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Wireless Sensor Network Localization Using An Hybridization of Trilateration and Variable Neighborhood Search

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Abstract

The twentieth century was marked by a major development in wireless communication technologies thanks to its good performance and low cost, as for the development in electronic science produced for us electronic components that are very small, easy to use and low in cost, with a processor and a large memory, which they called the sensor node so that when it is deployed in any environment, it interacts with each other independently and wirelessly, and from it the transmission of information from the source to the base station. This technique has been used in many fields such as determining locations or localization, in order to detect fires and mines, for example. Despite all these advantages, sometimes this technique is subjected to some errors in calculating the exact position and location of the node, especially in calculating the measurement and the distance between nodes, which causes us errors in locating. To solve these problems, the specialists have suggested and tried many solutions and options. There are those who use some nodes that are known to the site, that is, equipped with GPS to identify the rest of the unknown nodes, but this method has some problems such as identifying a small number of nodes in the network, and the big problem that this method is so expensive. In this research we tried to find some solutions to locate the position of node which relies on the use of spaces and anchors to one side, estimating the location of the contract and the other hand on the error control mechanism allowing more accurate locating of nodes and reducing spread and accumulation of errors across the network.

Keywords: Wireless sensor networks, localization, trilateration, variable neighborhood search.

Résumé

Le XXe siècle a été marqué par un développement majeur des technologies de communication sans fil grâce à ses bonnes performances et à son faible coût, quant au développement de la science électronique produit pour nous des composants électroniques très petits, faciles à utiliser et peu coûteux, avec un processeur et une grande mémoire, qu'ils ont appelée le nœud de capteur de sorte que lorsqu'il est déployé dans n'importe quel environnement, il interagit les uns avec les autres indépendamment et sans fil, et à partir de là, la transmission d'informations de la source à la station de base. Cette technique a été utilisée dans de nombreux domaines tels que la localisation ou la localisation, afin de détecter des incendies et des mines, par exemple. Malgré tous ces avantages, cette technique est parfois sujette à quelques erreurs dans le calcul de la position et de l'emplacement exacts du nœud, notamment dans le calcul de la mesure et de la distance entre les nœuds, ce qui nous cause des erreurs de localisation. Pour résoudre ces problèmes, les spécialistes ont suggéré et essayé de nombreuses solutions et options. Il y a ceux qui utilisent certains nœuds connus du site, c'est-à-dire équipés d'un GPS pour identifier le reste des nœuds inconnus, mais cette méthode présente certains problèmes tels que l'identification d'un petit nombre de nœuds dans le réseau, et le grand problème que cette méthode est si chère. Dans cette recherche, nous avons essayé de trouver des solutions pour localiser la position du nœud qui repose sur l'utilisation d'espaces et d'ancres d'un côté, l'estimation de l'emplacement du contrat et d'autre part sur le mécanisme de contrôle d'erreur permettant une localisation plus précise des nœuds et réduire la propagation et l'accumulation d'erreurs sur le réseau.

Mots-clés : Réseaux de capteurs sans fil, localisation, trilatération, recherche de voisinage variable.

ملخص

تميز القرن العشرين بتطور كبير في تقنيات الاتصالات اللاسلكية لأدائها الجيد وقلة تكلفتها ، أما بالنسبة لتطور العلوم الإلكترونية فقد أنتج لنا مكونات إلكترونية صغيرة جدًا وسهلة الاستخدام وغير مكلفة ، مع معالج وذاكرة كبيرة ، والتي أطلقوا عليها اسم عقدة الاستشعار بحيث عند نشرها في أي بيئة ، فإنها تتفاعل مع بعضها البعض بشكل مستقل ولاسلكي ، ومن هناك ، يتم نقل المعلومات من المصدر إلى المحطة الأساسية. تم استخدام هذه التقنية في العديد من المجالات مثل التعريب أو التعريب ، من أجل الكشف عن الحرائق والألغام ، على سبيل المثال. على الرغم من كل هذه المزايا ، فإن هذه التقنية تتعرض أحيانًا لبعض الأخطاء في حساب الموضع الدقيق وموقع العقدة ، خاصة في حساب القياس والمسافة بين العقد ، مما يتسبب في حدوث أخطاء في الموقع. لحل هذه المشاكل ، اقترح المتخصصون وجربوا العديد من الحلول والخيارات. هناك من يستخدم بعض العقد المعروفة بالموقع ، أي مجهزة بنظام تحديد المواقع العالمي لتحديد باقي العقد غير المعروفة ، ولكن هذه الطريقة بها مشاكل معينة مثل تحديد عدد صغير من العقد في الشبكة ، والمشكلة الكبيرة أن هذه الطريقة مكلف جدا. حاولنا في هذا البحث إيجاد حلول لتحديد موضع العقدة التي تعتمد على استخدام المسافات والمثبتات من جهة وتقدير موقع العقد ومن جهة أخرى على آلية التحكم في الخطأ التي تسمح تحديد موقع أكثر دقة للعقد وتقليل انتشار وتراكم الأخطاء على الشبكة.

الكلمات المفتاحية: شبكات الاستشعار اللاسلكية ، التعريب ، التثليث ، البحث المتغير في الأحياء.

Summary

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General introduction

Wireless sensors were the interest of researchers from computer scientists and engineers who tried to cover all solutions to the problems of layers of network systems because of their great importance, as many countries have supported this research.

When we say we want to localize in a wireless sensor network then what we are talking about is locating the base graph so we will have some terms with graph theory along the way so that each sensor network can be seen as a basic graph with the vertices representing the sensor nodes that we've published. At the edges is what we call signal range information and sometimes it's not available and sometimes it's not. When it's available we have a good set of information and it's basically an estimated Euclidean distance between one sensor and another, that they determine themselves by sending signals back And back and forth between each other like that there's something called the radio range of each sensor, and they can't communicate outside the radio range so they can pretty much see or exchange information with the nearby sensors that then make up the edge groupie the information so we don't really know where the sensors are by looking To this group for a list of sensor nodes and possible edges between each other so that the localization of our sensor network turns into a unique localization in this graph with sample vertices and edges.

One of the things that we talked about in our talk is the algorithmic techniques that can be centralized, that is, simply, all sensor nodes give the basic information, and then the synchronization node can then calculate the location of each distributed node because each node calculates its serial location or it can be distributed and Not centralized, the distance between nodes is calculated either by localizing nodes or algorithms to localize the entire network Some algorithms that run constantly on sparse networks and dense networks are obviously easier because there are more nodes available

For communication and global information exchange, so after we talked About Scope-Based Anchor-Based Techniques We will review some interesting algorithmic techniques such as Trilateration, Bilateration and Assisted localization.

In this research, we will try to find some solutions to locate the position of the node which relies on the use of spaces and anchors to one side, estimating the location of the contract and, on the other hand, the error control mechanism allows more accurate locating of nodes and reducing the spread and accumulation of errors across the network.

In the first chapter, we attempt to summarize the most important information's about wireless sensor networks such as definition, structure, characteristics, areas of use, and an overview about the area of its use in our research in particular.

For the second chapter, we will talk about the technique of localization and some of the algorithms that are used to locate nodes, such as DV-hop and PSO, then we touch on the algorithms that we worked on in this research, which are Trilateration and Variable Neighborhood Search (VNS) and the way they work. Our main goal is to combine the two algorithms, but we could not complete them, so we will work on them in the future.

The third chapter is about discussing the results we obtained using each of the two algorithms and the influence of parameters on them.

Chapter 1

Wireless Sensor Networks

I.1.Introduction

Nowadays, wireless sensor network technology occupies a large portion of researchers' interest, especially in the field of wireless communications and electronics. This interest has led to low-cost development, low-power, sensors with different functions that are compact and can communicate over short distances [1].

Meanwhile, the sweep of the Internet in all areas of life has made humans less immune to what could harm them or their property. Cheap, savvy, organized sensors, connected by means of remote connections and spread in enormous numbers, give phenomenal freedoms to screen and control homes, urban communities and the environment [1].

In this chapter we will attempt to provide an overview of WSN; Its definition, structure, characteristics, areas of use and the area of its use in our research in particular.

I.2.About Wireless Sensor Networks

Recently, technological development in electronics such as processor and memory, low energies, and wireless communications, has contributed to the development of small size, low power, and inexpensive sensor nodes[2].

These nodes, when assembled a large number of them, form a WSN for us, whose role - as its name indicates - is in sensing, wireless communication, and finally computation, all after being deployed in an unmonitored environment. Among these nodes, there is a special one whose role is to connect the sensor network to the outside world and it is called the sink node or the base station[2].

Functionally, the limited memory of the sensor units, and the difficulty of accessing the places in which they are deployed, make it possible and even necessary to use a set of other different sensors, such as mechanical, magnetic, thermal, chemical, etc., to measure the characteristics of the environment by connecting these sensors to the sensor node. In the sensor node, the battery is the main source of energy, and another secondary source can be used from the environment such as solar panels and others. We note that one of the most important limitations of WSN is energy conservation; Therefore, the greatest focus in these networks is on them [2].

What is the size of a WSN and where to place nodes? The size of the WSN, its topology and the deployment system are highly dependent on the environment. So, the difference in its size - the network - is depending on the environment. For example, in indoor environments due to limited space, we need to form the network to a small number of nodes, unlike outdoor environments which need a large number of nodes due to the large area [2].

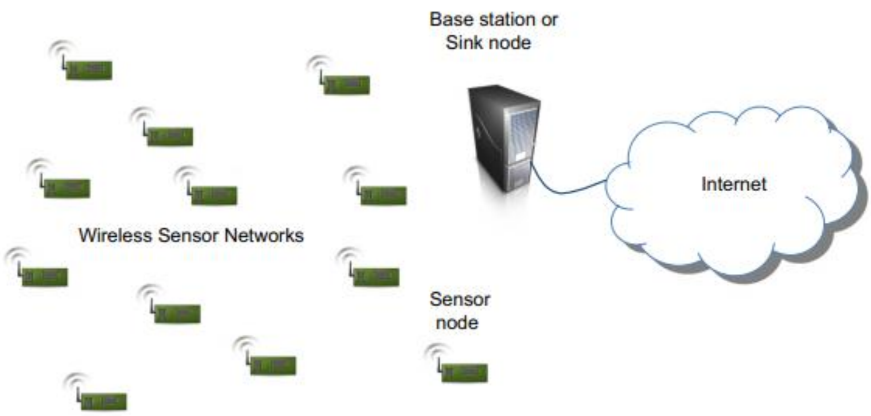

Figure I-1 : A typical wireless sensor networks

I.3.Wireless Sensor Network Structure

It includes for radio communications networks various topologies. Below, we will try to talk about some of the topologies used in wireless sensor networks:

- **Star network (single point-to-multipoint)**

It's an interchanges topology where only one base station can send or additionally get a message to various remote nodes. These nodes are not allowed to send messages to one another. These nodes are not allowed to send messages to one another [3].

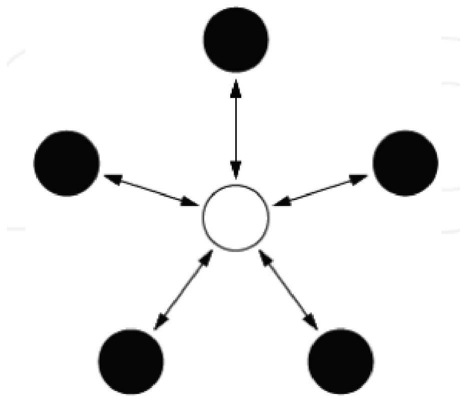

Figure I-2: A star network topology

- **Mesh network**

It permits communicating data nodes in the network that is inside its radio transmission range. So, if a node wants to send a message to another node outside the radio communication range, it can use an intermediate node to deliver the message to the desired node [3].

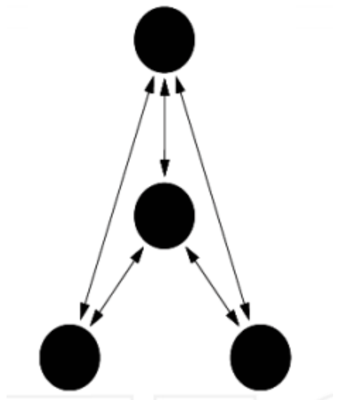

Figure I-3: Mesh network topology

- **Hybrid mesh – star network**

A crossover between the mesh and star network gives a strong and flexible communications network, while maintaining the capacity to reduce the WS nodes power consumption. In this network topology, sensor nodes with less energy are not allowed to forward messages. Whereas, other nodes on the network are enabled with the possibility of multiple hops. These latter nodes feature higher power that allows them to forward messages from lower-power nodes upward on the network [3].

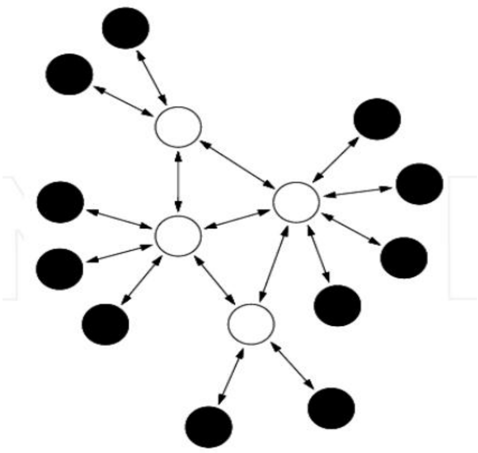

Figure I-4: Hybrid Mesh – Star network topology

I.4.Structure of Wireless Network Node

A sensor node is comprised of four fundamental segments, for example, processing unit, sensing unit, transceiver unit and a power unit -Figure 5-. It also has application dependent additional components such as a power generator, a location finding system and a mobilizer [3].

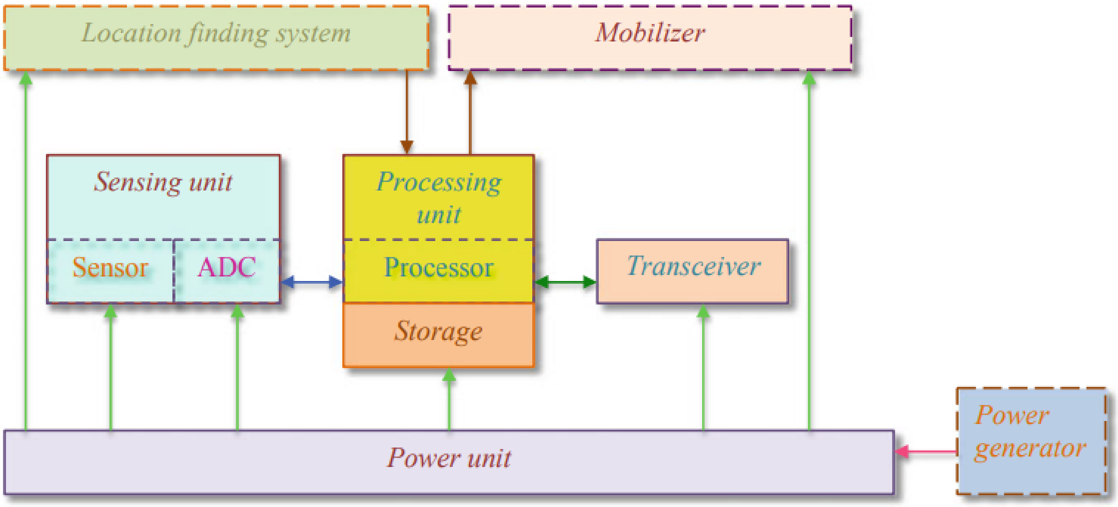

Figure I-5: Components of a sensor node

- **Sensing units**: are normally made out of two subunits: sensors and analogue to digital converters (ADCs). The analog signals are converted into digital signals by ADC and then fed into the processing unit [4].
- **Processing unit:**It is a small storage unit, manages the procedures that make the sensor node collaborate with other nodes to perform the assigned sensing tasks [4].
- **Transceiver unit:** It connects the node to the network [4].
- **Location finding system:** It used to find locations [4].
- **Mobilizer:** It is used to move sensor nodes when it's required to perform a specific task [4].

The sensors produce analog signals, which are converted into digital signals by the ADC. These signals are processed by the processing unit by managing the procedures that cause one group of nodes to cooperate with others to carry out the specific sensing tasks. The transmitter and receiver unit connects the node to the network. All actions are done using energy, therefore, one of the most important components of the sensor node is the power unit [3].

Sensor nodes are characterized by:

- Low energy consumption [2];
- It's inexpensive to produce, and easy to replace[2];
- Its independence is in the network, so any malfunction in one of them does not cause the other sensors to stop in the network[2];

- Adapt to the environment [2].

I.5.Architecture of WSNs

The main entities shown in Figure 6 make up our WSN architecture:

1. Sensor nodes, which are the main component of the sensor network, its goal is to identify the phenomenon in which it is located, in addition to forming a wireless network, and in the last it collects and routs data to the user by a sink (base station)[2].
2. The sink (base station), its role is to communicate with the user via the Internet or satellites. It is located close to the sensor field, or next to the nodes of the sensor network. The data collected from the sensor field is directed to the latter -sink-by a multi-hop infrastructure less architecture through the sink[2].

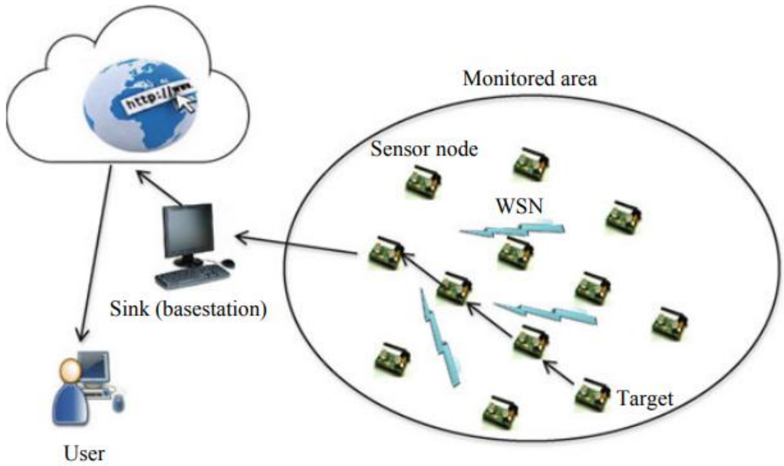

Figure I-6: Components of wireless sensor network

3. The phenomenon is sensitized and analyzed using sensor nodes, and it is considered one of the greatest interests of the user because it entails monitoring and measuring its behavior - the phenomenon[2].

I.6.Types of Wireless Sensor Networks

WSNs are deployed differently for their different uses. Functionally, five types or methods can be distinguished which are mobile, multimedia, terrestrial, underground, and underwater WSNs. Below, we will try to detail each type separately[2].

I.6.1.Terrestrial WSNs

This type of network is deployed in a specific area, and to deploy sensor nodes there are two ways:

- ♦ Unstructured WSN, characterized by a large number of sensor nodes, which are deployed in the field in an ad hoc manner, then leave the network to perform its functions unattended. In this way, when there is any failure in the network, it is difficult to maintain it due to the large number of nodes [2].
- ♦ Structured WSN, differs from the previous one in that the manner of publishing the contract or some of it is planned in advance. A structured network is characterized by low cost to maintain and manage due to the possibility of using a few numbers of nodes. This network excels in the specific locations, where nodes are usefully deployed to provide coverage, while in ad hoc deployment, not all areas can be covered [2].

In the field of sensor, we deploy the nodes keeping in mind that they are not out of transmission range between them, and in huge numbers that can reach 20 nodes/m3. To deploy this dense number of nodes, the structure must be maintained through three phases [2]:

- ♦ Pre-deployment and deployment phase. In it, we talk about the method of deploying and dropping sensor nodes, manually by a human or robot, by placing them one after the other, or throwing them as a single mass by an artillery shell or airplane [2].
- ♦ Post deployment phase. At this stage a change in the topology occurs due to the change in the position of the nodes affected by the moving obstacles in the field deployed in it, which impedes the reachability, and consequently a shortage of the remaining energy and a defect in the results [2].

- Redeployment of additional nodes. To replace faulty or broken nodes, or to account for changes in task dynamics [2].

I.6.2.Underground WSNs

In this type, the sensor nodes are buried underground, in a mine, or in a cave to monitor underground conditions. Additional sink nodes are used that are placed above the ground to serve as a mediator for transmitting information to the basestation from the sensor nodes. This type of network is more expensive than the ground type due to the equipment it needs, the method of deployment and maintenance in case of failure. Sensor nodes that are used underground are considered expensive and expensive due to the features that they must have from a reliable connection under any circumstance or place in which they are such as rocks, soil, water and others [2].

The underground environment poses a challenge for wireless communication because the signal is lost at any moment. Careful planning is critical to deploying a WSN underground given cost and energy. Energy is a worrying element in this type of network. After publishing the nodes, it is difficult to replace it or even recharge its battery if it runs out [2].

I.6.3.Underwater Acoustic Sensor Networks (UASNs)

This technology has provided opportunities to explore the oceans, so it has contributed to a better understanding of environmental issues such as animal life in the oceans, climate change and others. On the other hand, drones enhance underwater warfare by monitoring, taking measures against enemy mines after detecting them...etc [2].

Ocean monitoring systems are commonplace, given their use in the past decades. For example, traditional oceanographic data collection systems use individual equipment and do not communicate underwater. The process is done by collecting data and then sending it to a station that is either a vessel or on an onshore station by underwater communications by cables or by satellite. In this type of network, small size, inexpensive sensor nodes are used underwater as an alternative to this equipment. Sensing nodes are distinguished from conventional equipment by their network connection, and communication with each other underwater is via acoustics [2].

In underwater, the signals differ in their strength and weakness. Radio, for example, are characterized by their rapid weakness and intolerance over long distances, while optical signals can spread, but they can only travel for short distances as well. While the acoustic signals are strong enough to travel farther distances, unlike the previous optical and radio signals. Accordingly, we can say that acoustic communication is the ideal solution for underwater communication, despite its challenges as well [2].

Given the challenges facing this type of network, it is necessary to use sensor nodes that have the ability to adapt to the environment - underwater -, self-configuring, taking into account sufficient battery power as it cannot be replaced or even recharged it. To control the energy problem of underwater WSNs, efficient underwater networks and communication technologies must be developed[2].

I.6.4.Multimedia WSNs

To achieve the ability to monitor and track events in the form of multimedia such as imaging, audio, and video, a type of WSN dedicated to these media has been proposed. The components of these networks are a set of sensor nodes equipped with cameras and microphones and are characterized by their low cost.These nodes are interconnected with each other by wireless communication, for the purpose of data processing and retrieval, compression and correlation. As for its deployment in the environment, it must be planned in advance -preplanned- to ensure comprehensive coverage. Multimedia WSN, like other networks, also has challenges, including the following [2]:

- The need for high bandwidth [2];
- Too much energy consumption [2];
- The need to provide QoS [2];
- Data compression and processing techniques [2].

To quickly deliver multimedia content such as an image or a video stream, high bandwidth is required, and this necessarily leads to high power consumption. This necessitates the development of transmission techniques that do not consume large amounts of energy and have high bandwidth at the same time. Among the challenges in this network as well, is the provision of quality of service, which is considered difficult due to the variable channel capacity, and the variable delay, but this does not mean not providing reliable content by striving to achieve a certain amount of quality of service[2].

I.6.5.Mobile WSNs

From its name, we can define mobile WSNs as a group of nodes that are able to move themselves, and interact with the physical environment. We can distinguish between static and mobile sensor nodes by the issues of each type, which we explain in the table below[2]:

Mobile sensor nodes	Static sensor nodes
• The ability to sense, communicate, and compute	4. The ability to sense, communicate, and compute
• It has the ability to reorganize itself in the network	5. It has no ability to reorganize itself
• Data distribution is by flow using dynamic routing	6. Data is distributed using fixed routing

Tableau I-1: Mobile and static sensor nodes issues

In wireless networks, Mobility is a very useful addition for many reasons, including:

- ♦ Connectivity. The density of the WSN architecture is not requirement in this type of network thanks to the mobile nodes. Mobile components are able to handle even isolated areas, by easing restrictions on nodes deployment and redeployment, and on network connectivity. Therefore, we can adopt the sparse architecture of WSN [2].
- ♦ Cost. Mobile WSNs are inexpensive, as they can deploy only a small number of nodes. But the costly thing here is when trying to augment the nodes with mobility features, and to reduce the cost it is possible to attach sensors to the mobile objects that are in the sensing area (eg cars, buses, trains ...etc.) [2].
- ♦ Reliability. Due to the density of traditional static networks, reliability is at risk due to the large number of collisions and interference. In addition, the increase in hops affects the messages, as the number of the first -hops- increases the loss of the last - messages -. Therefore, mobile elements can be used as an alternative to fixed nodes by collecting data from the network with

single-hop transmissions directly. The benefit of this is to ensure that the message is not lost as well as reducing collision and contention [2].

Unlike static WSNs, WSNs have significant mobility challenges. Below we will try to explain this:

- Mobility-aware power management. Sometimes, knowing the mobility pattern further contributes to better detection of mobile elements. Sensor nodes can only react and operate if the mobile element is known to be within their transmission range, and if visit times are predicted or know [2].
- Reliable data transfer. Since there is the potential for few and scarcity of available contacts, we need to increase the number of messages that are properly transmitted to the sink. Furthermore, the movement of nodes during data transmission requires that the message exchange be mobility-aware [2].
- Mobility control. If it is possible to control the movement of the mobile elements, it is necessary to determine how the nodes in the network are visited. This means that, to improve network performance, the sojourn time or speed, and path of the mobile nodes must be specified [2].
- Other challenges include localization, deployment, control and navigation, coverage, data processing and maintenance [2].

I.7.Characteristics of Wireless Sensor Networks

WSN has a set of characteristics that make the deployment of the network efficient. Below, we try to described some of it as follows:

- **Low cost:** The low cost of the sensor, is one of the essential causes of using WSN. In this last, normally we use hundreds or thousands of SN to measure any physical environment. Therefore, the overall cost of the network be lower [5].
- **Energy efficiency:** Energy in WSN is utilized for various reason like computation, correspondence and storage. Sensor node consumes more energy, which if it runs out become unusable because there is no option to recharge it [5].
- **Computational power:** Sensor nodes has limited computational capabilities, because cost and energy must be considered [5].

- **Dynamic network topology:** Since the depletion of the sensor node battery leads to the node failure and thus the network failure, the dynamism of wireless sensor networks allows the addition of new nodes to continue communication and achieve the network mission [5].
- **Distributed sensing and processing:** the enormous number of sensor node is distributed consistently or randomly. WSNs every node is equipped for collecting, processing, aggregating and sending the data to the sink. Therefore, the distributed sensing provides the robustness of the system [5].
- **Self-organization:** the sensor nodes in the network should have the capability of organizing out themselves as the sensor nodes are sent randomly in an unattended environment. The sensor nodes have work in coordinated effort to adjust themselves to the distributed algorithm and form the network automatically [5].
- **Small physical size:** Due to the small size of sensor nodes, its energy is restricted which makes the correspondence capability low [5].

I.8.Applications of Wireless Sensor Networks

WSN profit by the advances in computing innovation, which prompted the creation of small, wireless, battery powered, smart sensor nodes. These nodes are dynamic devices with computing and communication abilities that not only does it take samples from the real world, it can also filter, share, merge and act on the data it senses [6].

- **Area monitoring:** In area monitoring, sensor nodes are distributed over an area in order to monitor some phenomena (temperature, pressure, etc.). When the sensors detect the event being monitored, it is reported to one of the base stations, which then takes the appropriate action [3].
- **Health applications:** Wireless medical sensor technology has offered enormous advantages to medical services applications, for example, persistent patient observing, mass-causality calamity monitoring, huge scope in-field clinical checking, emergency response, etc [7].

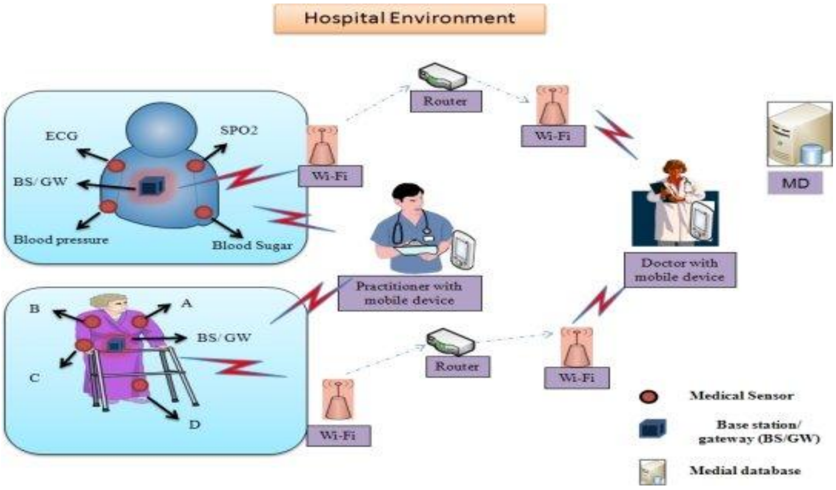

Figure I-7: Patient-monitoring-using-a-wireless-medical-sensor-network-in-a-hospital-environment

- **Transportation:** Real-time traffic data is being gathered by WSNs to later feed transportation models and alert drivers of congestion and traffic issues [3].
- **Military Applications:** WSN can be an indispensable piece of military Command, Control, Communications, Computing, Intelligence, Surveillance, Reconnaissance and Targeting (C4ISRT) frameworks [7].

A portion of the military utilizations of sensor networks are checking friendly forces, gear and ammo; war zone observation; battle damage assessment; and Nuclear, Biological and Chemical (NBC) attack detection and surveillance [7].

I.9.Conclusion

Wireless sensor networks have gained great interest on the part of researchers recently, due to the advantages and areas that have swept them.

In this chapter, we attempt to summarize the most important information about wireless sensor networks. Understanding these basics helps us understand and solve our topic.

In the next chapter, we will try to elaborate on the topic of localization of wireless sensor networks. In it we will list the previous algorithms and methods for solving this problem. Hence, getting a new method based on these experiences.

Chapter2

Wireless Sensor Networks Localization

II.1.Introduction

Localization in WSNs aims to estimate the locations of unknown nodes in order to be closer to the actual nodes. We can distinguish between localization algorithms by measuring their performance which includes accuracy level, error rate and computation cost. The accuracy of the algorithm is greatly affected by the position of the sensor node, if the SNs are scattered in areas with many obstacles, and thus the positioning accuracy is reduced [1].

In this chapter, we will discuss about the types of localization algorithms, and examples of them that enable us to choose the best algorithm to improve its performance and give better results in accuracy.

II.2.Localization Network Types

On general, localization algorithms are divided into range-based and range-free.

Below, we will try to talk about these two classes of localization, with examples of some algorithms in each.

2.1 Free-based

In this localization type, the relationships between the number of hops and the distance between two anchor nodes are inferred, as opposed to range-based in which the estimated distance is that between the SNs [1].

There are many algorithms for this type of localization. For example, we find an amorphous algorithm, the Centroid algorithm, and the distance vector algorithm (DV-HOP), which we will discuss later...etc. In common, these algorithms are simple to implement, low cost, and have strong network validity and no need for additional hardware [2].

2.2 Range-based

The distances and/or angles between two SNs are estimated in the range-based localization method by making use of the well-positioned anchor nodes. To achieve a distance estimate in this type, there are several ways, such as angle of arrival (AoA), time of arrival (ToA), time difference of arrival (TDoA) or received signal strength index (RSSI) [1].

II.3.Related work

In the context of improving localization outcomes, many studies have focused on range-based improvement. An attempt has been made to improve the accuracy of several proposed methods, such as least square estimation, and gradient descent models. Recently and in addition to the above, swarm intelligence (SI) methods have been proposed, such as Firefly Algorithm (FA), butterfly optimization algorithm (BOA), and Particle Swarm Optimization (PSO). The latter are known as heuristic methods whose aim is to search for an optimal solution to a problem, by trying to simulate social structures [1].

II.3.1.PSO

PSO differs from other SI methods in that it can find a more accurate answer in the least amount of time. This feature, which enables it to accurately and quickly estimate the positions of unknown nodes, qualifies it to estimate the locations on WSNs [1].

In addition, PSO has the advantage of having fewer computations to solve any problem, making it better handle the limited resources of WSNs [1].

So, in these steps, we will show how to apply the PSO method to estimate unknown node locations from the distances between the anchor nodes to these nodes -unknown- and the known node positions, they are as follows [1]:

(1) An anchor node sends its RSSI and position, then unknown nodes use this information to estimate the distance between them and the anchor node.

(2) To estimate the positions of the unknown nodes, the middle position or centroid between all used anchor nodes is calculated. This point is used as the initial estimating position.

(3) At random, we assign an initial position (xk) and velocity (vk) for each particle around the centroid in the previous step 2.

(4) We start applying PSO. We take each particle and calculate its fitness function by applying equation (1) shown below:

$$F(x_k(t)) = \frac{1}{m}\sum_{i=1}^{m}\left|\left(\|x_k(t) - (x_{Ai}; y_{Ai})\| - d_{Ai,Uj}^{est}\right)\right|, \qquad (1)$$

m: Number of anchor nodes (here, m ≥ 3);

xk(t): Coordinates (x, y) of the kth particle in the tth iteration;

destAi,U j is the estimated distance between Ai and Uj (the j th unknown node);

and (xAi,yAi) is the i th anchor node's position.

(5) Determine the optimal particle position in this iteration (pbk) and determine all particles' optimal positions (gb).

(6) Update each particle's position (xk) and velocity (vk) according to Eqs. (2) and (3).

$$V_k(t+1) = w(t) \times V_k(t) + cof_1 \times r_1(pb_k - x_k(t))$$
$$+cof_2 \times r_2(gb - x_k(t)), (2)$$
$$\boldsymbol{x_k(t+1) = x_k(t) + v_k(t+1)}(3)$$

vk(t): kth particle's velocity in the tth iteration; pbk: Optimal position found by the kth particle;

gb: Optimal position found by PSO; cof1 and cof2: Acceleration factors;

r1 and r2: Random numbers in the range of [0, 1]; And t is the current number of iterations.

(7) Repeat Step 4.

(8) When PSO stops, the positions gb are the unknown nodes' estimated positions.

II.3.2.DV-hop

The DV-Hop algorithm is characterized by simplicity, feasibility, and good coverage, which made it one of the most popular and widely used localization algorithms. This algorithm estimates the locations of unknown nodes in the sensor network using a set of anchor nodes whose locations are determined by GPS. However, there remains the possibility of error in estimating the distance between the anchor nodes and the unknown nodes, for several reasons, the most important of which is the error in estimating the distance hop of the anchor nodes. Therefore, the DV-Hop algorithm is often combined with at least another algorithm to improve localization accuracy and thus obtain better results [3].

Figure 1, below, is a concrete indication of the hop distance principle.

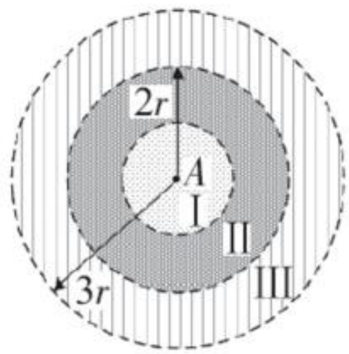

Figure II-1: The principle of hop distance

A: Anchor node **I, II and III:** First, second and third hop restricted regions of anchor node A.

r: Communication radius

In the process of localizing a WSN node, the DV-HOP algorithm estimates the average hop distance. It is divided into three stages [3]:

(1) The anchor node transmits both the position and hop information of the network to all WSNs. 0 is set as the initial hop value, then the location node records the minimum hop value of each anchor node, then the hop value is forwarded to the adjacent node after it is incremented by 1. Here, and by the distance vector exchange protocol, all nodes have the minimum hops between them and the anchor nodes.

(2) It is possible to calculate the average actual distance between the anchor nodes among them, by recording the information of the position of each node of these nodes and the distance between it and the other anchor nodes by stage A.

$$\overline{d_{DV-HOP}} = \frac{\sum_{i \neq j} \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}}{\sum_{i \neq j} h_{ij}}, i \neq j$$

(xi, yi) (xj, yj): Position coordinates of node i and node j respectively

hij: Number of hops between anchor node i and anchor node j

Then, the average hop distance as the correction value is broadcast throughout the whole WSNs. When the first correction value is received, the pending node will save it and then no longer receive other correction values. According to the correction value, convert the minimum hop count between the node and anchor node to the distance of them;

(3) When the location node gets three or more than three anchor nodes, the nodes to be located can be obtained by three or multilateral measurements.

II.3.3.Trilateration

Trilateration is one of the important algorithms in wireless communication that enables us to obtain satisfactory results.

This algorithm works on the basis of the technique of intersection of three circles and the point of intersection, which is the desired point, and we assume from it that we know the distance from point A, and this means in the circle that the radius is a point represented.And we know the distance from two other points called point B and point C, so they form for us three circles with the centers of the following points A.B.C, so we get the intersection of these three circles at one point and this point is the place that must be known.

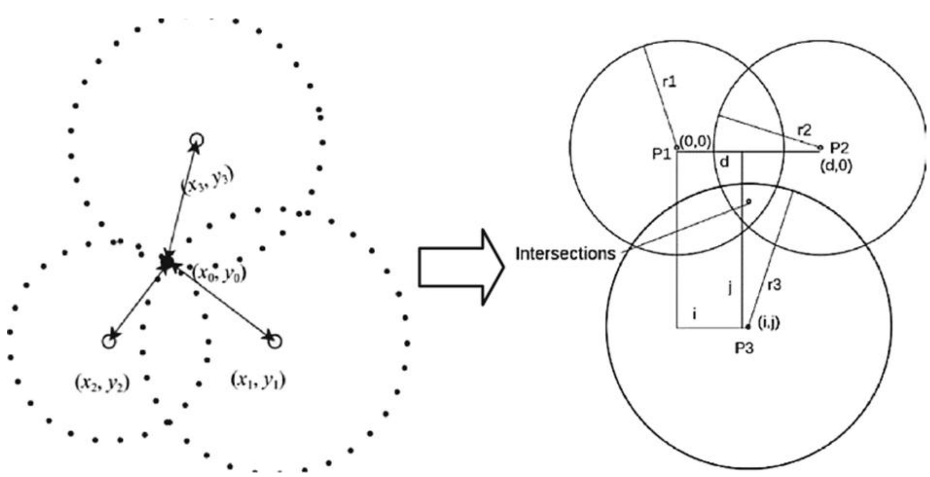

Figure II-2: The principle of trilateration localization

To solve this problem, we should find the solution with a mathematical way by formulating the general equation of the sphere as shown below:

$$d^2 = x^2 + y^2 + z^2$$

It has been:

$$d^2 = (x - x_a)^2 + (y - y_a)^2 + (z - z_a)^2$$

We obtain an equation sentence with three unknowns and three equations that can be solved by any mathematical method:

$$d_a^2 = (x - x_a)^2 + (y - y_a)^2$$
$$d_b^2 = (x - x_b)^2 + (y - y_b)^2$$
$$d_c^2 = (x - x_c)^2 + (y - y_c)^2$$

After arranging it will produce a new equation:

$$x(x_c - x_b) + y(y_c - y_b) = \frac{\left(d_b^2 - d_c^2\right) - \left(x_b^2 - x_c^2\right) - \left(y_b^2 - y_c^2\right)}{2} = v_a$$

$$x(x_a - x_b) + y(y_a - y_b) = \frac{\left(d_b^2 - d_a^2\right) - \left(x_b^2 - x_a^2\right) - \left(x_a^2 - y_a^2\right)}{2} = v_b$$

We solve equation 3 and 4 to get the unknowns x and y:

$$y = \frac{V_b(xc - xb) - V_a(xa - xb)}{(ya - yb)(xc - xb) - (yc - yb)(xa - xb)}$$

$$X = \frac{V_a - y(yc - yb)}{(xc - xb)}$$

After obtaining (x, y) the presence of signal propagation must be taken into consideration, here the error rate is almost zero, to surround the three anchors with the nodes whose occurrences you want to know.

There are anomalies that can fall into when we are not lucky, and we find three anchors, which are the presence of tow anchors or one anchor, and here the solution is as follows:

II.3.3.1.Two anchors:

In the presence of tow anchors, it results in the intersection of two circles. Therefore, for the presence of the solution, we have to solve a sentence of an equation with two unknowns, which makes us get two points, including two solutions, one of them is true and the other is false.

II.3.3.2.One anchor:

In the event that there is a single anchor next to the node in this case, the solution becomes a solution of a circle equation, which makes the error rate greater than the previous two cases. The solution is present in that existing circle, and of course it is better than we do not have any anchors.

II.3.4.Variable Neighborhood Search algorithm (VNS)

II.3.4.1.Definition

VNS is a metaheuristicalgorithm that help us to reach the best solution in a quick and easy way to implement the latter uses two methods that complement each other, condensation and diversification, which aim to:

- Improving the current solution
- Expand the area of solutions explored

II.3.4.2.How does the VNS algorithm work?

VNS works by the following way:

- S is the set of variables from which to extract the optimal solution.
- N(s) is the set of solutions obtained from group S.
- The current solution S is replaced by a better one S'∈ N (S) The search remains until we get the best solution among the solutions, then the process stops.

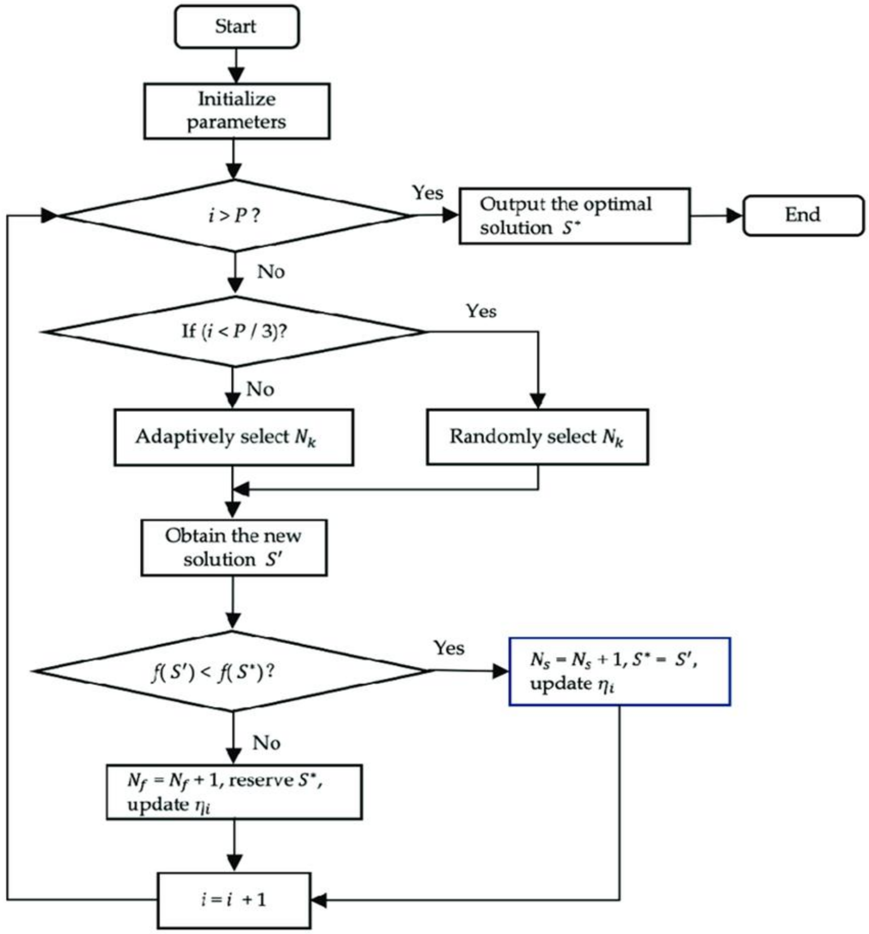

Figure II-3: VNS flow chart

II.3.4.3.The Local Search function:

The main objective of using metaheuristics is to obtain an improvement for the current solution so that it is the last and best solution, the local search will perform a set of transformations in order to improve the solution

- N (S) is the set of solutions that we get from the solution S by transformations again,
- N(S) is the neighborhood of S, we replace the solution S with a better solution,
- Where S ∈ N (S) stops the process when we do not find a better solution than the one in the neighborhood.

```
Input: S
Input: N
Let imp ← true
while imp = true do
    imp ← false
    foreach S′ ∈ N(S) do
        if S′ better than S then
            S ← S′
            imp = true.
        end
    end
end
return S
```

Figure II-4: Local Search algorithm

After completing the full exploration of the neighborhood N(s), we say that the local search has found the optimal level in this transformation.

II.3.4.4.The Shake function:

The function "shake" generates a set of solutions N from X .

II.3.4.5.Diagram of how VNS works:

This is a schematic diagram of how Variable Neighborhood Search works that shows us how easy it is to do.

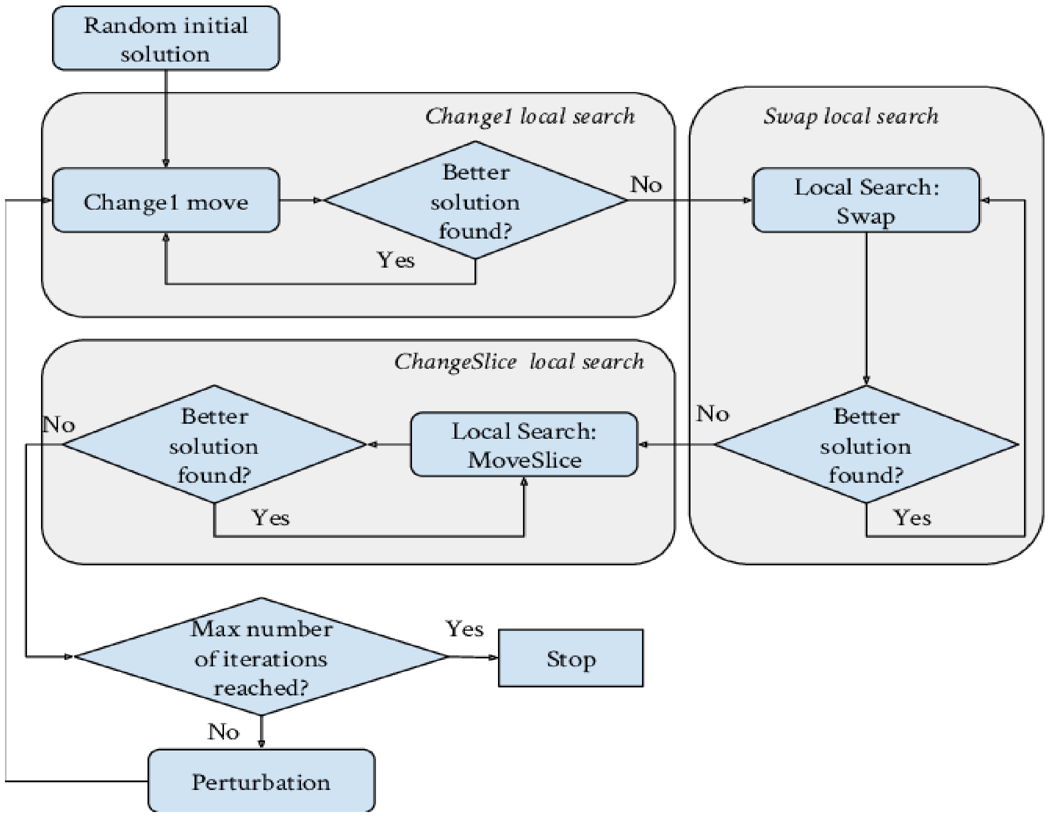

Figure II-5: Chart of the variable neighborhood search algorithm

II.1.Hybrid algorithm Trilateration and VNS

In a hybrid algorithm, two or more algorithms solve Collaboration and cooperation in introductory problems. Check types of hybridization, an algorithm that is not embedded in an identical algorithm for the sake of optimal coefficients of another algorithm, an algorithm that is different from algorithms All that is mutation and formation through uses to improve another algorithm is a hybrid structure. In what excites this Nature, the Hybrid algorithms can be divided into two categories:

1-Single-use hybridization

2-Multipurpose hybridization

In this category, a main algorithm is used to solve the problem, while the sub-algorithm is applied to settle the parameters of the main algorithm. As an example, the Particle Swarm Algorithm (PSO and VNS) can be applied to find the optimal value of the mutation rate in Genetic Algorithm (GA). Hereby the particle swarm algorithm does not solve the problem, but mainly helps find better solutions by finding the optimal setting for best performance. Hyper-heuristic algorithms can be considered as a kind of hybrid methods. In hyper-heuristic methods, the parameters are selected (by a sub-algorithm or via a learning mechanism)

There are two steps involved in this case, the first algorithm acts like the global optimizer while the second algorithm performs the local search.

The first algorithm able to explore the exact position of the search node and when it fails due to lack of conditions. The second algorithm uses extensive local searches to find the optimal solution and the closest in the neighborhood. A difficult problem with such an implementation is knowing when to switch to the second algorithm. Measures such as diversity should be incorporated to facilitate criteria for change. Therefore, he used the genetic algorithm as a global optimizer (the first algorithm is Trilateration), with the optimizer for Variable Neighborhood Search for local search (the second algorithm (VNS))

In this chapter, we tried to find a solution to help the Trilateration algorithm to reduce the error rate, as we know that this algorithm gives us a good result if we have all the conditions from enough anchors, that is, each node is surrounded by three points to find the exact location of the node and the signal strength that This makes the knot and the anchors attached to each other, so if we miss one of these conditions, we will feel turbulence and from it which increases the error rate. In fact, we proposed the Trilateration algorithm, which is based on the principle of the number of anchors, the arrival of signals, and the estimation of the distances between nodes to allow them to estimate their positions.

To help overcome the problem, we have incorporated a Neighbor Variable Search (VNS) algorithm, which we have attempted to embody in a localization technique that searches for the optimal solution in the vicinity. Therefore, here Trilateration technology helps to find the closest and best solution.

The main idea here is to use Trilateration technology in the first stage for accurate positioning, then in the second stage, the Variable Neighborhood Search (VNS) algorithm intervenes. The Figure II-6 below show a flowchart of the hybrid algorithm Trilateration and VNS.

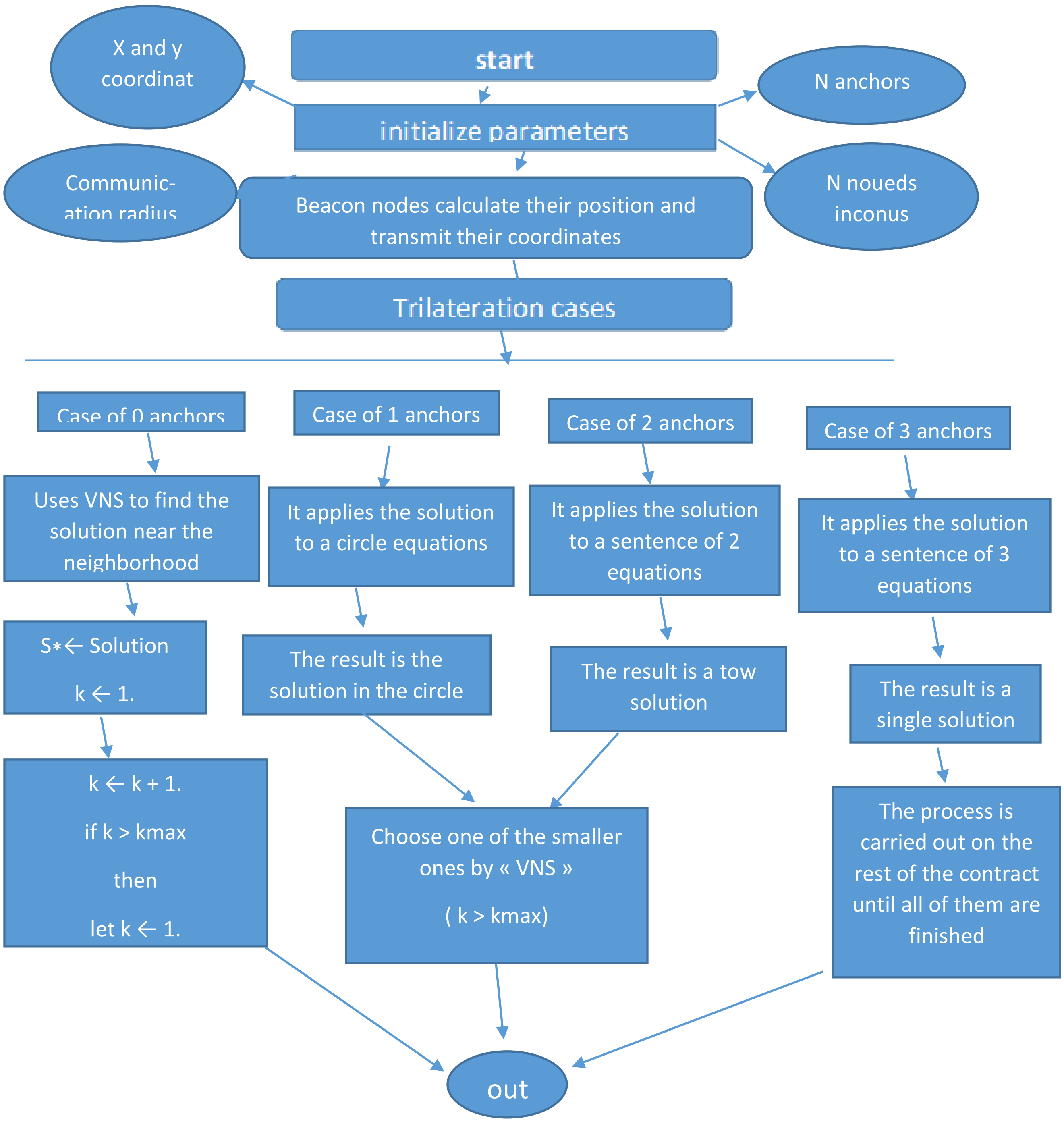

Figure II-7: flowchart of a hybrid algorithm Trilateration and VNS

Simply, the Trilateration technique is a mathematical technique in that the node location is calculated by calculating the distances from this node to a series of three geometric entities whose locations are known by solving the equation of the ball and it has to find the exact location of the required node, and thus this node also turns into anchors and here we need the stage The first only, the second issue when this node is surrounded by two geometric entities with known locations (tow anchors) here the solution is to solve the equation of the intersection of two circles which produces

Two solutions from which the program chooses a random solution, the third issue when the node is surrounded by a geometric entity known location (single anchors) Here the solution becomes a solution to the equation of a circle, so the solution is located in that circle, which produces a set of solutions and the choice is random (one of those solutions), Here the metaheuristic technique called the Variable Neighborhood Search (VNS) intervenes in the search for the optimal solution, the closest and the least wrong, and that is by comparing a solution to a solution in the solutions in the circle and taking the smallest solution and considering it the optimal solution. As for the fourth issue we have when the node is not surrounded by any anchors, here the value of the number of solutions is large, and so does their percentage, and therefore VNS technology intervenes to find the closest solution and the lowest error rate, and consider it the optimal solution found in the set of solutions.

II.2.Conclusion

So far, localization finds a problem in determining the exact location, especially in wireless sensor networks, but thanks to the algorithms and the difference between each of them from the other, it helped them a lot in developing and achieving results.

In this chapter, we talked about the technique of localization and some algorithms that are used to locate nodes, such as DV-hop and PSO, then we touched on the algorithms that we worked on in this research, which are Trilateration and Variable Neighborhood Search (VNS) and the way they work.

In the next and the last chapter, we try to discuss the application, VNS, and Trilateration results, and how parameters influence them.

Chapter 3

Implementation, Results and Discussion

III.1.Introduction

In the previous chapter we talked about some localization algorithms, which are divided into range-free and range-based, all with the aim of locating unknown nodes. Initially, localization is done using these methods, and to enhance accuracy, other methods are used, such as meta-heuristics. In our research, we will adopt two methods, one of which is the trilateration or 3-Anchors based localization approach, and the other is the variable neighborhood search (VNS).

To achieve the goal of using localization algorithms, we created a laboratory environment to test our chosen methods using a variety of different parameters. The main objective here is to get an overview of the results of these localization algorithms, and their effectiveness in finding the true locations of the unknown nodes, or even close to them, and will the difference in parameters affect localization errors? and how's that? Finally, we discussed the comparison between these two algorithms in terms of their accuracy.

III.2.Environment Implementation:

III.2.1.The programming language used:

We chose MATLAB (MATrixLABoratory), as an implementation environment for our application. MATLAB is a high-level scientific computing language and interactive environment for application development, data visualization and analysis, and numerical computing.

We use MATLAB® 2016 to solve scientific computing problems faster. The MATLAB language allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

It allows rapid development and execution with respect to MATLAB language we can program and test algorithms faster than with traditional languages because it is not necessary to perform low-level programming tasks, such as declaring variables, specifying data types, and allocating memory

III.2.2.Hardware Resources

We developed our application using MATLAB language version R2016a on Windows 10 64 bit, 6.00 GB of Ram., Intel(R) Core(TM) i5-5200U CPU @ 2.20GHz processor.

III.3.Trilateration & VNS methods

The trilateration method works with high accuracy if one unknown node is connected to three or more anchor nodes (provided that the node is within this anchor radius), in this case, the localization error is zero. Thanks to this feature, this node becomes a reference and can be relied upon to find other node locations nearby. But if there are unknown nodes surrounded by less than 3 anchor nodes, the method will always give us different probabilities. Besides the trilateration method, we use the variable neighborhood search algorithm.

Initially, our intention in this work was to combine these two methods, to take advantage of the accuracy of trilateration on the one hand, and meta-heuristics for variable neighborhood search on the other, but perhaps this will be as a future work.

III.4.Simulation results

To evaluate and demonstrate the performance of our chosen localization methods, we will use computer simulations in the MATLAB platform. First, we will run a simulation of the random method, then we will move to simulating the trilateration method to get accurate results in the cases of 3 anchor nodes and narrow the search space in the cases of nodes less than that (3). Finally, we will simulate the variable neighborhood search method, which will have better results in the case of few numbers of anchor nodes or the smallness of the range.

Because the simulation results change with the change of parameters that play an important role in determining the location error. In this section, we will rely on a feature-by-feature analysis to ensure the validity of the results and the effectiveness of the localization methods used.

We will now show the experiment area which will be a regular square grid topology with a fixed size of 50 * 50 m2.

First, we will fix the parameters of the algorithms, so that the number of anchor nodes is A=2, the connectivity range is R=25, and the sensor nodes N will be changed from 10 to 100 in the 2D field.

In Figure 3.1 an example network is shown with N=20, A=5, and R=20, the nodes being randomly deployed. The green spots represent unknown nodes, and the bleu spots represent anchor nodes.

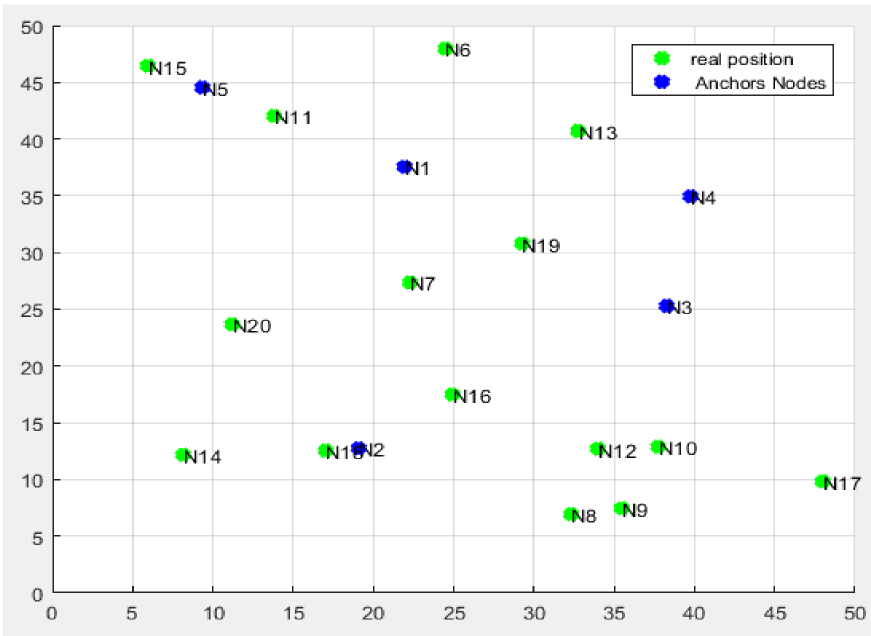

Figure III-1: Simulation example of random WSN with 20 nodes

Second, the variable parameter in this case will be the number of anchor nodes, which will be between 2 and 30 nodes, and we randomly deploy 50 sensors while keeping the rest of the algorithm's parameters.

Finally, we will change the connectivity range R which will be in the range between 10 and 50. Then randomly deploy 20 sensors, and 5 anchor nodes while keeping the rest of the algorithm's parameters.

The results appear as shown in the figures below.

III.4.1.Simulation Results when changing the number of deployed nodes

- **First example**

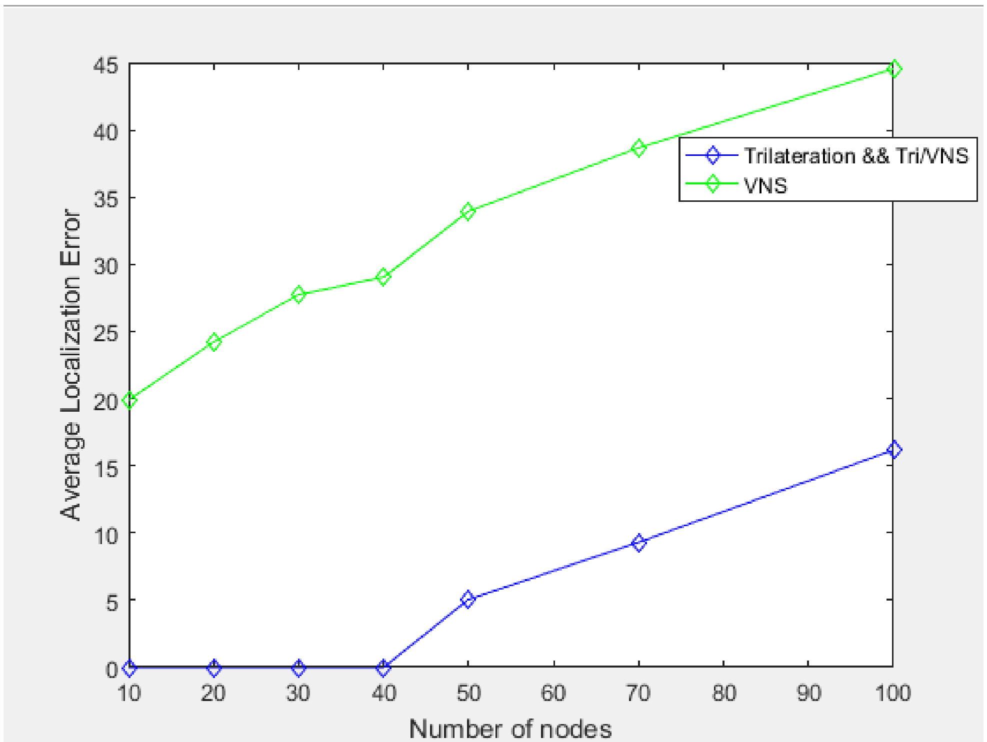

Figure III-2: Trilateration & VNS & Tri/VNS localization error with R=30, A=5

Through the experimental results, we note that the hybrid method is similar to the results of the trilateration algorithm and its accuracy decreases with the increase in the number of nodes in the field. The graph represents the average error in terms of the number of nodes, and it shows that it increases significantly when the number of nodes exceeds forty nodes after it was set to zero. This increase in error occurs because initially only a few nodes and five anchor nodes are enough to find the locations of these nodes with trilateration, which is superior to VNS in this case. We note that the latter -VNS- is also affected by the number of nodes, the higher their number, the lower the localization accuracy.

- **Second example**

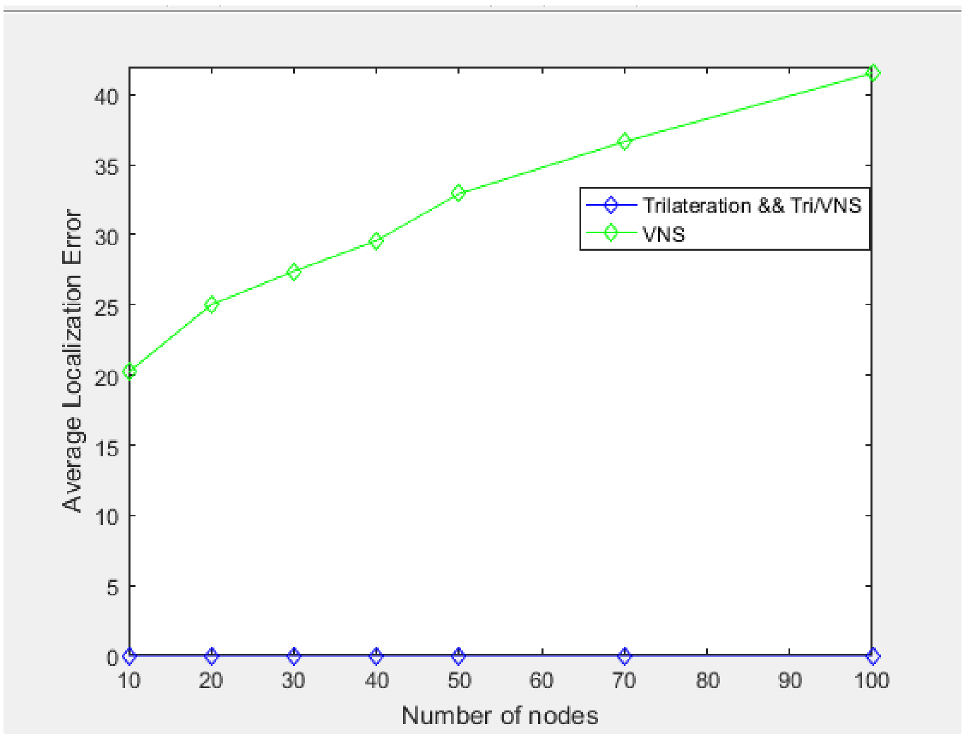

Figure III-3: Trilateration & VNS & Tri/VNS localization error with R=50, A=7

The results of the hybrid and trilateration method are the same in this case as well, but it is accurate this time, and this is shown by the localization error, which remained at zero despite the increase in the number of nodes. Access to all anchor nodes thus converting each unknown node surrounded by three anchor nodes to a new anchor node.

As for VNS, we notice that it is greatly affected by the number of nodes, as the increase of the latter was sufficient to increase the error and consequently the lack of localization accuracy.

- **Third example**

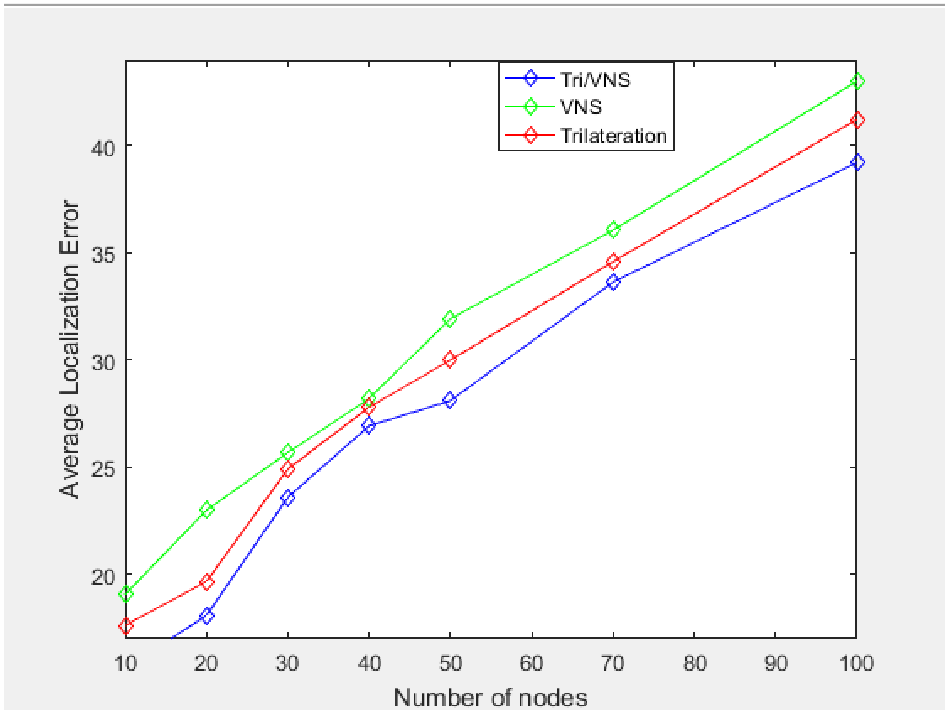

Figure III-4: Trilateration & VNS & Tri/VNS localization error with R=20, A=2

In this example, we notice that both the VNS, trilateration curves and the hybrid method are increasing due to the increase in the number of nodes and thus the increase in the localization error, due to the fact that the number of anchor nodes used in this case - two nodes - is very few in addition to the small connectivity range, which hinders the process of reaching anchor nodes and thus poor localization accuracy.

III.4.2.Simulation Results when changing the number of anchor nodes

- **First example**

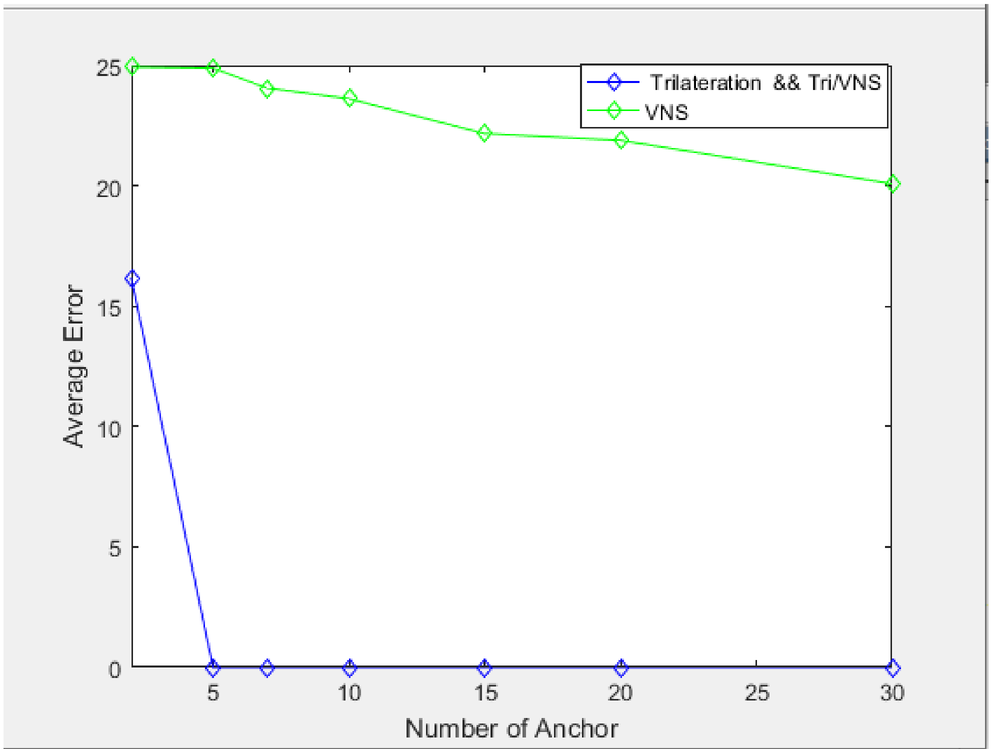

Figure III-5: Trilateration & VNS & Tri/VNS localization error with R=30, N=50

As we mentioned previously, the trilateration algorithm depends on the anchors, thus increasing the number of the latter gives more accurate results in determining the locations of unknown nodes. Even if there are less than five anchors, we will notice less localization error because the probability circle is small. Through the graph it appears that the localization error is at its peak when there are less than 5 anchor nodes and then decreases to reach zero after each increase in the number of these nodes.

Unlike the trilateration method, we notice that the influence of anchors on the VNS algorithm is minimal. It is shown in the curve that the localization error reaches a peak of 25 in the case of two anchor nodes, and then starts decreasing gradually by a very small percentage as the number of anchors increases. In the case of combining the two algorithms, we obtain the same results and accuracy of the trilateration method.

- **Second example**

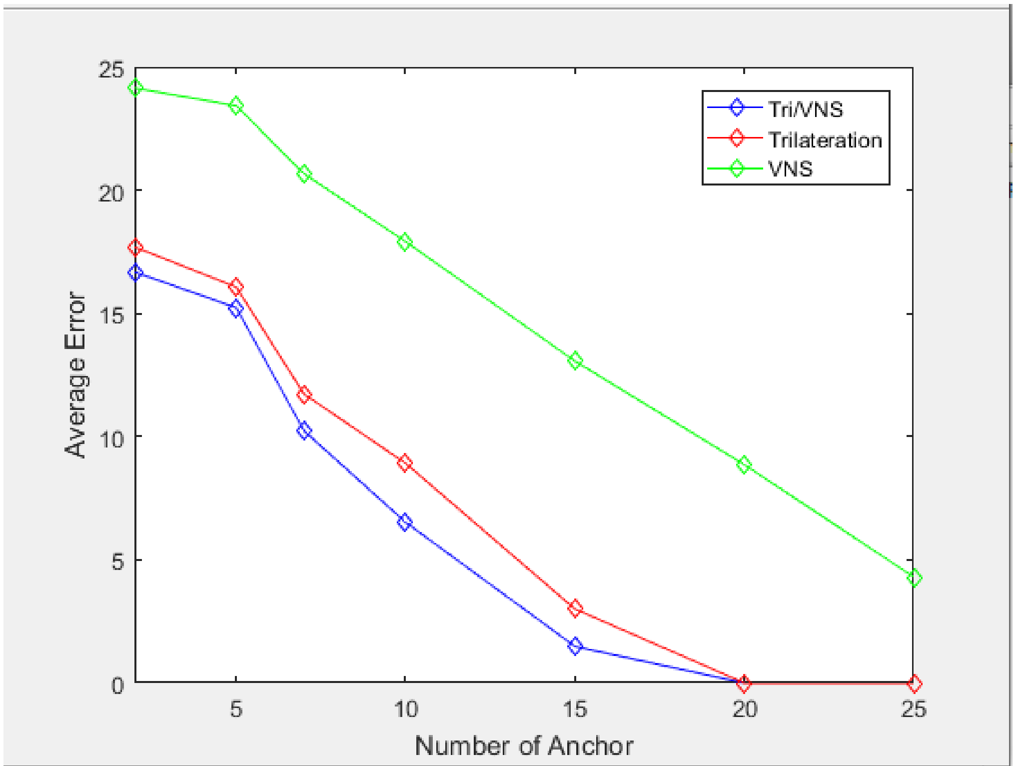

Figure III-6: Trilateration & VNS & Tri/VNS localization error with R=20, N=30

In this case, the curves of the three methods converge, and we notice that as the number of anchor nodes increases, the error decreases, that is, the localization accuracy is greater. Both the hybrid method and trilateration after the number of anchors greater than 20 decompile to zero due to the convergence of the number of anchor nodes from the unknown nodes. As for VNS, we notice that its curve also decreases with the increase in the number of anchor nodes, reaching less than 5 after it was greater than 24.

- **Third example**

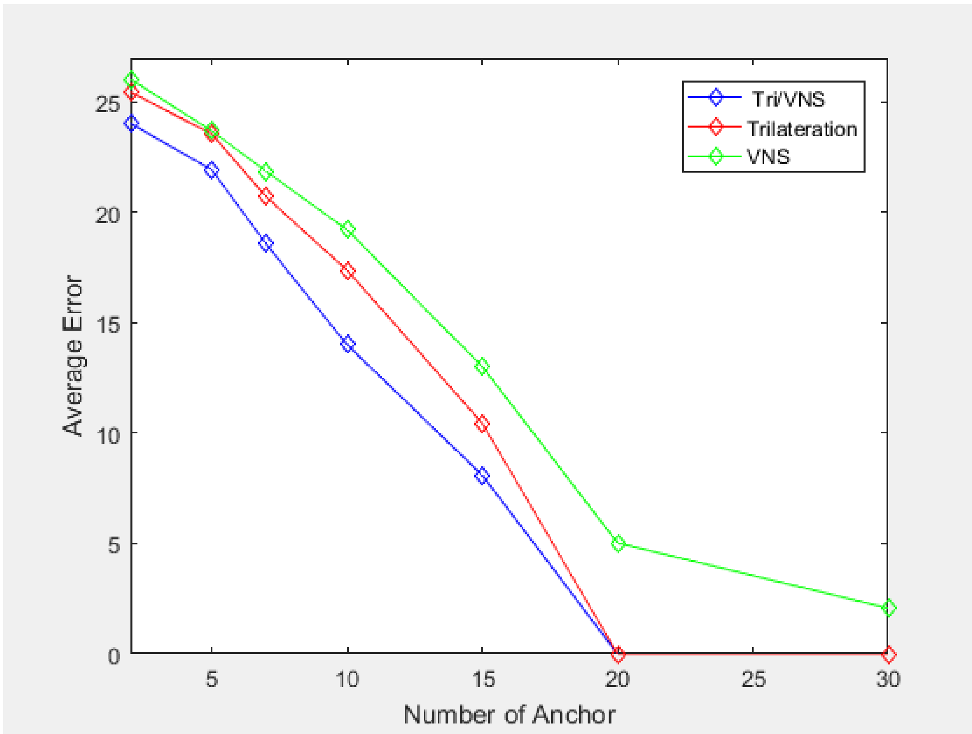

Figure III-7: Trilateration & VNS & Tri/VNS localization error with R=15, N=40

The three curves in this case appear very close to the previous one, and the error returns to zero in both the trilateration and the hybrid methods when the anchor nodes reach 20, while the curve of the VNS algorithm decreases to less than 5 when the number of anchor nodes reaches 30. As we mentioned Previously, the smaller the error, the more accurate the localization.

III.4.3.Simulation Results when changing the connectivity range

- **First example**

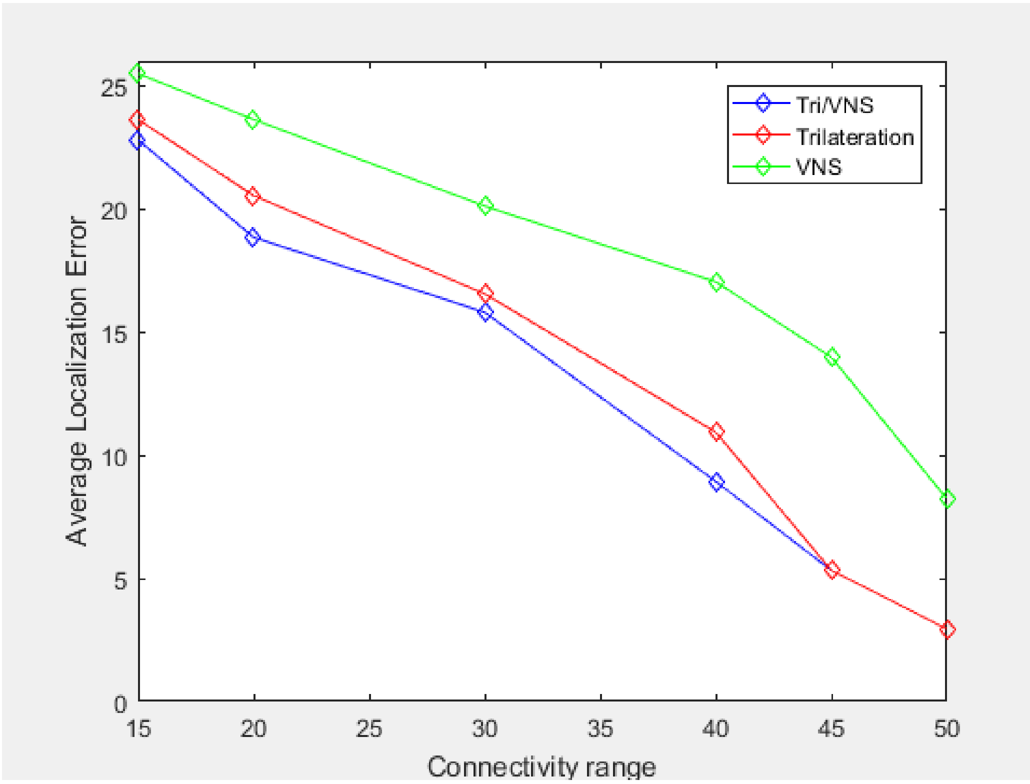

Figure III-8: Trilateration & VNS & Tri/VNS localization error with A=5, N=50

The localization error and its accuracy are affected by the connection range, as we note that the greater the latter, the smaller the error, due to the ability of the nodes to reach the largest number of anchor nodes as the range increases. We also note that both the trilateration method curves and the hybrid method have the same results whenever the value of the range exceeds 45 to reach less than 5 of the localization range. As for the VNS, it also decreases to a lesser degree than the previous two methods, reaching less than 10 when the range reaches 50.

- **Second example**

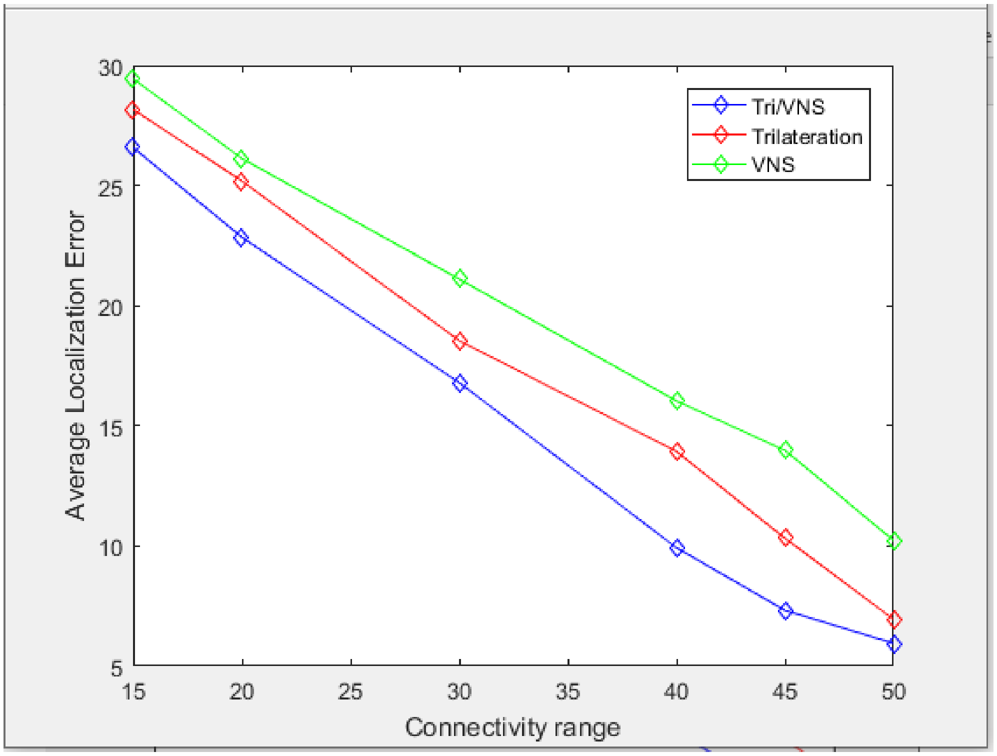

Figure III-9: Trilateration & VNS & Tri/VNS localization error with A=7, N=30

In this case the three curves converge more than the previous case, because the parameters used here are larger, since the number of anchors used is 7 with 30 unknown nodes. Therefore, we observe a decrease in the localization error with each increase in the range, because the increase of the latter - the range- leads to an expansion of the coverage area of the sensor node and thus an increase in the number of anchors adjacent to the unknown nodes.

- **Third example**

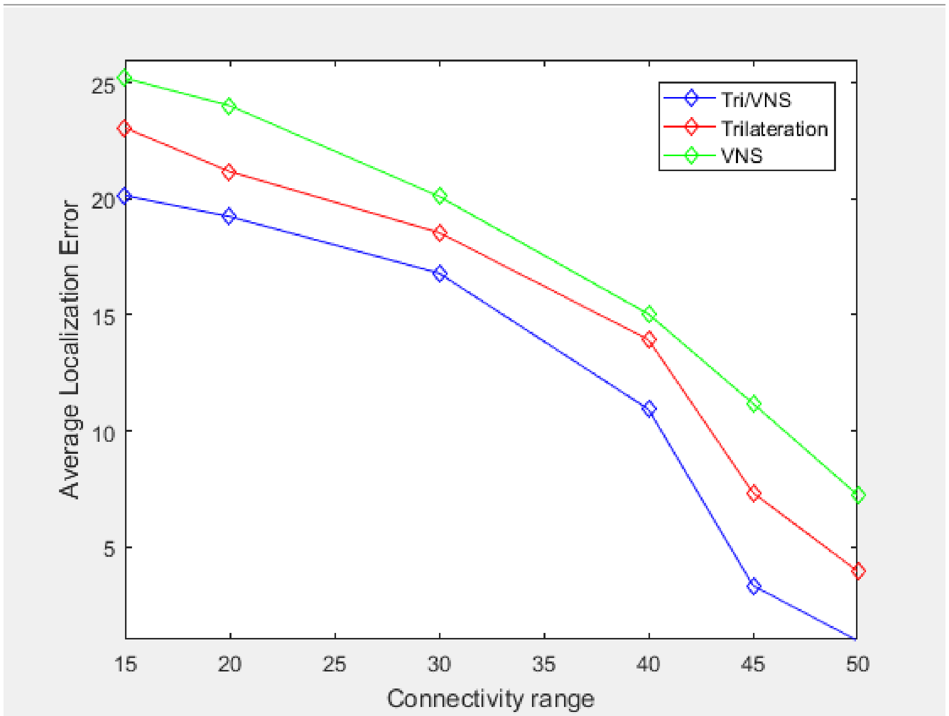

Figure III-10: Trilateration & VNS & Tri/VNS localization error with A=5, N=20

In this case the hybrid method succeeded in reaching a localization error of 0 at a range value of 50, due to the number of anchors used 5 in a few of the 20 unknown nodes which enabled a lower error and thus greater accuracy.

III.5.Conclusion

This chapter and the research as a whole aim at what the rest of the localization algorithms aim for, which is to find the true locations of the unknown wireless sensor nodes. These algorithms differ in the way they work, but they share the main goal of reducing the localization error between the real and estimated positions of the unknown nodes. Localization results for classical methods vary and are somewhat acceptable, but recently, meta-heuristic methods have been highlighted to improve these results. In our research, we crossed between the mathematical method - trilateration- and the meta-heuristic method - VNS- and the results were good compared to the results of each algorithm separately. In the beginning and after deploying the nodes, the trilateration algorithm is applied, which gives us the real position of the unknown nodes surrounded by three anchor nodes - which also become an anchor -, and gives us two possibilities in the case of two anchors, VNS intervenes to weight the closest and optimal solution between the two possibilities, and in the case of a node One where the solution is to solve the equation of the circle and we also use VNS to choose the appropriate location, the last case is there is no anchor and the solution will be the stochastic method.

The VNS algorithm selects one of the solutions adjacent to it and compares it with the current solution. If it is smaller than it, it keeps it based on the current solution, and if it is larger than it, it moves to the next solution, and so on.

Each algorithm had an impact on the localization results along with the parameters used such as anchor nodes, deployed nodes and connectivity range.

General Conclusion

The large size of WSNs, which can exceed thousands of nodes, makes GPS very expensive to use. Not only that, but GPS cannot find accurate results in indoor environments. Otherwise, in the case of a dense network, it is impossible to manually configure the site reference. This brings us to the problem of finding alternative solutions to GPS. Programmers and researchers have tried to find alternative solutions. Finding unknown sensor nodes is one of the wireless problems and one of the programmers' interest, especially in the problem of localization. Despite all the efforts made by programmers and technology scientists, it still suffers from some shortcomings in terms of Energy storage and its long life, as well as not specifying the exact locations of the contract, hence the idea of using localization techniques to facilitate the matter and make it less expensive. These algorithms use one or both parameters, the beacon node and the anchor node, because their current locations are known. These last two give some certainty the information that enables the rest of the nodes to know their locations. This does not mean that it does not face problems, as sometimes it is not able to determine the exact locations, and this is what made us engage in this confrontation and search for solutions.

In our research, we proposed a technique of integrating the trilateration algorithm with VNS to help some of them locate the largest number of nodes sites for wireless sensor networks when the first algorithm is unable to solve the problem of using the localization technique. The proposed protocol depends on the communication between the nodes with known locations and the signal strength of this nodes when the node is surrounded by three anchors It is precisely located, and when some conditions are missing, an imbalance occurs in the percentage of positioning, and it has an increase in the percentage of error, which made us think about finding an algorithm that helps it reduce the percentage of error when we decrease one of the conditions of the first algorithm

Among the developments that we aspire to in the future, we plan to find a way to improve the exact error calculation with precision, and the biggest goal is to find the exact location of the node without the intervention of any anchors.

We aim also to have better accuracy in determining the location of the contract and using a mechanism to reduce the spread of errors.

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