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Localization Techniques in Wireless Sensor Network

تقنيات تحديد المواقع المستخدمة في شبكة الحساسات اللاسلكية

A Research submitted in partial fulfillment for the requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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بسم الله الرحمن الرحيم

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قال تعالى:

{ رَبِّ قَدْ آتَيْتَنِي مِنَ الْمُلْكِ وَ عَلَّمْتَنِي مِنْ تَأْوِيلِ الْأَحَادِيثِ فَاطِرَ السَّمَاوَاتِ وَ الْأَرْضِ أَنْتَ وَلِّيي فِي الدُّنْيَا وَ الْآخِرَةِ تَوَفَّنِي مُسْلِمَاً وَ أَلْحِقْنِي بِالصَّالِحِين }

سورة يوسف
الآية {101}

صدق
الله العظيم

Dedication

To our supportive family and friends

To our wise teachers

Acknowledgment

In the name of Allah, the Most Gracious and the Most Merciful Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this research.

Special appreciation goes to our supervisor, Dr. Salaheldin Mohamed Ibrahim Edam, for his supervision and constant support, his help and constructive comments and suggestions throughout the topics have contributed to the success of this research.

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Abstract

Wireless sensor networks are widely deployed around the world; it has shown more popularity for both military mission and civil applications structure health monitoring habitat and environment monitoring, vehicle networks and intelligent transportation systems…etc. Localization techniques assist sensor nodes to find out their location in sensor network according to whether the actual distance or angle is measured between the nodes in the positioning process, range-based and range-free method is defined for localization process, in which range-based provide point-to-point information with reference node to estimate the node position, range-free obtains the position of non anchor nodes according to implicit information provided by anchor nodes to estimate their positions.

The purpose of this research is to cover all localization techniques in localization of Wireless Sensor Network and focuses on some of the recent range free localization algorithms that are widely used in many applications; HiRLoc, SeRLoc, Centroid, ADLA, PTA, DIL, and RAL schemes. In addition to implement these algorithms using the wireless sensor network localization simulator and compare the efficiency of each algorithm of them with each other in term of localization error and number of detecting sensor under constant parameters and analyze the results and referring it as a comparative study. Also an optimized and modified hybrid range free algorithm is suggested that minimize localization error.

المستخلص

شبكة الحساسات اللاسلكية متواجدة بكثرة حول العالم ولها العديد من التطبيقات المستخدمة، فهي تستخدم في التطبيقات المدنية و المهمات العسكرية، تطبيقات العناية الصحية، مراقبة العوامل البيئية، شبكات المركبات و شبكات المواصلات الذكية. ان تقنيات تحديد المواقع تساعد عقد الحساسات الموجودة في المنطقة على تحديد موقعها داخل الشبكة بواسطة المسافة الحقيقية المقاسة بين العقد أو زاوية الاشارة المستقبلة المقاسة عند العقد التي تدخل في عملية تحديد الموقع، ثم تستخدم خوارزميات تحديد المواقع التي تنقسم إلى : خوارزميات تحديد المسافة و خوارزميات التحديد الحر .

الهدف من هذا البحث هو تغطية التقنيات التي تدخل في عملية تحديد المواقع في شبكة الحساسات اللاسلكية و التركيز على خوارزميات التحديد الحر لتحديد الموقع التي تستخدم في كثير من التطبيقات. تم استخدام برنامج لتنفيذ المحاكاة الخاصة بالخوارزميات و مقارنة النتائج من حيث الفعالية لكل خوارزمية من حيث خطأ تحديد الموقع و عدد عقد الحساسات المكتشفة بواسطة كل خوارزمية. بالاضافة الى هذه الخوارميات تم اقتراح خوارزمية هجين تتمتع بصفات خوارزميتي التوزيع النشط و خوارزمية النقطة الوسطى لتحسين خطأ تحديد الموقع لعقد الحساسات المكتشفة.

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Abbreviations

ADLA	Active Distribution Localization Algorithm
AH	Anchor Heard
ANR	Anchors to Node Range Ratio
AOA	Angle Of Arrival
AP	Anchors Percentage
DIL	Distributed localization Algorithm
DOI	Degree Of Irregularity
GPS	Global Positioning System
HiRLoc	High Resolution Robust Localization Algorithm
MDS	Multidimensional Scaling
ND	Node Density
PTA	Power Tuning of anchors
RFID	Radio Frequency Identification
RSSI	Received Signal Strength
SeRLoc	Secure Range Independent localization Algorithm
TOA	Time Of Arrival
TDOA	Time Difference Of Arrival
UWB	Ultra Wide Band
WSN	Wireless Sensor Network

Chapter One

Chapter One: Introduction

1.1 Preface

There are two types of connections that can be deployed to connect several devices through a network, wired connections and wireless connections. Wired communication limits our mobility if we want to communicate on it wired communication has to be established. In wireless connection there is no need for wires, we can connect our devices to the network by Wireless topology, wireless network applications have been deployed widely, and wireless sensor networks have become a vital research area [1].

Wireless Sensor Networks (WSNs) is an infrastructure of thousands of spatially low cost, distributed sensor nodes connected by wireless media to form a sensor field that work together in order to monitor and collect data pertaining to physical or environmental situation such as temperature, pressure, motion, sound, and other phenomenon [1,2] then process, analyze, and send the data to the user through base stations [4, 5], these WSNs create smart environments by provide access to information concerning the environment .Wireless sensor networks have shown more popularity for both military mission and civil applications [6,7,8,11], structure health monitoring [9,10], habitat and environment monitoring [7,8], vehicle networks and intelligent transportation systems [11,12,13] , Sensor network can signal a machine malfunction to the control centre in a factory or it can warn about smoke on a remote forest hill indicating that a forest fire is about to start. On the other hand wireless sensor nodes can be designed to detect the ground vibrations generated by silent footsteps of a burglar and trigger an alarm. Also in the smart kindergarten node localization can be used to monitor the progress of the children by tracking their interaction with toys and also with each other. It can also be used in hospital environments to keep track of equipments, patients, doctors and nurses [14].

Wireless sensor networks have at least one base station that works as a gateway among the sensor network and external world. Sensor nodes sense the physical quantity and send the data to base station through single or multi-hop communication. Users can access the data stored at base station [3].

Sensors are low-cost, low power devices with limited sensing, computation, and wireless communication capabilities. A sensor node consists of a sensing unit, a data processing unit, a communicating unit, storage unit (memory) and a power supply unit. The power supply unit contains a battery that provides a limited amount of energy to the node [3, 15].

Localization in Wireless Sensor Network is the process of determining the physical coordinates of the sensor nodes, the call for of location arises because the number of nodes is huge and it is impossible for the Base Station to locate the nodes location, so the node has to send the location information along with the information collected in order to provide the accurate position to the user. This means the node must localize itself [2]. Nodes with known locations are called anchor nodes and nodes whose locations are to be determined are simply known as sensor nodes or unanchored nodes, coordinates required being either global or relative, the node can compute its distance and\or angle between itself and the reference points, its location can be determined in 2D space if a node knows its distance from three reference points, one more reference point is needed in the 3D space to decide the current position of the target device [1, 2].

Accurate location information could greatly enhance the performance of tasks such as routing, energy conservation, data aggregation and maintaining network security. Location estimating approaches essentially consists of two basic phases: distance (or angle) estimation and distance (or angle) combining. For determining the location of a sensor node, two types of techniques exist: range-free and range-based. Range-free techniques use connectivity information between neighboring nodes to estimate the nodes" position, range-based techniques however require ranging information that can be used to estimate the distance between two neighboring nodes more details about localization techniques in chapter3 [2, 14-17].

Localization Algorithms are categorized into: Centralized localization algorithms: It is based on forwarding all the node measuring quantities to a central base station where the final computation or processing is carried out to derive either absolute or relative positions of the nodes, Distributed localization algorithms: depend on each sensor node being able to determine its location with only limited communication and every node is responsible for performing computations to derive its position [2,14-16].

1.2 Motivation

To report information that has geographical meaning, sensor nodes require being capable to estimate their own positions. Localization can be done earlier by using manual configuration or by using GPS system. In manual configuration localization is done by human interaction and calculations. In real world human interaction is not always possible just like in military field, we need airplanes for deployment and the calculation is not always correct. Another is the Global Position System (GPS) is used to locate an entity using satellite, but GPS is expensive and infeasible, require higher energy consumption, sensor nodes are have to be small, but the size of GPS and its antenna increases the sensor node form factor, in the presence of dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites so GPS cannot be implemented [2, 14, 16], therefore we need to implement a localization algorithm for every node. Localization algorithm uses the reference nodes [16]. The accuracy of the estimated node locations depends on the precision of the distance measurements among the nodes and the density of the algorithms used [18].

1.3 Problem Statement

Using range base localization techniques provide good accuracy but it need to use additional hardware for updates information and synchronization which increases size and cost of sensor nodes Although using range free localization techniques solve this problem because range free algorithms using a proximity information to estimate the location of the nodes in a WSN because of that these algorithms produce high localization error and few detected sensor nodes in any deployed area.

1.4 Proposed Solution

To overcome most of the problems facing the localization algorithms, a suggested hybrid algorithm used to improve the accuracy and the localization error, using Wireless Sensor Network localization Simulator to examine the suggested algorithm.

1.5 Aim and objectives

The location of a sensor node is as important as the data collected by the sensor, knowing the location can be effective in critical situations and can also provide security. Enhancing the techniques and algorithms used in the process of localization is essential to provide better location estimation and with minimum error.

1.6 Methodology

The first phase was searching for information about wireless sensor networks, its applications and the localization techniques and methods used, second phase was gathering information about range free algorithms used in the localization process in sensor nodes, third phase was installing the wireless sensor network localization simulator v 1.1 which is used to explore, analyze and compare between six range free localization algorithms: HiRLoc, SeRLoc, Centroid, ADLA, DIL and RAL. Finally the simulator was used to present a proposed algorithm that helped improving localization error and number of detecting static sensor in a deployed area, then the results was concluded and summarized in easy and helpful way to understand.

1.7 Thesis Layout

Chapter 2 present literature review about sensors, sensor nodes, localization procedure, wireless sensor network applications and review about localization techniques and algorithms.

Chapter 3 it talks about the techniques used in localizing a node in WSN and it is classification in details.

Chapter 4 is case studies about range free localization algorithms simulation it is efficiency and proposed more efficient algorithm.

Chapter 5 it discusses conclusion and future work.

Chapter Two

Chapter Two: Overview of Localization in WSN

2.1 Background

Localization in Wireless Sensor Network is the process of determining the physical coordinates of the sensor nodes, the call for of location arises because the number of nodes is huge and it is impossible for the Base Station to locate the nodes location, so the node has to send the location information along with the information collected in order to provide the accurate position to the user. This means the node must localize itself [2]. Nodes with known locations are called anchor nodes and nodes whose locations are to be determined are simply known as sensor nodes or unanchored nodes, coordinates required being either global or relative, the node can compute its distance and\or angle between itself and the reference points. In the 2D space, if a node knows its distance from three reference points, its location can also be determined. One more reference point is needed in the 3D space to decide the current position of the target device [1, 2].

Accurate location information could greatly enhance the performance of tasks such as routing, energy conservation, data aggregation and maintaining network security.

2.2 Literature Review

To report information that has geographical meaning, sensor nodes are require to be capable to estimate their own positions. Localization can be done earlier by using manual configuration and by GPS system. In manual configuration localization is done by human interaction and calculation, but, in real world human interaction is not always possible or impractical, [18]. Global Position System (GPS) is used to locate an entity using satellite, but GPS is expensive and infeasible, require higher energy consumption and need the line-of-sight connection [2, 14, 16, 18].

To overcome the limitations of GPS, technologies such as laser scanning, Bluetooth connectivity and RFID have been estimated for use in outdoor construction. Laser scanners are installed on vehicles to detect the location information of surrounding objects to avoid collisions. Another device normally seen on construction job sites is RFID tags. RFID tags are involved to material stacks, so as to collect radio signal data to estimate the target's location when the RFID reader changes around the jobsite [20]. Thus we need to implement a localization algorithm for every node. Localization algorithm uses the reference node. The accuracy of the estimated node locations depends on the accuracy of the distance measurements among the nodes and the density of the algorithms used. There are many technical approaches that may be applied to localization: ultrasonic localization, infrared, computer vision, and radio frequency (RF) based technologies, including time-of-arrival (TOA) received signal-strength index (RSSI).

Ultrasonic systems use a mixture of RF and ultrasonic techniques to estimate the location information of the host device. An ultrasonic pulse is transmitted by the beacon simultaneously with a RF signal. The host device can estimate the distance by using the Speed difference between RF and ultrasonic waves. Using the distance between the host device and multiple transmitters, the location of the host device can be determined by localization Algorithms such as trilateration. Generally, Ultra wide band (UWB) based systems have a higher deployment price than other RF techniques due to the need for high sampling rates and precise internodes time synchronization; such systems are also less robust due to problems with interference and need for high signal reliability.

The recent researches have reconnoitered the use of RF technologies that measure the parameters of the received signal. Such RF based technologies assume there are some transmitting nodes with known location and performance as beacon points to localize other nodes with unknown location [20]. The main idea of ranging technologies in WSN system terms is transmitting of the signal from a node with unknown position to a node or a group of nodes with fixed known position. These fixed nodes can process radio signal in many different ways on the basis of the received radio waves properties. For example time difference between transmitted and received radio signal (TOA - Time of Arrival), angle of arrival (AOA) and on the received signal strength (RSS) basis [19].

2.3 Sensors

Sensors are devices that can produce a measurable response to a change in a physical condition, like temperature or thermal conductivity, or a change in chemical concentration. They are useful for making inset measurements such as in industrial process control.

2.3.1 Classifications of Sensors

Sensor is a deep field to study but in this node there are three classifications of sensors [19]:

Passive and Omni Directional Sensors**:** Passive sensors collect the data without manipulating the environment by active probing. They are self powered; energy is needed only to amplify their analog signal. There is no direction involved in this classification.

Passive or narrow-beam sensors: These sensors are passive but they have well-defined notion of direction of measurement. Typical example is ‘camera and infrared sensors’.

Active Sensors: These sensors are actively probe the environment, such as, a solar or radar sensor, which generate shock waves by small explosions.

2.3.2 Characteristics of Sensors

The characteristics features must be in any sensor node re explained briefly [25]:

Range: maximum and minimum value range over which a sensor works well. Sensors will work properly outside this range, but needs special or additional calibration. However, generally if you try to operate a sensor outside its range, it will not work (give a constant output at the max, significantly change sensitivity or give erratic results) or be damaged e.g. a 130 m pressure sensor deployed at 200 m depth

Accuracy: how well the sensor can measure the environment in an absolute sense. That means is how good the data is when compared with a recognized stored standard. .

Resolution: it is the capability of a sensor to detect small differences in readings. If temperature sensor have a resolution of 0.000,001º C, but only be accurate to 0.0001º C. That means the size of relative small changes in temperature, are smaller than the accuracy of the sensor. Resolution is usually controlled by the quantization in the analog to digital convertor – e.g. one bit is equal to 0.0005º C. This is not a function of the sensor, but the sampling process.

Repeatability: This is the capability of a sensor to repeat a measurement in the same environment. It is often directly related to accuracy, but a sensor can be inaccurate, yet be repeatable and able to make observations.

Drift: This is the low frequency change in a sensor with respect of time. Drift generally decreases with the age of a sensor as the component parts mature. A smoothly drifting sensor can be corrected for drift.

Hysteresis: A linear variable input to a sensor, that makes an output that lags the input e.g. you get one curve on increasing temperature and another on decreasing. Hysteresis is the dependence of the output of a system from its current input and its history of past inputs.

Stability: is another way of stating drift. That is, with a given input you always get the same output. Drift, short and long term stability are really ways of expressing a sensor's noise as a function of frequency. Sometimes this is expressed as guaranteed accuracy over a certain time period.

Response time: estimate of the frequency response of a sensor with an exponential behavior.

2.4 Sensor Node

Sensor nodes are low cost, low power devices that are used to gather physical data and observe environmental situation from remote locations

[15], Sensor nodes consist of sensing hardware, processor, memory, power supply, and a transceiver. These sensor nodes have partial energy, memory, and computational power and therefore, a great number of them are necessary to be efficient. Denser WSNs can give higher accuracy and have a bigger total amount of energy available [18].the type of sensor nodes is [1, 2]:

Settled Nodes: These nodes were originally unknown nodes and capable to estimate their location by using the localization system. The number of settled nodes and the predictable position error of these nodes are the main parameters for determining the quality of a localization system.

Beacon Nodes: Also known as anchors or locators, these are the nodes that do not need a localization system in order to estimate their physical positions. Their localization is obtained by manual placement or external means such as GPS. These nodes form the base of most localization systems for WSNs [20, 25].

2.5 Wireless Sensor Network

WSN is an connections of thousands of spatially low cost, distributed sensor nodes connected by wireless media to form a sensor field that work together in order to monitor and collect data pertaining to physical or environmental situation such as temperature, pressure, motion, sound, and other phenomenon [1, 2] .In recent years, there has been a growing interest in wireless sensor networks. Wireless Sensor Networks (WSNs) doesn’t always have nodes of same type, this means WSNs are not always homogeneous, but some nodes of higher energy can be used to increase the lifetime and reliability of WSNs**,** Heterogeneous wireless sensor networks (HWSNs) have some sensor nodes of relatively higher energy [21].

A wireless sensor network (WSN) increases the capability to monitor and control the physical environment. It is especially useful in emergency scenario where human participation maybe too dangerous. The sensor networks have evolved over a period of time. The failures are unavoidable in wireless sensor networks because of unwelcoming environment and unattended deployment; therefore sensor nodes must operate potentially in large numbers. The latest generation of sensors encompasses self-organizing, flexible and scalable networks. Wireless sensor networks have at least one base station that works as a gateway between the sensor network and outside world. Sensor nodes sense the physical amount and send the data to base station via single or multi-hop communication. Users access the data stored at base station [3].

Ad-hoc Network: Ad-hoc is Latin and means “for this purpose”. An ad hoc network is a wireless decentralized structure network comprised of nodes, which autonomously set up a network. No external network infrastructure is necessary to transmit data – there is no central administration. Freely located network nodes participate in transmission when direct communication between each pair of nodes is usually not possible. Generally, ad hoc network can consist of deferent types of multi-functional computation devices [27, 29].A mobile ad-hoc network (MANET) is a self-configuring infrastructure-less network of mobile devices connected by wireless. Ad Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. MANETs are a kind of wireless ad hoc networks that usually has a routable networking environment on top of a Link Layer ad hoc network. Table 2.1 explains the main difference between Ad hoc and WSN [27, 28, and 29].

Table 2-1: Differences between WSN and Ad-hoc networks

Differences	WSN	Ad-hoc
Number of nodes	Can be more than 100 nodes connected to the network	Can be less than 100 nodes connected to the network
Fault tolerance	Have low redundancy	Have high redundancy
Type of communication	Broadcasting communication – single hop	Point to point communication – multi hop
Data rate	High data rate	Low data rate
Batteries	Usually irreplaceable	Replaceable and/or rechargeable

2.6 Application of Wireless Sensor Network

Applications of WSN vary according to the specific needs of an individual or an organization [6 - 11]**:**

Area monitoring: Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over an area where some observable fact is to be monitored. The term Environmental Sensor Networks, has evolved to cover many applications of WSNs to earth science research. This includes sensing volcanoes, oceans, glaciers, forests, etc.

Medical application: WSN systems are used in medicine application for measuring and analyzing various physical parameters of the patients, as well as relevant environment variable, WSNs are used for collecting data and transmitting data to the central monitoring systems, but also for alerts and location tracking.

Home care: Automatic monitoring systems can provide non-stop supervision of vital signals. Data may automatically send (using an existing infrastructure) to a hospital/ medical center .Wearable Body Sensor Networks (WBSN): Allow long term monitoring for specific activities, e.g. measurements of athletes vital signals during training. Typical examples of signals that are monitored are: ECG/ rhythm, oxygen saturation, blood pressure, temperature, perspiration, respiratory rate, activity (movements).

Forest fire detection: A network of Sensor Nodes can be installed in a forest to detect when a fire has started. These primary techniques are inefficient due to the unreliability of human observation towers and difficult life condition. This has allowed some countries to use forest-fire detection systems based on the satellite imagery.

Landslide detection: A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. Through the data gathered it may be possible to know the occurrence of landslides long before it actually happens.

Natural disaster prevention: Wireless sensor networks can effectively act to prevent the consequences of natural disasters, like floods. Wireless nodes have successfully been deployed in rivers where changes of the water levels have to be monitored in real time.

Industrial monitoring: WSN are used in so many industrial fields to sense or locate a certain machine:

Machine health monitoring: Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionalities

Data logging: Wireless sensor networks are also used for the collection of data for monitoring of environmental information.

Industrial sense and control applications: In recent research a vast number of wireless sensor network communication protocols have been developed.

Agriculture and green houses: A greenhouse is a structure covering land often used for growth and development of plants that will return the owner's risk time and capital. This structure is mounted with the intention of protecting crop and of allowing a better environment to its development. Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses.

2.7 Localization Process in Wireless Sensor Networks

Localization is still a new and exciting field, with new algorithms, hardware, and applications being developed at a feverish pace; it is hard to say what techniques and hardware will be prevalent in the end [2, 14, 15, 16], figure 2-1below describes flow chart of the process of locating an unknown node**:**

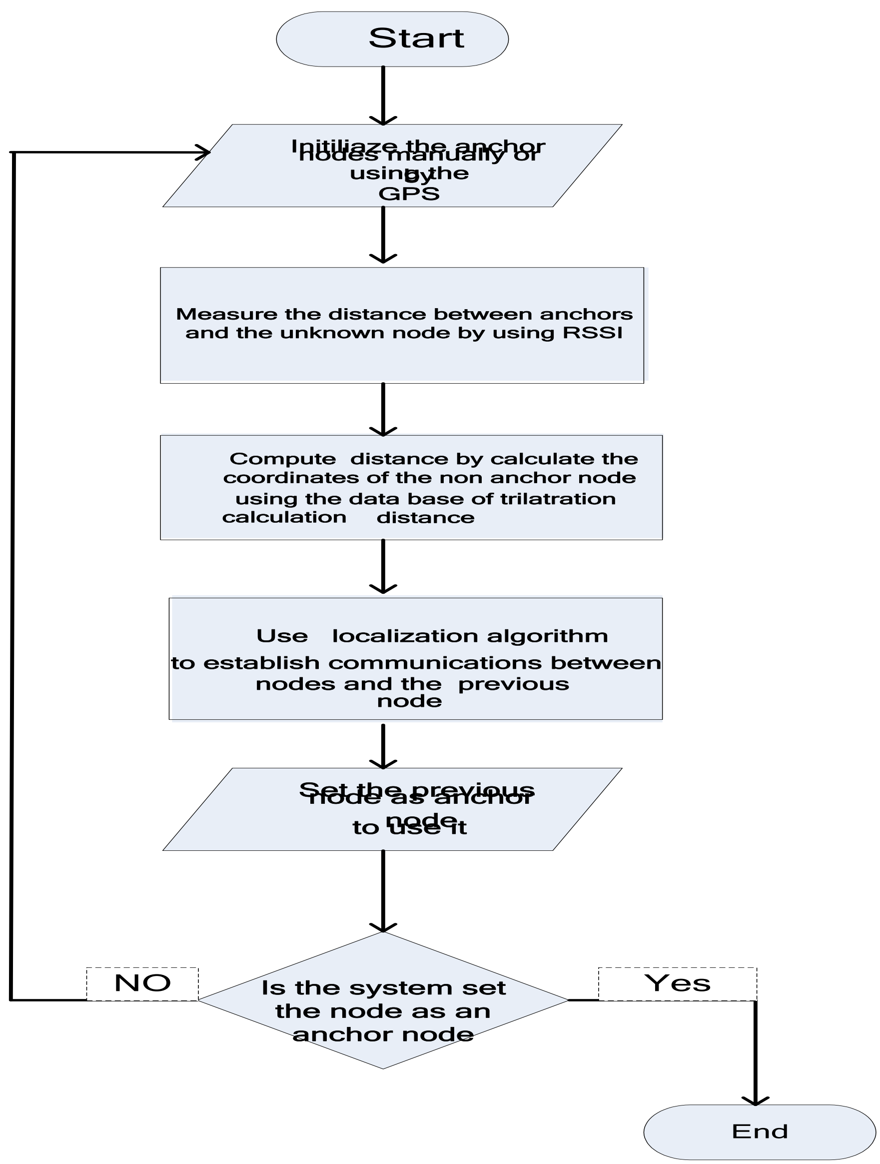

Figure 2-1: Flow Chart of Localization Process in WSN

But there are some existing techniques which use two localization techniques such as multidimensional scaling (MDS) and proximity based map (PDM) or MDS and Ad-hoc Positioning System (APS).

Localization problem in WSN can be divided into two main levels: Estimating the distance between pairs of nodes in the network and determining the position of all unknown nodes in the network [27].

2.7.1 Distance Estimation:

It can be measure either by rang base methods by measured the distances between two nodes (RSSI, TOA, TDOA) or estimating the angle between the destination node and reference axis (AOA), or by using range free methods by count the hops and estimate distance (hop count, DV hop, centroid in 2D, APIT) the distance estimation will be discuss briefly in chapter 3

2.7.2 Position computation:

The process of calculating the coordinates of each node [27]:

2.7.2.1 Trilateration and Multiletration:

The most basic and intuitive method is called hyperbolic trilateration. It locates a node by calculating the intersection of 3 circles. To estimate its position using trilateration, a node needs to know the positions of three reference nodes and its distance from each of these nodes. Distances can be estimated using one of the methods explained in the previous section. The circles formed by the position and distance to each of the references can be represented by the formula:

$$(x^\circ - xi)^2 + (y^\circ - yi)^2 = \mathrm{di}^2 \qquad (2.1)$$

In equation (2.1) where (x°, y°) is the position we want to compute, (x_i , y_i) is the position of the i^{th} reference node, and d_i is the distance of the i^{th} reference node to the unknown node. In this case we have three equations with two unknown variables, which can be solved, theoretically, in one solution [14, 27]. Furthermore, when a larger number of reference points are available, we can use multilateration to compute the node's position. In this case an over determined system of equations must be solved, depicts this case. Usually, over determined systems do not have a unique solution. When considering *n* reference points and also the error of the distance estimations, which makes, the system of equations becomes

$$(x^\circ - x)^2 + (y^\circ - yi)^2 = \mathrm{di}^2 - \mathrm{e} \qquad (2.2)$$

In (2.2) 'e' is normally considered to be an independent normal random variable with zero means [2, 14, 16, and 27].

2.7.2.2. Triangulation:

In triangulation information about angles is used instead of distances. Position computation can be done remotely or by the node itself; the latter is more common in WSNs. In this last case, depicted in , at least three reference nodes are required. The unknown node estimates its angle to each of the three reference nodes and, based on these angles and the positions of the reference nodes (which form a triangle), computes its own position using simple trigonometrically relationships. This technique is similar to trilateration. This method is used when the direction of the node instead of the distance is estimated, as in AOA systems. The node positions are calculated in this case by using the trigonometry laws of sins and cosines [2, 27].

2.8 Localization Algorithms

Algorithms act an important role in optimizing in calculating the coordinates of a node after calculating the distance by one of the techniques. Algorithms are classified into [2, 14-16].

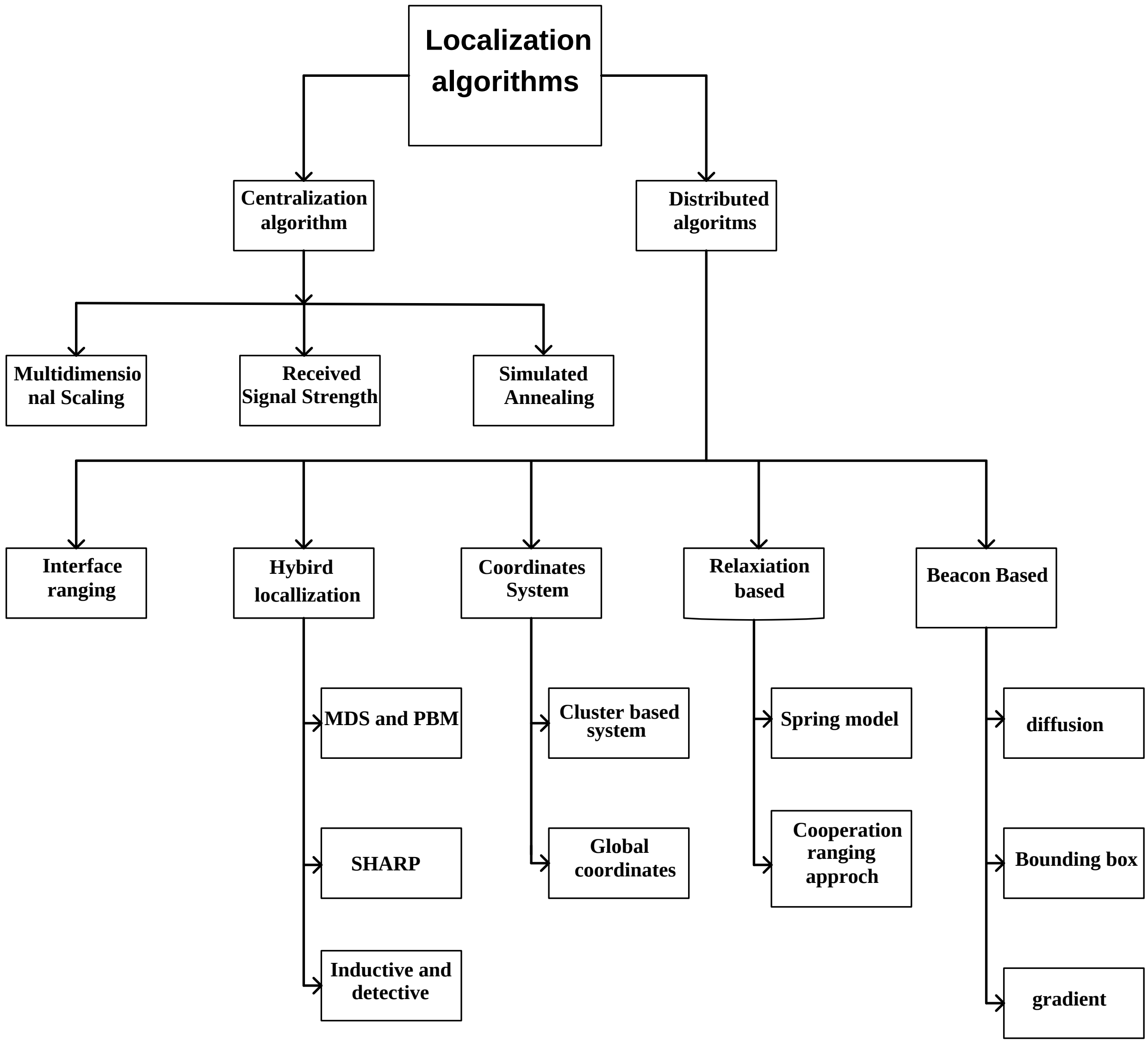

Figure 2-2: Localization Algorithms in WSN

2.8.1 Centralization Localizations

Centralized localization is mainly movement of inter-node ranging and connectivity data to a suitably powerful central base station and then the movement of resulting locations back to particular nodes. The advantage of centralized algorithms are that it eliminates the trouble of calculation in each node, at the same time the limits lie in the communication cost of moving data back to the base station [2, 13, 14, 15 and 24], table 2-2 explains the main difference between its type.

2.8.1.1 Multidimential Scaling (MDS-MAP): Centralized algorithm called MDS-MAP which basically consists of three steps.

1. First the system computes shortest paths among all pairs of nodes in the area of consideration via the use of all pair shortest path algorithm such as Dijkstra's or Floyd's algorithm. The shortest path distances are used to create the distance matrix for MDS.
2. Next the classical MDS is useful to the distance matrix, retaining the first 2 (or 3) largest Eigen values and eigenvectors to build a 2-D (or 3-D) relative map that gives a location for each node. Although these locations may be perfect relative to one another, the whole map will be randomly rotated and flipped relative to the true node positions.
3. Based on the location of plenty anchor nodes (3 or more for 2-D, 4 or more for 3-D), transform the relative map to an absolute map based on the unlimited positions of anchors which includes scaling, rotation, and reflection. The objective is to reduce the sum of squares of the errors between the right positions of the anchors and their transformed positions in the MDS map [13].

The advantage of this system is that it does not require anchor or beacon nodes to establish with. It builds a relative map of the nodes even without anchor nodes and next with three or more anchor nodes; the relative map is transformed into total coordinates. This method works well in situations with low ratios of anchor nodes. A downside of MDS-MAP is that it requires global information of the network and centralized computation.

2.8.1.2 Localize node based on Simulated Annealing: Suggest an innovative approach based on Simulated Annealing to localize the sensor nodes in a centralized manner. Since the algorithm is centralized, it enjoys the access to estimated locations and neighborhoods information of all localizable nodes in the system. This method is based on neighborhood information of nodes and it works well in a sensor network with medium to high node density. However when the node density is low, it is possible that a node is flipped and still maintains the correct neighborhood. In this situation, the proposed algorithm fails to identify the flipped node.

2.8.1.3 Received Signal Strength (RSS) based centralized localization technique: There is suggest that the scheme which localizes nodes through RF attenuation in Electromagnetic waves. The system basically consists of three stages:

1) RF mapping of the network: It is obtained by conveying short packets at different power levels through the network and by storing the average RSSI value of the received packets in memory tables.

2) Creation of the ranging model: All the tupelos recorded between the two anchors are processed at the central unit to compensate the non linearity and calibrate the model.

3) Centralized localization model: An optimization problem is solved and provides the position of the nodes. The final result can be obtained by minimizing the function Where N is the number of nodes, solve the minimizing problem by sequential quadratic programming (SQP) method [24].

The benefit of this scheme is that it is a practical, self-organizing system that allows addressing any outdoor environments. The limitation of this scheme is that the scheme is power consuming because it requires wide-ranging generation and need to forward much information to the central unit [15].

Table 2.2: Differences between centralization techniques

Centralization Algorithms	Advantages	Disadvantages
MDS	-requires few numbers of beacons. -does not need a beacon node to establish with.	-Requires global information about the network. -centralized computation.
Simulated and Annealing	-more accurate. -well work in high and medium density node.	Depend on the neighbor's computations.
RSSI	Practical, self organizing.	-power consumption

2.8.2 Distribution Localization:

In Distributed localizations all the relevant computations are done on the sensor nodes themselves and the nodes communicate with each other to get their positions in a network. Distributed localizations can be categorized into five classes:

2.8.2.1 Beacon based distributed localization:

Beacon based approaches can be categorized in Diffusion, Bounding Box and Gradient which are described as follows:

- Diffusion:

In diffusion the most likely position of the node is at the centered of its neighboring known nodes. APIT requires a heterogeneous network of sensing devices where some devices are equipped with high-powered transmitters and location information. These devices are known as anchors. In this advance the location information is performed by dividing the environment into triangular regions between beaconing nodes. An unknown node chooses three anchors from all audible anchors and tests whether it is inside the triangle formed by connecting these three anchors. APIT repeats this tests with different audible anchor combinations until all combinations are exhausted or the required accuracy is achieved. At this point, APIT calculates the centre of magnitude of the intersection of all triangles in which the unknown node resides to determine the estimated position. The benefit of APIT lies in its simplicity and ease of implementation. But APIT requires a high ratio of beacons to nodes and longer range beacons to get a good position estimate. For low beacon density this system will not give exact results.

- Bounding Box :

Bounding box forms a bounding area for each node and then tries to process their positions.

  - Collaborative Multilateration.
  - Node localization assuming the region as square box.

- Gradient:

The authors express an algorithm for organizing a global coordinate system from local information. In this approach ad-hoc sensor nodes are accidentally distributed on a two dimensional plane and each sensor communicates with nearby sensors within a fixed distance r, where r is much smaller than the dimension of the plane. In their algorithm they assume some set of sensors as “seed” sensors which are identical to other sensors in capabilities except that they are programmed with their global position. The algorithm consists of two parts:

Gradient Algorithm: Each seed sensor produces a locally propagating gradient that allows other sensors to guesstimate the distance from the seed sensors. A seed sensor initiates a gradient by sending its neighbors a message with its location and a count set to one. Each receiver remembers the value of the count and forwards the message to its neighbors with the count incremented by one. That’s why a wave of messages propagates outwards from the seed. Each sensor maintains the minimum counter value received and ignores messages containing larger values, which prevents the wave from traveling backwards. If two sensors can converse with each other directly then they are considered to be within one communication hop of each other. The minimum hop count value, that a sensor i maintains will finally be the length of the shortest path to the seed in communication hops. In the proposed ad hoc sensor network, a communication hop has a maximum physical distance of r related with it. This implies that a sensor is at most distance from the seed. However as the average density of sensors increases, sensors with the same hop count tend to form concentric circular rings, of width approximately r, around the seed sensor.

- Multilateration Algorithm:

Each sensor uses a multilateral procedure to combine the distance estimates from all the seed sensors to produce their own positions. After receiving at least three gradient values, sensors combine the distances from the seeds to estimate their position relative to the positions of the seed sensors. In particular, each sensor estimates its coordinates by finding coordinates that minimize the total squared error between calculated distances and estimated distances.

The advantage of this algorithm is that it can be easily adapted to the addition of sensors, addition of seeds and also death of sensors and seeds. But it requires substantial node density before its accuracy reaches an acceptable level. Besides this hop count is not reliable in measurement because environmental obstacles can prevent edges from appearing in the connectivity graph.

2.8.2.2 Relaxation based distributed algorithm:

Spring model: An Anchor Free Localization (AFL) algorithm where nodes start from a random primary coordinate assignment and converge to a dependable solution using only local node interactions. The algorithm profits in two phases and it assumes the nodes as point masses connected with strings and use force-directed relaxation methods to converge to a minimum-energy configuration. General simulations show that the proposed algorithm outperforms incremental algorithm by both being able to converge to correct positions and by being significantly more robust to errors in local distance estimate.

Cooperative Ranging Approach:

In [14] the authors explain a Cooperative ranging approach which uses assumption Based Coordinate (ABC) as its primitive to solve the localization problem. ABC algorithm determines the location of the unknown nodes by making assumptions when necessary and compensating the errors through corrections and redundant calculations as more information. The advantage of this approach is that no global resources or communications are needed. The disadvantage is that convergence may take some time and that nodes with high mobility may be hard to cover.

2.8.2.3 Coordinates system approaches:

Cluster based approached: The algorithm is basically consists of two phases. Phase 1 is cluster localization where each node becomes the centre of the cluster and estimates the relative location of its neighbors which can be unambiguously localized. For each cluster, all the robust quadrilaterals as well as the largest sub graph composed solely of overlapping robust quads are identified. The authors define robust triangles to be a triangle which satisfies $B\sin 2\theta > d\ min$

In this equation, B is the length of the shortest side and θ is the smallest angle and d min is the threshold based on the measurement noise. If a quadrilateral has four robust sub-triangles then the quadrilateral is a robust quadrilateral. The algorithm starts with a robust quadrilateral and when two quads have three nodes in common and the first quad is fully localized, the second quad can be localized by trilaterating from the three known positions.

In the second phase i.e. cluster transformation, the position of each node in each local coordinate system are shared. As long as there are at least three non-collinear nodes in common between the two localizations, the transformation can be computed by rotation, translation, reflection.

The advantage of this scheme is that cluster based localization supports dynamic node insertion and mobility. The limitation is that under condition of low node connectivity or high measurement noise, the algorithm may be unable to localize a useful number of nodes.

2.8.2.4 Hybrid localization:

Hybrid localization technique is a combination of centralized and distributed techniques, in centralized localization there are a back-up node, a super-sink node for storing the database and distributed localization of all the sink nodes. It has a sink node, a backup node, super sink node. The entire network is first divided into overlapping sub regions consisting of only one sink node. For example- The sink node along with its one-hop neighbor forms a sub-region. In the sub region so obtained a centralized algorithm like SDP (semi definite programming) or MDS-MAP (multi-dimensional scaling) is applied to localize the sensor nodes.

The backup node handles the condition of the failure of a sink node. It is a mirror image of the sink node and dynamically updates its information. It is activated by the super sink node, through an ALERT message, in case the sink node fails or its energy level decreases beyond the threshold value. The backup node thus takes over causing no harm to the network. The dynamic updating of the lookup table by the super sink node leads to a fast access and reduces the time taken, thus increasing the throughput [15].

Complexity of Multi Dimensional scaling (MDS) and Positional Based Map (PBM): The main advantage of this scheme is to minimize the computation cost. For classical MDS, the complexity is f (n3) where n is number of nodes. The complexity for PDM is f (m3) where m is the number of anchors. But the scheme composed of MDS and PDM has a complexity of f (mx3) where mx is the total number of primary and secondary anchors. So by keeping mx as a reasonable number, the complexity can be made similar to the complexity of PDM. The limitation of this scheme is that it does not perform well when there are only a few anchors [14].

Simple hybrid relative positional (SHARP): SHARP outperforms MDS if both the localization error and the cost are considered. The limitation of this scheme is that for anisotropic networks SHARP gives poor performance.

Localization scheme composed inductive and deductive approach: There are two main methods to estimate the position in indoor environments. On the one hand, there are the so-called deductive methods. These take into account the physical properties of signal propagation. They require a propagation model, topological information about the environment and the exact position of the base stations. On the other hand, there are the so-called inductive methods. These require a previous training phase, where the system learns the signal strength in each location. The main shortcoming of this approach is that the training phase can be very expensive. The complex indoor environment makes the propagation model task very hard. It is difficult to improve deductive methods when there are many walls and obstacles because deductive methods work estimating the position mathematically with the real measures taken directly from environment in the training phase. In [24] the authors present a hybrid location system using a new stochastic approach which is based on a combination of deductive and inductive methods.

The advantage of this method covers a hard indoor environment without many base stations. Besides that, this technique reduces the training phase without losing precision [25].

Interferometric ranging based localization:

Radio interferometric positioning exploits interfering radio waves emitted from two locations at slightly different frequencies to obtain the necessary ranging information for localization. Table 2-3 clarifies its type and differences.

Table 2-3: Differences between distributed algorithms

Distributed Algorithms	Advantages	Disadvantages
Beacon based D-AL (Diffusion)	Simplicity and easy to implement	Requires a high ratio of beacon and longer range beacon
Beacon based D-AL (Gradient)	Easy to update for addition sensor by add or delete	Requires substantial node density
Relaxation based D-AL (Spring model)	-Able to correct position more significantly. -more robust to errors,	susceptible to local minima
Relaxation based D-AL (Cooperative ranging approach)	No global resources and are needed.	-convergence make take time that nodes
Hybrid localization (composed MDS and PDS)	Minimize computation.	Does not perform well when there are few anchors.
Hybrid localization (SHARP)	Perform multi alteration to estimate its position.	Limitation for anisotropic networks gives poor performance

Chapter Three

Chapter Three: Localization Techniques

3.1 Introduction

One of the most crucial issues in wireless sensor network is to determine the location and direction of sensor nodes. Location information is useful for both network organization and for sensor data reliability. In many wireless sensor network applications sensor nodes are required to identify their locations with high degree of exactness such as forest fire detection etc. In many applications the position itself is the information of interest in monitoring and tracking the target, routing based on the position information. Localization techniques in assisting sensor nodes to find out their location in sensor network According to whether the actual distance or angle is measured between the nodes in the positioning process [2, 16].

For determining the location of a sensor node, two types of techniques exist: range-free [19, 20, 21] and range-based [16, 18, 22, 33]. Range-free techniques use connectivity information between neighboring nodes to estimate the nodes‟‟ position, range-based techniques however require ranging information that can be used to estimate the distance between two neighboring nodes. On the one hand, range-free techniques do not require any additional hardware and use proximity information to estimate the location of the nodes in a WSN, and thus have limited precision. On the other hand, range-based techniques use range measurements such as time of arrival (TOA), angle of arrival (AOA), received signal strength indicator (RSSI), and time difference of arrival

(TDOA) to measure the distances between the nodes in order to estimate the location of the nodes. These different ranging techniques are described as follows [18]

The characteristics of wireless communication are partially determined by the distance between sender and receiver, and if these characteristics can be measured at the receiver they can serve as an estimator of distance. The most important techniques are Received Signal Strength Indicator (RSSI), Time of Arrival (TOA), and Time Difference of Arrival (TDOA) [14, 16, 35, and 36], table 3-1 explains the outlines difference between them [2, 14, and 15]:

3.2 Range Base Localization methods

Range base methods calculate the distance or the angel between the sensor nodes as following:

3.2.1 Time Of Arrival

The most simple and instinctive is Time Of Arrival (TOA); In this case the distance between two nodes is directly proportional to the time the signal takes to transmit from one point to another, the sending node sends a signal with a synchronization message and the sending time to the receiving node, and the latter receives both the signal and the synchronization message, recording the receiving time at the same time. If the signal transmission speed is known, the distance between two nodes can be calculated according to the signal transmission time [2]. Then the unknown node's location can be estimated by the trilateration method or this way, if a signal was sent at time t_1 and reached the receiver node at time t_2, the distance between sender and receiver is

$$d = (t_2-t_1)*s. \qquad (3.1)$$

In equation (3.1) where “S” is the propagation speed of the radio signal (speed of light), “t_1” and “t_2” are the times when the signal was sent and received.

In realistic application, the ranging results are generally greater than the real distance due to synchronization offset; multi-path Interference, Line Of Sight (NLOS) and transmission delay increase caused by noise, there are ranging and positioning errors in the wireless signal transmission [32].

3.2.2 Time Difference of Arrival

These methods record the time-of-arrival (TOA) or time-difference-of-arrival (TDOA). The propagation time can be directly translated into distance, based on the known signal propagation speed. These methods can be applied to many different signals, such as RF, acoustic, infrared and ultrasound. TDOA methods are impressively accurate under line-of-sight conditions. But this line-of-sight condition is difficult to meet in some environments. Furthermore, the speed of sound in air varies with air temperature and humidity, which introduce inaccuracy into distance estimation. Acoustic signals also show multi-path propagation effects that may impact the accuracy of signal detection [2, 14, 16, 27 and 32].

The main drawback of this technique is the need of two types of senders and receivers on each node introduce high mathematical effort to compute the position. In TDOA, measurement of distance depends upon the time difference between two waves reaching same or different destinations with following combinations:

- Both at Radio frequency.
- One at radio and other at Ultrasonic frequency.
- Both at Ultrasonic frequency.

Table 3-1: Signals used in TDOA Localization Technique

The signal	Additional hardware	Synchronization of nodes	Effect of speed of sound
RF-RF	NO	Require	No
RF- Ultrasonic	Yes	Not require	Yes
Ultrasonic-Ultrasonic	Yes	Require	No

3.2.3 Angle of Arrival

Angle-of-Arrival (AOA): It is also called DOA (Direction of Arrival). This method estimate the location of the target from the intersection of the several pairs of angle direction lines, each formed by the circular radius from a base station.

Generally, AOA techniques provide more correct localization result than RSSI based techniques but the cost of hardware of very high in AOA. The estimation of the AOA is done by using directive antennas or an array of receivers-usually three or more - that are uniformly separated. In the last case, based on the arrival times of the signal at each of the receivers, it becomes possible to estimate the AOA of this signal. The need for extra hardware and a minimum distance between the receivers results in some disadvantages in terms of the cost and size of nodes [2, 14, 16 and 27].

Advantages:

- It only needs two measuring units for 2D positioning and for 3D.
- It doesn't need synchronization between the measuring units.

Disadvantages:

- Works well in situations with LOS (Line of Sight) but the accuracy and precision decrease when there are signal reflections (Multipath). So it is not good at indoors.
- Large, costly and complex hardware
- The accuracy also decreases when the mobile target moves further from the measuring units.

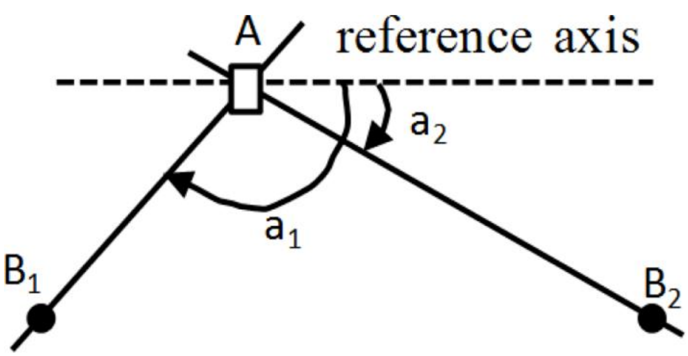

Figure 3-1: Angel Of Arrival measurement

Where:

A is the unknown location node.

B_1: the Known location node number one.

B_2: node number two with known location.

$a_{1:}$ the angle between the reference axis and B_1.

$a_{2:}$ the angle between the reference axis and B_2.

3.2.4 Received Signal Strength Indicator

Received Signal Strength Indicator (RSSI) is a Radio-Frequency (RF) term and stands for Received Signal Strength Indicator. It is a measure of the power level that a RF device, such as Wi-Fi or 3G client, is receiving from the radio infrastructure at a given location and time. For instance, the power level a laptop is detecting from a nearby AP.

Higher RSSI gives better the quality and speed of the communication through the radio segment.

RSSI-based localization methods can be further classified into groups, such as propagation model, proximity, or fingerprinting. Propagation model localization methods analyze the relationship between RSSI values and distances to learn parameters such as the path loss exponent of the propagation path-loss model in the calibration phase. The calibrated propagation model is then applied to convert the signal strength to the estimated distance between transmitter and receiver in the localization phase. In proximity localization methods, an unknown node broadcasts a localization packet to initiate the localization process. Nearby location-known reference nodes then report the RSSI values measured from the packet to a nominated node. The order of reported RSSI values is then used to determine the location of the unknown node. Fingerprinting localization methods measure RSSI values from a set of static nodes during a calibration phase at several locations. The measured RSSI values at a particular location are then used to fingerprint the location. In the localization phase, a node measures RSSI values from the same static nodes and then estimates its location by finding the fingerprinting that is the closest match with the measured RSSI values [31, 32, and 33].

The received signal strength indicator (RSSI) is one of the Range-based methods that calculate the location between neighboring sensors.

RSSI can be used to estimate the distance based on the received signal strength from another sensor nodes. Theoretically, the signal strength is inversely proportional to squared distance, and there is a known radio propagation model that is used to convert the signal strength into distance. However, in real environments, it is hard to measure distance using RSSI because of noise, obstacles, and the type of antenna. In these cases, it is common to make a system calibration, where values of RSSI and distances are evaluated ahead of time in a controlled environment. The advantage of this method is its low cost, because most receivers can estimate the received signal strength and does not require additional hardware, which will not increase the size of the nodes. The disadvantage is that it is affected by noise and interference. So, distance estimation may have inaccuracies [29].

RSSI problems:

Obstacles that are on the direct line between sender and receiver are a further cause for signal attenuation. Of course, this attenuation effect, also known as shadowing, depends on the object's size, the material it is made of, as well as the radio technology and the utilized frequency.

RSSI measurements are affected by many radio frequency variations which are divided to:

Radio Propagation fading effects: The general term fading is used to describe fluctuations in the envelope of a transmitted radio signal [30].

(1) Large-scale fading or path loss: Large scale fading is explained by the gradual loss of received signal power (since it propagates in all directions) with transmitter-receiver (T-R) separation distance. Received power or its reciprocal, path loss, is generally the most important parameter predicted by large-scale propagation models. It is valuable to examine the three main propagation mechanisms that determine path loss [32, 33].

(2) Small scale fading or multi-path: This occurs at the spatial scale of the order of the carrier wavelength, and is frequency dependent, due to the constructive and destructive interference of the multiple signal paths between the transmitter and receiver [32- 34]. Figure 3-2 below shows the advantages and disadvantages of those techniques.

Table 3-2: The Differences between Distance Estimation Techniques

Measurement technique	Advantages	Disadvantages
TDOA	-No synchronization problem - It is not affected by channel fading -recorded good accurate under line-of-sight conditions.	-delay in the second node of communication. -cannot deal with multi path or overlapping signals. - It is difficult to meet line-of-sight condition in some environments.
RSSI	-Less expensive. -does not need extra devices. -easy to estimate -Good accuracy is in short distance.	-Effected with reflection, refraction and scattering. -Power strength is fad out with increase in distance. -Accuracy is affected by obstacles. - the most realistic model for sensor network communication
AOA	More accurate than others	-Costly (need more than two stationary antenna). -problem with weak signal, multi path signal, shadowing and reflections. -channel interference.

3.3 Range Free Localization in Wireless Sensor Network

This technique obtains the position of non anchor nodes according to implicit information provided by anchor nodes, usually based on messages exchanged, commonly called beacons. This information is usually made up of different aspects, such as number of hops between devices or radio coverage membership. The most common ones are Hop Count, APIT, Centroid (CL) [15] and DV-hop and more in [16, 37-41].

Range-free localization schemes:

The main advantage of Range-free algorithms is minimizing the localization error without any additional hardware cost. The range-free algorithms, in most of the cases, estimate the location of normal nodes (which location is unknown) from the signals sent by locator and beacon nodes (which locations is known). There are many parameters that directly affect estimation error in range-free localization algorithms:

1- Node density (ND).

2- Anchors heard (AH).

3- Anchors to node range ratio (ANR).

4- Anchor percentage (AP).

5- Degree of irregularity (DOI).

In the following subsections, we focus on the most recent algorithms as well as the most used in WSNs.

3.3.1 Hop Count Localization Algorithm

This method is used to estimate the distance between two nodes. A signal takes the number of hopes from sender node to receiver node and multiplies with the maximum communication range of a node. This method gives an accuracy of approximately 50 % of maximum range of a node and does not require complex calculations. Errors can be reduced up to 20 % of the maximum range when neighbor nodes are more than 15. Hop count is discussed in detail in [17].

- DV-hop: in DV-hop algorithm, the unknown node calculates the minimum hops between the node and the anchors and the length of every hop is estimated which is then used to obtain the distance between unknown nodes and anchors by multiplying the minimum hops. Finally, the position of the unknown node can be obtained [2, 16].

3.3.2 Approximate Point in Triangle

Approximate point in Triangle (APIT) is an algorithm is proposed in [17], [18] in which an unknown node determines whether it is inside a triangle formed by three anchors in the neighborhood or not. This is determined by reading RSSI values coming from anchor nodes. Node position is estimated to be centre of the triangle if it is inside the triangle of three anchors, Sometimes errors occurs deciding whether an unknown node is inside the triangle or not, especially when it is near the edge of a triangle formed by anchors. The modified version of Approximate point in Triangle (APIT) in [19] overcomes this error by calculating individual areas of the triangles formed in both in case and out case and then comparing it with total area. APIT is more accurate than simple centroid method but has slightly larger communication overhead than Centroid. More the number of anchor nodes, more the triangles formed around unknown node and hence more the accuracy.

3.3.3 Centroid Localization Algorithm

In Centroid based Algorithm in 2D [20], all anchors first sends their positions to all sensor nodes within their transmission range. Each unknown node listens for a fixed time period and collects all the beacon signals it receives from various reference points. Secondly, all unknown sensor nodes positions are calculated by a centroid determination from all n positions of the anchors in range. The centroid localization algorithm is simple but the location error is high due to the centroid formula.

3.3.4 Active Distributed Localization Algorithm

Active Distributed Localization Algorithm (ADLA) is a simple distributed range free algorithm for determining the range of un-localized node. ADLA for sensor node is based on the existing localization schemes and convex programming approach. In this approach for determining the coordinates of node, a grid based structure is used to for capturing the sensor nodes.

3.3.5 High-Resolution Robust Localization

The High-Resolution Robust Localization (HiRLoc) method allows sensors to determine their location with high accuracy even in the existence of security threats. However, it is not interested in the security threats discussed by HiRLoc it is interest in the localization techniques proposed in HiRLoc. The algorithm considers that there are two types of nodes:

locator/anchor nodes which transmit beacons with location information and normal nodes (unknown location nodes). The algorithm considers that ordinary nodes determine its own location by received beacon signal from locator. The beacon signal transmitted by locator node contains locator coordinates, angle of directional antenna, and locator communication range, Locator nodes reorganized this information every time and retransmit it to normal nodes. Based on SeRLoc, in order to reduce the area of sector intersection without increasing the number of locators and sectored antennas, (HiRLoc) achieves greater localization accuracy during directional antennas and variable transmission power, while increases computational and communication density. It permits sensors to find out their location with high accuracy even if there are some security threats, HiRLoc it provides passive sensor localization based on beacon information transmitted from the locators. Locator's communication range is variable and each locator sends beacon information more than once (multiple rounds). This method is more accurate and robust as in each round the locator may change its direction or its range or may be both, the sensor first decides the locators in which they are concerned and determines the primary calculation for its location, the sensors then collect the beacon information in the multiple rounds, The locators may change its direction and range in the multiple rounds [36-40].

3.3.6 Secure Range-Independent Localization for Wireless Sensor Networks

Range-Independent localization algorithm sensor nodes find out their position based on the beacon information which is transmitted by the locators.

Secure Range-Independent Localization for Wireless Sensor Networks (SeRLoc) is a distributed algorithm which is based on two-tier network architecture it allows sensor nodes to inactively find out their position without cooperates with other sensor nodes in the network. Each locator transmits different beacons at each antenna sectors, which is received by the sensor nodes within their range R. Each beacon contains the particular beacon coordinates and the sector boundary lines. They send anchor beacons to unknown nodes, in which contains their positions and the sectors of the antenna. When a node hears multiple locators, it computes the center of gravity of the sectors matching to locators as its position (COG) [39] of the overlapping area of the different sectors.

The SeRLoc is robust against severe WSN attacks, such as the wormhole attack, the Sybil attack and compromised sensor nodes. However, SeRLoc[39] is based on the supposition that no blocking of the wireless medium is feasible. And it does not protect against attacks on locator's information, which are avoided by checking network properties [39] such as sector exclusivity and communication range. In order to minimize the region of sector intersection to improve localization, we need to increase the number of locators and sectored antennas [39].

3.3.7 Distributed localization algorithm

Distributed localization algorithm (DIL) algorithm it is proposed three types of nodes normal nodes (have no location information), beacon nodes (have location information), and anchor or locator nodes (have angle information), beacon nodes are deployed randomly over the network while anchor nodes are deployed manually or randomly.

The WSN is divided into several clusters each one should be have at least one anchor. For the algorithm to operate, it assumes a rectangular outdoor monitoring region and it assumes that normal nodes get their angle information from anchor nodes, the nodes are assumed to be deploy on m ×n monitored area and the communication range of the anchor node is dual the sensing range, RA=2Rs, Where Rs is the sensing range of each normal nodes.

For distance measurement DIL uses the received signal strength indicator (RSSI) to achieve the distance between the beacon nodes and normal nodes, due to the procedure of RSSI, the wireless communication channel could be affected by fading and shadowing. Therefore, average path loss is computed according to the Equation.

3.3.8 Restricted Area based Localization Algorithm

Restricted Area based Localization Algorithm (RAL) algorithm considers two types of nodes which are normal nodes and locator or anchor nodes. Location purpose for normal node is done by measuring the received signal at normal node according to different power levels for locator and using radio connectivity and standard of perpendicular bisectors are used to form restricted area.

3.3.9 Power Tuning Of Anchors

In Power Tuning Of Anchors (PTA) algorithm, it is assumed that all the locators are capable to adjust their transmission power and transmit beacon signals at different power levels starting from maximum to minimum received by the normal nodes or sensors. The algorithm considers two types of nodes which are normal nodes and locator or anchor nodes. In addition, the algorithm assumes the mobility of normal nodes.

Location purpose for each mobile node is done by using the received beacon signals from different three locators. The mobile node then acknowledges the locators and requests for retransmission of beacon with reduced power. After that, locators will reduce the power level and retransmit the beacon signals again. Mobile nodes choose two power levels for each selected locator; based on this information mobile node can determine its own location.

Chapter Four

Chapter Four: Simulation and Results

There are several localization schemes that allow sensors to determine their physical locations in absence of special hardware. Many localization schemes (anchor-based) assumes that some special sensors (anchors) know their true physical locations. Other sensors determine an approximate relative location to anchors based on some measurements. However, there are some other schemes (anchor-free) in which there are no anchor nodes. In these schemes, sensors locations are calculated according to some virtual coordinates. Other than the GPS, there are many schemes/algorithms that are recently proposed for localization in WSNs.

In this chapter we focused on some of the recent algorithms that are widely used in many applications; HiRLoc, SeRLoc, Centroid, ADLA, PTA, DIL, and RAL schemes. In addition, we will show the implementation and simulation results to these algorithms and the point of view on the efficiency (number of detect and the localization errors of each one of these schemes.

After the implementation of the algorithms, five case studies are discussed in this chapter, the first case study discuss the impact of the antenna type of the locators (directional-omni-directional) on the number of detected nodes and the localization error. Second case study discusses the effect of increasing and decreasing the number of beacons on the detected sensors number and the localization error. Third case study discusses the effect of increasing and decreasing the number of locators on the detected sensors number and the localization error. Fourth case study compares between the different localization algorithms in terms of number of static nodes. Fifth case study compares between the different algorithms in terms of detected sensors number and the localization error.

4.1 Wireless Sensor Network Localization Simulator

It designs and implements an integrated framework used for localization in WSNs, available for the analysis of different types of localization schemes (Range-free, Range-based and Hybrid localization algorithms). The obtained framework is simple and easy to be used to demonstrate the performance evaluation and comparison of different types of localization schemes. It can also be extended to include many localization algorithms by future researchers.

The proposed simulation tool is a discrete event simulator which is written in the C# programming language. This discrete event simulation tool operates on the basis of chronological consecutive events to change a system's state. These events are processed by the simulation kernel. User-defined localization algorithms are implemented as C# classes and mostly utilize simulation tool concepts. Node composition and network layout along with environmental and setup parameters are set via user interface. The modules are compiled and linked with the simulation kernel, and result in the simulation application. The simulation tool architecture design is flexible, and modular, allowing for customizations to be made using an object oriented component files. Such an approach allows for users to adapt the simulation tool, or extend it to different localization algorithms.

Assumptions:

This section describes the assumptions for the proposed scheme in terms of network model and the directional antenna model

4.1.1 Network Model in WSN Localization Simulator

Network generation: the network is assumed to contain a set of sensor nodes N of unknown location and a set of specially equipped nodes L we call *locators*, with known location, Locators' position can be acquired through GPS receivers, all network nodes are deployed randomly in a specific network region of area A.

The random deployment of the network nodes can be modeled as a spatial homogeneous Poisson point process, the random placement of the locators with a density $\rho_L = \frac{L}{A}$.

The random deployment of sensors with a density $\rho_S = \frac{N}{A}$, Let LH_S denote the set of locators heard by a sensor *s*.

In (4.1) the probability that *s* hears exactly *k* locators $P(|LHs| = k)$ is equal to the probability that *k* locators are deployed within an area of size $\pi R2$, where *R* is the locator-to-sensor communication range. Since locators deployment follows a spatial Poisson process (randomly deployed in a specific area):

$$P(|\text{LHs}| = K) = \frac{(\rho_L \pi R^2)^K}{K!} e^{-\rho_L \pi R^2} \qquad (4.1)$$

4.1.2 Antenna model in WSN Localization Simulator

Sensors are assumed to be equipped with omni-directional antennas having a sensor-to-sensor communication range *r*. Locators are assumed to be equipped with sectored antennas with M sectors and directivity gain G (M), locators transmit with higher power than sensors $R > r$. Due to the directivity of the locators antennas, and the higher locator transmitting power, the locator-sensor link is asymmetric. The sensor-to-locator communication range is $d = rG$.

4.2 Simulation Results of Range Free Localization Techniques:

The major parameters that measured localization algorithms efficiency is localization error (distance between the actual position and estimated position of a sensor node) and number of detected unknown sensor nodes in a deployed area.

4.2.1 Case Study One: Algorithms efficiency Vs Locator’s antenna type directional and omni-directional

One of the challenges facing the development and adoption of wireless sensor networks is achieving wireless communications with minimum cost and power. Many studies have shown that wireless data transmission is the most expensive operation in terms of energy consumption, the energy cost to transmit a single bit is approximately the same needed to process thousand operations in node's CPU, In our study of using directional and omni-directional antenna for transmit signal we found that using directional antenna minimize power consumption and decrease the Localization as in figure4-1 and figure 4-2, and decreases the number of detected sensors, but using omni-directional antenna increase localization error and increase the number detected sensors.

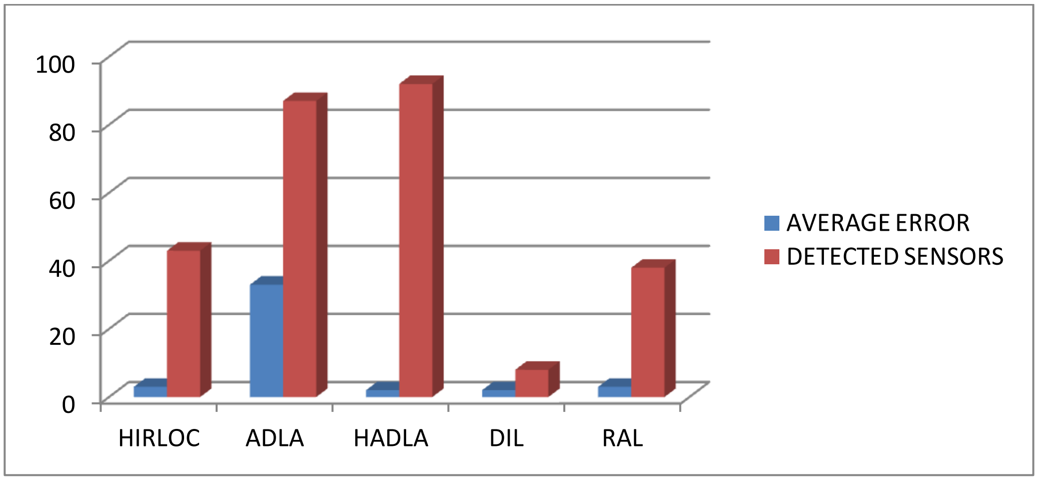

Figure 4-1: Algorithms efficiency Vs Locators Omni-directional antenna.

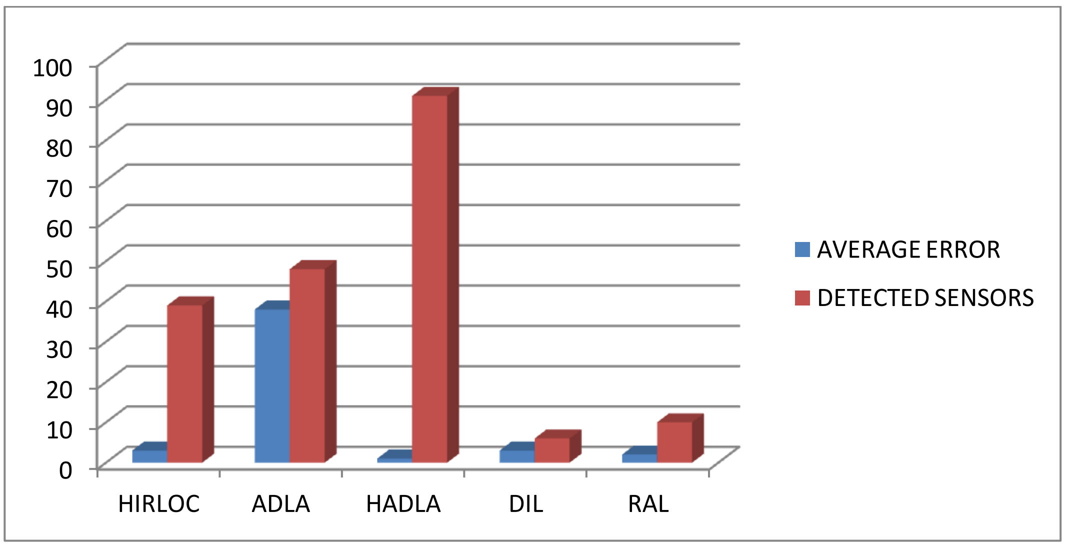

Figure 4-2: Algorithms efficiency Vs Locators' Directional antenna.

4.2.2 Case Study Two: Comparison between Algorithms in term of Localization Error and Number of Detected Sensors

The table 4-1 contains the constant parameters used in the simulator, the simulation shows that the highest score of detected sensor recorded by ADLA and Centroid algorithm, in the other side RAL, DIL, HIRLOC algorithms registered minimum average localization error and the figure 4-3 below clarify these relations.

Table 4-1: simulation parameters

Parameters	Values
Localization parameter	Position estimation
Type of sensors	Static
Locator radio range	250m
Beacon radio range	40m
Locator beam width	45°
Number of beacons	50
Number of random locators	8
Number of static sensor nodes	200
Locator antenna type	Directed
Locators deployment Strategy	Grid with 8 locators

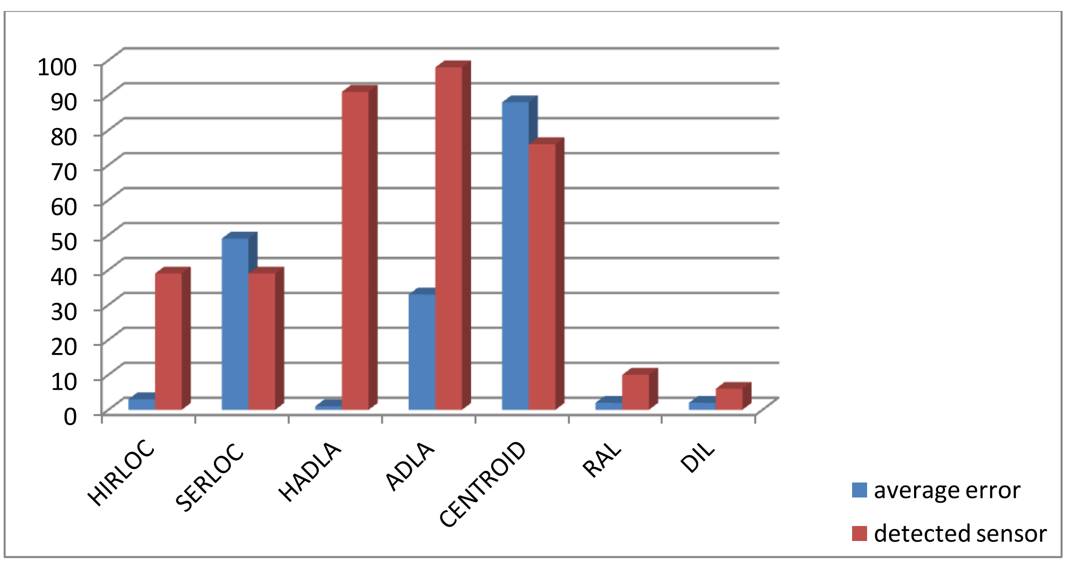

Figure 4-3: Comparison between Algorithms in Localization Error and Detected Sensor

4.2.3 Case Study Three: Number of Beacon Nodes and it is effect on Range Free Localization Algorithm

Theatrically, increasing the number of beacons nodes enhances results -decrease localization error and increase number of detected sensor node - and so the simulation experience confirmed it as shown in figures 4-4 to 4-9.

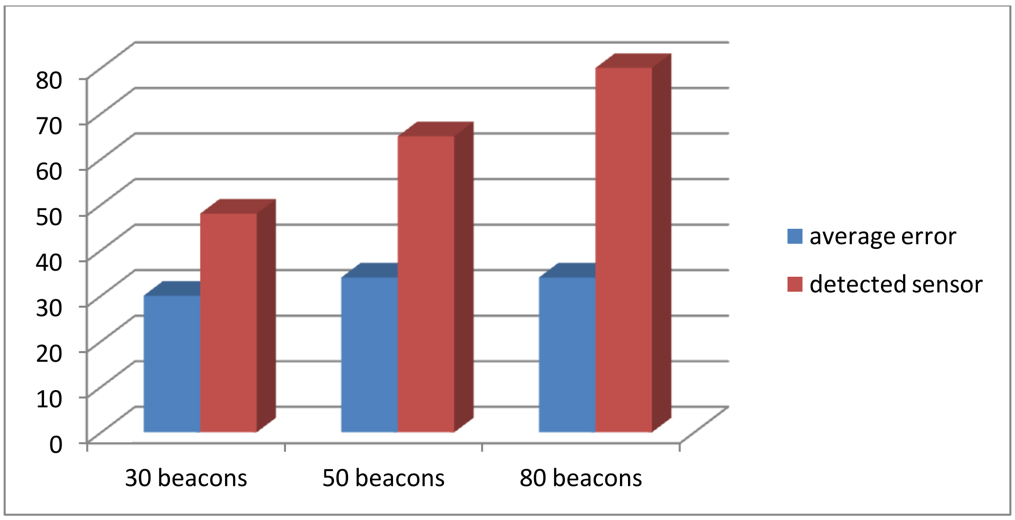

Figure 4-4: ADLA Efficiency Vs Number of Beacons.

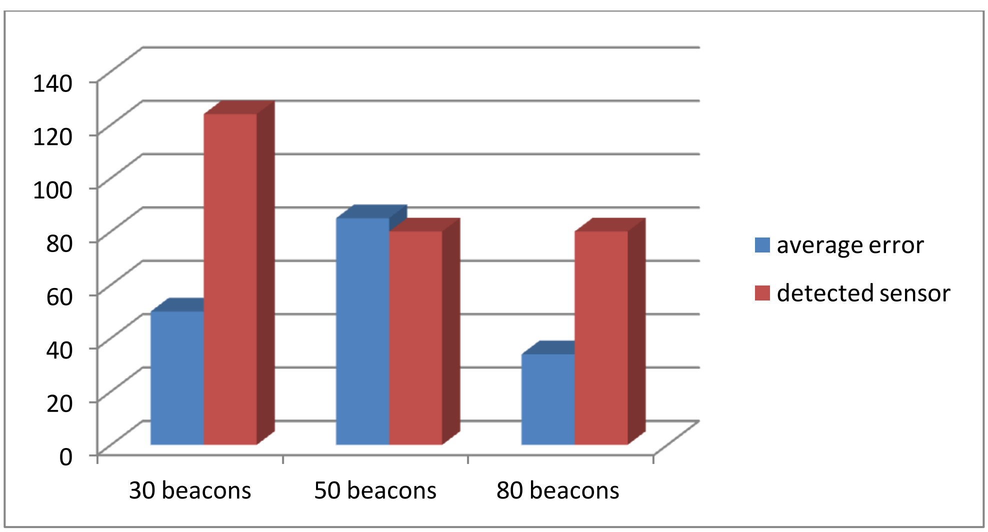

Figure4-5: Centroid Efficiency Vs Number of Beacons.

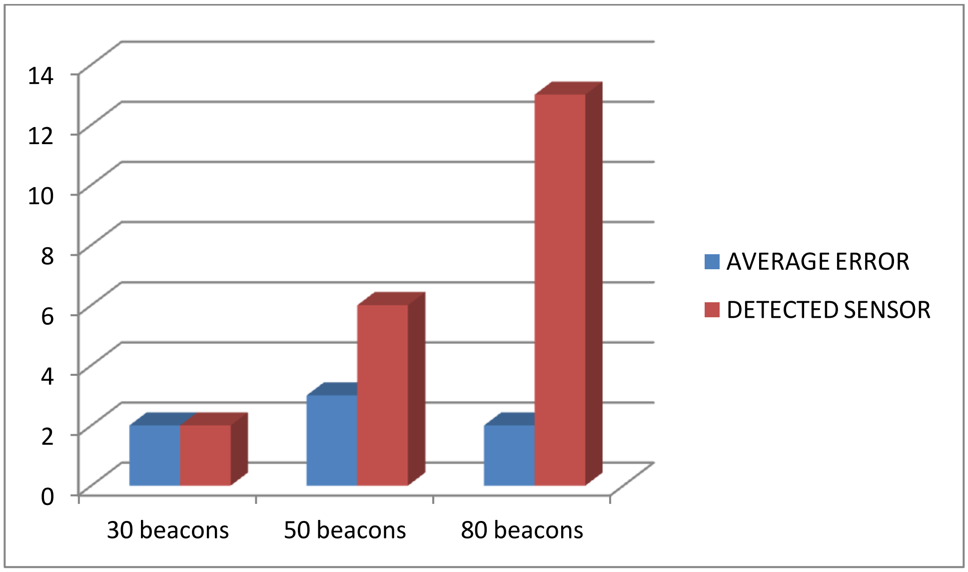

Figure4-6: DIL Efficiency Vs Number of Beacons.

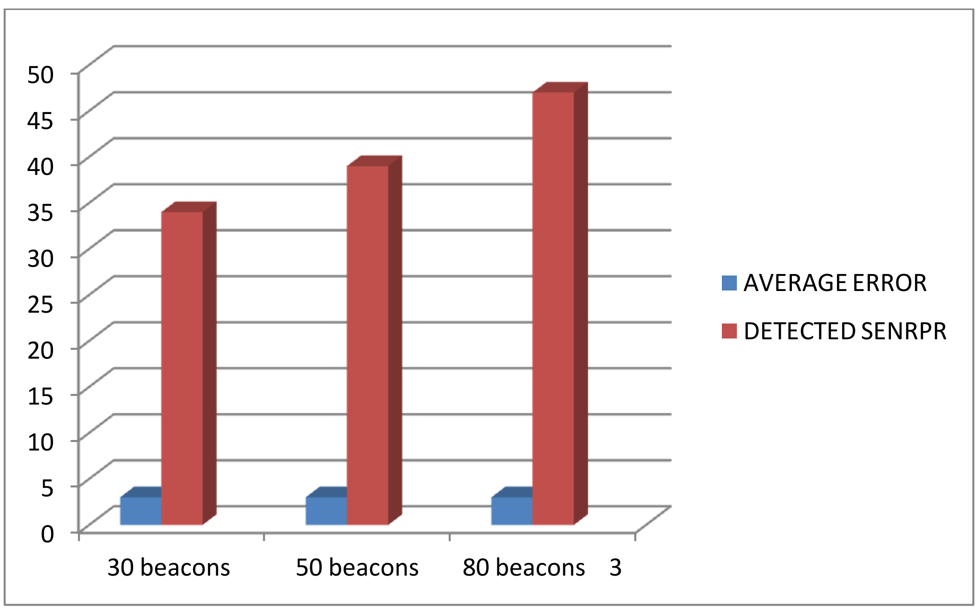

Figure 4-7: HiRLoc Efficiency Vs Number of Beacons.

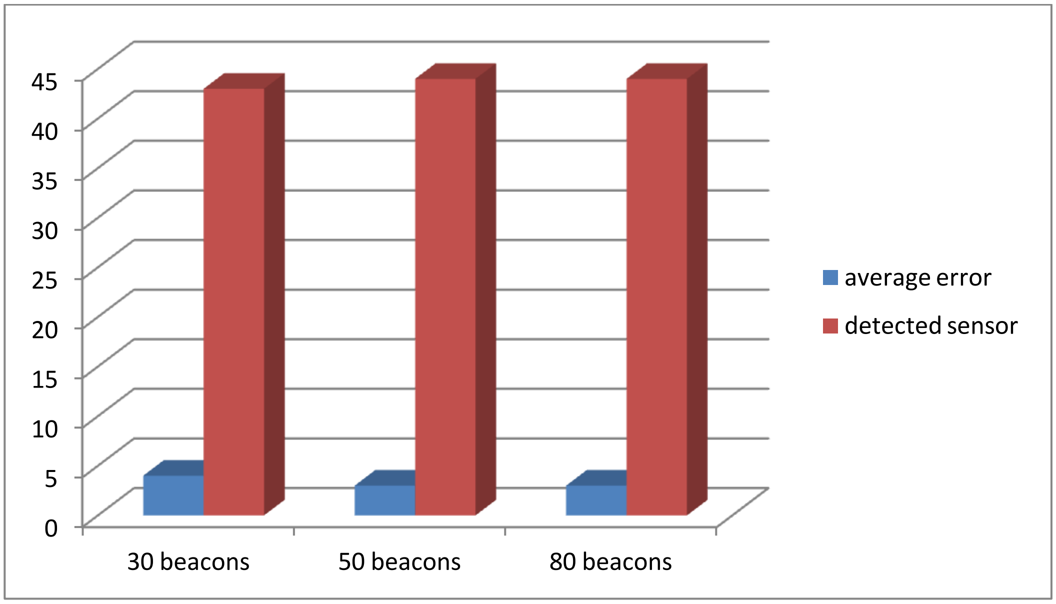

Figure4-8: RAL Efficiency Vs Number of Beacons.

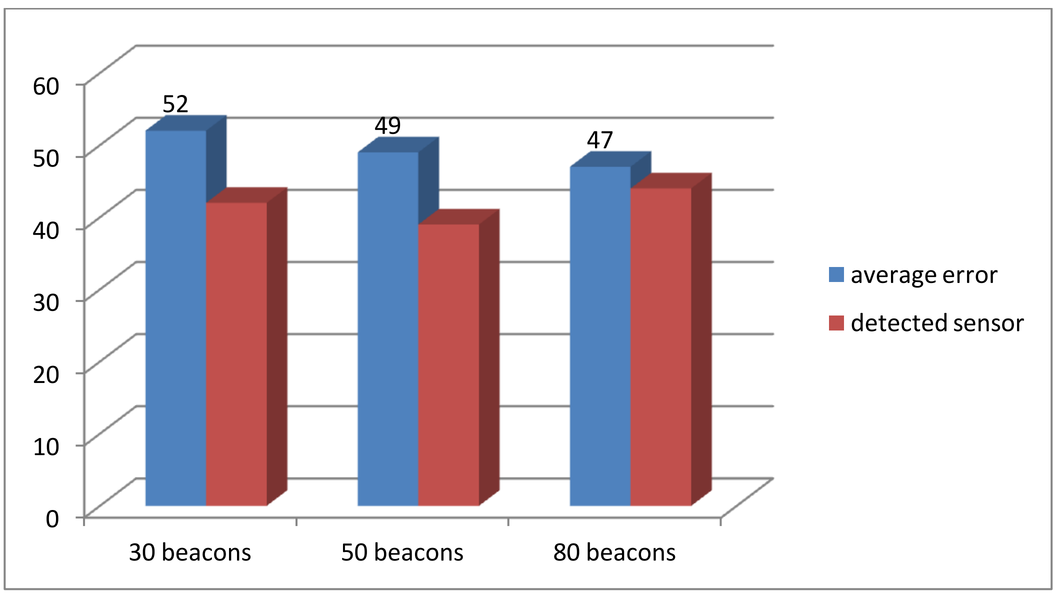

Figure4-9: SeRLoc Efficiency Vs Number of Beacons.

4.2.4 Case Study Four: Number of Locators and it is Effect on Algorithms Efficiency

From simulation results, increasing the number of locators decrease localization error and increase the number of detected sensor nodes as shown in figure 4-10 to 4-15.

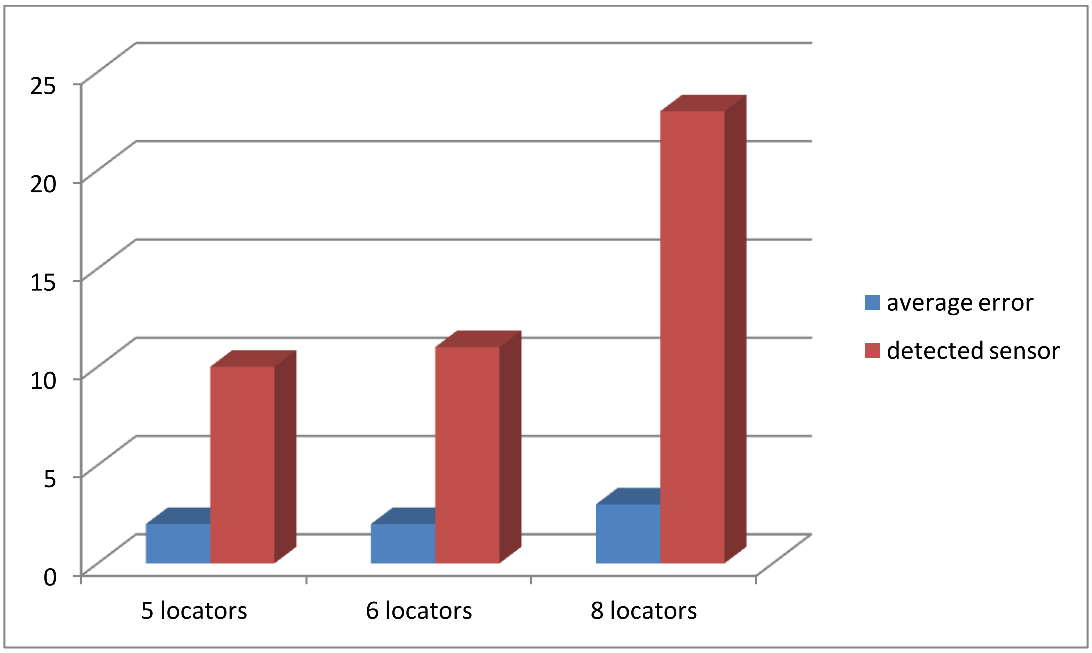

Figure 4-10: Hirloc Efficiency Vs Number of Locators

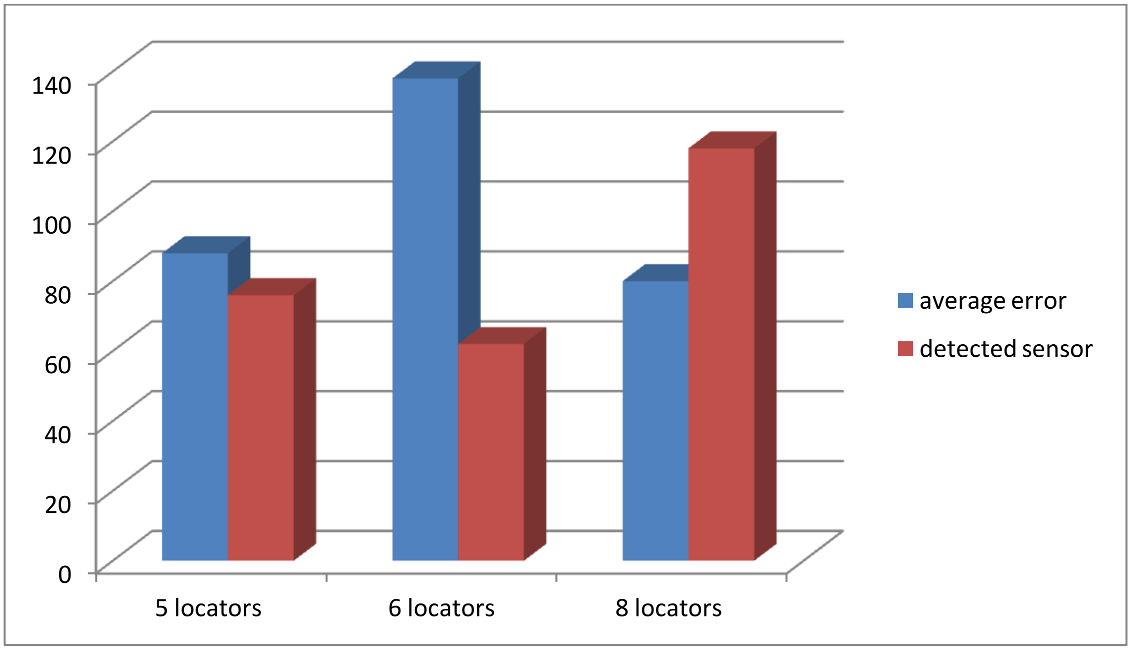

Figure 4-11: Centroid Efficiency Vs Number of Locators

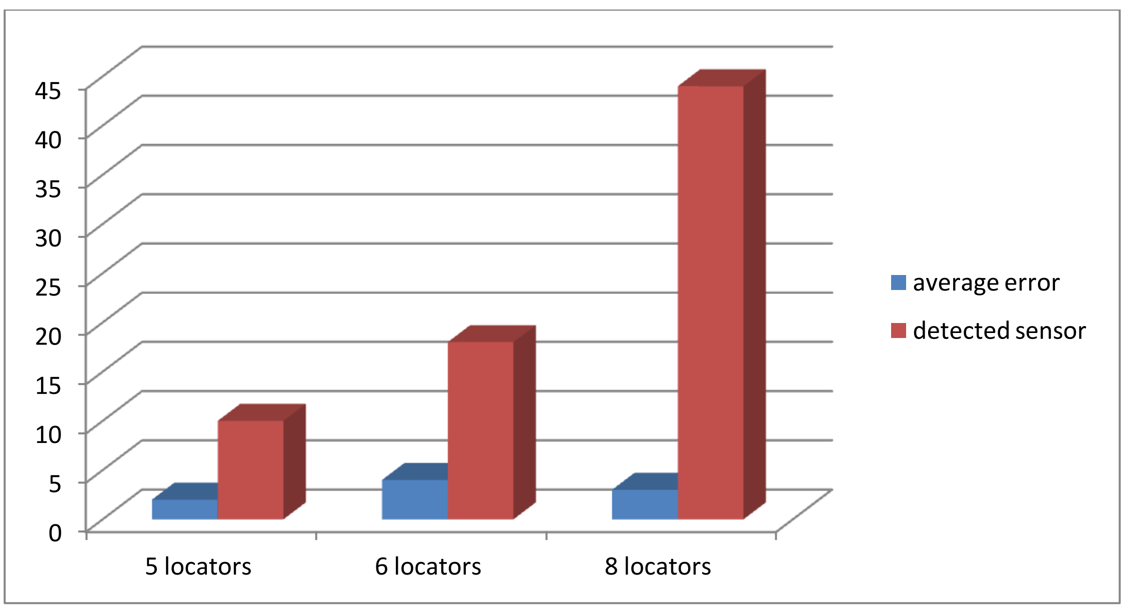

Figure 4-12: RAL Efficiency Vs Number of Locators

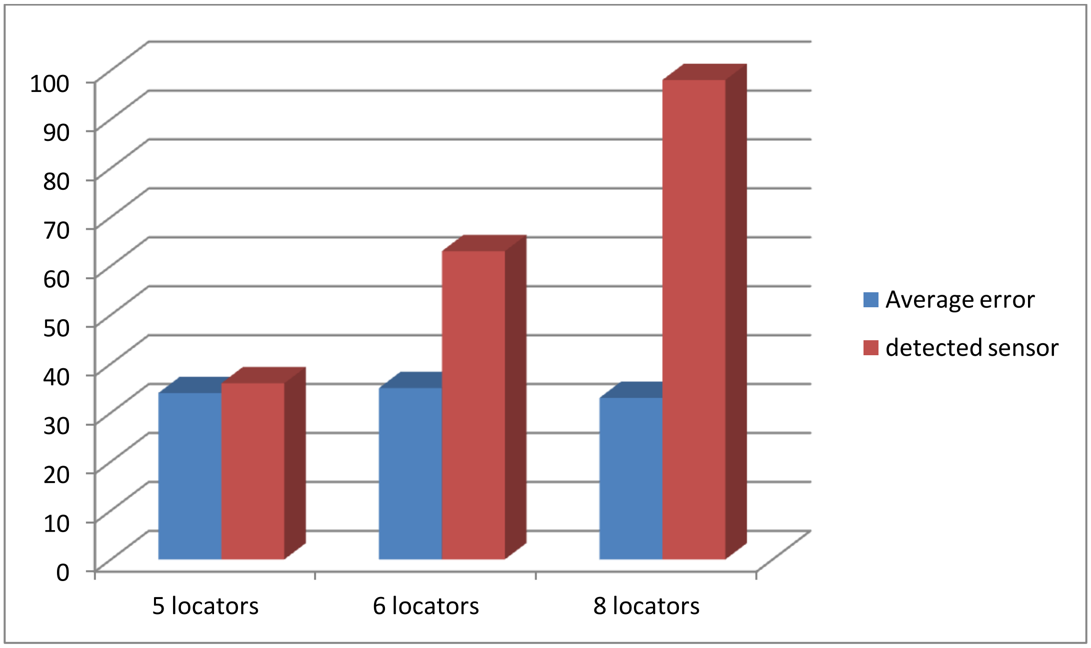

Figure 4-13: ADLA Efficiency Vs Number of Locators

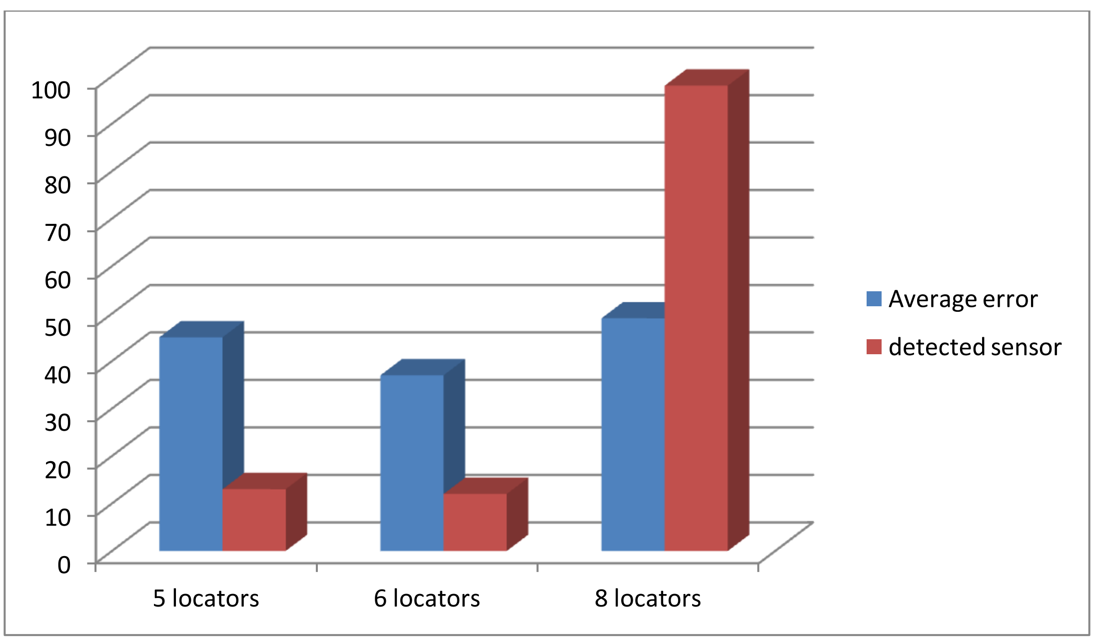

Figure 4-14: SeRLoc Efficiency Vs Number of Locators

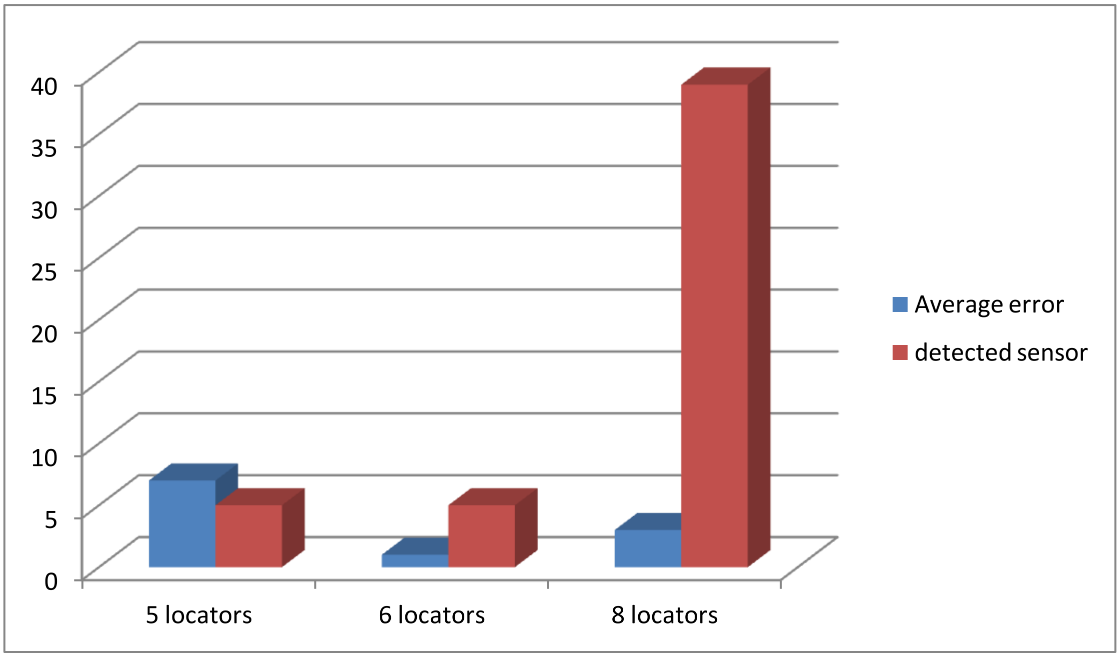

Figure 4-15:DIL Efficiency Vs Number of Locators

4.2.5 Case study Five: Number of Static Nodes deployed in area and it is effect on Algorithms Efficiency:

According to the results of simulation, when we increased number of static nodes the localization error decreased and the number of detected error increased.

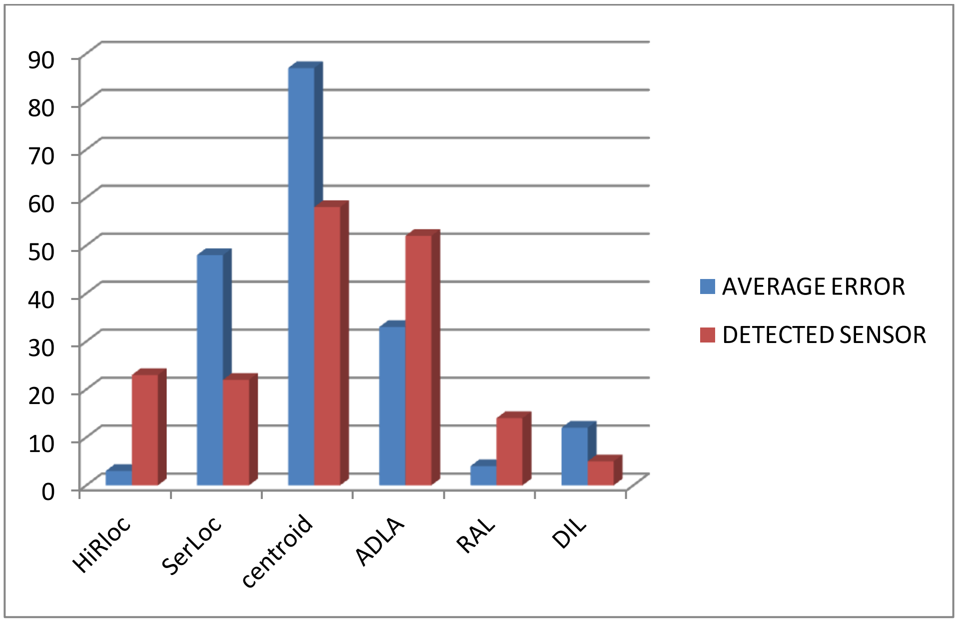

Figure4-16: Range Free Algorithms Efficiency Vs 100 Static Sensor Nodes

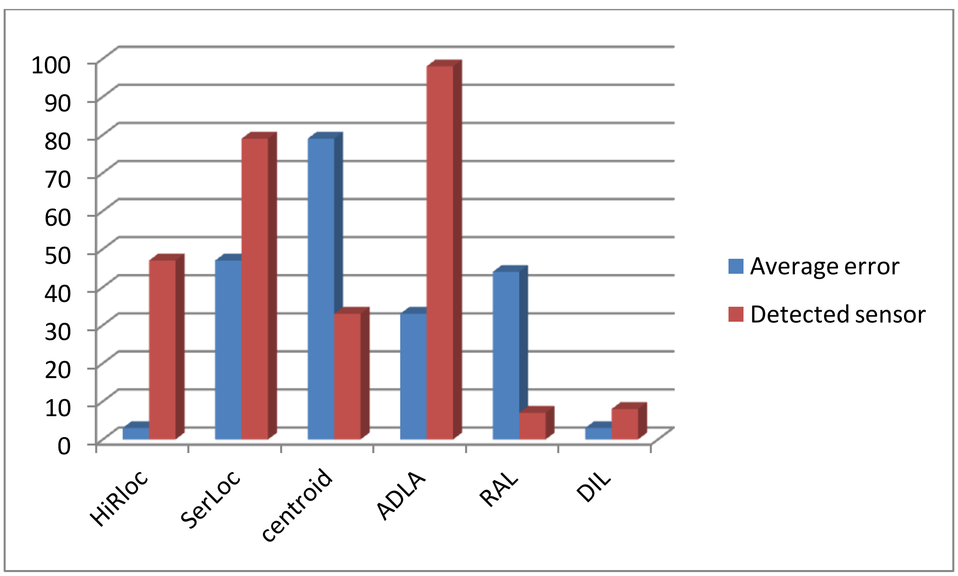

Figure4-17: Range Free Algorithms Efficiency Vs 200 Static Sensor Nodes

4.3 Hybrid Proposed Algorithm

In our hybrid algorithm we purpose a combination between centriod algorithm and ADLA algorithm, centroid algorithm has a high localization error and a good percentage of detected sensor nodes, ADLA algorithm has a better percentage of detected sensors nodes and a good localization error compare to centroid, combining these two algorithms can provide a better localization error and good percentage of detected sensor nodes as clarified in figure4-18 and 4-19.

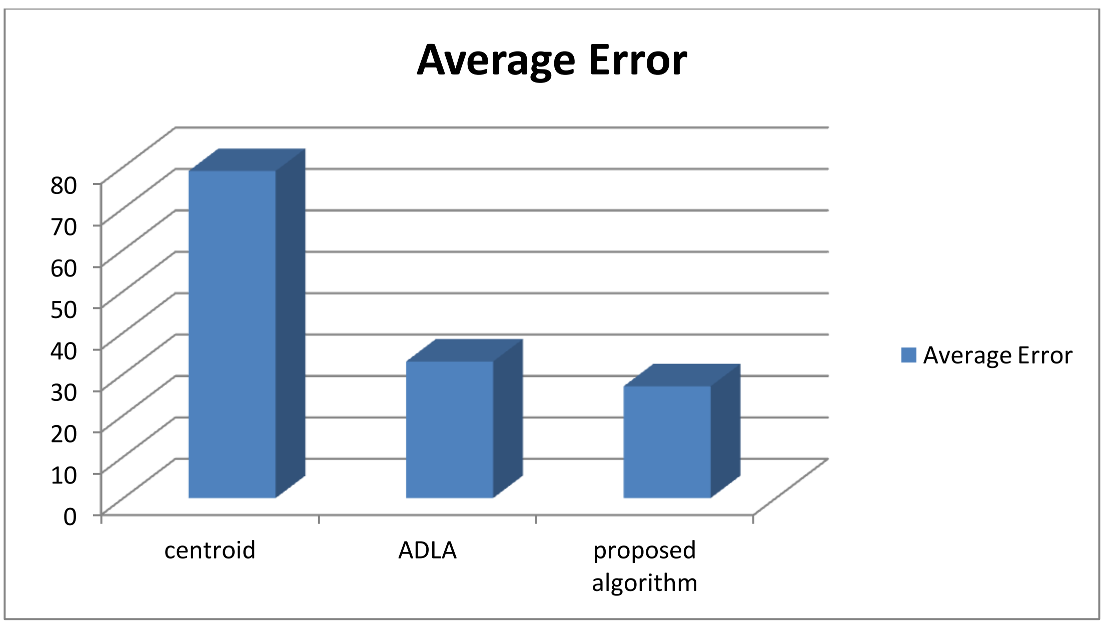

Figure 4-18: Hybrid proposed Algorithm Vs Centroid and ADLA.

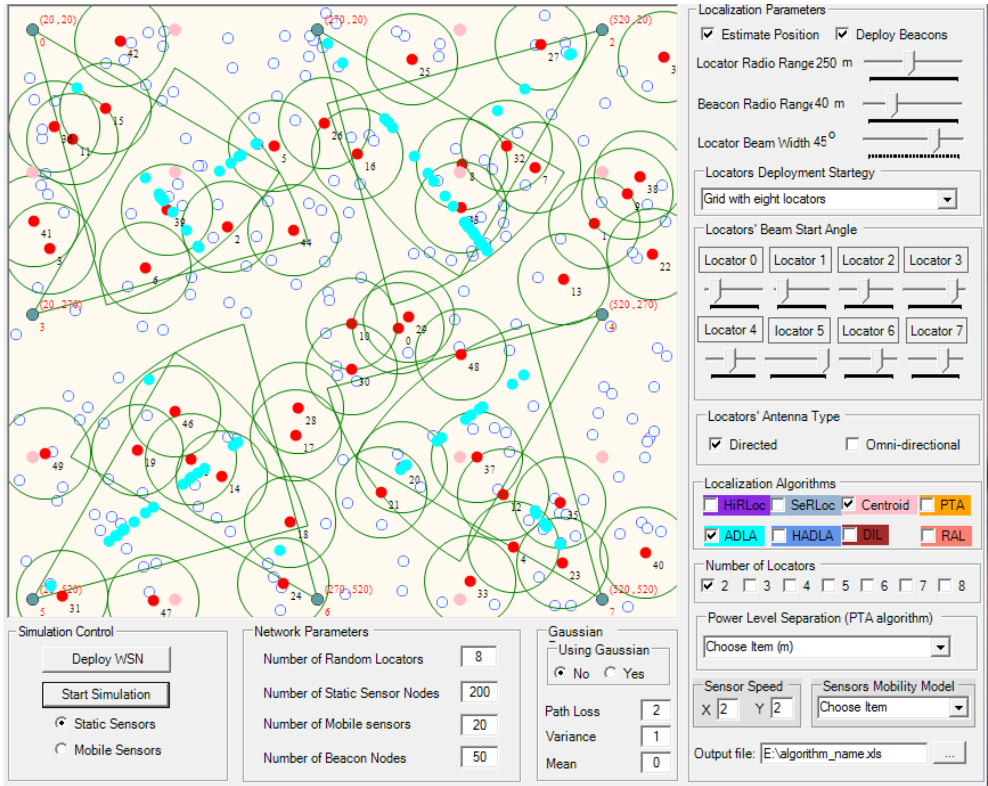

Figure 4-19: Hybrid proposed Algorithm Simulation

The modified algorithm considers that there are two types of nodes: locator/anchor nodes which transmit beacons with location information and normal nodes (unknown location nodes), and also considers that normal nodes determine its own location by received beacon signal from locator. The beacon signal transmitted by locator node contains locator coordinates, angle of directional antenna, and locator communication range.

Locator nodes updated this information every time and retransmit it to normal nodes. In this algorithm Simulation shows that since the ROI indicates the confined region where the sensors are tracked, therefore reducing the size of the ROI leads to a decrease in average localization error. The size of the ROI is precisely reduced by reducing the beam width of the locators having a fixed position on a grid.

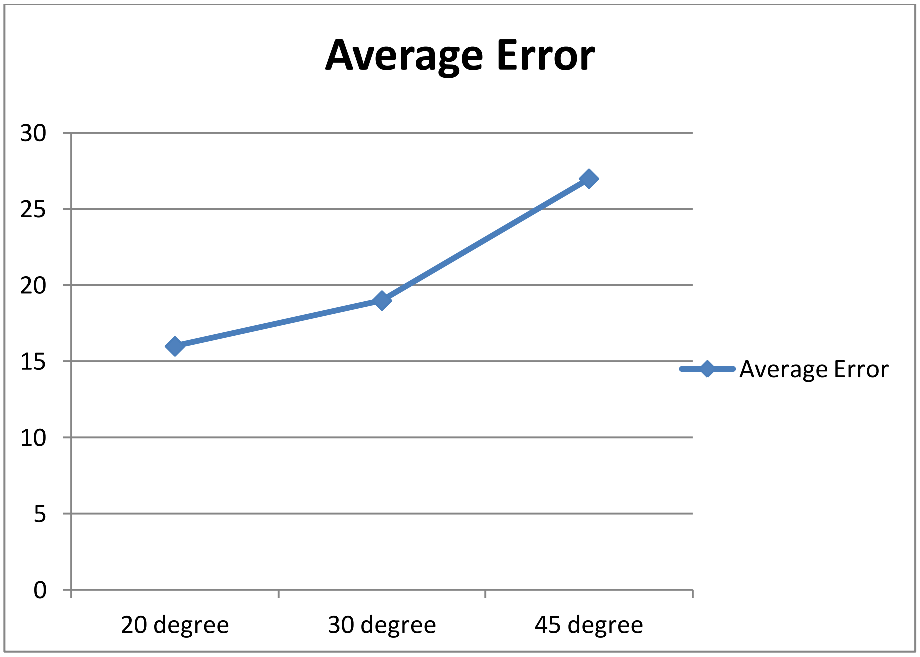

Figure 4-20: Localization Error in Hybrid proposed Algorithm with Different ROI by Changing the Fixed Locators Antenna’s Beam Width.

Chapter Five

Chapter Five: Conclusion and Future work

5.1 Conclusion

By the end of this search after implemented six of the main localization algorithms and compared among them with different problem settings. The results of comparison will be helpful for WSNs designers in selecting the best localization algorithm to use in ordering to their purpose of use, also suggested a modified hybrid localization algorithm, combining both centroid and ADLA algorithm in addition to decrease the locator's antenna beam width making the Degree of irregularity zone small, achieved better location estimation and reducing the localization error.

5.2 Future work

The enhancement of the algorithm that was proposed in this search in order to detect larger number of unknown sensors in essential, also an important side that must be studied, which is the effect of different mobile models on the range free localization algorithms.

The need of using wireless sensor network techniques localization is increasing by every day because of its easy implementation and efficient results so in future work developed techniques as well as the methods and connect them to internet would be a revolution in world of localization.

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