Localization System on Multiple Mobile Beacon in Wireless Sensor Networks

by

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Abstract

Wireless Sensors Network, which is referred to as WSN, constitutes a scientific revolution in the field of wireless communications and embedded systems. It has opened the way for the creation of a new generation of applications in fields as diverse as the environment, weather monitoring, health monitoring, building and facility safety inspection, and security. Such as intruder detection, intrusion into restricted areas, traffic and fire detection

Nowadays, WSNs are emerging as an active research area including different topics such as power consumption, routing algorithms, hypothesis selection of sensors, robustness, efficiency, etc. Wireless sensor networks contain various types of sensors such as low sampling rate, seismic, magnetic, as well as thermal, optical, infrared, radar, and sound that are intelligent to monitor a wide range of surrounding situations. Sensor nodes are also used for continuous sensing, event ID, event detection, and local actuator control. Applications of wireless sensor networks primarily include health, environmental, home and other commercial areas.

Setting up a positioning system in WSN is challenging. Provided with a geographical link between sensed information, we can utilize position information to disseminate data rules to identify collected data and recognize regions and nodes. In general, nodes require location data from at least three reference points for position prediction. This research tackles simulation by utilizing N mobile anchors (single, two/double, three, 5 & ten moving anchors) given a settled sensor node. It investigates MSE & latency derived from the detected sensor nodes in various network densities, noise ratio, and signal interference. There are tuning parameters in simulation linked to the prospective implementation of a WSN (Wireless Sensor Network).

The advantage of wireless sensor networks is their ability to achieve the same function as the internet by transmitting data over wireless communications without using wires, where repetitive data is relayed, and these sensor nodes send data to the internet gate safely, where the gate in turn sends the data to a server or to cloud computers and this is where large systems analysis techniques begin their work.

In this research paper, using greater moving anchors introduces more ameliorations in simulated WSN. This is in regards to MSE and latency. We have introduced multiple moving anchors to localize the sensor nodes in WSN. It's noted that the scenarios yield a relatively minimal localization time in localizing nodes in a sensor network. Localization error is observed for different nodes and several received SINR. It was noted in every scenario that the MSE decreases with an increasing number of sensor nodes.

Keywords: Localization algorithm, WSN, multiple mobile Anchors/Beacons.

Introduction

1.0 Overview

A WSN is Wireless Sensor Network which is defined as an ad-hoc network consisting of small furnished sensors. The sensors are wireless capable. WSN consists of several sensor nodes that track distinct physical courses in an ecosystem, collecting whole data, and transmitting it to the primary station such as smart buildings, agriculture, surveillance, and security.

WSN studies an environment under observation that may be redistributed anywhere, for instance, in open fields. When deploying sensors, there is no set limitation on the number to redistribute. The number varies based on the objective to be met. The sensor nodes disseminate the collected data to the primary station wirelessly.

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A major desired characteristic of the WSN is information localization. It is key for other WSN aspects such as routing. For routing to work, position information is essential. Localization requires GPS in locating sensor nodes, this is quite expensive to use in the low-cost sensors. Furthermore, common sensors cannot handle GPS data. It is possible to use GPS-equipped sensors as Anchors or Beacons. This entails dispensing GPS information to other sensors, helping the sensors in localizing.

Beacons are more expensive than normal sensors, thus, they should not be utilized one time. The effectiveness of the beacon can be extended by a mobile beacon (MB) rather than a static beacon. Mobile beacons can be moved around an area of interest, acting as numerous static anchors. It is reusable and flexible, making investing in anchors very cost-effective. Since mobile anchors are movable, there is a need for designing a fixed path for trying to localize unknown sensors. Under other conditions, it is a blind choice without taking into consideration the distribution and density of the sensors.

There is a niche for a localized system that positions nodes based on their communication capability, coverage, node addressing algorithm, and displacement between nodes.

Figure 1 briefly describes WS, its localization, static anchor algorithms, and mobile anchor algorithms. This clearly outlines the motivation behind the objectives of this research.

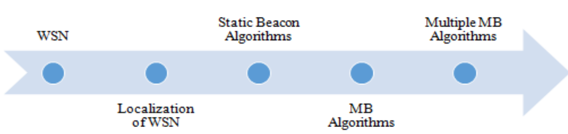

Fig 1 Transformation of MB(Mobile beacon)

1.1 Research Inspiration and Objectives

1.1.1 Inspiration

WSN is common in diverse fields such as agriculture, surveillance, disaster management, traffic management, and healthcare. Thanks to demands in automated management and microelectronics development. Our country is economically diverse, with many individuals working in the agricultural sector. WSN development will enhance agricultural productivity through aggregation. This is the major inspiration for this project.

1.1.2 Research Goals

This study aims at designing an ideal localization algorithm for many WSN mobile beacons. Some of the benefits of utilizing multiple mobile beacons include:

Accuracy: Mobile Beacons can move on demand by unknown sensors. This implies mobile beacons will pass unknown sensors as well as serve them. When the MB issues three anchor messages, accuracy is advanced.

Coverage: Every movement made by mobile beacons is persistent in covering certain sensors regardless of the distribution and density of sensors. This is different from static anchors in which planning happens before the real action, making sensors fixed trajectories.

Short Trajectory: Mobile beacons aim at settling the location of all the sensors, not covering an entire area. They are different as real-life sensor distribution is not uniform. Compared to static beacons, the trajectory of mobile beacons might be longer for improved coverage or accuracy, at least there exists a time and performance choice.

Practicability: A field of interest cannot be always smooth and regular, making static beacons inapplicable. Mobile beacons are flexible and can be compromised in ways to conquer particular terrains.

The core aim of the design of an algorithm in mobile beacons is for serving unknown sensors. Every movement made by the mobile beacon must be convenient to locate unknown sensor nodes. Regarding this, the focus will be on minimum localization time, efficient energy consumption, and short trajectory.

There is no existence of an algorithm that is close to or perfect in relating to the MB path. Almost all existing methods use graph theory. This is the natural WSN method. The graph is intuitive, playing a role in understanding the algorithm and problem. Graph methods are not acceptable for sensors due to their computational complexity.

This research will be designing and implementing algorithms for the MB path in WSN localization and utilization of simulation data for improvements on the accuracy, time, trajectory, error date, and energy. Compared to other existing algorithms, my algorithm has several distinct features and principles. They are outlined below:

Low Cost: WSN is disposable, making low cost a target. Neither massive memory nor extra hardware is needed. The design requires a powerful processor.
Economical energy consumption: Sensors have strong energy consumption tendencies for computation and communication. Only obligatory communication will occur in the former, the latter does not apply graph theory and probability since computation is expensive.
RSSI: Though error-prone, regarding the above two principles, RSSI is a better compromise as it's built-in to the sensors, requiring no additional hardware. Furthermore, there are alternative technologies overcoming RSSI faults.

Central: With regards to the initial two principles, an unknown sensor will handle restricted indispensable computation and communication. Algorithms won't be distributed in a pattern as energy embracive and exhaustive tasks occur in the mobile beacons.

1.2 Methodology

The flow of the research work is clearly outlined in Figure 2. The problem to be addressed by this thesis has been identified. From the identified problem, there are gaps in the current research on this problem. Although many researchers have done works on beacons, there is minimal research on mobile beacons. This is how to "Localize a System using Multiple Moving Beacons in WSN" was settled on in my thesis.

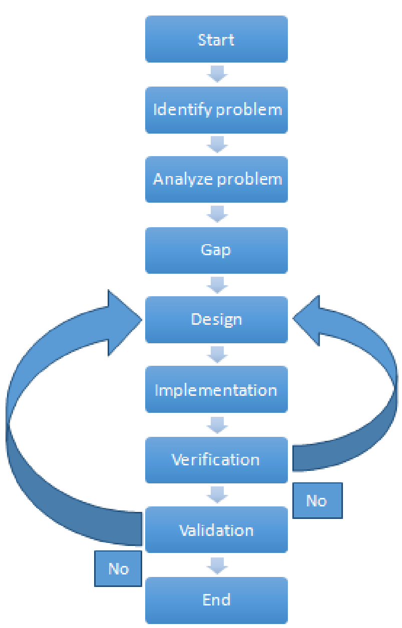

Fig 2 Study Methodology

The algorithm built from the research will be verified after development using simulations for consistency with the study's theoretical aspect. In case of inconsistencies, the algorithm must be modified and retested until satisfactory results are obtained. The primary objective is to apply the algorithm to various real-life projects to check its validity outside the laboratory, then practically implementing the algorithm. A designed algorithm that passes the flow must be applicable and reasonable.

Precceding section looks into the literature review on WSN localization. It reviews basic factors on WSN localization technique from estimating the distance to computing position of conventional localization algorithms. This research concentrates on MB-based algorithms and using various mathematical methods in research.

In the research, many contributions on the significance of mobile beacons in WSN localization were addressed. This research makes essential contributions on the significance of mobile beacons in WSN localization. Initially researcher introduces WSN and beacon node selection in fulfilling localization. Then researcher focuses on previous studies to identify research gaps in localized sensor nodes utilizing different methods and proposing the ideal localization scheme given 'N' mobile anchors. Simulating localization algorithms and scheme are detailed in chapter three. After that the researcher compares localization schemes under different cases or scenarios, showing simulation and theory results. And finally researcher focuses on achievement made in this research and necessary future works to be looked into.

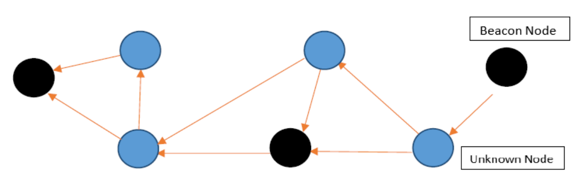

Fig 3 Alogrithim for the localization

1.3 WSN Applications

The applications of sensor networks are multiple and can be applied in different fields as indicated below:

1.3.1 Surveillance and Security

WSN's play an essential role in the monitoring and surveillance of dangerous environments. Adding video sensors in WSN, then installing them in the sensitive areas play a major role in security monitoring and surveillance.

1.3.2 Vehicle Tracking

Getting information on vehicles using various lanes is facilitated by WSN. This is important due to heavy traffic on the roads. It records the registration number, speed, and make of the vehicle. On a road bridge, it is possible to mount sensors almost four meters above a road or a bridge to collect needed data. Sensors can be mounted on different vehicles which allow the monitoring of traffic density.

1.3.3 Smart Buildings

Almost every electrical appliance of smart buildings is operated by sensors. Sensors can be applied at a building's entry point and exit area, allowing only authorized personnel.

1.3.4 Health Care

The WSN's have been used widely in the health sciences. Pressure and temperature sensors allow checking of blood pressure and body temperature or fever respectively. This data can be collected remotely to the primary station. This allows disease identification in a patient.

1.3.5 Agriculture

Crops can be monitored using sensors. They detect water levels, humidity, and temperature respectively which at times will dictate the fertilizer and temperature requirements. It is possible to do this remotely with the use of robot-equipped sensors which in turn transmit data to the primary station. There is a feedback system that can be used in filling required amounts of essentials for crop growth.

1.3.6 Environmental Monitoring

WSNs are often used in weather forecasting such as measuring temperature, parameter changes and direction, and speed of the wind. Collecting such information from different areas easily determines the weather forecast.

1.3.7 Animal Tracking

Sensors can be used in monitoring animal activities in their natural habitat. This is done without destroying the animal's habitat.

1.3.8 Disaster Management

A WSN is beneficial in disaster management as it allows the collection of accurate data on a disaster. Gyro sensors are used in monitoring the intensity of an earthquake. Fore and smoke sensors are used in animal parks and buildings while water level sensors are used in monitoring water levels in flood-prone regions.

1.4 WSN Features and Limitations

1.4.1 Data Routing

We define routing as information or data transmitting process to a receiver from a transmitter along a channel. Routing protocol always finds the optimum route for information transmission.

Routing protocols outline sensor node communication in spreading information or data to a primary station. Features of WSN sensor nodes vary in many cases, making it challenging to define the single routing protocol. A routing protocol should be energy efficient. Node positions can be mobile or fixed. This makes it necessary to use location-based or position-based routing protocols.

1.4.2 Data Collection

Sensors generate similar information data packets for several sensor nodes. This means that it is possible to sense the same event using many nodes at the same time. This creates data redundancy. Processing redundant data consumes high power, causing delays in information transmission. Reducing extra transmission in data collection methods achieves energy efficiency.

1.4.3 Limitations on Energy Consumptions

When using WSN, battery power is used, making energy a challenge. The performance of WSN sensor nodes is affected when the battery power is at a lower threshold. Sensor nodes are powered off, saving them from being damaged, this makes accessing the desired node challenging. Energy-efficient nodes have to be designed for low energy consumption, thus, the active time for a node increases.

1.4.4 Sensor Node Localization

Node localization is used in finding the sensor location. This makes it a key WSN parameter and is essential in various applications in knowing the location. Before sensed information is transmitted to the primary station, the sensed information is compelled with position data.

Node localization is important in observing sensor nodes to obtain detailed continuous data on their communication. Therefore, we require affordable, low weight, accurate mechanism, low power and low form factors.

1.4.5 Limitations of Transmission Domain

Limited processing facilities, storage and power are hardware limitations facing nodes. The limited transmission range requires placing them closer for uninterrupted communication.

1.4.6 Channel Utility

Sensor nodes are of limited bandwidth but a sensor node's operating algorithm requires an adequate bandwidth amount for improved channel use and performance of the system. To obtain channel utilization, the formula is thus:

$$U = \frac{Active\ time\ of\ sender}{Total\ time\ of\ 1\ cycle} \quad (1.1)$$

1.5 WSN Architecture

There are two types of network architecture:

1. Architecture of the layered network
2. Architecture of the clustered network

1.5.1 The Layered Architecture

A network is broken down into distinct layers with a primary station where all nodes are connected. Different nodes located in the various layers communicate to nodes in the first layer, sharing data until the primary station. In a layered network, one-hope layer is an architecture's inner layer. Thus, to access the primary station, one-hope is utilized. A 2-hop layer is second with two hopes required to access the primary station. This stage is scalable with low energy consumption and better tolerance to falls.

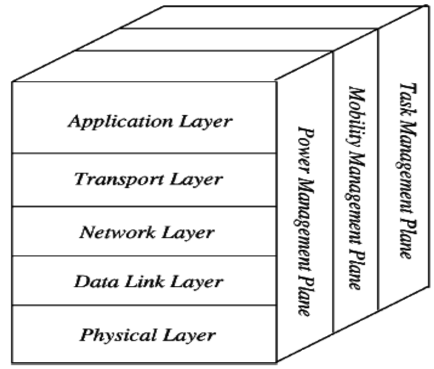

Fig 4 WSN Architecture

1.5.2 The Clustered Architecture

This is an architecture based on the 'LEACH' technique. For instance, it has a primary station, nodes in clusters, and different clusters. Here, 3 cluster heads for all 3 clusters are formed and information is obtained by cluster heads. Cluster heads communicate information to the primary monitoring station.

Every node transmits information into slots in TDMA. This is energy efficient due to data fusion where data going through the base station goes through one node. The LEACH protocol has two phases: the setup phase for network construction and forming of cluster heads, and the steady phase dealing with data transmission.

WSN Localization; A Literature Review

2.0 WSN Localization

Here researcher focuses on the study's literature review on WSN localization. It starts with describing localization schemes and algorithms as proposed on mobile beacons. For many applications, locating sensor nodes is essential as sensor information requires coupling with location data for transmitting to the primary station. For this reason, there is a need for a low weight, cheap, low form factor, low power, and a responsibly accurate mechanism. GPS cannot work in dense areas and indoors. Furthermore, power consumption in GPS is quite high.

To obtain sensor location, there isn't a fixed infrastructure and it is not possible to have prior measurements at all times. The sensor network works under the idea of few sensor nodes with known location data/information. The sensor nodes transmit periodic anchor signals as other nodes estimate distance using beacon triangulation and measurement.

Why is there a need for performing localization? Some of the reasons for localization are: most applications have to report geographically meaningful data, numerous routing protocols will need location information and it's unrealistic that many applications have to rely on the careful arrangement or placement of sensor nodes that man the nodes performing localization. There exist few drivers in indoor localization. This is localizing sensor nodes in indoors networks through GPS signals often used in outdoor localization. The ones for outdoor localization are quite weak indoors, thus, unreliable for an indoor environment. This creates a market niche for big technological players such as Apple and Google to enter the market with their innovative applications. Generally, indoor localization is an interesting problem.

2.1 Localization Plans

The range-based localization scheme (plan) can be classified as either RSSI-based and arrival time-based. The RSSI-based scheme is a low accuracy and low complexity scheme without the need for time synchronization and low power consumption. The arrival-time-based scheme is highly accurate, paying in terms of time synchronization, high power, and high complexity.

This research implements the RSSI-based scheme. Its accuracy has been improved through:

Instantaneous RSSI-based samples might be having random variations from shadowing, noise, interference, etc., thus, the samples are time-averaged for filtering out variations. From the filtered samples, the mode is obtained for distance estimation. This most likely represents the sight path line.

Firstly, the distance between sensor nodes using RSSI is estimated. The estimated distance of 3 already localized neighbors is used in estimating positions with use of recursive location estimation. Subsequently, routing algorithms are then implemented to gather localization data.

Localization systems are in three phases, namely:

1. Localization algorithms
2. Position Estimation
3. Angle or Distance Estimation

2.2 Estimating Distance

The chances are for ToA (Time of Arrival), RSSI (Radio Signal Strength Indicator), AoA (Angle of Arrival), TDoA (Time Difference of Arrival) and the trade-off between accuracy and computation.

To obtain the distance between sensor nodes, different techniques can be used. According to [1], theoretically and ideally, the radio strength will proportionally decrease with squaring the distance. Lymberopoulos (2006) states that wireless technology is utilized in the implementation of RSSI and WSN connectivity. Wireless is unstable to multi-paths or obstacles, making it a barrier to using RSSI for various applications in real life.

For instance, provided with anchors (a collection of constituent nodes), one has to obtain distance between target nodes for localization and the beacon nodes. The log-normal shadowing model will be used in estimating the distance from the RSSI. The log-normal gives RSSI as a distance function.

$$RSSI(d) = -10nlog(d) - C \qquad (2.1)$$

The path loss exponent is n, C is the atmospheric constant. Before installation, calibration of the environment is important.

Savarese et al. (2002) state there are other more accurate ways for measuring distance compared to RSSI, among them is ToA and TDoA (improved version of ToA). The equation below expresses this as:

$$d = s \times (t_2 - t_1) \qquad (2.2)$$

d = distance of the two sensors.
s = signal speed
t_2 = Difference of received time stamp
t_1 = sent timestamp of any other sensor

'
s' value must be part of a known sensor parameter, and, since it is a single-chip machine, sensors accurately record the timestamp. However, the two sensors have to be synchronized precisely for the time difference to be meaningful due to errors. According to Millner et al. (2007), the error is amplified even when the t_2-t_1 error is quite small for a high speed of 's'. Without a mechanism for adjustment, maintaining synchronization is challenging. WSN will not synchronize due to energy-hungry communication. To avoid synchronization and TDoA improvement, TDoA comes to play.

For TDoA to function, it requires another signal source such as sound or ultrasound. The objective is to make an arrival time difference regardless of the starting point of the transmission. Thus, equation (2.2) is transformed to:

$$d = (s_r - s_s) \times (t_2 - t_1 - t_d) \quad (2.3)$$

S_r – Speed of radio
S_s– Sound
T_d – Time difference between starting of the two sources

All these parameters are known.

2.3 Estimation of an Angle

Klukas&Fattouche (1998) proposed AoA (Angle of Arrival) as the alternative for TDoA. This was from two viewpoints:

The first viewpoint is angle ϴ. Angle relates directly to time by:

$$\theta = \omega \times t \quad (2.4)$$

Here, w is the signal's angular velocity. Let's say, for TDoA having another source of signal adds an extra burden to the signal, therefore, having one signal source plus two or even more, receivers will be the better alternative. AoA plays alongside these same principles but buys a distinct TDoA implementation.

To implement this, extra hardware in terms of the array of receivers like electronic compass or antennas is required. The accuracy is highly dependent on the utilization of quality extra hardware, however, it strengthens the TDoA problem, having complex extra hardware. Presently, considering size and cost, this is more preferred in a lab. Najjar&Nasipuri (2006) offered an optical approach. The approach provides an accurate location estimate within few units in the indoor applications.

2.4 Position or Location Estimation

The primary goal in distance estimation is computing sensor position. For instance, if a sensor is collecting adequate distance information, the position is found through the utilization of different methods of mathematics. Methods to be used in position computation depend on information availability. The required information is on a sensor's computing power and distance estimation.

The prospects are probabilistic or triangulation techniques, bounding box, trilateration, accuracy, & computation trade-off.

According to Navidi et al. (1998), trilateration is a solution on computing sensor position when a message or messages are received by the sensor from the three distinct references. Trilateration is the technique for identifying the intersection point for three sphere surfaces widely utilized in GPS. For this, the radii and centers of the spheres are given.

Given three sensor node's positions and distances, three quadratic equations were obtained. The quadratic equations have two unknown values which one can solve to a single solution. During implementation, the first step will be performing offline calibration. This is divided into two:

Part one: This is implemented using quantity where the RSSI is measured at ground zero from the package sent by beacons located at distinct distances from ground zero.

Part two: This calibration part happens on implementation in MATLAB. The mod plus filtering technique is used on RSSI samples. A straight line is a curve fitted through RSSI Vs log (d) for the estimation of N & C.

Localization is done after calibration. The implementation will be in quantity. RSSI is measured at ground zero and localization information is used in estimating the distance to the beacons. From the beacons, ground zero (target) will be located by performing trilateration using location data from anchors.

2.5 WSN Localization Algorithms

A localization algorithm is an idea of integrating known information on position and distance to infer or estimate the position of most or all sensors of WSN. Ji &Zha (2003) state several issues have to be taken into consideration in designing a WSN localization algorithm. They include:

- Resource constraints: Localizing is a prerequisite in some WSN applications, thus, energy consumption should be frugal
- Network density: This entails sensor proximity. Closer spaces imply low communication costs as well as more collection of data, thus low estimation error. It's normal to ignore some sensors. With a sparse network, every sensor is valued.
- Network scale: This is the number of sensors in a field based on similar density. Therefore, more sensors imply larger fields, high total communication distance and time, and more hop counts [9].

- The beacons percentage: Beacons are more expensive compared to normal sensors. Localization algorithms aim at having more static sensors as well as few anchors.

2.6 Proposed Study Methodology

There exist numerous options and many distinct localization algorithms being utilized for various reasons. Some reasons are:

- Recursive Positioning System
- Mobile Position System
- Ad hoc Positioning System

This is an implication of the numerous probable combinations. It must be selected according to quality service requirements and specific applications. In this thesis, RPE (Recursive Position Estimation) algorithm is chosen as it is assumed the best solution in regards to accuracy and cost.

In the method proposed, collected information is efficiently applied in cosine similarity and area in overcoming issues from previous algorithms through replacement of distance with sensor direction (Tan et al. (2005). My localization scheme implements both settle nodes and mobile beacons. This useful technique estimates positions of sensors set up in regions using distances consistent from the target nodes with RSSI. The triangulation technique applies in distance calculation.

The research methodology has five cases:

1. Using a single mobile beacon in localization in WSN
2. Using two mobile anchors in WSN localization
3. Using three mobile anchors in WSN localization
4. Using 'N' mobile beacons in WSN localization
5. Using mobile beacons and settle nodes in WSN localization

Simulating Proposed WSN Localization Algorithms

3.0 Introduction

Setting up a functional positioning system in WSN is quite challenging. Location data is often used to disseminate protocols for identifying collected information and recognizing regions and nodes given a geographical link between sensed data. In general, nodes require position data from at least three reference points in predicting their position. This work shows simulating different localization algorithms using N mobile anchors (single, 2, 3, 5, and 10 mobile anchors with a settled node). This report doesn't investigate Mean square error and latency over the detected nodes in distinct network density, signal, noise ratio, and interference. Besides, simulation has several tuning parameters linked to prospective implementation in WSN.

3.1 Simulations

The simulations here focus on different cases where localization using mobile beacons is implemented. They are the utilization of general 'N' mobile beacons for localization and settle nodes in mobile beacons.

In the two scenarios, localizing sensor nodes in sensor fields use single, double, three, and N mobile anchors. On starting the algorithm, the mobile beacon will transmit its ID to sensor nodes using coordinates from at least 3 non-linear positions. The positions are from the network's area. After, computation of the distance for each un-localized node is done from the positions of mobile anchors. Triangulation is used in calculating position coordinates using three distances, subsequently, the placement of every node is approximated. This procedure is repetitive until all the sensor nodes in a network are positioned. Based on sensor allotment distribution in a field, the trajectories of moving anchors is described as either random or predetermined.

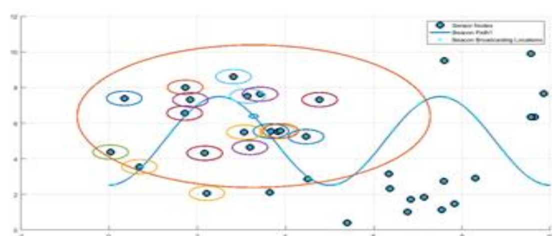

Fig 5 Localixzation of sensor_nodes 1st Case by implementing 01 mobile radar

In diagram 5, a 1-mobile anchor is shown. The reference point in such sensor field is known, following a random or pre-defined track. For this case, the sinusoidal form using the random amplitude in a range ensures N beacon trajectories do not intersect.

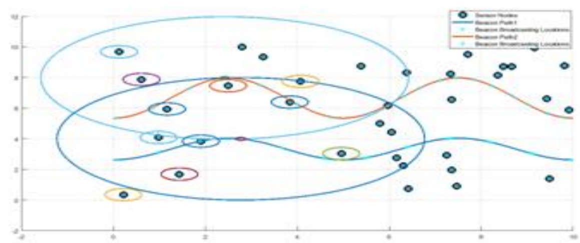

Fig 6 Localization of sensor_nodes 2nd Case by implementing 02 mobile radar

For Fig 6, double MB(mobile_beacons) are shown. The mobile beacon will follow a waveform (sinusoidal) with constant velocity & Tx points.

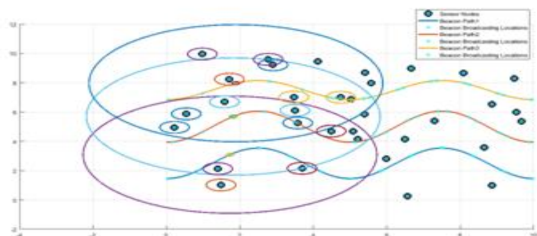

Fig 7 Localization of sensor_nodes 3rd Case by implementing 03 mobile radar

This is still the case for Figure 7. This part used three mobile anchors in finding sensors. Beacons move at a constant velocity, stopping at specific points for message broadcasting. Traveling distance is similar. The mobile anchor moves forward and backward along the path on reaching the simulation space's front edge.

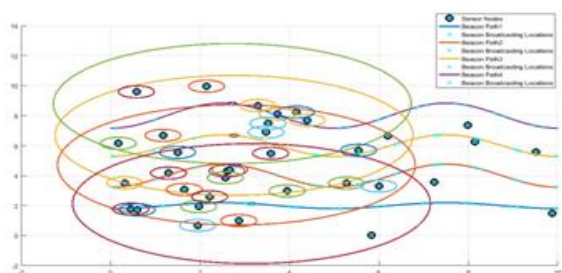

Fig 8 Localization of sensor_nodes localization 4th Case with 04 mobile radar

For above cases 01, 02, 03, and 04 moving anchors are utilized. The selected sensors are placed randomly in a simulation space, such that, any detected sensors is surrounded by circles. The anchor route is randomly determined and location of a broadcasting anchor is highlighted. Current transmission locations are enclosed with small circles and the large circle shows an anchor's current communication domain R.

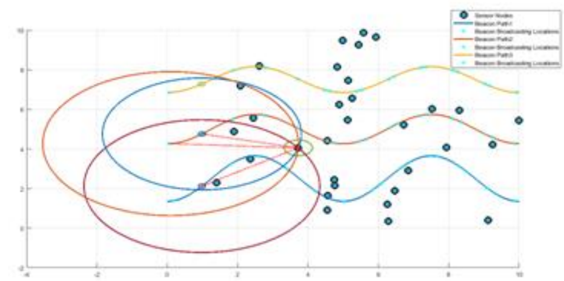

Fig 9 Localization with triangulation

From Figure 9, Using triangulation for WSN localization is presented. A requirement is for any N beacons, a minimum of 3 anchor-node communication for estimating localization of certain nodes. Thus, a single moving anchor has to go through 3 distinct broadcasting iterations.

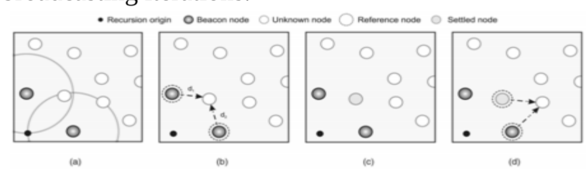

Fig 10 Several stages of the established nodes system

Fig 10 is an implementation phase for settled nodes cases. When a mobile beacon starts transmitting the location of a sensor node, two reference points will be selected and the distance found from a referenced point. In this way, the sensor node's location is found. After localization of a node, the settled node transmits the localized position for localization of other unknown nodes.

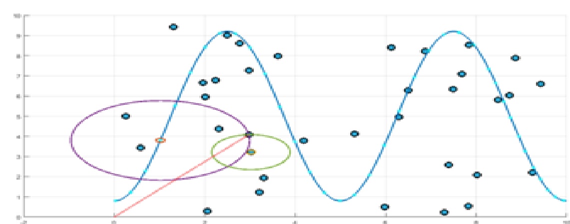

Fig 11 Localization using an established nodes

In regard to settled nodes case, this can be found in Figure 11. This is after localizing the first collection of sensor nodes. It is similar to the single mobile beacons case.

A settled sensor node is selected in this algorithm such that a settled node and an unallocated node are in close proximity. Using RSSI, it is possible to estimate the distance from the settled node and an anchor to unallocated nodes. Through this technique, two joining points are found and the estimated location is very far from the point of origin (0, 0).

3.2 Utilization of Triangulation and Distance Estimation for WSN Localization

Using triangulation for WSN localization relies on anchor position & anchor-node distances. Using RSSI for distance estimation acts as the leading parameter. From Table 3.1, results in using RSSI and MATLAB coded script in distance estimation are presented.

Table 3.1 Approximation results of distances using RSSI in Matlab

Real distance (m)	RSSI (dBm)	Estimated distance (m)
1	-40.2636	1.0055
2	-46.2573	2.0047
3	-49.7926	3.0118
4	-52.3006	4.0199
5	-54.2398	5.0259
6	-55.8248	6.0321
7	-57.1426	7.0189
8	-58.2765	7.9981
9	-59.3340	9.0342
10	-60.2562	10.0459

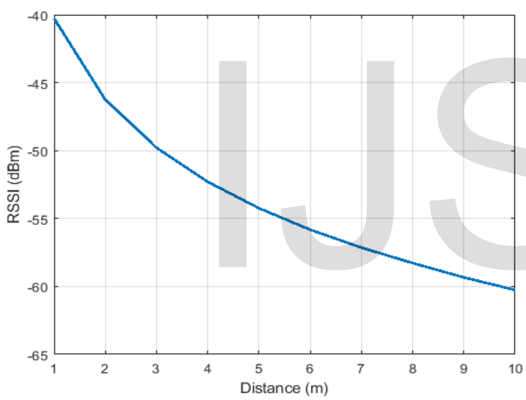

Fig 12 Using real distance for RSSI estimation

In conclusion, Table 3.2 shows the localization results using 3 random nodes. It shows received RSSI power using estimated positions and distances with each sensor node.

Table 3.2 Random sensor nodes localization using triangulation.

	Random RSSI	Distance	Position
Node 1	-44.5962	1.6536	[1.8063, 4.2109]
	-48.79373	2.6811	
	-49.5125	2.9125	
Node 2	-49.662	2.9631	[1.0693, 1.6839]
	-35.9023	0.6078	
	-40.8436	1.0735	
Node 3	-38.7332	0.8420	[0.9097, 6.0782]
	-42.9611	1.3699	
	-44.9864	1.7296	

Test Simulations and Results

4.0 Simulation and Results

The research uses different parameters in simulating perspective WSN including a total number of mobile beacons (b_n), total randomly distributed (placed) sensors (s_n), total broadcasting positions for every beacon in its routes (nsamp), length of WSN simulation space (S1), the total traveled distance for every beacon from start to end of the simulation (t_b_leng), communication covered (R) between beacons and network nodes.

Sensor nodes may also be mobile during the simulation. It is important to highlight that the beacon movement ought to be faster for the estimations to be reliable. Modeling the mobility of a sensor network requires the timer (parameter) for specifying the time when the network will be perceived fixed in regards to anchors. SINR is the Signal to Interference and Noise Ratio Parameter. Triangulation requires a minimum of 3 nonlinear broadcasted locations already known, thus, the parameter (to1) is the representative of the tolerance for the 3 positions considered nonlinear. Finally, there are three fixed parameters (v, c, tp) representing the constant velocity of every anchor in simulation. Network calculations are delayed by node computation period and light speed.

N anchor algorithms will be constructed through the establishment of a random route of anchors, and for every transmission location of an anchor along a sensor node's path. Subsequently, there will be computation of precise distances between every sensor node & anchor at a specific iteration. Later, every broadcasting message to sensor nodes from beacons is transmitted and is received under IEEE 802.15 principles. Transmitted messages contain anchor ID and position. After the message is received, every node will decode the anchor position and compute the distance to the sender anchor using RSSI.

Every sensor node has a counter. It counts received messages and when the number is more than three, the binomial coefficient of probable nonlinear anchors is computed and checked if nonlinear then triangulation follows. When the clock is not more than a node's timer, the position estimated accumulates since we presume nodes are fixed within the window. Otherwise, every parameter will be reset after the calculation of performance parameters for a network. The parameters include clock incrementation, latency calculation, and total detected nodes.

Initialization parameters of Matlab simulation

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To model a realistic environment, initial assumptions are:

1. Mobile anchors in a network are originally set at 5
2. In every case, we set 100 as the number of the randomly allotted sensor nodes
3. Space length of sensor fields is equal to ten
4. Several anchor route samples for every anchor is 20
5. Broadcasting the position of every anchor as it traverses in its path is 20 anchor path samples
6. Total distance traveled for every beacon from simulation start to end along the path is 18
7. The to1 parameter is set at 0.1% and it represents tolerance for 3 positions considered to be nonlinear
8. SINR is at first set to 50
9. All mobile anchors and nodes communicate less than 802.15 standards
10. Broadcasting messages are transmitted & received through IEEE 802.15 standards to the sensor nodes from beacons
11. The timer is the sensor nodes periodicity originally set at 2
12. The communication distance R is originally a 5
13. Fixed parameters (v, c, tp) represent constant velocity of every anchor in a simulation

With initialization, other than b_n which varies in every scenario as one, two, three, five, and ten.

In Figure 13, latency is calculated and graphed in semiology and linear scale against localized nodes.

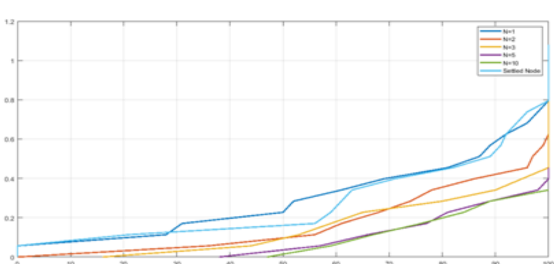

Fig 13 Linear latency scheme over localized node

Localization latency increases with an increase in detected nodes. Every mobile anchor-based scenario is the same as the settled node case requiring longer periods to detect the sensor nodes. Initial localization requires 3 broadcasting iterations, then two, three, five, and ten mobile anchors respectively. In Figure 14, a Semi-Log mathematical graph of latency against the localized sensor nodes is plotted.

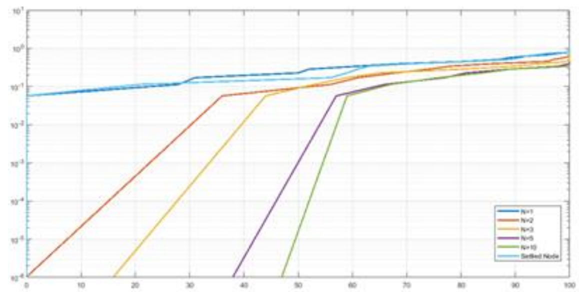

Fig 14 Semi-Log Arithmiclatency scheme plot over localized node

The Figure 15 below shows a graphical presentation of simulations performed using varying nodes from five to fifty with a five incrementation and graphing the Mean Square Error (MSE) against detected nodes. For a denser network, all scenarios have less error. A scenario having 2 beacons has less loss in comparison to the single beacon case and similar for the five-anchor in comparison to three-anchor. The loss in fifty nodes decreases with an increased number of anchors. Low-density sensor nodes compare to sensor nodes and beacons.

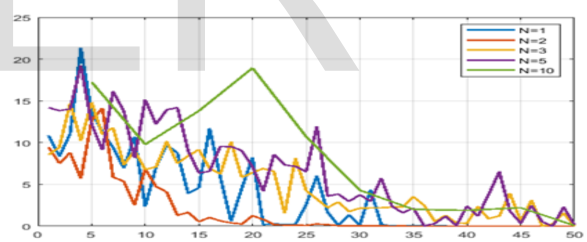

Fig 15 Network density using the LMSE error method

In a similar manner, The Semi-Log arithmetic graph of MSE over network density is shown in Figure 16.

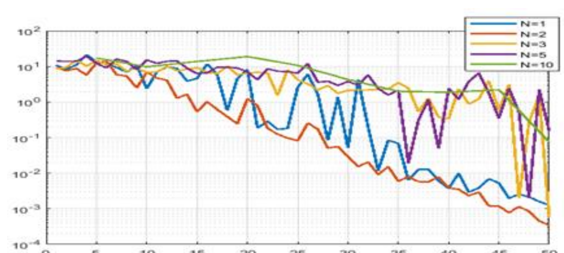

Fig 16 Semi-LMSE scheme over the network density

By limiting the number of sensor nodes to 50 and increasing the SINR level from 5 to 50, simulations are performed. From Figure 17, MSE and SINR levels are represented. Utilizing higher N anchors compares to the single anchors. The general MSE for every case decreases with increased signal interference to noise ratio.

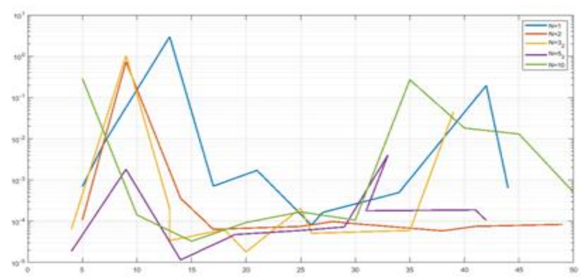

Fig 17 LMSE scheme over signal interference to noise ratio

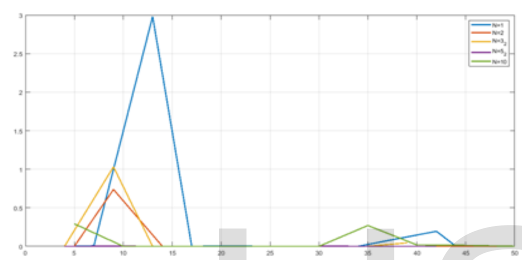

Fig 18 Semi-LMSE scheme over the Signal interference to noise ratio

Conclusion and Recommendations

5.0 Conclusion

Implementing WSN localization systems built on N mobile anchors is dissected in this paper. Using greater moving anchors introduces more ameliorations in simulated WSN. This is in regards to MSE and latency. It might need extra hardware in return, but the exercise is worthwhile.

This research introduces a new mobile anchor-based localization procedure where multiple moving anchors localize the sensor nodes in WSN. There are four distinct cases evaluated in this paper dissecting error performance. The technique proposed in the paper locates a node's position in a network wither without or partially engaging network nodes. Mobile beacons relieve network additional nodes that are installed on fixed positions. The four scenarios are evaluated for localization time or latency. It’s noted that the scenarios yield a relatively minimal localization time in localizing nodes in a sensor network.

Beacons are necessary for localization. Based on the weaknesses noted, it is unrealistic to apply it heavily. Therefore, moving beacons are proposed in overcoming the limitations of static anchors.

Localization error is observed for different nodes and several received SINR. It was noted in every scenario that the MSE decreases with an increasing number of sensor nodes. However, in scenario 4, it was noted a fast decrease in the localization error in comparison to the other scenarios. This implies this scenario works well in a denser network.

The basic principle in the algorithm design is frugality, resulting in low energy consumption and economic costs. The principle reflects in the algorithms, turning out simple in arithmetic yet complicated when applying logic. This results in algorithms employing RSSI prone to errors eliminating communication and representing the distance between unknown sensors.
Many improvements have to be made in future works as simulation results are based on reliability. Regarding Vural &Ekici (2004), future research ought to identify different mobile beacon routes for WSN localization.

The path of moving anchors is necessary and it is an inevitable trend based on WSN localization reviews. Path planning aims at settling all sensor locations not covering an entire area. This is an essential topic for any future studies (Hu and Evans, 2004).

WSN can be viewed as ad-hoc self-organizing networks used in gathering data from a sensor wirelessly (Sivalingham, 2004). It is simpler when compared to the other wireless networks based on its functionality. The most distinct feature of WSN is that it is a resource constraint. It demands strategic use of resources. Generally, resource consumption is significant in judging how WSN algorithms performed.

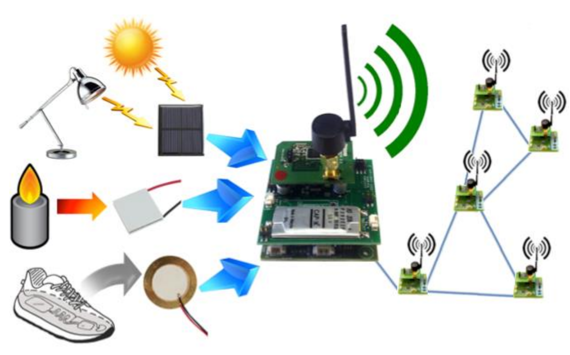

Fig 19 Future of Wireless Sensor Networks

5.1 Future Work

Energy efficiency: This is a technique for reducing energy consumed by the use of less energy and still attaining the same useful output. Through energy reduction, energy costs decrease resulting in financial savings to a consumer. This should be further addressed in future works.

Quality Sensor Networks: Sensor networks should report and maintain events taking place in an area. Quality depends on density, sensitivity, location, and range of nodes. Future research should aim at improving WSN quality.

Security: The sensor nodes in WSN ought to be localized securely. Regardless of the environment, during transmission, data should be protected. Unsecured sensor nodes might result in the delivery of false messages and information. Challenges noted are minimal resources such as the unguided medium of transmission, low processing power, self-organization of network topology, and limited bandwidth. Sensor nodes are resource-constrained therefore small in size. This means minimal processing power and less storage space, implying large programs cannot be executed on initiating the operating system. Less bandwidth means traditional algorithms cannot be used in WSN. When a sensor node performs computation plus inter-process communication, there is power communication. Using the old-day security algorithms will result in high power consumption. Research in security in WSN localization will be a great asset.

Robustness: Future studies can focus on applying complex networks in localization. Different models can be combined in addressing robustness in a heterogeneous WSN. If a node is faulty, the performance of the entire network cannot be affected. Many large-scale networks use a clustering approach. In future research, it can be applied in WSN. Future studies can employ adaptive signal processing in minimizing localization errors. It can employ mobile beacons as the link to disconnected areas of a network, consequently evaluating beacon performance. Employing artificial intelligence (AI) techniques as well as power management algorithm will allow moving beacons to identify critical locations and nodes for the deployment of more sensor nodes in WSN.

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