

**TURKISH REPUBLIC
ERCIYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES
DEPARTMENT OF COMPUTER ENGINEERING**

**A COMPARATIVE STUDY OF LOCALIZATION
ALGORITHMS FOR WIRELESS SENSOR NETWORK**

**Prepared By
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**Supervisor
Assoc. Prof. Dr. Selçuk ÖKDEM**

M.Sc. Thesis

**August 2018
KAYSERI**

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COMPLIANCE WITH SCIENTIFIC ETHICS

I say that all of the data obtained in this work, in accordance with the principles of the academic and moral. The results are also the exchange of all the materials that were not at the heart of this work and communicated through to give a signal as required referred to, he pointed to each one of the materials and the results are unique in this work.



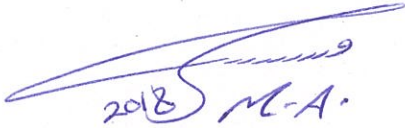
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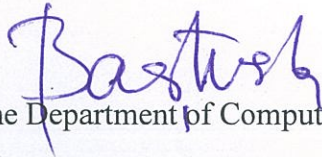
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ACCEPTED AND APPROVAL PAGE

A thesis study entitled "A comparative Study of Localization Algorithms for Wireless Sensor Network" prepared by **Marwa Abood NAMA** under the supervision of **Assoc. Prof. Selçuk ÖKDEM** was accepted as an M.S.c. thesis in Erciyes University, Graduate School of Natural and Applied Science, Department of Computer Engineering.

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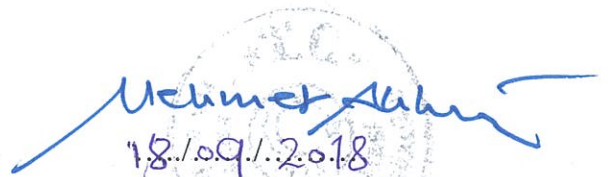


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Marwa Abood NAMA
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A COMPARATIVE STUDY OF LOCALIZATION ALGORITHMS FOR WIRELESS SENSOR NETWORK

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M.Sc. Thesis, August 2018

Thesis Supervisor: Assoc. Prof. Dr. Selçuk ÖKDEM

ABSTRACT

Currently, wireless sensor networks (WSNs) and their applications have attracted many researchers attention. The prominence of the sensor networks has clearly emerged in numerous vital and critical applications. The location information of all sensor nodes in WSNs is crucial especially in WSN applications where the collected information must be associated with a physical occurrence happening in a particular region and time. The idea of WSN localization is to estimate physical coordinates of each node with an unknown position. In this sense, target nodes estimate their physical coordinates using noisy distance measurements from anchors within communication range of the target node. The aim of this study is to seek for the geographical position of unknown nodes with the assistance of anchor nodes in WSN. In this study, the results will be compared using the algorithms to find the optimal solution in the accuracy of localization of nodes in the wireless sensor network by getting less error and time to find the unknown nodes. To deal with this problem, the work was done in the Matlab environment while the nodes were deployed randomly within the required network area where GWO algorithm showed better results than others by employing a variety of transactions (Anchor nodes, Intensity, variation of errors and range of communication and time).

Keywords: Wireless sensor network, WSN localization, metaheuristic, optimization, Grey Wolf Optimization (GWO) Algorithm, BAT algorithm, Dragonfly algorithm (DA)

KABLOSUZ SENSÖR AĞLARI İÇİN KONUMLANDIRMA ALGORİTMALARINA YÖNELİK KARŞILAŞTIRMALI BİR ÇALIŞMA

MARWA ABOOD NAMA

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ÖZET

Bugünlerde, kablosuz sensor ağları (WSNs) ve uygulamaları birçok araştırmacının dikkatini çekmektedir. Kullanılan sensor ağlarının ehemmiyeti çeşitli hayati ve kritik uygulamada açıkça ortaya çıkmıştır. KSA'lardaki bütün sensor devrelerinin konum bilgisi bilhassa toplanan bilginin belirli bir bölge ve zamanda meydana gelen fiziksel bir vaka ile ilişkilendirilmesi gerektiği KSA uygulamalarında hayati öneme sahiptir. KSA yerleşiminin amacı belirsiz bir konuma sahip her bir devrenin fiziksel koordinatlarını tespit etmektir. Bu bağlamda, hedef devreler onların iletişim kapsamı içerisinde bulunan tutturuculardan elde edilen gürültülü mesafe ölçümlerinden faydalanarak fiziksel koordinatları tespit etmektedir. Bu tez çalışmasının amacı WSN'deki sensor devrelerin yardımıyla belirsiz devrelerin coğrafi konumunu aramaktır. Bu çalışmada, belirsiz devreleri bulmak için daha az hata ile ve daha kısa zamanda kablosuz sensor ağındaki devrelerin yerleşim tutarlılığı için en uygun çözümü bulmak amacıyla sonuçlar algoritmalar kullanılarak karşılaştırılmıştır. Bu sorunu çözmek için döğümler gerekli ağ alanı içerisine rastgele yerleştirilerek MATLAB ortamında çalışma uygulamaya konmuştur. GWO algoritması çeşitli işlemleri (tutturucu devreler yoğunluk, hata değişimleri, iletişim ve zaman kapsamı) kullanarak diğerlerinden daha iyi sonuçlar vermiştir

Anahtar Kelimeler: Kablosuz sensor ağı, WSN konumlandırma üstsezgisel, optimizasyon, Grey Wolf Optimizasyon (GWO) algoritması, BAT Algoritması, Dragonfly Algoritması (DA)

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LIST OF SYMBOLS AND ABBREVIATIONS

<u>Symbol</u>	<u>Description</u>
ABC	Artificial Bee Colony
AoA	Angle of Arrival
BA	Bat Algorithm
CS	Cuckoo Search Algorithm
DV-HOP	Distance Vector-Hop
DA	Dragonfly Algorithm
E	Ranging error
EHO	Elephant Herding Optimization
FA	Firefly algorithm
GWO	Grey Wolf Optimization
GPS	Global Positioning System
IoT	Internet of Things
MIT	Massachusetts Institute of Technology
MLE	Mean Localization Error
M	Anchor nodes
N	Target nodes
NL	Localized Node
PSO	Particle Swarm Optimization
QoS	Quality of Service
RSSI	Received Signal Strength Indicator
TDOA	Time difference of arrival
TOA	Time of Arrival
W	Inertia weight
WSN	Wireless sensor network

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INTRODUCTION

Modern optimization algorithms are often nature-inspired, typically based on swarm intelligence [1]. The ways for inspiration are diverse and as a result, there can be many different types of algorithms. Yet, all these algorithms are liable to utilize some specific features to formulate the key updating formula. The optimization problems are quite significant in various fields of science such as physics, chemistry, and engineering and they aim to figure out the best possible answer for an obvious problem [2]. The need for searching is the reason that many different searching algorithms have been provided. The evolutionary algorithms rely on random exploration that the natural biological evolution modeling originated. They focus on potential answers with superior characteristics and the longer generation survival that estimates the optimized answer more accurately. New applications become available via wireless sensor networks (WSNs) which necessitate novel paradigms for protocol design owing to various limitations. Owing to the requirement for low device complexity together with low energy consumption (i.e., long network lifetime), an exact balance between communication and signal/data processing and possibilities must be identified. This encourages a huge endeavor in research activities, standardization procedure, and industrial investments in this field over the last ten years. Therefore, this thesis will provide a definition of what is the WSN and what is the purpose of the process of localization for the nodes and thus propose this thesis scenario to take advantage of the best salutation algorithms for the settlement of the nodes WSN and then the results are compared based on the lowest error rate taking into account the time the algorithm takes its work within the proposed scenario and the Matlab environment in a simulation. The originality using of the thesis word relies on using various parameter values (for node number, network size .etc) for common WSN algorithms.

CHAPTER 1

GENERAL INFORMATION

1.1 What is WSN?

Wireless sensor networks are an idea that goes back as far as 30 years. It was conceived for military purposes in a conceptual phase, rather than the physical combination of sensor and computer connected wirelessly [1]. Wireless Sensor Networks (WSNs) are widely accepted as an influential technology of the 21st century [2]. As a result of current enhancements in microelectronic mechanical systems (MEMS) and wireless communication technologies, miniscule, inexpensive, and smart sensors are physically in a device and connected through wireless communication. In addition, internet supplies unique civilian and military facilities for a variety of such as environmental monitoring, battlefield surveillance, and industrial process control [3]. WSNs, which differentiated from conventional wireless communication networks such as cellular systems and mobile ad hoc networks (MANET), have unprecedented features, for example, more intense level of node deployment, higher unpredictability of sensor nodes, intense energy spending, and storage limitations [3], which lead to a lot of new challenges in the development and application of WSNs. Over the past ten years, WSNs have attracted tremendous interest for both researchers and industrialists all around the world. A lot of studies have been conducted to explore and sort out various design and application issues, and thus the development and deployment of WSNs have been significantly enhanced. Experts predict that WSNs will soon envelop a multitude of uses both in the private and military sectors and completely revolutionize human activity and work [3].

1.1.1 WSN Technologies

The WSN is comprised of nodes that can be anywhere from very few to several thousand and linked to one another. These nodes often include an antenna (with or without a radio transceiver), micro-controller, electronic circuit, and power source [4].

How complex the node is will impact its cost, ranging between minimal amounts to several hundred dollars. These size and cost-related limitations also restrict memory, energy, communication bandwidth and computational speed. The WSNs can be designed as either a simple star network or an advanced multi-hop wireless mesh network. The hops of the network can be propagated by either routing or flooding. One or more sinks (or base stations) can be included into WSNs in general and maybe tens or thousands of sensor nodes are propagated in a real-world area [5]. Each sensor node has the ability to sense and process physical information before delivering it to the sink through its wireless connectivity, sensors, and processor. The sink then gains information from these nodes by looking for something specific. WSNs have some distinguishing characteristics as follows:

- a) Unparalleled network topology
- b) Assorted applications
- c) Unparalleled traffic features
- d) Serious resource limitations

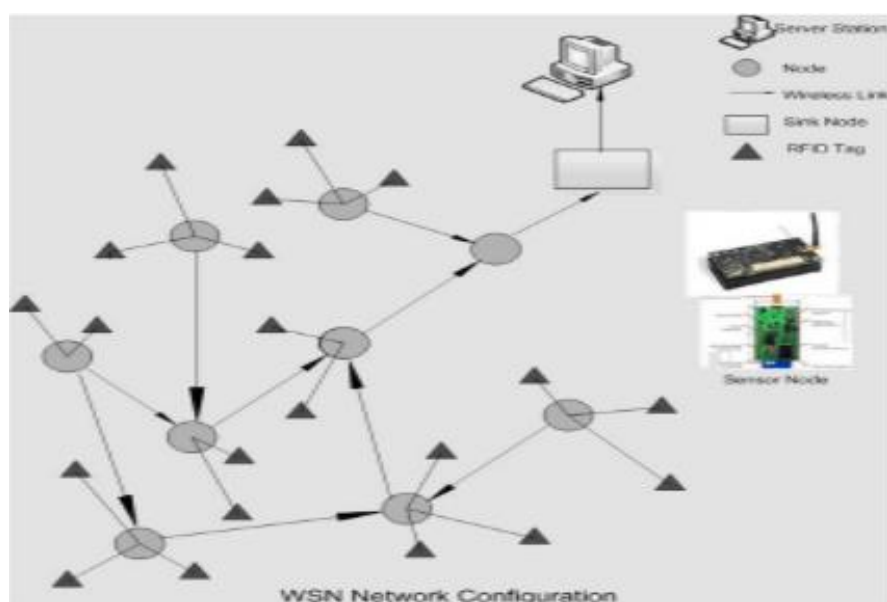


Figure 1.1 WSNs Technologies [4].

1.1.2 WSN Categories

In current technology, there are a great number of WSNs used everywhere from land-based systems, and those used below ground and below water [6]. Each of these systems have limitations and difficulties based on where they are used. In this thesis, we will mention about five types of WSNs depicted below.

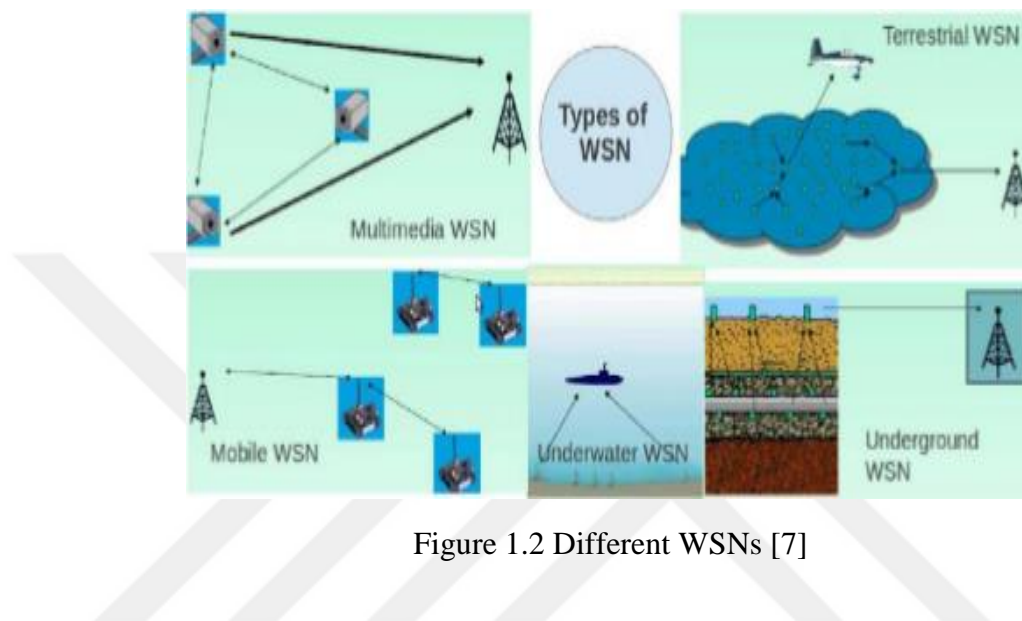


Figure 1.2 Different WSNs [7]

- **Terrestrial WSN:** This network is made up of a few hundred or a few thousand cheap nodes that are located on the land in a given location. They are often ad-hoc networks set up on the fly (such as being released from an airplane). These sensor nodes must deliver data to the base station and often have extra power sources, such as solar cells, attached to them [7]. This is because the energy is low within these systems and the batteries are not rechargeable. As such, there are various ways to improve power usage, such as limiting the range of transmission, using multi-hop routing, aggregating data within the network, and minimizing processes that consume power. Terrestrial WSNs are often used to: sense the environment, explore a location, and monitor an industrial zone [8].
- **Underground WSN:** These networks have many nodes and are placed in a cave or mine to monitor the conditions [9]. Sink nodes above the ground are used to as support in the delivery of information to the base station. These networks cost more than terrestrial networks because of the expensive equipment necessary for communicating through water, stone, and earth. Wireless communication is difficult due to constant signal loss. It is also difficult to constantly replace the batteries due to their location, so

developing energy efficiency is critical so that the network's lifetime can be adequate for the needs. Underground WSNs can be used for the monitoring of: a military zone, agricultural setups, the landscape, water, and soil [10].

- **Underwater WSNs:** These networks have sensors that are placed beneath a body of water, usually in the ocean [11]. They are extremely expensive, and because of this, it is not possible to deploy a great number of nodes. As such, submarines and other submerged vehicles are tasked at collecting the information of the network. Wireless communication beneath the sea is challenging because there is a strong delay of propagation, increased latency, decreased bandwidth, and signals that tend to fade. As such, these nodes are permanent, and their batteries cannot be replaced. Also, they must configure themselves according to the present conditions. These networks are used to: explore the deep ocean, prevent disasters, and monitor equipment, pollution, and seismic conditions [11].
- **Multi-media WSN:** Multimedia networks are made up of items such as a camera and microphone so that coverage is maximized [12]. They detect such information as: images, video, and audio for storages and processing. These networks are often cheap to implement, but there are several issues including: the need for bandwidth stability, using a lot of energy, and compressing the received data [13]. When streaming video, for example, the network must use minimal energy whilst retaining a high bandwidth. Maintaining Quality of Service is hard but must be implemented for the delivery of high-quality media. Existing monitoring and tracking processes are often improved through these WSNs [13].
- **Mobile WSN:** Sensor nodes in a mobile WSN must, as the name implies, be mobile. As such, they receive information from the external conditions as they move around [14]. The nodes in this network must be able to rearrange themselves in order to receive and process data, before sending it to the base station. As such, the routing algorithm must be dynamic and differs a great deal from those used in stationary WSN systems. Mobile WSNs have various issues, including: deploying them, adequate coverage, a constant connection to the network, transmission of data, and localizing the signal. Mobile sensor nodes must cover more area and have a more reliable connection than nodes that remain in place [15]. These WSNs are used for: surveillance (military), locating and tracking a target, rescue missions, and to monitor the environmental conditions of a given location.

1.1.3 Application domains for WSNs

The rapid evolution of sensor's technology has led to the design of tiny and smart sensors, which allow WSNs to be employed in a variety of applications. WSNs' operations can be separated into two types; monitoring and tracking [16], which is demonstrated in (Figure 1.3).

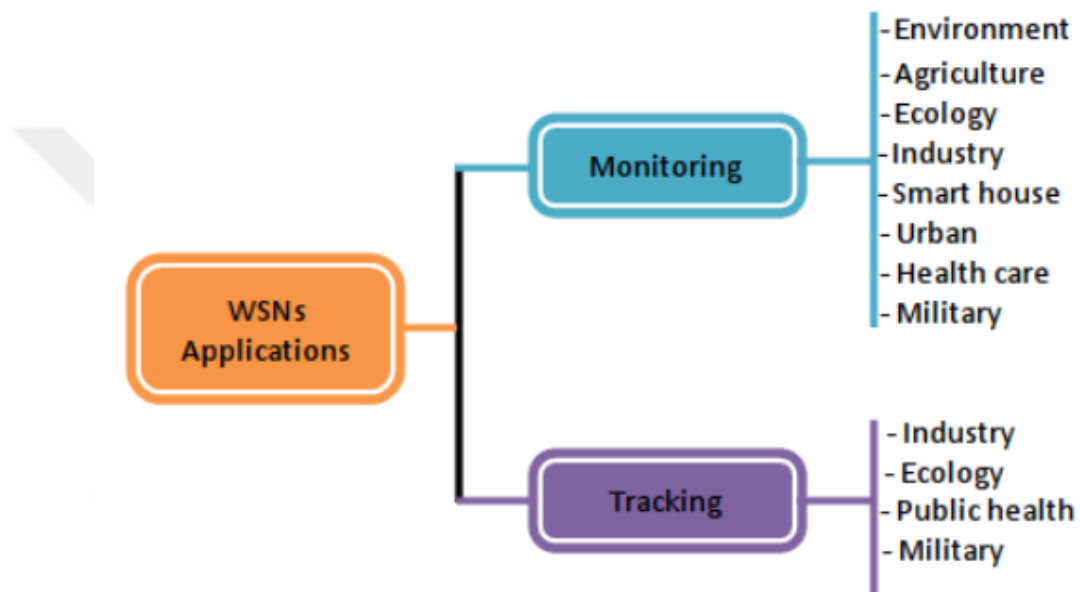


Figure 1.3 Application domains for WSNs [15].

WSNs are used across many fields. Current predictions point to most items used in daily life having some type of sensor that will allow for interaction with human and similar items, as well as be aware of their environment. There are two types of WSNs: those to monitor and those to track. As shown in Figure 1.3 above, there are many types of WSN usages, including: military, healthcare, agriculture, industry, and environment. There is an increased focus on using WSNs for assisting militaries, such as forward-operating bases built from sensors. Other military examples are: the monitoring of a soldier's body for injury and health information, self-surveillance, and mines connected to a network that can self-regulate. WSNs are also in the attention of homeland security for the watching of airports, ports, and other high-traffic areas to ensure crisis control, border safety, and the detecting of situations. Within the health field, BANs (Wireless

Body Area Networks) are made up of smart sensors that can regulate a patient's health [17].

1.1.4 Sensor

Sensors are the integral parts of any network. They measure external conditions and translate the information so as a machine or skilled professional can gain insight from the data [5]. All wireless technology relies on these sensors in our daily life we take advantage of various sensors [18].

1.1.4.1 Sensor device components

The following units of shape consist of the sensor device components:

- Sensor unit
- Storage unit and Micro-controller
- Receiver and Transmitter unit

In the (Figure 1.4) sensor unit is a tool to convert analog data to digital format as the main task of this unit is receiving and sending data conversion formula match with the nature of the data used in the storage and processing unit which in turn consist of tiny chip with limited possibilities. The reception and transmission unit consists of an antenna sensor to send and receive radio waves[18].

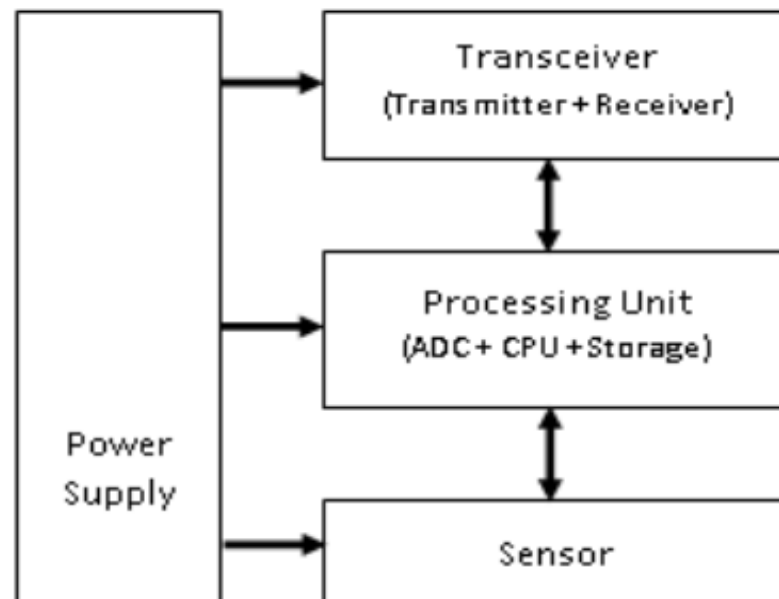


Figure 1.4 Sensor device components [18]

1.1.4.2 Type of sensor

- 1) Thermal sensors: They measure and monitor temperature and are used computers for indicating when a critical temperature has been reached.
- 2) Electromagnetic sensors: This type measures physical characteristics (pressure or volume) and changes them into an electronic signal.
- 3) Mechanical sensors: They include pressure sensors like barometer, vibration and shock sensors.
- 4) Car sensors: Reversing sensor and rain sensor are the examples [19] [18].

1.1.5 Features of wireless sensor network

A wireless sensor network must:

- Consume power when batteries are used on nodes
- Deal with failings of any given node
- Scale based on what is being distributed
- Have a level of mobility
- Endure difficult conditions found in the environment
- Be easy to use
- Be cross-level designed [20]

1.1.6 Advantages of wireless sensor network

Advantages of WSNs include:

- Can be assembled in unfixed networks
- Can reach difficult environments (sea, forest, farmland)
- Are highly flexible (such as adding an additional workstation)
- Inexpensive operation
- Limits the excessive use of wires and cables
- Can be modified to suit various tasks
- Can be monitored from a central location [20, 21]

1.1.7 Limitations of wireless sensor network

Limitations of WSNs include:

- Limited storage (several hundred kilobytes)
- Average processing power (8MHz)
- Short communication range
- High power consumption
- Necessity for minimal energy – restricts protocols.
- Batteries with a limited lifetime [22, 21].

1.2 Localization

The process of localizations is when sensor nodes indicate their location on the network. In other words, this means how nodes relate to one another [22]. There are nodes that have a set location, known as anchors and beacons. The remaining nodes are relocated based on their reference to the anchor. The mathematical formulation is: a specific network is represented by the graph $G=(V,E)$, and a set of beacon nodes B , their positions $\{x_b,y_b\}$ for all b belong to B , the goal is to find the position $\{x_u,y_u\}$ for the remaining nodes belonging to U [23].

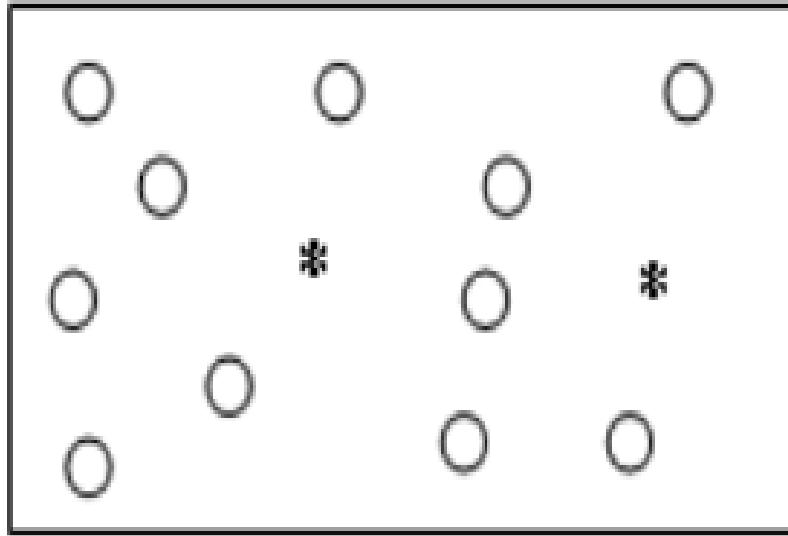


Figure 1.5 A Wireless Sensor Network contains sensor and beacon/anchor nodes. Circles represent sensor nodes and "*" symbol represent beacon/anchor nodes [23].

1.2.1 Localization in WSN

To specify the physical coordinates of a group of sensor nodes in WSN [24], using GPS is unrealistic due to the application context; hence, sensors need to self-organize a coordinate system. Therefore, the localization in WSN is crucial as it reports data that is geographically meaningful and services such as routing depending on the location information; context-based routing protocols, geographic routing protocols, and location-aware services. By and large, almost all the sensor network localization algorithms operate in three main stages.

- Distance estimation: This phase reckons the relative distance between the nodes through measurement techniques [25]. There are four methods in conventional use for it; also, there are some new techniques for calculation.
- Position computation: This phase reckons the coordinates of the unknown node with respect to the known anchor nodes or other adjacent nodes through algorithms [26]. The common methods for position computation techniques are:
 - (a) Lateralization techniques based on the accurate measurements to three noncollinear anchors. Lateralization with more than three anchors is called multilateral [27].

(b) Angulation or triangulation relies on information about angles instead of distance.

- Localization algorithm: How the information regarding distances and positions is manipulated in order to allow most or all of the nodes of a WSN to approximate their position is determined by the localization algorithm [28]. Optimally, the localization algorithm may include algorithms to diminish the errors and refine the node positions. This section through which the unknown contract is measured to determine a localization process is crucial.

1.2.2 Classification of Localization algorithms in WSN

A number of algorithms classifications are employed in the process of localization of Wireless Network Sensor nodes [29] [23]. Many researchers in the field of networks in general and wireless networks in particular classified the operating algorithms into the process of resettlement as depicted in (Figure 1.6.)

On the other hand, some researchers classified the algorithms working on wireless sensor nodes resettlement depending on the measurement distance demonstrated in(Figure1.6) Localization schemes specify the position of an object or person compared to another known location or within a coordinate system [14]. Over the last few years, several techniques have been proposed to obtain a precise estimation of the location of an unknown sensor node. Localization algorithms can be classified mainly into two categories as outlined below.

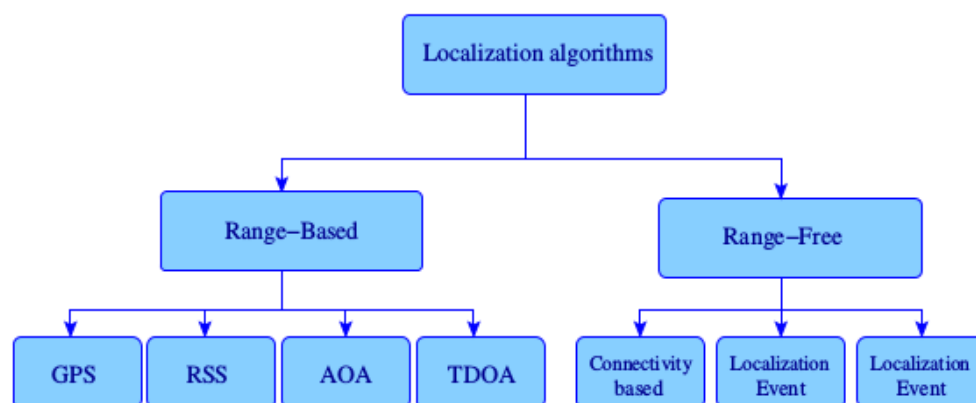


Figure 1.6 Localization algorithms classification in WSNs [29].

(A) Range-Based Schemes:

Range-Based Schemes rely on distance and angle estimation between sensor nodes to specify the location of the unlocalized node [30]. The Range-Based schemes obtain the correct information about the location of sensor nodes but in a costly way. It can be classified as GPS Based and GPS Free.

- Due to equipping every node with GPS receiver, GPS-based schemes which provide quite high localization accuracy are quite costly [31]. As its name suggests, GPS-free algorithms measure the distance between the nodes with respect to the local network without GPS and are cheaper than GPS-based schemes [31]. Some nodes called anchor or beacon nodes that launch the localization process need to be localized through GPS.
- Received Signal Strength Indicator (RSSI): The RSSI technique is reliant upon the exponential attenuation of the radio signal as distance increases. With respect to the receiving power, the distance can be measured by interpreting the power loss with the theoretical model [32]. RSSI has also been implemented for range estimation.
- Time-based methods (ToA, TDoA): The distance is measured by interpreting the propagation time between two nodes with the known signal propagation speed through ToA and TdoA techniques [33].
- Angle-of-Arrival (AoA): The position is estimated through AoA- also known as DOA (Direction of Arrival) techniques geometric relationships with the angle where signals are delivered. ToA, TDoA and AoA techniques can generally maintain better accuracy than RSSI techniques as radio signal amplitude is influenced by environmental variables [34].

(B) Range-Free Schemes:

Range-Free schemes exploit the connectivity information between unknown nodes and anchor nodes. These schemes are more efficient as no information regarding distance, angle or range of nodes is required [35]. Range-Free Schemes have proved effective in acquiring precise location information.

1.2.3 Localization Techniques in WSN

Localization techniques can be classified into two groups depending on inter-node communication [27].

- Centralized localization techniques include data transfer to a central node to calculate the location for each node [36]. Communication with centralized computing is costly, and sending data swiftly by time within the network causes latency, and it also consumes energy and network bandwidth.
- Decentralized or distributed localization techniques rely on each sensor node which can identify its location merely through limited communication with nearby nodes. Centralized computation isn't essential for distributed localization techniques [37].
- Anchor free and Anchor based techniques: Anchor nodes recognize their coordinates through GPS or manual placement [38]. With the help of anchor nodes, we can obtain global coordinates, yet high cost of GPS receivers and their inability to be used indoors for localization pose problem in terms of using anchor nodes as GPS employs Line of Sight communication [31]. Pre-programmed nodes with their locations, which is cumbersome (for instance, while implementing 10,000 nodes with 500 beacons) or even impossible (e.g. while distributing nodes from an aircraft) alternates GPS [31]. Regarding indoor localization, anchor free nodes can be employed and can easily provide relative coordinates or we can employ some anchor based nodes which recognize their coordinates by manual placement.

1.2.4 Performance Localization Techniques in WSN

- Beacon/Anchor Nodes: Beacon nodes recognize their coordinates through supplementary hardware (like GPS) or through physical assignment. The placement of beacons greatly affects localization [39].
- Node Density: Many localization algorithms are responsive to node density. For instance, hop-count based algorithms typically necessitate high node density so that the number of hops calculation of the distance can be accurate [40]. Hence, while designing or analyzing an algorithm, it is significant to take into account the node density requirement of algorithm.

- **Accuracy:** Accuracy is the crucial component of localization algorithm when WSN is used for disaster control, finding a target, and search and rescue [41]. Localization algorithm should provide the precise location of sensor nodes so that appropriate action can be taken with regard to that task. Location accuracy of localization algorithm indicates how the localization matches the computed physical locations of nodes.
- **Cost:** By and large, the cost of a localization algorithm is defined by hardware, computation, and communication. The cost of hardware can include gear for measuring and the density of both normal and reference nodes. Cost of communication is a twofold system based on both how nodes communicate with one another and with the base station. The centralized localization process frequently includes the communication between sensor nodes, yet it uses more energy than inter-node communication or computation cost [42]. Therefore, distributed algorithms are frequently more conclusive than centralized algorithms as computation cost and inter-node communication is more involved in distributed approach than communication between BS and nodes [43].
- **Comparison:** Comparison can be used Range based, Range free, Distributed, Centralized, Beaconbased and Beacon-free algorithms according to the performance parameters outlined above.

1.3 Problem of Study

Various applications exploit Wireless Sensor Networks (WSNs) [8]. However, there are several applications where the sensor data is impractical and can lead to a false interpretation of the available data especially if the coordinate information is unknown. Hence, localization is of great significance in different operations of WSNs. This thesis dwells on the major problem of how to localize nodes in the wireless sensor networks, which is not identified regarding the predefined nodes while maintaining accuracy in performance and obtaining accurate information through the data transfer procedure between these nodes in WSN within a specific space.

1.4 Objective of Study

The process of localization of nodes in WSN appeals to many researchers, in addition, the work of localization with specialized algorithms is the most common theory, as it provides the least error in the largest number of the localization process of the nodes. In this thesis, we aim to localize the largest number of nodes within a given network and

compare the results of these algorithms in terms of MIL, NL and time without considering the number of the errors, which is another approach adopted by researchers in the field. The originality of the thesis main focuses on obtaining performance metrics for different algorithms using several test bench scenarios.

1.5 Literature Review

This problem is one of the most fundamental challenges in this field and its aim is to find the coordinates of unknown nodes haphazardly deployed in the monitoring field. Localization problem in WSN with M sensor nodes is to identify locations of N unknown nodes through location information of $M-N$ anchor nodes, with transmission range (R) [44]. Researchers show interest in network science in general and wireless operators in particular. Hence, we will outline some of these studies which have adopted traditional methods and other modern methods using the best solution algorithms.

Ke.M et al. (2018) conducted a research about distributed power allocation for WSN localization through a possible game approach where anchor nodes' utility function relates to its use of energy and how precise the localization is for agent nodes. The study which relied on learning algorithm for optimization through simulation process was conducted to obtain reliable accuracy of hardware power consumption [45].

Chunxiang.W et al. (2018) explored the solutions for a problem of target localization in WSN via received signal strength (RSS) and angle of arrival (AoA). The research focused on a group of localization algorithms such as SDP, SOCP and WLS which have been recently developed and the unknown location of the target by sorting out the original problem of a tight approximation which provides a sound framework even under premature network configuration and heavy measurement noise. The research results yield precise rounding process by iterating merely once [46]

Kim.Y and Shin.Y (2018) studied a distance boundary to enhance the localization accuracy in the corner and side areas. They proposed an intersection threshold to make up for the localization accuracy so as to address the requirements of the hardware installation cost and accuracy in the localization procedure of wireless sensor network nodes based on the algorithm optimization through a weighted centroid localization (WCL) [47].

Ma et al. (2018) suggested a scalable total solution by employing a distributed localization technique in WSNs using “mobile ultraviolet-visible spectrometer probes”. Water quality is monitored via a wireless sensor network, which involves unmanned surface vehicles and buoys acting as the mobile and stationary nodes [48]. These nodes include UV-visible spectrometer probes to collect on-site various water-quality measurements. An optical path device that adapts on its own was made to serve the range of measurement. A new distributed algorithm called Dual-PSO is put forward to explore the cause of water pollution, where one particle swarm optimization (PSO) process calculates the multi-parameter measurements of water quality on each node through UV-visible absorption spectra. Another algorithm figures out the universal solution of the pollution source position, considering the mobile nodes as particles. Moreover, this algorithm utilizes entropy to briskly identify the most sensitive parameter during the search [49] [48].

Daely.T and Shin.Y search operators (2018) conducted research on WSN localization problems by Elephant Herding Optimization Algorithm and RSS method employed for predicting the range between nodes. No matter which ranging method is being operated, inaccurate measures can emerge. According to the simulation results, the EHO algorithm proved solid and influential meta-heuristics when addressing localization problem in WSN. [50].

Alomari et al. (2017) found out that increasing swarm size does not raise the accuracy of localization in their subject analysis of DA for wireless node localization. Adjustments on the parameters of DA with suitable values also provide the optimal result proving that increase in the maximum frequency also enhance the performance with the tradeoff of computational time [51].

In [52] (2017) designed two dynamic avoidance path planning models by employing GWO algorithm called GWPP and WOA algorithm called WOPP for mobile anchor-assisted localization in WSNs. The models focus on optimizing the path design depending on the synchronous information from the network. The optimization models both avoid the obstacles located in the MA’s way and provide a salient optimized path when the MA has a restricted movement.

Gopakumar. and Jacob. (2017) proposed to solve the issue of node localization [54]. This algorithm is effective based on how the bats adapt to the speed using a hybrid

Doppler effect for performance boosting. It is named the Dopeffbat. Therefore, Dope beat uses evolution to calculate the nodes' positions repetitively via the Euclidian distance as fitness. Through the implementation of this algorithm on a massive WSN built using a few hundred sensors, there was a solid localization measurement. The simulations point to Dopeffat being accurate with a higher rate of convergence compared to PSO and Bat [53].

Mihoubi et al (2017) proposed methods to sort out k-coverage node deployment on target based WSN. With reference to the methodology in nature, moths navigate in transverse orientation maintaining a fixed angle. Hence, depending on Moth-Flame algorithm the convergence problem to minimize the nodes and maximize the coverage in a wireless sensor network was overcome [54].

Cheng et al. (2016) dwelled on CS algorithm to settle the contract. Formed out of the step-size adjustment, this method provides the population the ability to deal with the optimal global solution quickly. How fit each solution is was used to formulate statistics that can limit convergence.

and the fitness of each solution is employed to build the probability of a surge to avoid local convergence. The experiments reveal that the proposed CS algorithm can not only raise the convergence rate but also diminish the average translation errors compared to the normal CS and PSO algorithms [55].

CHAPTER 2

MATERIALS AND COMPARATIVE METHOD

2.1 Overview

The process of localization of wireless sensor network nodes is of great necessity in the modern era of technology and frequent mobile internet data. Many researchers try to source of progress and find solutions to the problems of science and access the best ways. Therefore, this chapter will outline some theories used in the proposed method which this thesis is based on it.

2.1.1 Grey wolf algorithm (GWO)

Meta-heuristic optimization methods have become extremely popular over the past two decades because of their simplicity, flexibility and features [56]. Ordinary concepts such as natural phenomena, animals' behavior or evolutionary concepts have generally set a basis for these methods.

Grey wolf optimization is a swarm intelligent technique developed by Mirjalili in 2014 which imitates the leadership hierarchy and hunting behavior of wolves which are well known for their group hunting [57]. Apart from the social hierarchy of grey wolves, pack hunting is another attractive social action of grey wolves. Encircling, hunting and attacking the prey constitute the major segments of GWO.

Grey wolf belongs to Canidae family and mostly prefer to live in a pack. They have a firm socially dominant hierarchy; the leader, a male or female, is called Alpha (α).

The alpha is generally in charge of decision-making. The whole pack must follow the instructions of the dominant wolf. The Betas (β) which advises alpha and disciplines the pack are subordinate wolves helping the Alpha in decision making. Omega (ω) as the lowest ranking grey wolf, must obey all other dominant wolves. If a wolf is neither an alpha or beta nor omega, it is called delta (δ) which dominates omega and reports to alpha and beta [56].

The GWO algorithm consists of the following steps:

Step 1: Begin with the GWO strictures such as search agents (G_s), design variable size (G_d), vectors a , A , C and maximum number of iteration (*iteration max*)

$$A=2a \cdot r - a \quad (2.1)$$

$$C=2 \cdot r, \quad (2.2)$$

The values of a are linearly reduced from (2) to (0) over the course of repetitions.

Step 2: The generation of random wolves based on the size of the pack. The mathematic expression is:

$$Wolves = \begin{bmatrix} G_1^1 & G_2^1 & G_{Gd-1}^1 \\ G_1^2 & G_2^2 & G_{Gd-1}^2 \\ G_1^{Gs} & G_{Gd-1}^{Gs} & G_{Gd}^{Gs} \end{bmatrix} \quad (2.3)$$

Where G_{ij} is the initial value of the j^{th} pack of the i^{th} wolves.

Step 3: The estimation of each hunt's fitness value with the following formulas:

$$D = |C \cdot C p(t) - G(t)| \quad (2.4)$$

$$G(t+1) = G p(t) - A \cdot D \quad (2.5)$$

Step 4: The identification of the best (G_1), second (G_2) and third best hunt agent (G_3) from the following equations:

$$D_a = |c_1 \cdot G_a - G| \quad (2.6)$$

$$D_\beta = |c_2 \cdot G_\beta - G| \quad (2.7)$$

$$D_\delta = |c_3 \cdot G_\delta - G| \quad (2.8)$$

$$D_1 = G_a \cdot A_1 - (D_1) \quad (2.9)$$

$$D_2 = G_\beta \cdot A_2 - (D_2) \quad (2.10)$$

$$D_3 = G_\delta \cdot A_3 - (D_3) \quad (2.11)$$

Step 5: Current hunt agent location renewal with these equations:

$$G(T + 1) = \frac{G1 + G2 + G3}{3} \quad (2.12)$$

Step 6: Estimate the fitness value of all hunts.

Step 7: Update the value of $G1, G2$ and $G3$.

Step 8: Check for the stopping condition i.e., whether the iteration reaches the iteration maximum. If yes, print the best value of solution, otherwise go to step 5.

```

Initialize the Grey Wolf population  $X_i$  ( $i=1, 2, \dots, n$ ) and algorithm parameters
Evaluate the fitness of each search agent fit  $i$ 
Initialize the first best solution as  $X\alpha$ ,
Second best solution as  $X\beta$ 
Third best solution as  $X\delta$ 
While (<maximum number of iteration or stop criteria obtained)
  For  $i=1:n$ 
    Update the current search agent position
  End for
  Evaluate the fitness fit  $i$ 
  Update the coefficient vector  $a$  and  $C$ 
  If any better solution the number | date the best agents  $X\alpha$  and  $\delta$ 
     $k=k+1$ 
Endwhile
Stop the process and visualize the first best agent  $X\alpha$  found so far

```

Algorithm1:Pseudo code for the GWO.

This part elaborates the justification for employing the meta-heuristic techniques to sort out many problems one of which is localization in WSN using optimization solving the problem. Moreover, a background review of the modern meta-heuristic technique namely GWO is outlined. These are a set of steps especially for GWO employed in this study [57].

2.1.2 BAT algorithm

The Bat algorithm is a novel meta-heuristic population-based algorithm developed by Yang [59] originated from bats' echolocation system. The microbats make use of an echolocation to detect prey, find locations to roost, and evade dangers. They find prey using a series of high and low audio signals and then locating the echo of the collision. The fundamental steps of Bat algorithm are as follows:

- 1) All bats utilize echolocation to sense distance, and they are incredibly able to distinguish prey, food, and the bottom wall.
- 2) Bats fly haphazardly with the initial values: velocity v_i , position x_i , loudness at i , frequency $f_i[f_{min}, f_{max}]$ based on the domain size of the problem of interest, emission pulse rate $r_i \in [0, 1]$, and D-dimensional space.

$$x(i, j) = LB(j) + rand(0, 1) * UB(j) - LB(j) \quad (2.13)$$

Where $rand \in [0, 1]$ is a random vector drawn from a neat distribution. The values of Upper Bound (UB) and Lower Bound (LB) rely on the domain size of the problem handled.

- 3) Movement of virtual bats: New positions and velocities at time step t are updated by:

$$f_i = f_{min} + (f_{min} - f_{max}) \times rand, \quad (2.14)$$

$$V_i^{t+1} = V_i^t + (X_i^t - X_*) \times f_i, \quad (2.15)$$

$$X_i(t + 1) = X_i^t + V_i^{t+1}. \quad (2.16)$$

Where $r \in [0, 1]$ is a random vector drawn from a neat distribution, and x is the available global best location (*solution*). Regarding the local search section, just one solution is opted among the real best solutions, and for each bat, a novel solution is locally created by using haphazard walk based on the following equation:

$$if(rand(0, 1) > r_i, \quad (2.17)$$

$$X_{new} = X_{old} + A * A^t \quad (2.18)$$

Where $A \in [-1, 1]$ is a random vector drawn from a neat distribution, A_t is the average loudness at time step t , and $r_i \in [0, 1]$ is the rate of their pulse. If the best value obtained by the total N bats is higher than the precedent $f(x^*)$, the global best solution x^* can be updated at this time. Only if the novel solutions are updated, the loudness and emission rates can diminish and rise, seriatim, which suggests that these bats are steered for their prey. The connection is expounded in the following equation:

$$\text{if } (r \text{ and } (0, 1) < A_i^t \text{ and } f(x_i) < F(x)) \quad (2.19)$$

$$F(x) = f(x_i) \quad (2.20)$$

$$A_i^{t+1} = a * A_i^t \quad (2.21)$$

$$r_i^{t+1} = r_i^0 + (1 - e^{-yt}), \quad (2.22)$$

Where $a \in [0, 1]$ and y ($y > 0$) are constants; in fact, a is similar to the cooling factor of a cooling schedule-simulated an nealing. This study used, $a = y = 0.9$, so, A_i belongs to 0; r_i belongs to r_i^0 and t represents (∞).

This algorithm has revealed a solid methodology for localizing nodes effectively through adaptation. The Bat algorithm is a novel meta-heuristic model designed for global numerical optimization. The results prove the localization rate by the proposed algorithm crucial [59].

```

Objective function:  $F(x)$ ,  $x = (x_1, x_2, x_3, \dots, x_n)$ 
Initialize bat population  $X_i$  and velocity  $V_i$ ;  $I = (1, 2, \dots, n)$ 
Define pulse frequency  $F_i$  at  $x_i$ 
Initialize pulse rate  $r_i$  and loudness  $A_i$ 
While ( $t <$  maximum number of iterations)
    Generate new solutions by adjusting frequency,
    and updating velocities and locations/solutions
    If ( $\text{rand} > r_i$ )
        Select a solution among the best solutions
        Generate a local solution around the selected best solution
    End if
    If ( $\text{rand} < A_i$ ) and  $f(x_i) < f(x^*)$ 
        Accept new solutions
        Increase  $r_i$ , reduce  $A_i$ 
    End if
Ranks the bats and find current best  $x^*$ 
End while
Display results.

```

Algorithm 2: Pseudo code for the BAT.

2.1.3 Dragonfly Algorithm (DA)

The dragonfly algorithm (DA) is a novel metaheuristic optimization algorithm, based on a simulation of dragonfly swarming. In order to simulate the swarming act of

dragonflies, three primitive principles of swarming in insects were proposed by Reynolds in addition to two other novel concepts: separation, cohesion, and alignment a distraction from enemies and attraction to a food source. These five concepts enable us to simulate the behavior of dragonflies in both dynamic and static swarms [50]. The DA algorithm is developed based on the framework of the Particle Swarm Optimization (PSO) algorithm, thus there are two major vectors: step vector and position vector. These vectors store the movement directions/speed and position of dragonflies, seriatim [50].

Corresponding to the majority of optimization methods based in SI, the DA begins the process through a generation of haphazard solutions to the problem at hand. Obviously then, the algorithm's effectiveness is related to how many dragonflies the process begins with (M) [60]. With a larger starting point, there is an increased probability of locating the universal optimal level. However, the largeness of this input also extends the time each repetition takes, which extends the entire algorithm. Once the position of each dragonfly is located in the upper and lower boundaries of the variable, it is updated for each repetition through a reckoning of the step position vector for each using: cohesion, separation, predator distraction, food attraction, and alignment. The process is repeated until it reaches the termination point.

```

Initialize the dragonflies population  $X_i$  ( $i = 1, 2, \dots, n$ )
Initialize step vectors  $\Delta X_i$  ( $i = 1, 2, \dots, n$ )
while the end condition is not satisfied
    Calculate the objective values of all dragonflies
    Update the food source and enemy
    Update  $w, s, a, c, f,$  and  $e$ 
    Calculate  $S, A, C, F,$  and  $E$ 
    Update neighboring radius
        if a dragonfly has at least one neighboring dragonfly
            Update velocity vector
            Update position vector
        else
            Update position vector
        end if
    Check and correct the new positions based on the
    boundaries of variables
End while

```

Algorithm 3: Pseudo code for the DA

2.2 Tools of study

Researchers usually need a set of tools to implement what they want and obtain the results during a particular action in a particular area. Hence, two main tools outlined below are utilized in this thesis.

2.2.1 Software

The software used in this study was 15 version of MATLAB program and the reason why this program is selected is that it deals with mathematical and knew the numbers so dramatically and makes use of the camel code that were utilized during the process of translating work phrases.

2.2.2 Hardware

The simulation environment was made into reality through MATLAB. Also, we employ a computer with a specification processor of Intel® Core™ i7-7500 CPU @ 2.70 GHz 2.90 GHz, system type windows 10 and random access memory of 8.00 GB.

2.3 Methodology for comparison of algorithms

Stay hubs are equipped with GPS gadget, which is naturally able to decide its position. A large portion of the hubs in the WSN is not outfitted with GPS because of the high cost. The network is spread randomly where you work on $(250n)$ nodes $(125n)$ of which represent reference nodes or called the anchor nodes representing a reference point from which unknown points are identified [61]. This takes place within the coordinates the work of two values (x,y) $(200 * 200) m^2$ after selected points range is defined as a component of $(25m)$ while repetition is within score source $[25:25:125]$ after giving initial details as input to the proposed study within a process simulation, the distance is calculated between the known and unknown points.

(Figure 2.1) illustrates the general structure of the study. WSN localization aims to identify the coordinate of so many target nodes through anchor nodes with single hop range-based distributed technique and the coordinates of (N) target nodes to identify the position of the unknown node coordinates (x,y) with the help of anchor nodes (position of known nodes) coordinates (x,y) .

Hence, in order to access these unidentified nodes, we must know the distance between nodes known and unknown. To that end, the proposed methodology was followed in this study to identify these nodes through some important details:

(1) (N) represents the target nodes and (M) represents the anchor nodes which are haphazardly located in the sensor field. There is a range of transmission for each of the target and anchor nodes (R). Anchor nodes calculate their position and communicate their coordinates to their neighbors and reckon their location's awareness to deliver their coordinates. The nodes settled at the end of the repetition, work as reference nodes during the next repetition behaving like anchors.

(2) Three or more anchor nodes within the communication range of a node are considered as a localized node, which is a must that is common to many researchers. The hub that falls inside transmission scope of at least three grapples is considered as a confined hub.

(3) Adjacent anchor node helps to calculate the location of localized node, thus each

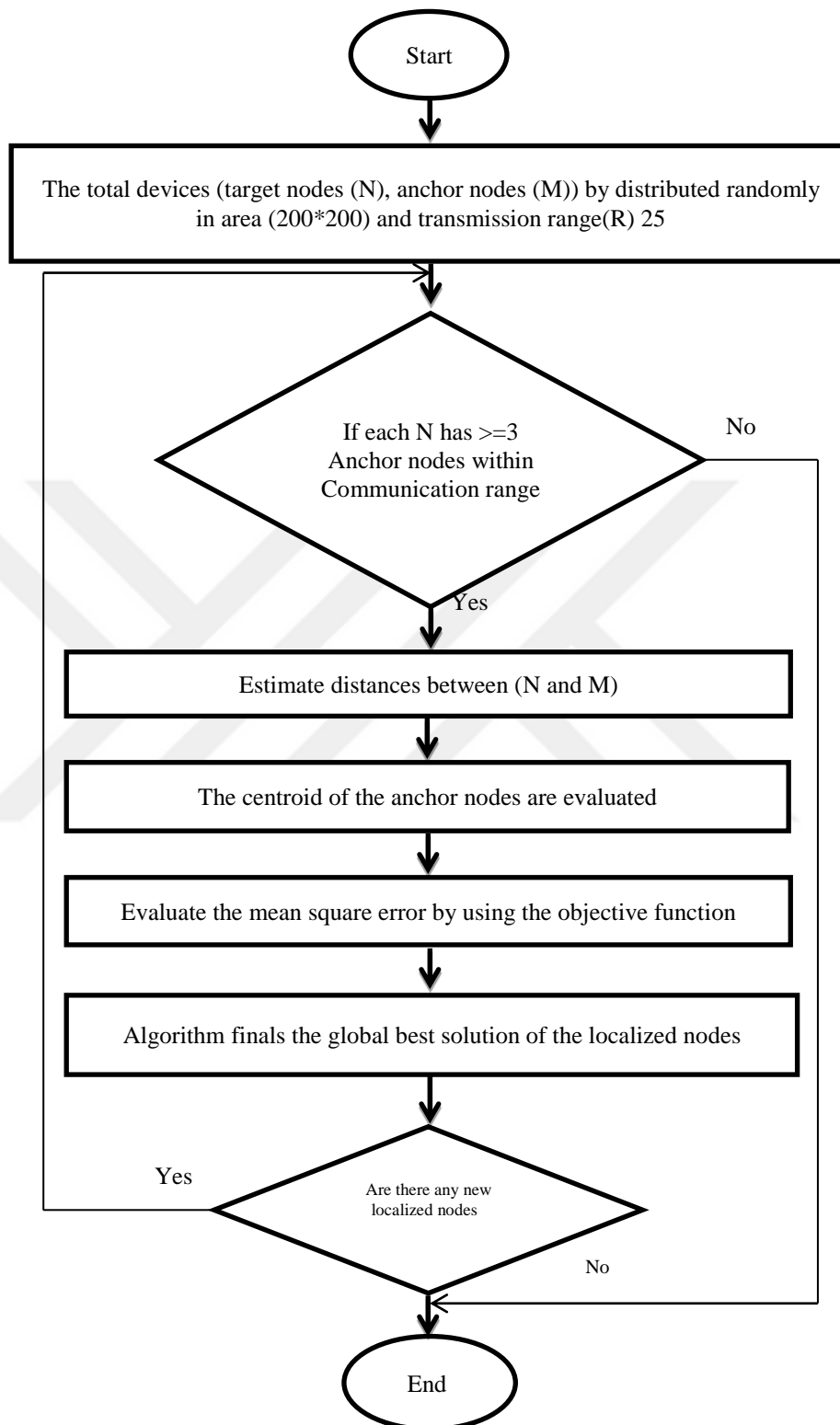


Figure 2.1 General structure study.

(4) Localized node calculations measure the distance from each adjacent anchor.

(5) Distance measurements are ruined as a result of environmental effects; in order to avoid it, the Gaussian noise is incorporated with the actual distance termed as N_i [63]. A node reckons its distance from the anchor through the following equation:

$$D(i) = \sqrt{(X - X_i)^2 + (Y - Y_i)^2} \quad (2.28)$$

Where (x, y) represents the location of the target node and (x_i, y_i) represent the location of the anchor node in the neighborhood.

(6) The node estimates its distance from its anchor as follows:

$$\tilde{D}(i) = [D_i + N_i] \quad (2.29)$$

Where (x, y) represent the coordinates of unknown node/target node and (X_i, Y_i) represent the coordinates of the (i) anchor node in the neighborhood within the area.

(7) Each selectable target node implements the algorithms independently to localize itself through searching the coordinates (x, y) [64]. The optimization problem is formulated to diminish the error in wireless sensor network localization problem, so the error box is located between the estimated distance to coordinates of unknown nodes which represent the calculated objective function and coordinates of the actual contract which are present and formulated as the following equation:

$$f(x, y) = \min \left(\sum_{i=1}^m |D_i - \tilde{D}(i)| \right) \quad (2.30)$$

Where \min represents the number of anchor nodes within the transmission range (R) of the target node.

(8) After identifying the coordinate of all localizable nodes, the question now is how the resulting error value is calculated from the previous calculations as mean square distances calculated decade coordinates (x_i, y_i) and for $i=1, 2, \dots, NL$ is determined for optimal algorithms used. The coordinates of the physical node and signified NL normally can be seen from the interval between native and resident areas of the mysterious knot and this is calculated via the following equation:

$$E_L = \frac{\sum_i^n = m + 1 \sqrt{(X_i - eX_i)^2 + (Y_i - eY_i)^2}}{(NL) * R} \quad (2.31)$$

(9) Finally, the step is iterated from *(a to f)* until all the target nodes are localized in the area. Location of the error (EL) and the number of undiminished nodes (NL) determine the performance of the translation algorithm. The number of nodes is unclear (NL) depending on the gap between the total number of nodes and localized nodes.

Evaluation of the results depends heavily on the performance of the algorithms, therefore, that it can optimize algorithm to find less error possible settlement sufficient time and there are many contrary target nodes and there's the biggest mistake which is perhaps the balance between the two, considering the time. Therefore, the results of the proposed study will be outlined in the next chapter.



CHAPTER 3

RESULTS AND DISCUSSION

3.1 Background

In the previous chapter, details about the mechanism used in these algorithms were outlined. In addition, this thesis deals with the proposed study on how to make use of these algorithms and employ in the area proposed for the participation of researchers in sorting out the problem of localization of nodes in the networks economically [50]. Hence, in this chapter we present the results obtained through the proposed science and also discuss them in a scientific manner so that the positive and negative results can be explained and then the results are compared with the work of algorithms implemented in this thesis within the framework of theoretical work and simulation for realistic environment in terms of performance and the number of errors and the resettlement sites and finally the time for each algorithm [19].

3.2 Results

In this part of the thesis, all the results obtained through the comparative study are reviewed and supported by diagrams and tables.

3.2.1 Results for GWO algorithm

The comparison results of work and performance optimization algorithms worked in random network deployment by measuring (200m * 200m) within the coordinates of value (x,y). Aesthetic nodes are at (250n.,125n.) of which represent anchor nodes and the remaining represents the unknown nodes. Unknown nodes are identified through the nearest (25) anchor nodes which represent the initial value, then it is increase (25) nodes until at (125) nodes with a constant value of range (R) which is equal to (25).

In (Figure 4.1) which gray box contain green shape represents a number of anchor nodes, red circle shape represents the number of blind nodes (target), star shape represents the number of measured nodes localized and finally Blue Diamond represents the estimated localization as can be seen below, illustrates the results from GWO optimization algorithm for anchor nodes (125).

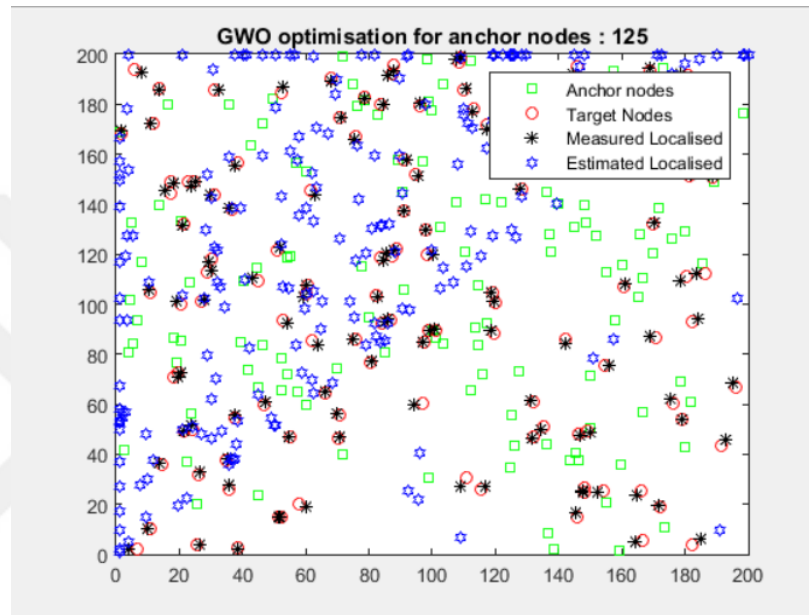


Figure 3.1 GWO optimization algorithm for anchor nodes 125

The (Table 3.1) outlines Mean Localization Error for GWO optimization algorithm for (125) anchor nodes with the largest value in (25) to anchor nodes.

Tables 3.1 Results of MIL for GWO optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of MIL%
25	39.99017591
50	12.9237875
75	6.654003088
100	7.746382837
125	7.309228596

Also this study provided a higher number of localization nodes through GWO algorithm as presented in (Table 3.2).

Table 3.2 Results of NL for GWO optimization algorithm for anchor nodes 125

Number of Anchor nodes	Results of NL
25	15
50	47
75	78
100	89
125	87

One of the most remarkable results obtained through this study is the implementation of the GWO algorithm, which is the time, as depicted in (Table4.3).

Table 3.3 Results of the time for GWO optimization algorithm for anchor nodes 125

Number of Anchor nodes	Results of time (sec)
25	96.0532157
50	85.2596728
75	85.7180817
100	73.8210539
125	64.875898

3.2.2 Results for BAT algorithm

The localization purposes to identify the geographical coordinates to each device whose location in the placement area is not known. Lately, applying optimization algorithms to sort out the localization problem has gained popularity. In this study, the BAT algorithm was applied to approximate the sensor's position, as in GWO algorithms. The (Figure 3.2) illustrates the results of BAT optimization algorithms for anchor nodes.

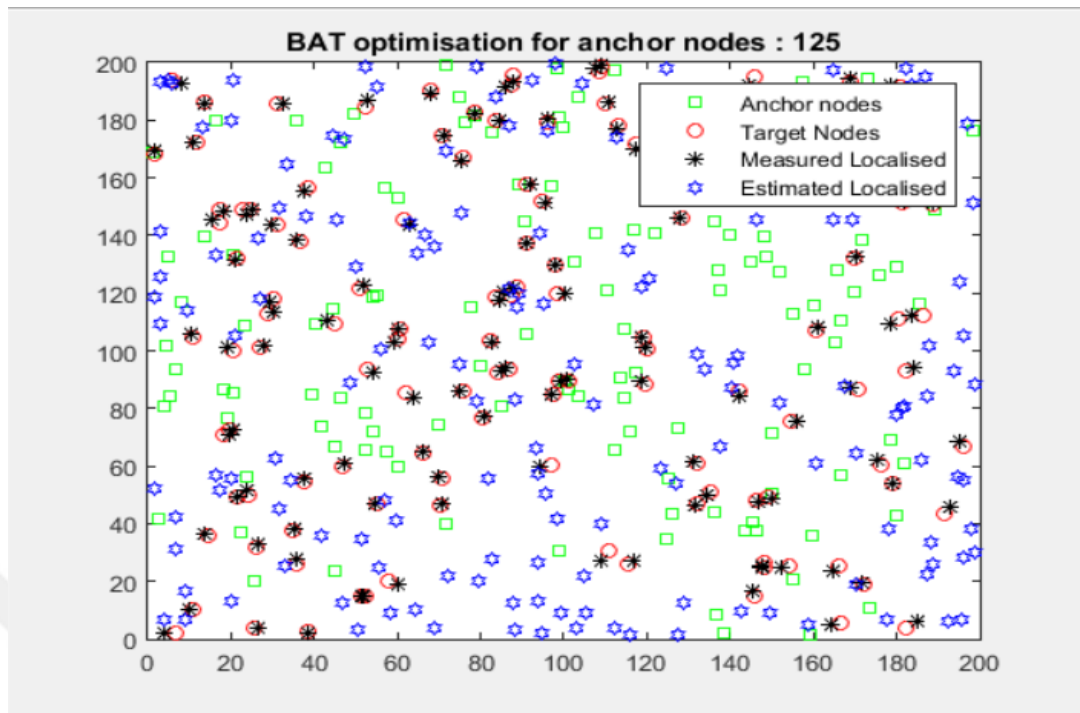


Figure 3.2 BAT optimization algorithms for 125 anchor nodes

The simulations were done using the BAT algorithm in the Matlab software. BAT evolves the optimal location of target nodes, i.e. (x, y) through the reduction of the error function. (Table 3.4) outlines the results of BAT from MIL.

Table 3.4 Results of MIL for BAT optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of MIL%
25	25.59425737
50	8.72145845
75	6.538105898
100	6.384880233
125	8.729224529

WSN localization aims to identify the coordinate of a maximum number of target nodes through anchor nodes, which is depicted in (Table 4.5) outlining the NL results for BAT optimal solution algorithm.

Table 3.5 Results of NL for BAT optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of NL
25	18
50	54
75	66
100	74
125	60

This study hoped to optimize WSN localization using the Bat algorithm. The results of the simulations are shown in (Table 3.6) and outline the time taken by the algorithm.

Table 3.6 Results the time for BAT optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of time (sec)
25	138.7236978
50	105.4313973
75	104.0810906
100	90.8712003
125	77.7496782

3.2.3 Results for DA algorithm

Many studies on localization have been conducted through the nature-inspired algorithm. We examined DA based localization relying on the range measurement between one unknown node and anchor nodes. (Figure 4.3) illustrates the simulation results for DA algorithm.

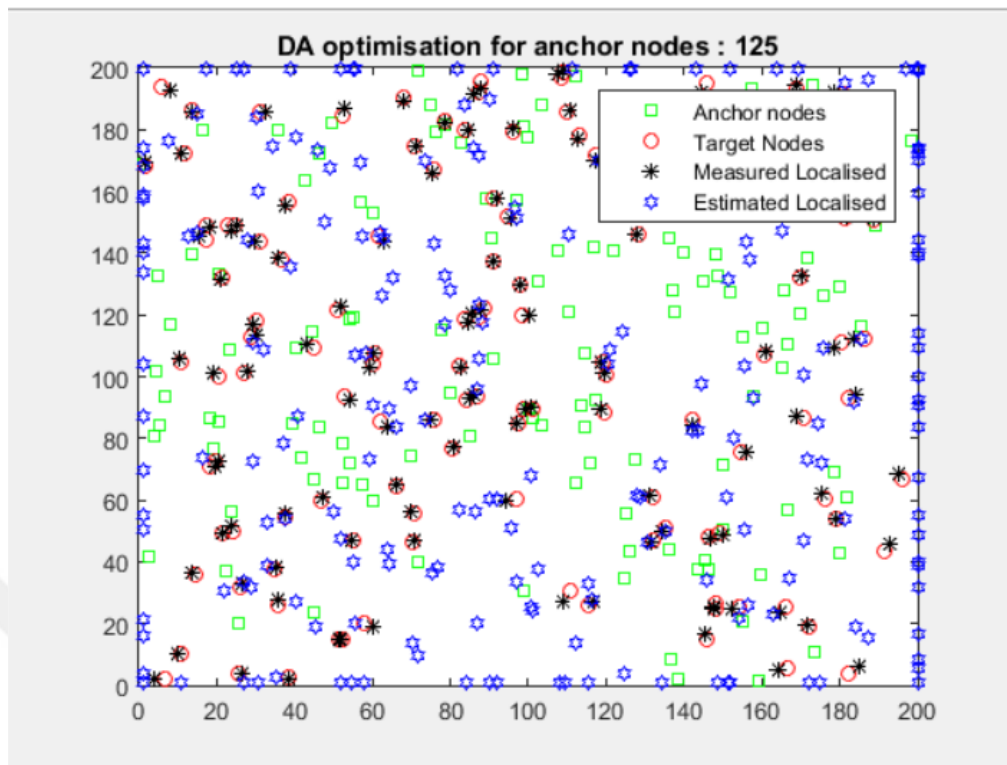


Figure 3.3 DA optimization algorithms for 125 anchor nodes

DA is a meta-heuristic algorithm that originated from the behaviors of dragonflies in the swarm for random searching or optimization purpose. Regarding the localization problem as an optimization problem, this study employed DA to calculate the location of a wireless node in a specific area. As outlined in (Table 4.7).

Table 3.7 Results of MIL for DA optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of MIL%
25	33.58782248
50	11.52614616
75	7.738807779
100	7.115827095
125	6.432908692

The result of the DA algorithm in NL corresponded to the previous algorithms with the comparison process illustrated in (Table 4.8).

Table 3.8 Results of NL for DA optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results DA of NL
25	16
50	40
75	71
100	64
125	67

In order to optimize the solution by DA algorithm, we must know the time taken by the search for the unknown nodes within the methodology used in this study including the other algorithms. In the (Table 4.9) summarizes the time taken by DA algorithm to obtain the results.

Table 3.9 Results of the time for DA optimization algorithm for 125 anchor nodes

Number of Anchor nodes	Results of time (sec)
25	112.9752377
50	97.7229403
75	85.2741457
100	78.0203025
125	68.4021022

3.3 Discussion

In this section, the results of the study are compared based on optimal solution by GWO, BAT and DA algorithms. The results were analyzed through the parameters such as mean localization error (MLE), Computational time, and a number of Localized nodes (NL). The anchor nodes varied from (25) to (125) for better efficiency in determining the positions of unknown node. Firstly, sensor nodes were distributed with 25 anchor nodes in the deployment area.

The (Figure 4.4) compares the results of algorithms for MIL. GWO algorithm provided the highest percentage of MIL during the initial group from anchor nodes and less than the BAT algorithm. When the number of Anchor nodes equaled to (125) points, DA rendered a lower percentage than the other algorithms. Nodes in deployed (250) sensor

nodes. When the number of anchor nodes was increased, the localized nodes were identical [20], which can be seen in the figure below.

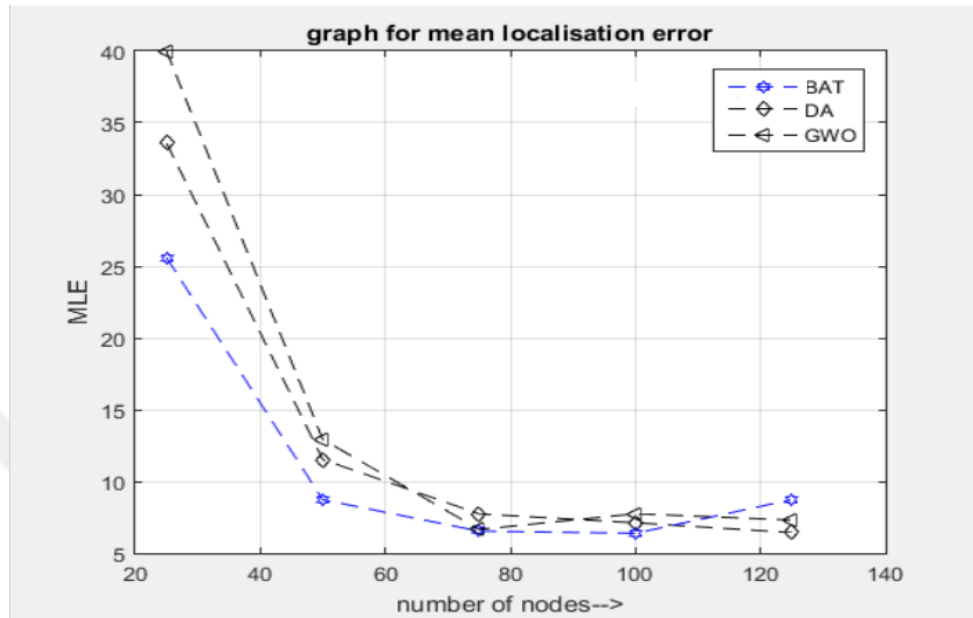


Figure 3.4 Comparison of the algorithm results for MIL

By reviewing the aforementioned results of the algorithms, it is noted that the highest percentage of NL was achieved through GWO algorithm to set the total number of anchor nodes while it was less valuable than NL study obtained through BAT algorithm, illustrated in (Figure 4.5).

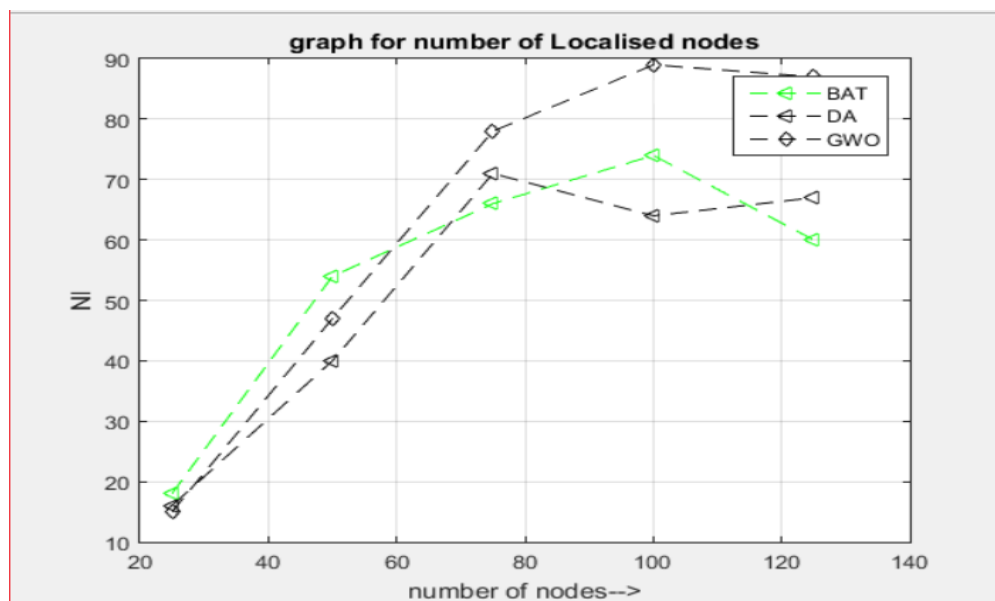


Figure 3.5 Comparison of the algorithm results for NL

As the number of anchor nodes increased within the area specified in the wireless sensor network, unknown nodes were easily identified within the shortest time [65]. The algorithms worked within its strategy in this study and through the performance of algorithms in terms of localized nodes and error value work. DA spent the least time whereas the highest time was spent by BAT algorithm, which is illustrated in (Figure 4.6) comparing the computation time results of the algorithms.

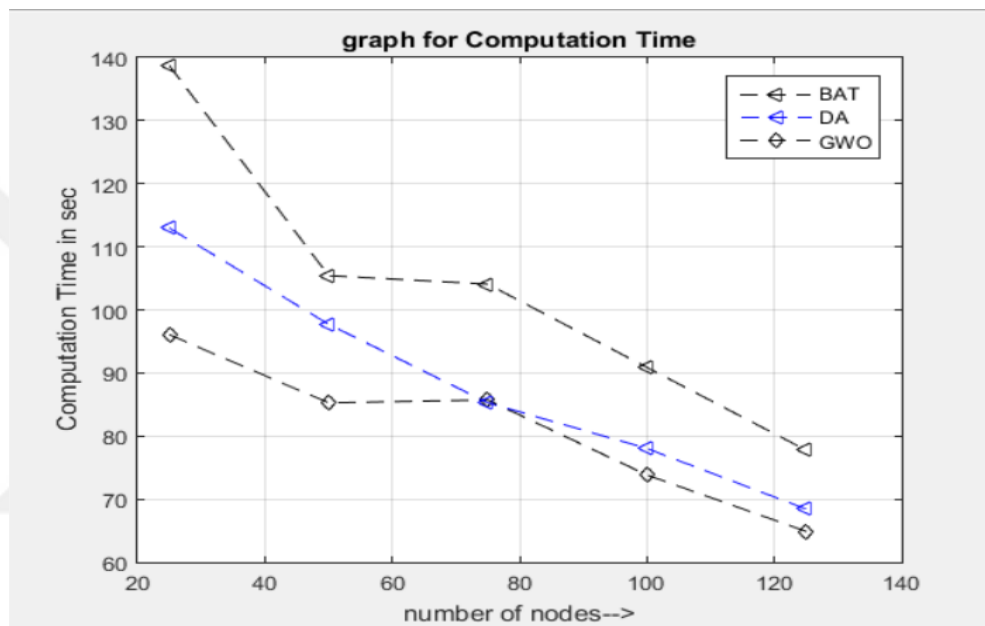


Figure 3.6 Comparison of the computation time results of algorithms

Considering the previous results, the GWO algorithm was better in terms of performance within the proposed scenario for this study. Despite having a large percentage of MIL than the other algorithms, it obtained (106) from NL by spending less time whereas DA algorithm received less MIL with (98) from NL. BAT algorithm in this study was regarded as the lowest performer, as it took longer time and dramatically less MIL than DA. The algorithms discussed above were iterative in nature and after every iteration, the number of localized nodes increased. The density of anchor nodes enhanced the performance of localizability of the target node. We can summarize and compare the results obtained by the algorithms within the scenario adopted this study in (Table 4.10).

Table 3.10 Comparative results for algorithms with 125 anchor nodes

Anchor nodes	MIL%			NL			Time(sec)		
	GWO	BAT	DA	GWO	BAT	DA	GWO	BAT	DA
25	39.99017591	25.59425737	33.58782248	15	18	16	96.0532157	138.7236978	112.9752377
50	12.9237875	8.72145845	11.52614616	47	54	40	85.2596728	105.4313973	97.7229403
75	6.654003088	6.538105898	7.738807779	78	66	71	85.7180817	104.0810906	85.2741457
100	7.746382837	6.384880233	7.115827095	89	74	64	73.8210539	90.8712003	78.0203025
125	7.309228596	8.729224529	6.432908692	87	60	67	64.875898	77.7496782	68.4021022

CHAPTER 4

CONCLUSION AND RECOMMENDATION

4.1 Conclusion

How to optimize WSN localization has been addressed by a great number of studies. Based on the range measurement dependency, the suggested methodology is broken down into two types: range-based and range-free [30]. It remains a challenge to place hybrid methods into one of these categories because they combine different methods as the basis for connectivity. This research used MATLAB to simulate localization with the GWO, DA, and BAT algorithms. It used a series of (125m) target and (125n) anchor nodes in a haphazard deployment within a (200m * 200m) sensor field of 1 unit. The anchor nodes' range of transmission was 25 units.

WSN node localization has been implemented using GWO, BAT and DA algorithms. The localized nodes and node localization performances of the GWO, BAT and DA algorithms have investigated.

The simulation results shows that WSN localization with GWO algorithm gives improved position performances of the node than BAT and DA algorithms. Therefore, GWO algorithm has better results in terms of performances, time and localized nodes than that of BAT and DA algorithms.

4.2 Recommendation

Based on the results of work on the three algorithms, some further studies could be conducted. For instance, developers can take the pros and cons of working towards each algorithm. GWO is beneficial towards general optimization because it uses the three best agents and limits the convergence. Its benefits are to be noted and it can be combined with DA and BAT. Any future work can focus on improving the GWO

through using hybrid and adapting optimization techniques. GWO has a significant advantage over the other meta-heuristics: it uses less randomized input and users can input their own parameters. Because of this, it can be used to solve many issues with minimal input. As a result of probabilistic nature of BAT algorithm, the same solution can't be expected in every test with the similar deployment. This is why many test results are taken in average. Moreover, DA is a meta-heuristic algorithm that was designed based on the behaviors of dragonflies in swarm for random searching or optimization purpose. Considering the localization problem as an optimization problem, you can employ DA to calculate the location of wireless node in a specific area. Besides, raising the maximum repetition can enhance the performance of DA. The effectiveness of algorithms proposed in this study may be verified on experimental setup of sensor network.

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