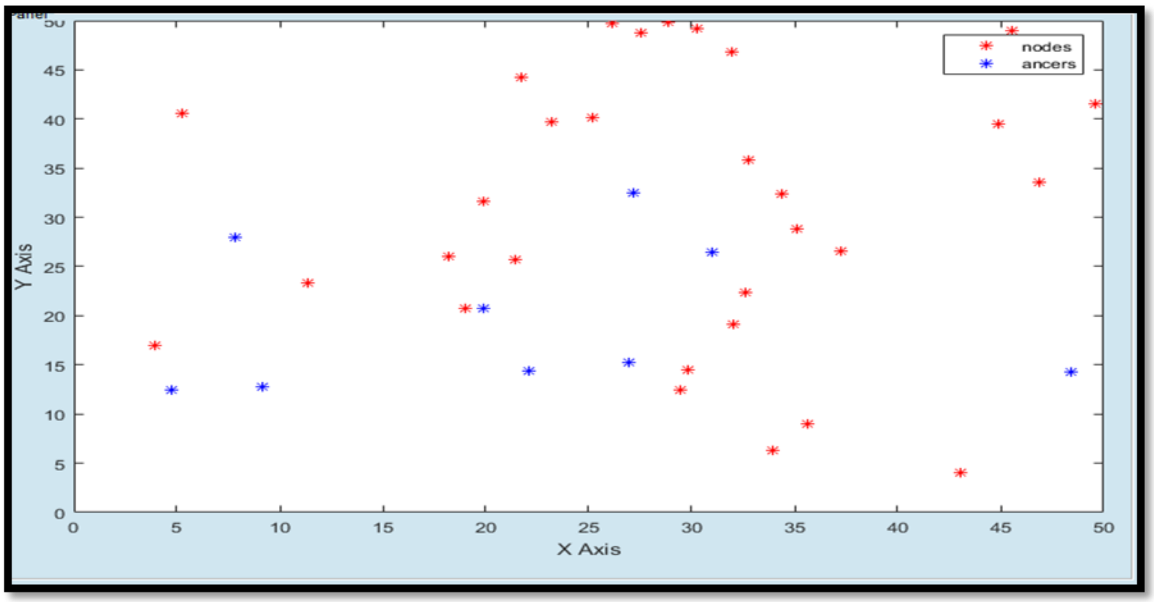


Figure 3.1 Simulation example of WSN with 30 nodes randomly placed in 2-d field

3.3.1 Trilateration algorithm:

The purpose of this technique is to use anchors to locate a node. Therefore, each node must communicate with at least three anchors based on distance estimation. We'll show you the outcomes of implementing this method and adjusting the various inputs in the following sections.

- **Simulation Results when changing the number of deployed nodes**
- **radius=20 and anchors=3**

Experiments suggest that this algorithm performs better and provides more accurate results when the number of nodes is between 15 and 35. **Figure 3.2** depicts the outcome. As a result, the number of nodes in this algorithm should be proportional to the number of anchors, not too little nor too high, especially when the contact radius is short and there are few sensor nodes.

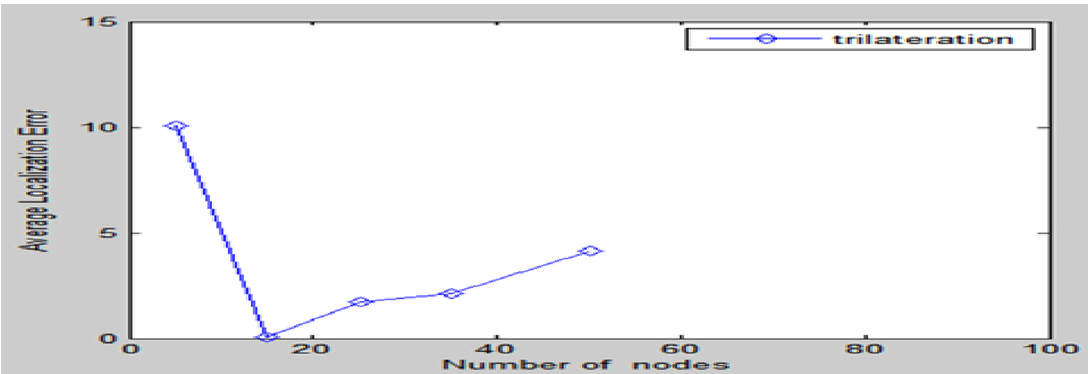


Figure 3.2 Localization error when changing the number of deployed nodes with radius=20 and anchors=3 (trilateration)

- **radius=50 and anchors=3**

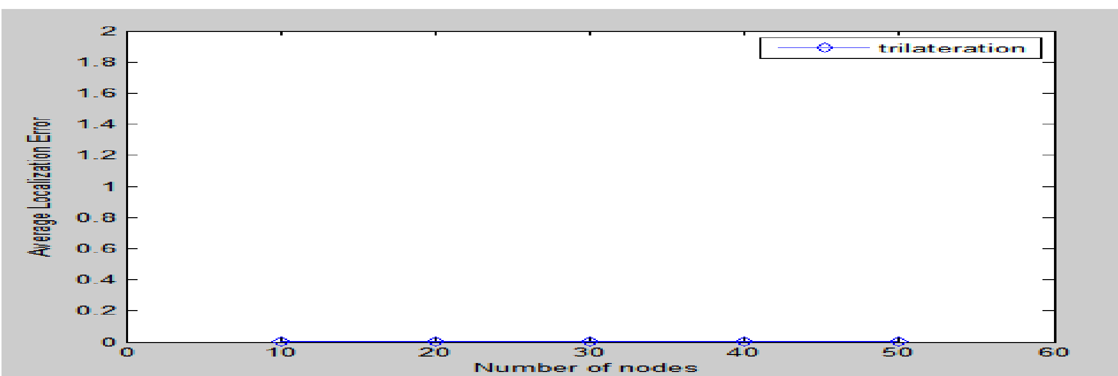


Figure 3.3 Localization error when changing the number of deployed nodes with radius=50 and anchors=3 (trilateration)

The localization error rate is always equal to zero in this example (3 sensor nodes only), and as shown in **Figure 3.3**, the number of nodes does not matter if the communication radius is very broad and covers all nodes (equivalent to the size of the plane).

- **radius=20 and anchors=15**

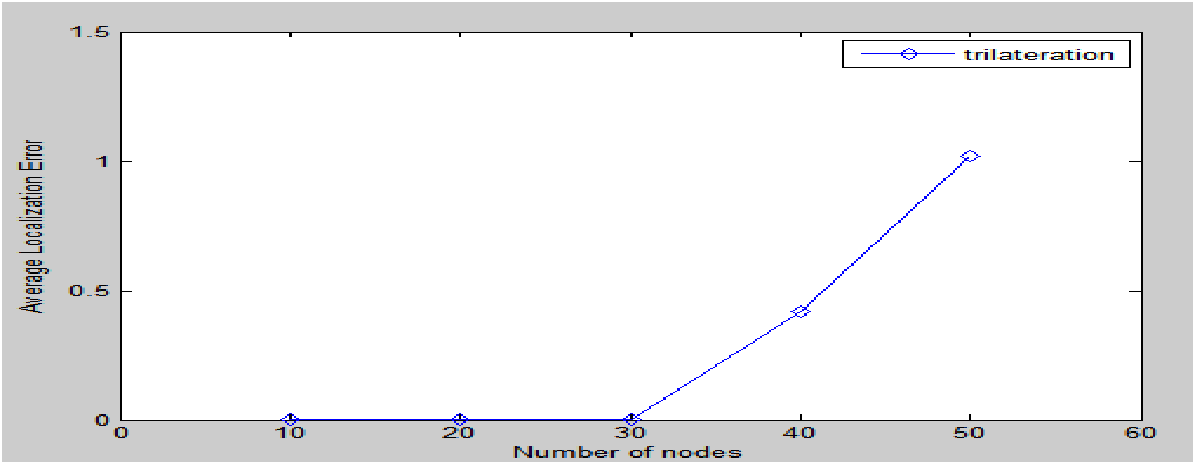


Figure 3.4 Localization error when changing the number of deployed nodes with radius=20 and anchors=15 (trilateration)

Experimental results show that the number of nodes is more than twice the number of sensor nodes. The higher the average localization error.

- **Simulation Results when changing the number of anchor nodes**

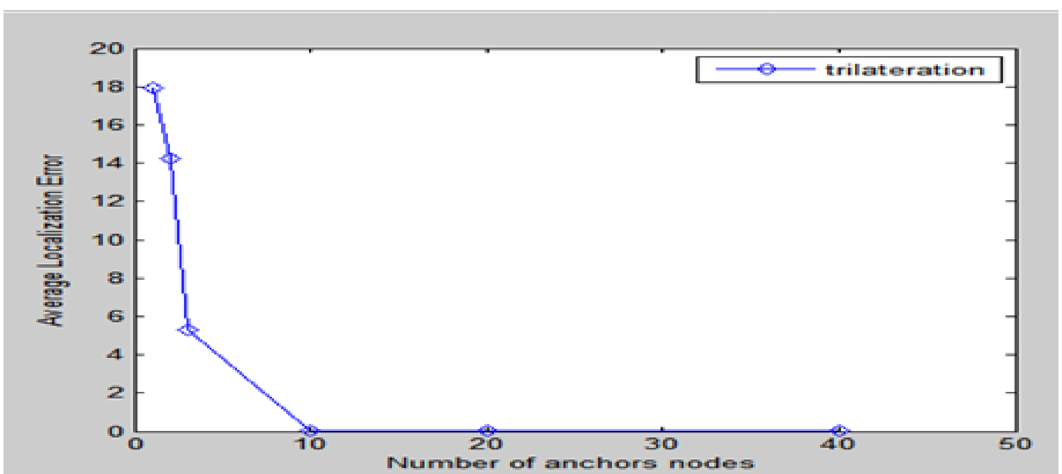


Figure 3.5 Average localization error when changing the number of anchor nodes (trilateration)

Figure 3.5 shows that the average localization error decreases with increasing number of sensor nodes, which is logical considering that this algorithm requires all nodes to be connected to at least three anchors to function very effectively but still gives us good results in the case of one or two anchors.

➢ **Simulation Results when changing the connectivity radius with number of deployed nodes=100 and anchors=30**

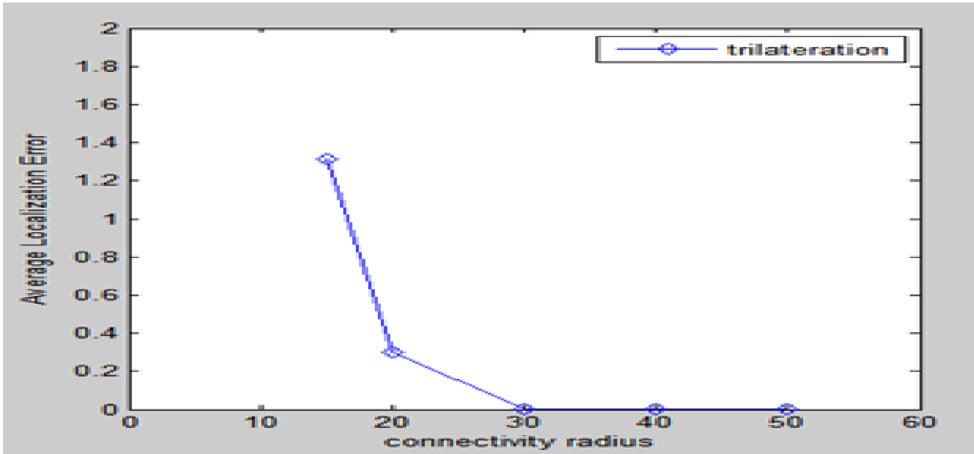


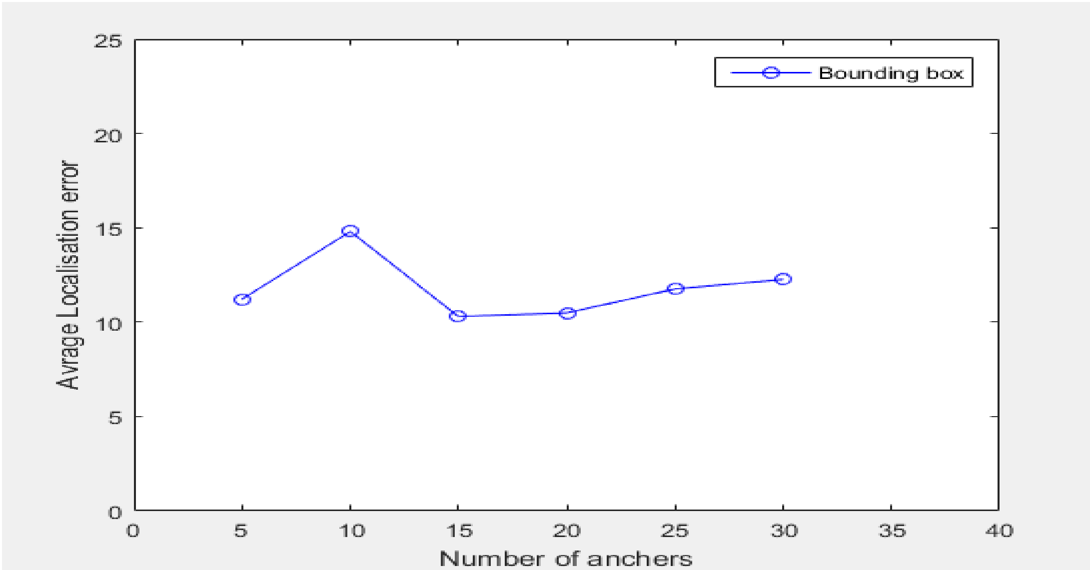
Figure 3.6 Average localization error when changing the connectivity radius of nodes (trilateration)

As seen in **Figure 3.6**, the average localization error improves as the communication radius increases. Therefore, this strategy is best used when the communication radius is very vast, spanning all nodes in the network. Aside from that, when the communication radius is exceedingly small, trilateration isn't a good idea.

3.3.2 Bounding box :

➢ **Simulation results when changing the number of anchors :**

We randomly deploy 50 sensors in the 2D space. We change the number of anchor between 5 and 20 anchors and we keep fixed all the parameters of the algorithms radius R= 50, nodes=50



.

Figure 3.7 Localization errors when changing the number of deployed anchors (Bounding Box)

The experimental results show that the bounding box. Method does not give accurate position if we add a large number of anchors. Graph shows significant reduction in mean error when the number of posted anchors is between half and a quarter of the number of nodes

- **Simulation results when changing the radius :**

We randomly deploy anchors in the 2D space. We change the radius between 10 and 40 anchors and we keep fixed all the parameters of the algorithms: anchors = 25, nodes=50.

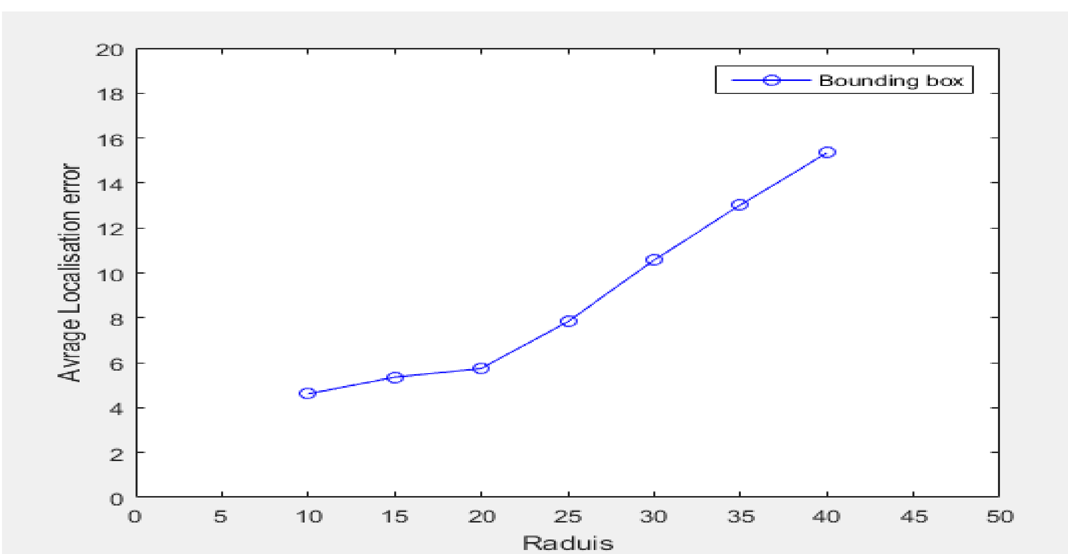


Figure 3.8 Localization errors when changing the radius (Bounding Box)

Experimental results show that the bounding box method works best if the radius is medium with a good number of anchors .As we can see in the graph that the higher the radius value is above 20, the higher the error rate

- **Simulation results when changing the radius :**

We randomly deploy anchors in the 2D space. We change the number of anchor between 25 and 55 anchors and we keep fixed all the parameters of the algorithms: anchors = 25, radius=30.

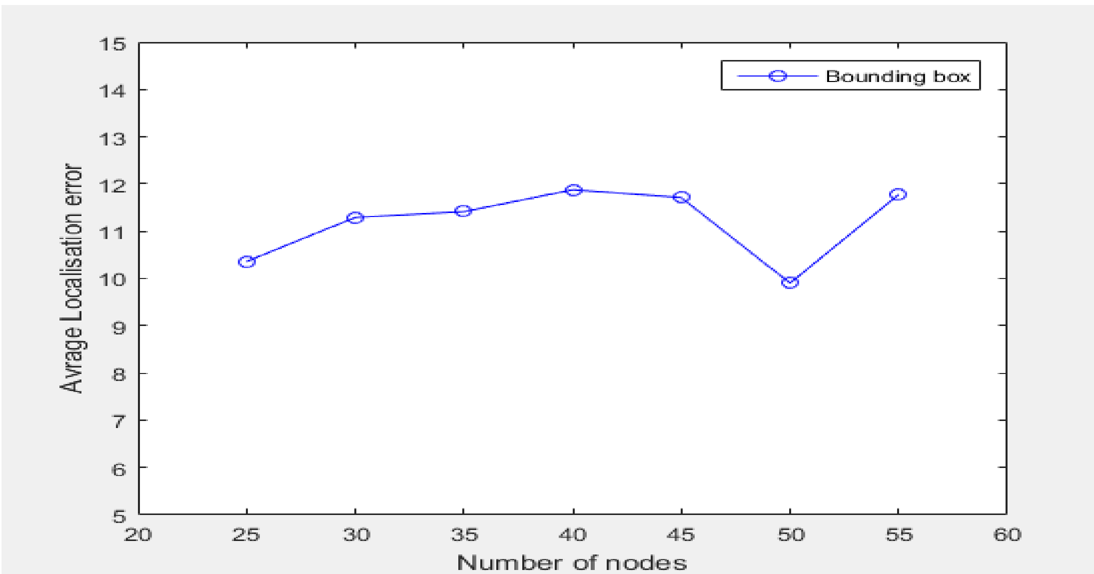


Figure 3.9 Localization errors when changing the number of deployed nodes (Bounding Box)

The experimental results show that the bounding box method is not affected much by the change in the number of nodes, provided that a good number of anchors is distributed and of course in an area proportional to the number of nodes. As the graph shows, the error rate is between 10 and 12 despite the increase in the number of nodes.

- **Simulation results when changing the area:**

We randomly deploy nodes in the 2D space. We change the area between 15 and 45 cm and we keep fixed all the parameters of the algorithms: anchors = 10, radius=15 nodes=15.

We notice from the graph (figure 1.5) that there is a relationship between the area and the distribution of the number of nodes, the anchors and the distance between them. As the larger the area, the greater the distance between the nodes and the anchors, and from it the transmission may be interrupted, and this causes the anchors to be unable to accurately determine the locations, and hence the high error rate. But a small error rate can be obtained if the anchors are distributed in places close to the nodes, as the drawing shows, despite the expansion of the area, but we obtained a small error rate and this thanks to the excellent distribution of anchors

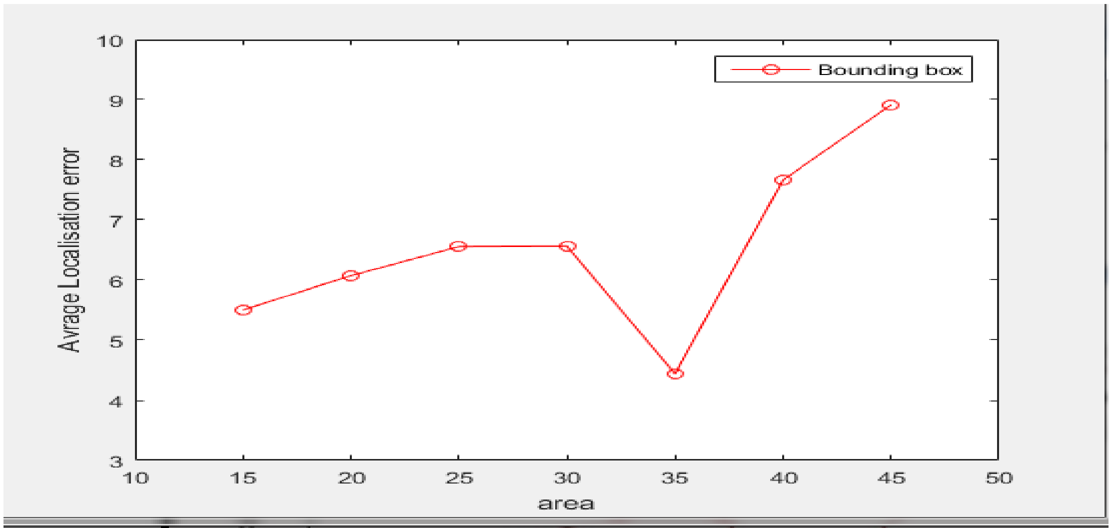


Figure 3.10 Localization errors when changing the area (Bounding Box)

3.3.3 BBAHS1(Bounding Box And Harmony Search1):

- **Simulation results when changing the number of anchors :**

We randomly deploy 50 sensors in the 2D space. We change the number of anchor between 5 and 30 anchors and we keep fixed all the parameters of the algorithms radius R= 50, nodes=50.

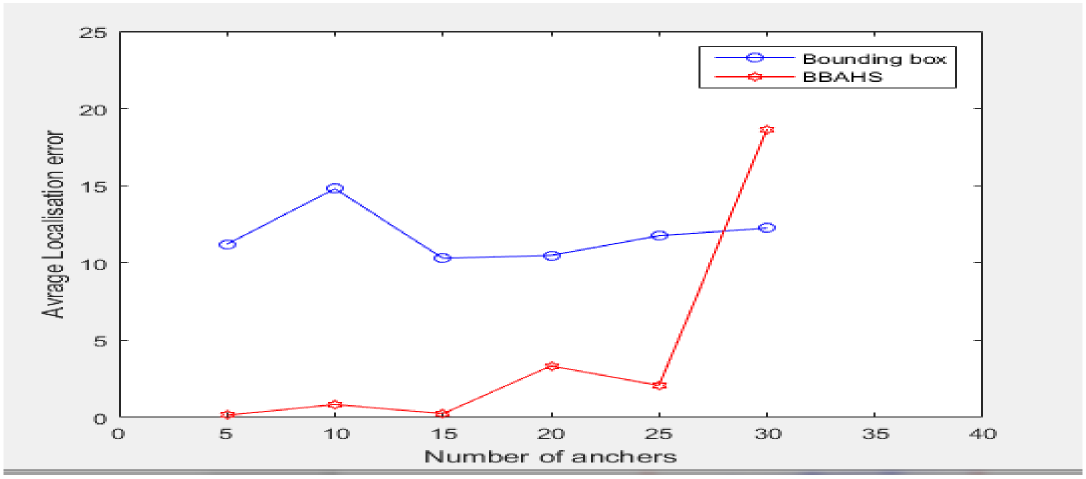


Figure 3.11 Localization errors when changing the number of deployed anchors (BBAHS1)

The experimental results show that the BBAHS1 method is affected, like the bounding box method, by the change in the number of anchors, as the greater the number of anchors, the greater the error rate. As we note in the graph that the largest results recorded were after the number of anchors exceeded half of the number of nodes

- **Simulation results when changing the radius :**

We randomly deploy anchors in the 2D space. We change the radius between 10 and 40 anchors and we keep fixed all the parameters of the algorithms: anchors = 25, nodes=50.

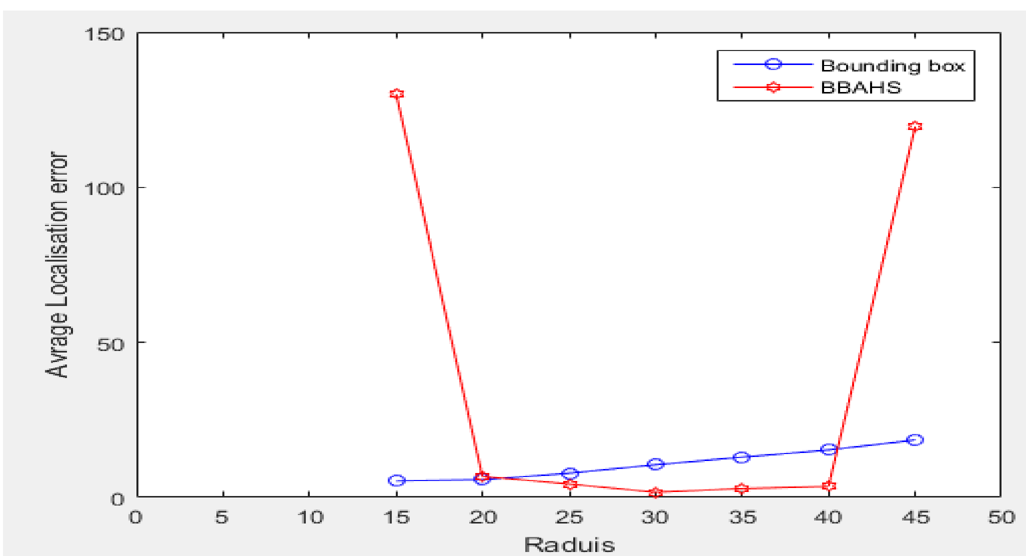


Figure 3.12 Localization errors when changing the radius (BBAHS1)

From our experience, we note that the BBAHS1 method works better if the radius value is between 40% and 60% of the total area as shown in the graph inside this field we get good results, outside it we get worse results than the bounding box method.

- **Simulation results when changing the number of nodes :**

We randomly deploy anchors in the 2D space. We change the number of nodes between 25 and 55 anchors and we keep fixed all the parameters of the algorithms: anchors = 25, radius=30.

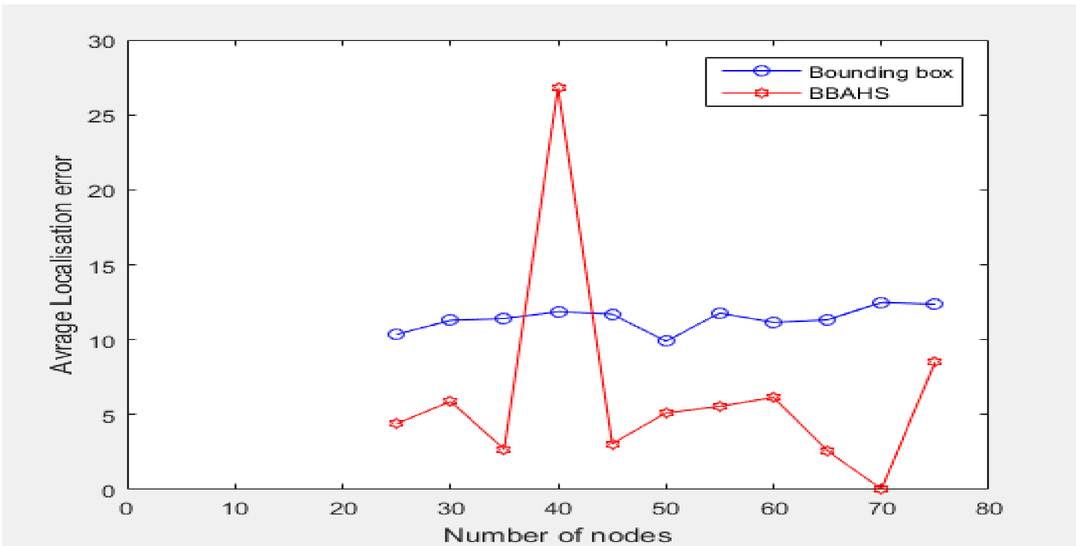


Figure 3.13 Localization errors when changing the number of deployed nodes (Bounding Box and BBAHS1)

The experimental results show that the BBAHS1 method is not affected much by the change in the number of nodes, but it is affected by the method of distributing these nodes where each node must be associated with at least two anchors. As we can see in the graph, there is a large variation in the error rate, and this is due to the way the anchors and nodes are distributed

- **Simulation results when changing the area:**

We randomly deploy nodes in the 2D space. We change the area between 15 and 45 cm and we keep fixed all the parameters of the algorithms: anchors = 10, radius=15 nodes=15.

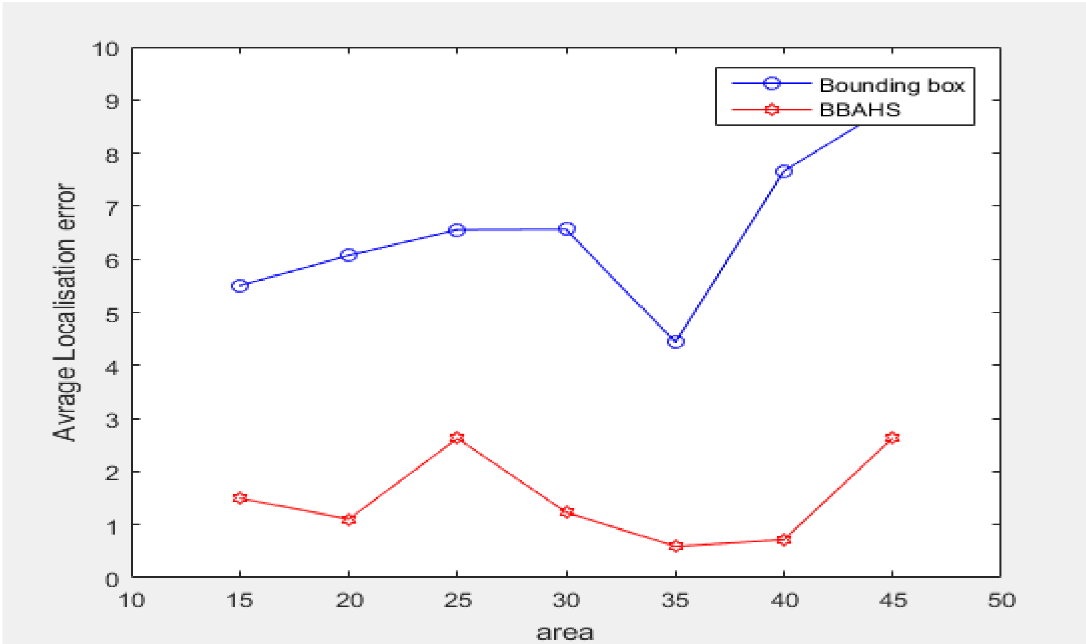


Figure 3.14 Localization error when changing the area (BBAHS1)

We note from the graph that there is a similarity between the bounding box method and BBAHS1 where we always notice that there is a relationship between the area and the distribution of the number of nodes, anchors and the distance between them. The larger the area, the greater the distance between the nodes and the anchors, and may cause transmission interruption, which leads to the inability of the anchors to accurately locate the nodes, and thus the higher the error rate. But a small error rate can be obtained if the anchors are distributed in places close to the nodes, as the figure shows (Figure 2.4).

- **Simulation results when changing The number of iteration of the operation:**

We randomly deploy nodes in the 2D space. We change the number of iteration of the operation between 20 and 140 and we keep fixed all the parameters of the algorithms: anchors = 15, radius=15 nodes=30

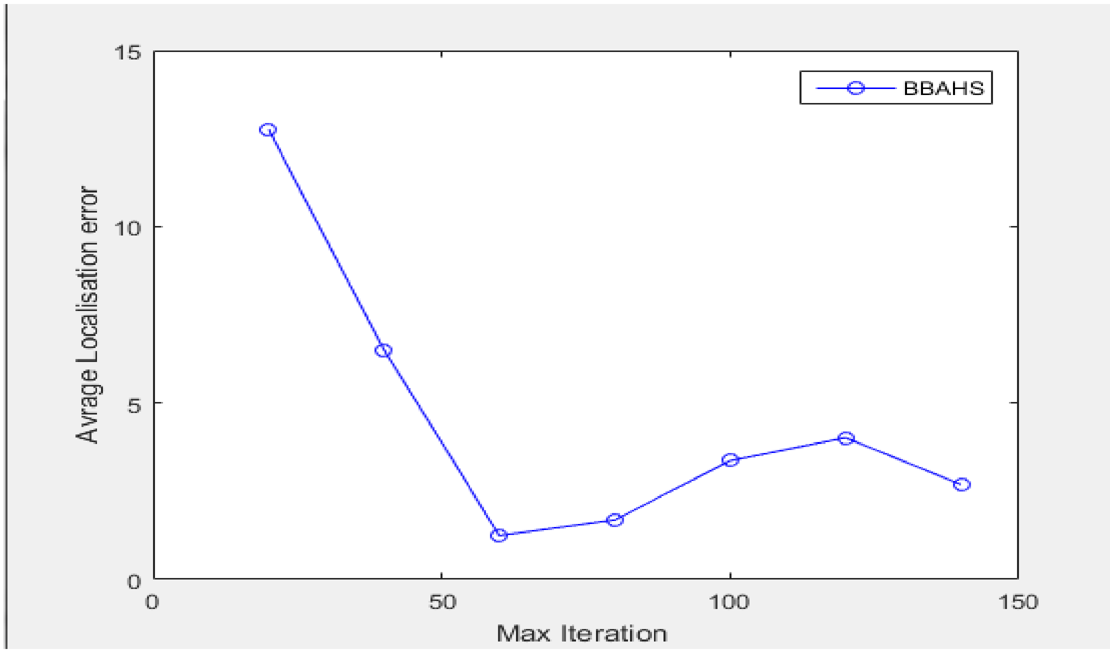


Figure 3.15 Localization error when changing the number of iteration of the operation (BBAHS1)

From our previous experiments, we conclude that the BBAHS1 method works better in the case of increasing the number of iterations, as this enables it to better locate the nodes. As we note in the graph, there is a wide difference in the error rate between 20 iterations and 100 or 140 iterations

- **Remark:**

We note from the above that this method, despite its good results, had flaws. This made us focus and think again about how to fix it.

We were able to find another method that is not very different from the first method, but its results are much better, which is BBAHS2

3.3.4 BBAHS2(Bounding Box And Harmony Search2) algorithm

- **Simulation results when changing the number of deployed nodes**

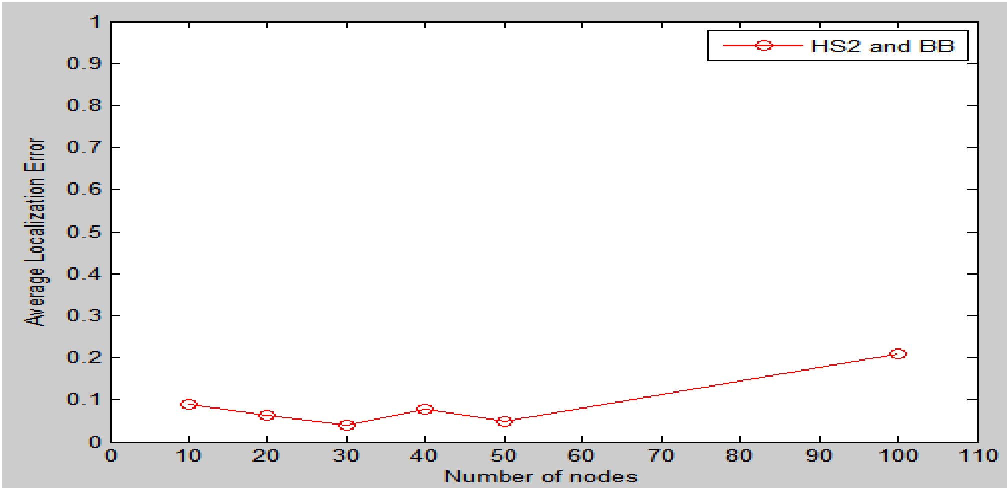


Figure 3.16 Localization error when changing the number of deployed nodes with radius=50 and anchors=20 (BBAHS2)

The number of nodes has no effect on the average localization error in this algorithm that we built, as seen in **Figure 3.16**, where the error rate is always less than 0.

- **Simulation Results when changing the number of anchor nodes**

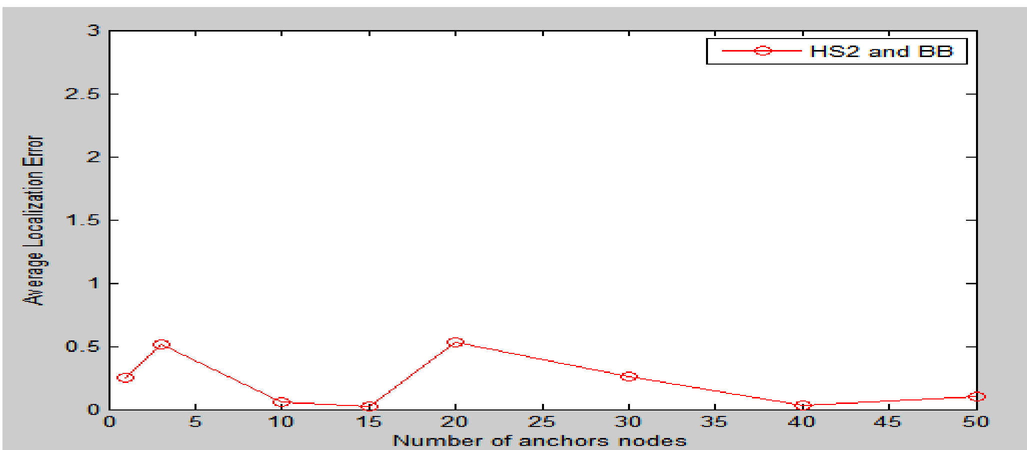


Figure 3.17 Average localization error when changing the number of anchor nodes (BBAHS2)

The number of sensor nodes has no effect on the HS2 BB algorithm, according to the experimental results in **Figure 3.17**, even when the contact radius is very large. Although the localization error rate fluctuates, it is always less than zero. The experimental results show that this technique performs well even when only one sensor node is used.

➢ **Simulation Results when changing the connectivity radius with number of deployed nodes=50 and anchors=20**

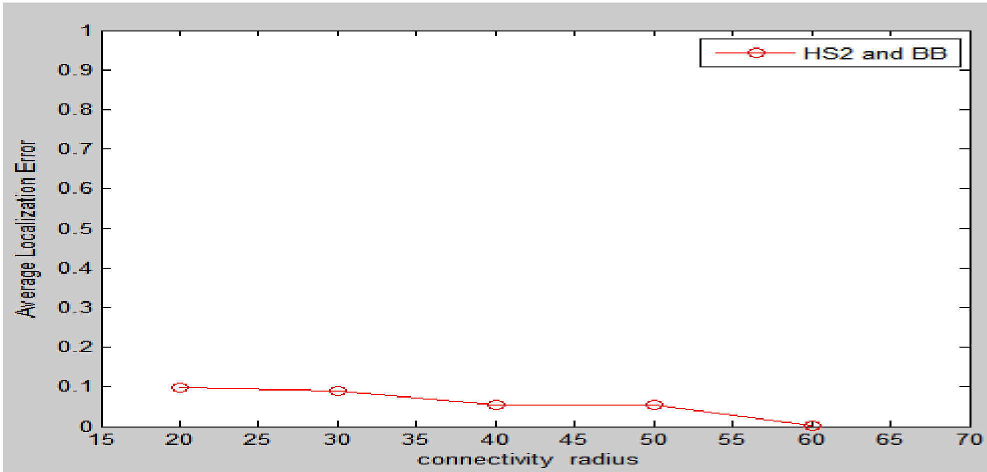


Figure 3.18 Average localization error when changing the connectivity radius of nodes (BBAHS2)

We can see from the experimental results in **Figure 3.18** that modifying the connection radius has a minor influence on the average localization error, as long as all nodes are connected to at least one sensor. The connection diameter should be increased until all nodes in the network are joined.

➢ **Simulation results when changing the number of iteration with number of deployed nodes=50 and anchors=20**

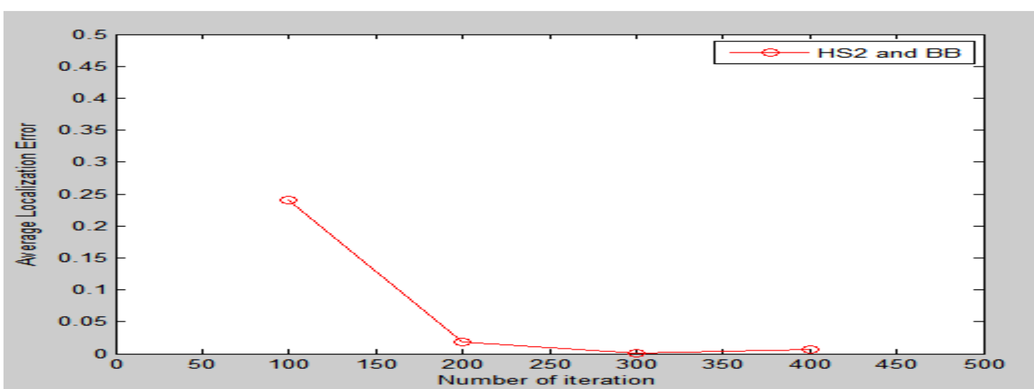


Figure 3.19 Average localization error when changing the number of iteration (BBAHS2)

The experimental data in **Figure 3.19** shows that the higher the number of iterations, the more likely the error rate will approach zero.

3.4 A comparison of the Trilateration Algorithm and the BBAHS2 Algorithm and Bounding Box Algorithm:

The number of nodes has an impact on the trilateration algorithm and the bounding box algorithm. In contrast to the BBAHS2 algorithm, the average localization error increases as the number of nodes increases.

The trilateration algorithm the bounding box algorithm, on the other hand, does not perform well with a small number of anchors, nor does it work well with nodes that are in contact with one or two anchors, but the BBAHS2 algorithm does.

The communication radius should be big enough that all nodes in the BBAHS2 algorithm are connected to at least one sensor and at least three anchors in the trilateration technique and at least two anchors in the bounding box technique.

Finally, we can deduce from this comparison that the BBAHS2 algorithm is superior to the trilateration and bounding box algorithm in terms of determining node location.

3.5 Conclusion:

Our experiments show that locate the node depends on many variables, all of which have an instrumental effect, and any defect in one of them makes the task of finding the correct node location nearly impossible.

However, we were able to find a method that is affected only by some of these variables and has good results compared to other methods

Conclusion

Recently, the field of positioning has attracted the attention of researchers and programmers, as WSN it consists of thousands of nodes that must be located, and creating a reference position manually is difficult and impossible, especially if the location is difficult to access, in addition to using GPS , is expensive. From it, a lot of research relied on localization techniques that depend on the binding node that knows its current location and through the information provided by this node, the other nodes know their location, and in our research we used three techniques. trilateration, bounding box, harmony search.

The trilateration technique is considered the best technique in terms of locating where the error rate obtained is always close to zero and depends on determining the location of the nodes on three anchors at most for each node. As for the Bounding Box technique used, determining the location of the contract does not depend only on a specific number of anchors, as the greater the number of anchors, the lower the error rate.

This is what made us use a genetic algorithm, which is Harmony Search, to develop the results of the Bounding Box, where we merged both Harmony Search and the Bounding Box, and we got a new algorithm that we called HSBB. At the beginning of our research, we got a good algorithm in terms of error rate, but it is not accurate in positioning, and this is what made us continue experiments to develop it until we got an excellent algorithm in terms of error rate and accurate in positioning, and so we named both algorithms BB AHS 1 and BB AHS2.

In the future, we aspire to discover a new technology that does not exist, without relying on pre-existing technologies, and of course, that is inexpensive and accurate in its work.

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