



# Node localization in wireless sensor networks using a hyper-heuristic DEEC-Gaussian gradient distance algorithm

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## ARTICLE INFO

### Article history:

Received 26 March 2022

Revised 13 January 2023

Accepted 17 January 2023

Editor name: DR B Gyampoh

### Keywords:

Clustering Algorithms

DEEC-Gaussian Gradient distance

Heterogeneous system

Localization Estimation Error

Wireless Sensor Networks

## ABSTRACT

In the recent age of technological advancements, wireless sensor networks are an important application for smart modernized environments. In WSNs, node localization has been an issue for over a decade in the research community. One of the goals of localization in a wireless sensor network is to localize sensor nodes in a two-dimensional plane. Localization in wireless sensor networks helps to supply information to aid decision-making from the aggregated data that are sent from packets to base stations. Internet of Things with the use of Global Positioning Systems for tracking sensor zones is not a cost-effective means of solution. In the extant literature, there have been a variety of algorithms to identify unknown sensor locations in wireless sensor networks. This research paper aims to address the problem of determining the location of the sensor node at the base station with minimum localization error when the data between the nodes is transmitted wirelessly. To detect the location of an unknown sensor node packets sent to the destinations, the total number of anchor nodes, location error and distance estimation error were considered. The DEEC-Gauss Gradient Distance Algorithm has a lower localization error than the Weighted Centroid Localizations algorithm, Compensation Coefficient algorithm, DV-Hop algorithm, Weighted Hyperbolic algorithm and Weighted Centroid algorithm for the same ratio of anchor nodes and WSN configuration. According to the study's findings, the DG-GDEA has an average localization error of 11% for anchor nodes (20-80), and an average localization error of 11.3% for anchor nodes 200-450. Hence, the DEEC-Gaussian Gradient Distance Elimination Algorithm (DGGDEA) showed higher accuracy with comparison to the modern-day approaches.

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## Introduction

In recent times node positioning is a new form of technology that has been discussed in the literature on node localization. A sound node localization scheme is central to the accuracy and effectiveness of wireless sensor networks (WSNs) [1–3]. Wireless Sensor Network is a collection of many sensor nodes shared over a geographical area for monitoring the area of interest. In many applications of WSN, the data is meaningless without the accurate location of sensor nodes [4].

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While considering the challenges of WSNs and their associated applications, base stations receiving processed data from an unknown source are worthless [5]. This will make the data not useful, therefore, location estimation of the data source is an important area in WSNs. Localization is allied to the fast-paced development in the field of IoT (Internet of Things) [5], with the location of a node determined by a variety of methods [6]. WSNs comprise many rounds, small nodes that are constrained by the limited power and wireless bandwidth. This network has a broad range of applications such as industrial automation usage, area monitoring applications and measuring phenomena. Node localization estimation is of great importance for the Gaussian Elimination Method [7]. WSNs consist of several sensor nodes that are used in transmitting both small and large-scale packets. The growth of electronic technology in WSNs has seen the performance of small and high-size sensor nodes applied to system controls, tracking, environmental monitoring and security applications [8].

Node localization has a primary role in a variety of network applications [9–11]. Node localization and energy consumption are considered as one of the challenges in WSNs. The processing and computational capabilities of sensor nodes are restricted to the battery life. The transmission of packets is an important task in WSN as sensor nodes utilize energy for processing, sensing, and storing data. Furthermore, different routing protocols were classified in the network which are either flat or hierarchical protocols. In regard to flat protocols, the nodes have the same role and are interconnected with the neighbouring sensor nodes that are within their range for transmitting data packets to their destination. On the contrary, hierarchical protocols have different role-play. The normal sensor nodes send their information to the cluster head (CH) node which helps to send the data packet to the base station after aggregating and compressing the information. These cluster head nodes make use of more energy than the other nodes because of their functions [12–14]. In WSNs data are sent from the source node to a base station (BS), using the cluster head (CH) that is higher in residual energy compared to other nodes in its cluster [15].

Over the past decade, the findings of a variety of research on localization for WSNs show that the coordinates of unknown sensor nodes are detected by one or more GPS-equipped nodes. Clustering is a technique that is widely used in WSNs to help provide energy-efficient solutions that are carried out within the nodes. The communication networks are divided into two small segment regions that are named cluster heads and member nodes. The member nodes in the clusters are headed by a cluster head. The sensor nodes fetch information that is sent across their respective channel which the CH aggregate the packet of information and transmits towards the sink. However, it is expected that the CH is rotated among all nodes since the sensor node acting as CH depreciate energy faster and dies.

The objective of this paper was to decrease node localization estimation error with the use of the DEEC-Gaussian Gradient Distance Elimination Method Algorithm. This paper simulates the proposed algorithm in a WSN environment and determines the location of unknown sensor nodes. The results of unknown sensor nodes are compared with modern algorithms and discussed. This paper provides two distinct contributions to the subject of WSN localization. First, we provided an efficient and simple localization algorithm that optimizes localization error and hence ensures high accuracy for WSNs. Second, the proposed approach decreases the probability of error by ensuring the precision of node localization for WSNs.

The arrangement of this paper consists of five sections which are as follows: section 1 outlines the background and the research problem. Section 2 includes discussions about the related works. Section 3 provides the technical background of this research work. The proposed node localization DEEC-Gauss algorithm is presented in section 4 while, section 5 provides an analysis of the simulated results. A conclusion and further recommendations are provided in section 6.

## Related works

The Internet of Things (IoT) uses WSNs however node localization, data aggregation and energy usage are the challenges in WSNs [2,16,17]. Localization in WSNs has nuances in different domains, be it large-scale or small-scale, but the major key factor of the networks is that they have multi-hop topologies. A representation from the literature is that the sensor nodes must localize according to the pieces of information from the nodes that are in their vicinity [18,19]. Abdurrohman, Supriadin and Fahmi [20] proposed the use of a modified end-to-end secure low-energy adaptive clustering hierarchy (ME-LEACH) to enhance the lifetime of WSNs. The results showed that ME-LEACH was more stable and produces higher throughput than the recommendation for the E-LEACH algorithm. In WSNs to aggregate information or packets of data, there is a need for lesser cost and the provision of accurate location information [21,22]. More importantly, clustering algorithms fall into the hierarchy of communication algorithms in WSN, the first level of the algorithms in WSN was low energy adaptive clustering which is LEACH that was used by Heinzelman, Chandrakasan, and Balakrishnan in [24] and some others have proposed various algorithms to achieve clustering and node localization.

Random deployment of the mobile beacon was used to transverse the region of interest (ROI) [23–25]. An iterative multiliterate algorithm was used to decrease localization accuracy when the unknown node position is estimated with further evaluation on the path planning algorithm according to the based grid scan with the comparison of the static beacon that is randomly deployed mobile path of the sensor nodes [26]. Localization techniques are divided into two types which are range-based localization algorithms [3] and non-ranging, range-free based algorithms [27].

Moreover, there has been non-line of sight (NLOS) identification to calculate the position of mobile nodes to determine whether the real-time measurement of location is obtained under NLOS conditions and propagating conditions are both correct compared to support of vector machine-based NLOS identification algorithm. Admittedly, distance measurements are also one of the major factors that are prone to affect localization considering the types of nodes on the line of sight (LOS) [28–31].

Several modifications have been proposed for node localization with non-uniformly distributed nodes which are aimed at balancing the energy consumption and improving the network lifetime [32,33]. In recent times, the time taken for a packet to be delivered is one of the major concerns and over the decades there have been vast research activities to grow and improve the time taken for a packet to be delivered from different research works [34]. Particle swarm optimization [35] and Ant colony optimization algorithms were both used for the selection of CH and gravitational search. They were deployed for routing data from the CH to the sink [36]. The use of these algorithms resulted in optimal clustering and hop path selection for better performance of the system [37].

A triple mobile anchor for localization (TMAL) was deployed for three mobile sensors that form a mobile triangle for locating the unknown sensor nodes to receive signal strength indicator (RSSI). Localization is interpreted as the ability to know where the event occurs with relative side coordinates (RSC) to simulate results with comparison using the RELMA method [38]. In a like manner, the use of social networks which is termed as small-world (SW) characteristics was proposed to conduct the performance of analysis of time synchronization and node location errors over the SW-WSN which help to yield improved results compared to state-of-the-art regular WSNs. Likewise, an optimized distance range free (ODR) localization algorithm helps to limit the use of the size of hops and hop count without increasing an extra communication channel. DV-Hop helps to identify sizes and the centroid is obtained from the minimum distant anchor nodes [39,40].

Research on localization approaches focuses on energy, clustering techniques, enhancing lifetime, load balancing, increasing throughput, reducing delay and decreasing overhead. There are still challenges and disadvantages [41] with benchmarks for node localization clustering in WSNs [42]. Another approach of energy-aware fuzzy unequal clustering algorithm (EAUCF) and fuzzy-based unequal clustering (FBUC) was discussed to only change the node degree that was added to find the absolute radius in the fuzzy logic system [43,44] and to add to that, the approach of cluster formation balance cost and CH based on fuzzy interference system (FIS) was used by Zytoune, Fakhri, and Aboutajdine in [45]. Kernel extreme learning machines (KELM) based on node localization were proposed to employ a real number of hop counts between unknown nodes and anchor nodes as the training inputs and locations of anchors as the target for kernel extreme learning (KEL). In the same token, a three-dimensional distance distributed range free algorithm for error correction-based hops localization algorithm was proposed for WSN IoT [46].

Alrajeh et al. in [47] discussed localization techniques that were used for the collection of information and to determine the location of sensor nodes in WSNs and design the low-cost mechanisms and their applications. Energy maximization with PEGASIS methodology in conjunction with mobile node sink for WSNs was proposed to uplift hotspot issues and distance communication gaps with their consumptions [48]. Ant colony optimization, heuristic methods and particle swarm approaches were used for clustering solutions [46,47].

Furthermore, the functions that are situated around sensor nodes have been consuming nodes resources and adding to network complexity which made the CH to be unbalanced with associated issues. The balancing of CH loads power methodology was suggested in [48,49]. Cheng et al. in [51] used the indoor localization method based on justified joint prediction data gathering for WSNs to prove the prominent performance of large NLOS errors. The distance correction element for three directional measurement error corrections according to the hop localization method was delved into for WSNs IoT devices [50,52]. WSN node localization is a method to obtain absolute data of sensor nodes within a certain circumference for simple centroid localization proposed by Kaur et al. in [53]. MA\*3DDV-Hop was proposed for calculating error average measurement for hop's correction with the use of multi-objective optimization in putting the Pareto principle in the limelight and higher localization expectations were achieved for 3DDV, N2-3DDV, PSO-3DDV and GA-3DDV Hops serially [17].

The LaGrange matrix was used for categorizing the distance in the matrix between the sink node, and sensor nodes within the network under the identified Gaussian noise [52]. Distance measurements are also over-elaborated with non-line of sight (NLOS) [53]. The Kalman filter (KF) principle was applied to predict their estimation based on unbiased, homoscedastic, and Gaussian to get a desired output on the accuracy level [54]. Parallel compact cat swarm optimization and its associated application of sensor node hop localization were explored by Li et. al. in [55]. Some of the data from the measurement that are compiled from the NLOS are not correct due to the positive variance [56,57]. The approach of Voronoi and vector support machine were deployed by Hao et al in [58] to improve the accuracy and the performance of localization. Single anchor node localization was applied [59]. Similarly, the efficient paradigm approach was deployed by Sruthi and Sahadevaiah [65].

The table below provides details of relevant works that were recently published to show gaps and how this research paper contributes to the body of knowledge.

It is evident from the extant literature and Table 1 that DEEC and the Gaussian Gradient Distance Algorithm have not been previously considered for Node Localisation of unknown sensor nodes in a WSN. Furthermore, another weakness of existing research works is that they consider smaller networks as reflected in Table 1 column 2. Simulations with larger networks consisting of 200 to 450 sensor nodes are considered in this research study. Hence, a scope exists for this research work to be conducted.

## Technical background

Figure 1 shows anchor nodes and unknown sensor nodes. An anchor node is a sensor node that has a location that is known, either with the use of GPS or human geo-placing prior to deployment. The relative distance estimation between the anchor nodes and the unknown sensor node is estimated. Different localization methods are used to manipulate the existing

**Table 1**  
Recent Works on Node Localisation.

Year	Author & Title	No. Sensor Nodes	Methodology	Findings	Strength of Approach
2021	Khattak et al. in [59] <i>A Novel Single Anchor Localization Method for Wireless Sensors in 5G Satellite-Terrestrial Network</i>	Only one cluster with 50 sensor nodes is considered. The same method applies to all clusters.	Localisation is performed using Anchor node optimization	The anchor node uses directionality information along with mobility to localize the SN.	The anchor node technique is used to determine the shortest path and localization errors.
2021	Agoramoorthy and Joe in [60] <i>Hybrid cuckoo-red deer algorithm for multi-objective localization strategy in wireless sensor network</i>	20-100 target nodes	the integration of the red deer algorithm (RDA) and the cuckoo search algorithm (CSA) is adopted for the localization of unknown nodes.	A hybrid metaheuristic algorithm named the hybrid cuckoo-red deer algorithm (HC-RDA) Localisation Error HC-RDA 20 nodes (0.4551m) 40 nodes (0.73979m) 60 nodes (1.1108m) 80 nodes (1.5856m) 100 nodes (2.1757m)	The convergence throughput improved location performance with an optimal convergence rate of 8% when compared to classical metaheuristic methods that are Grey Wolf Optimization, 18.6%.
2022	Ahmed et al. in [61] <i>Localization in Wireless Sensor Network</i>	25 – 150 sensor nodes	Distance between sensors and anchors measured by Received Signal Strength (RSS). Butterfly Optimization Approach (BOA) to estimate the location of all sensor and anchor nodes.	Localisation Error RSS-BOA 25 nodes (0.207908m) 50 nodes (0.0318m) 75 nodes (0.0357m) 100 nodes (0.0339m) 125 nodes (0.0326m) 150 nodes (0.1227m)	The overall performances of RSS-BOA were evidenced in consistency enhancement by 7% comparing the accuracy and localization error average
2022	Prateek and Arya in [62] <i>Exploiting perturbed and coalescent anchor node geometry with semidefinite relaxation for sensor network localization</i>	40 & 60 sensor nodes 100 & 120 sensor nodes	The geometrical framework functional approach with the use of semi-definite programming (SDP) was explored	The interrelation of sensor node geometry to harness inefficient operation in WSNs	The SDP approach for nodes based on the convex formulation of estimation for unknown nodes has applications in dynamic network arrangements such as underwater and flying networks.
2022	Jin et al. in [63] <i>A Novel Range-Free Node Localization Method for Wireless Sensor Networks</i>	150 sensor nodes	a novel iterative localization algorithm called CVX-DV-hop is proposed	The proposed algorithm has higher localization accuracy and lower computational burden than those of the particle swarm optimization algorithm	A matrix transformation approach was presented to transform the non-differential and non-convex problem into an interactive convex optimization problem APPA performance was able to find the unknown locations better than Grey Wolf Optimisation and Particle Swarm Optimization
2022	Singh et al. in [64] <i>Three-Dimensional Optimum Node Localization in Dynamic Wireless Sensor Networks</i>	80 sensor nodes	The optimization adaptive plant propagation (APPA) approach with the use of a Three-Dimensional (3D) approach	80 nodes (0.3841m)	

aggregated data of distances that are calculated, and positions for localization algorithms to be established the other nodes in the WSNs.

In this research works the proposed DEEC-Gaussian Gradient Distance Algorithm (DGGDEA) is used to determine the location of a sensor node. The results of this algorithm will be compared to other state-of-the-art algorithms.

Figure 2 presents the novel DGGDEA method for node localization for WSN which is discussed in the Section of this paper.

Figure 2 shows the combination of the **Distributed Energy Efficiency Clustering (DEEC) algorithm; the Gaussian Elimination (GAUSS) algorithm and Gradient Distance Algorithm (GDA)**. The novel DGGDEA represents the hyper-heuristic solution for node localization having 20 anchor nodes and 200 to 450 sensor nodes [77].

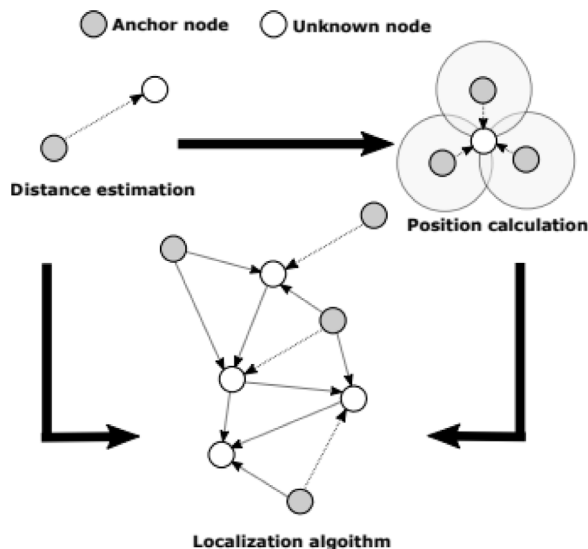


Fig. 1. Node localization estimation processes ([65]).

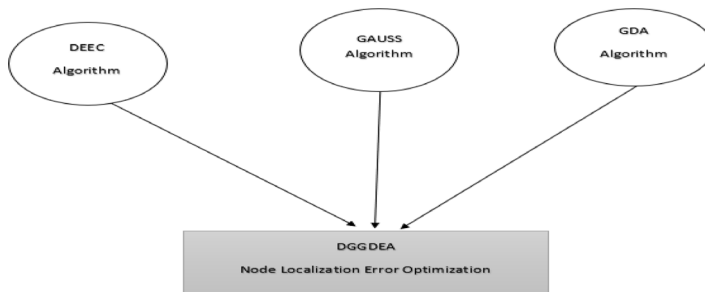


Fig. 2. Hyper-heuristic DGGDEA for Node Localization.

**The study methodologies**

In this work, we contemplate a new approach for node localization using DGGDEA. We assume that the sensor nodes are deployed randomly to maintain their static position after they are deployed.

- 1) Individual sensor node cluster heads of 20 will have a unique identity to be able to spot them from others deployed.
- 2) We will also assume that the nodes have the same initial energy and power source which cannot be changed but at a different level of significance.
- 3) We will also assume that the nodes are linked bidirectionally. The parameters used for DEEC-Gauss are  $P_{opt}=0.1$  (this is the parameter for period mode). The nodes are randomly deployed from a base station (BS). All nodes are equal with limited energy of 0.5J.
- 4) The probability of error (PoE) is computed by dividing the localization error by the total number of sensor nodes per round ranging from 200 sensor nodes to 450 nodes calculation is used.

*Proposed DEEC-Gauss gradient distance algorithm*

The node localization estimation gradient error model helps to dissipate energy to acknowledge data and dispatch the packets sent to the base station within the network size of 100 by 100, we then assume the 10% of the total sensor nodes for the anchor nodes which is tagged to be the cluster heads. The hop count is set to zero where the  $(X_i, Y_i)$  with the anchor nodes identity  $(i)$  and  $Hop_{ij}$  is assumed to be the hop count value that is dispatched to the base stations. The proposed DGGDEA as presented in Fig. 3 seeks to carry out the proposed solution as follows using the pseudocode process below:

**Step 1.** Set the network model criteria.

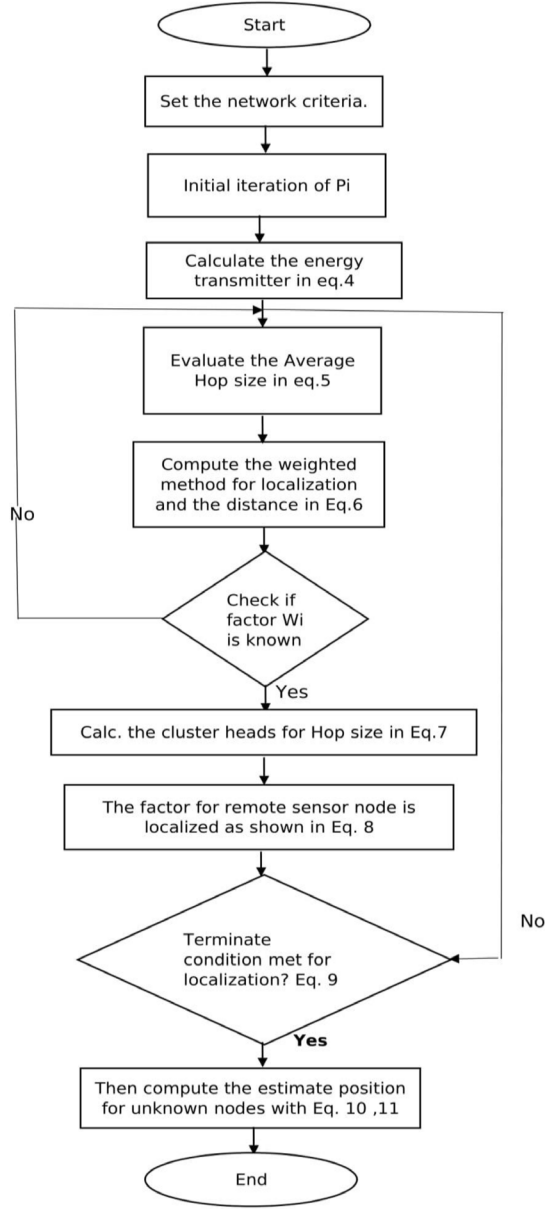


Fig. 3. The system model of the proposed DEEC-Gaussian Gradient algorithm.

**Step 2.** homogeneous energy for all sensor nodes [48]

$$\text{using } E_{Total} = \sum_{i=1}^n E_0(1 + a_i) = E_0 \left( \left( n + \sum_{i=1}^n a_i \right) \right) \quad (1)$$

**Step 3.** Start iteration of the computation of  $p_i$  for heterogeneous nodes [65]

$$\text{using } p_i = \frac{p_{opt} N(1 + a) E_i(r)}{(N + \sum_{i=1}^N a_i) \bar{E}(r)} \quad (2)$$

a. Calculate the energy that is needed by the transmit amplifier [66]

$$E_{TX}(l, d) = \begin{cases} lE_{elec} + l\epsilon_f d^2, & d < d_0 \\ lE_{elec} + l\epsilon_{mp} d^4, & d \geq d_0 \end{cases} \quad (3)$$

And the computation of energy needed by the receiver using [66]

$$E_{RX}(l) \text{ using } E_{RX}(l) = E_{elec} \tag{4}$$

**Step 4.** We then calculate [66] ( $AvgHopSize_i$ ) (5)

**Step 5.** The average hop size for the distance between the sensor nodes are

computed with Eq. (6) [66]

$$AvgHopSize_i = \frac{\sum_{j=1}^m \sum_{j \neq i} \sqrt{(X_j - X_i)^2 + (y_j - y_i)^2}}{\sum_{j=1}^m \sum_{j \neq i} Hop_{ij}} \tag{6}$$

**Step 6.** We computed the average size of the Hop, where  $u$  and  $l$  are variable and  $j$  is constant [67]  $d_{iu} = AvgHopSize_j \times hop_{iu}$  (7)

**Step 7.** The weighted centroid method for the sensor localization as  $m$  is determined to be the anchors' nodes for the total sum  $(X_u, Y_u)$ ,  $m$  is the assumed to be the total number of anchor nodes

$w_i = \frac{1}{mHop_{ui}}$  is assumed to be the weighted factor for the  $i$  and the sensor that are unknown are computed from [68]

$$X_u = \frac{\sum_{i=1}^m w_i x_i}{\sum_{i=1}^m w_i}, \quad y_u = \frac{\sum_{i=1}^m w_i y_i}{\sum_{i=1}^m w_i} \tag{8}$$

**Step 8.** The factor of  $w_i$  for the remote sensor for unknown sensor nodes is localized [69]

$$w_i = \frac{\sum_{i=1}^m Hop_{ui}}{mHop_{ui}} \tag{9}$$

**Step 9.** We assume the number of anchor nodes to be cluster heads as  $q$ ; matrix  $A$  represents the energy consumption of every node chosen as cluster head and  $q$  is the number of cluster heads.  $a_{ij}$  Denotes the energy consumed by a cluster head  $i$  which is taken to be a normal node if cluster head  $j$  is its cluster head. Additionally,  $b_i$  denotes the residual energy of cluster head  $i$ , while  $x_i$  expresses the times that cluster head  $i$  can become a cluster head [70,71]. In this way, matrices  $B$  and  $X$  are formed, so that  $A \cdot X = B$ , as shown in Eq. (10) below:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1k} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2k} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3k} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{k1} & a_{k2} & a_{k3} & \dots & a_{kk} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_k \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ \vdots \\ b_k \end{bmatrix} \tag{10}$$

The snippet of code is used to calculate the number of rounds within the network and to obtain the optimal number of clusters [71 and 72].

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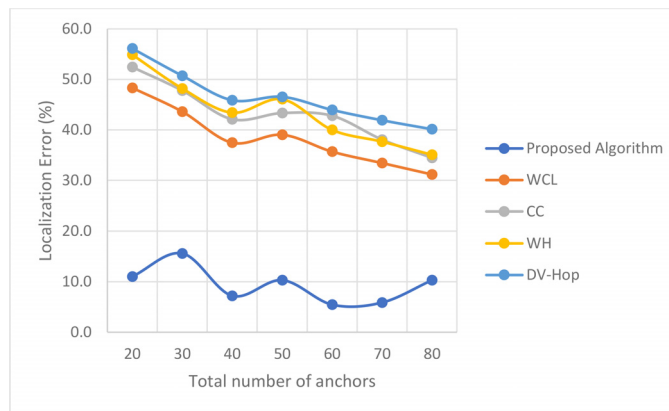
1 For (k=1; k<m+1; k++)
2 For l_max:= argmax(i=k...m, abs(A[i,k]));
3 If (A[l_max,k] = 0)
4 For Error "Matrix is singular!";
5 Swap rows (k,l_max);
6 {Calculate snippet code for a packet sent to base station
7 Calculate snippet code for the tenth node dead}
8 For (i=k+1; i<m+1; i++)
9 For (j=k+1; j<n+1; j++)
10 A[i,j]:= A[i,j] - A[k,j] x (A[i,k]/A[k,k]);
11 A[i,k]:=0;
12 end
    
```

**Step 11.** The localization error is computed and the estimated position of the various unknown nodes is estimated [66,73]

$$\frac{1}{n \times r} \sum_{i=1}^n \frac{Guass \ localization \ error =}{\sqrt{(X_{ai} - X_{ui})^2 + (y_{ai} - y_{ui})^2}} \tag{11}$$

**Table 2**  
Simulation Network Parameters.

Parameters	Value
Network Field	(100,100) m <sup>2</sup>
Number of nodes	200 to 450
E <sub>0</sub> (Initial energy of normal nodes)	0.5J
Message Size	5000 Bits
Anchor node numbers	The num
E <sub>fs</sub>	10 nJ/bit/m <sup>2</sup>
E <sub>amp</sub>	0.0013pJ/bit/m <sup>4</sup>
EDA	5Nj/bit/signal
D <sub>0</sub> (Threshold Distance)	100m
P <sub>opt</sub>	0.1
Total number of simulations	<b>450</b>



**Fig. 4.** The localization error vs the number of anchor nodes.

The energy homogeneous is set to 0.5J initiated for every point of the clustering sensors in the entire network connection [45]. The proposed approach with the use of the DEEC-Gaussian Gradient Estimation algorithm provides an adaptive node localization efficient use of energy resources of sensor nodes. The node probability error was determined for 250–450 for benchmarking the DEEC-Gauss to the state-of-the-art algorithm. However, the probability of error (PoE) was computed with the localization error divided by the number of nodes for each full operation during the simulation.

The area of interest is set to  $m \times m$  meters where  $m = 100$ . The base station is present at the centre of the field of the location. The system configuration was Intel Core i7-8650U CPU @1.90GHz, 2.11 GHz, installed memory (RAM) 8,00GB (7,85 GB usable). System type 64-bit operating system, the x64-based processor running Windows 10. The network consists of  $n = 200$  to 450 nodes just as shown explicitly enough which is summarized in Table 2.

## Results and discussion

In this section, we present the simulation results of the proposed novel DGGDEA and the comparative analysis of performance with the state-of-the-art clustering algorithms such as weighted centroid localizations (WCL), DV-Hop, Compensation Coefficient (CC) and Weighted Hyperbolic (WH) approach. The Weighted Centroid Localization (WCL) procedure of setting is used to evaluate the scalability, error performance, and mobility model [75,76,80]. WCL techniques are suited for localisation since they do not solicit assistance and rely exclusively on easily accessible RSSI data [81]. Unlike some range-based Centroid localized algorithms, WCL always finds a solution and does not require an earlier forecast of the path loss exponent. DV Hop processes are used to determine the accuracy and routing position of localized coordinates [74], whereas Compensation Coefficient (CC) is utilized to correct average hop distances between anchors and nodes and reduce error [53]. Furthermore, The compensation Coefficient (CC) algorithm, which is simple and resistant to changes in wireless transmission parameters like route loss, guesses the unknown node's position. As a result, CC are reliable for increasing distance reliability and precision [81]. A weighted hyperbolic (WH) was constructed to facilitate full localization by measuring the distance between node localization error noise and their actual predicted position along the routing path [79].

The simulation was carried out in MATLAB 2021 environment, with 20 anchor nodes and varieties of sensor nodes between 200–450 with the random deployment of the nodes and gradient distance were applied to the novel DGGDEA which was run more than 300 times consecutively for the best result to be obtained. Fig. 4 presents the average localization error for sensor nodes between 200 and 450. The results presented show that the DGGDEA outclasses the other algorithms due to the optimization of localized sensor nodes for identifying the most preferred position of sensors.

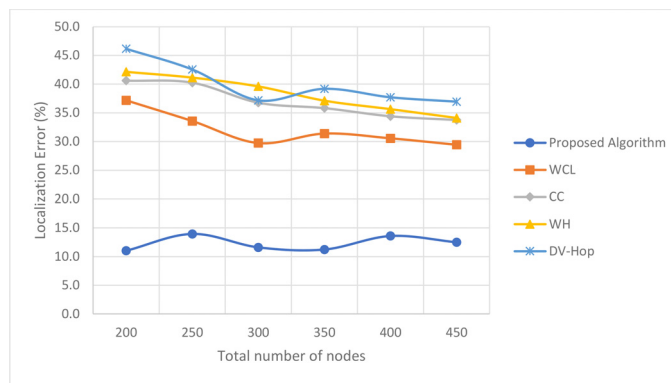


Fig. 5. The localization error vs the number of sensor nodes.

Table 3

The Localization Error vs the Number of Anchor Nodes.

No. of Anchor Nodes	Proposed DGGDEA	WCL	CC	WH	DV-Hop
20	11.0%	48.3%	52.4%	54.9%	56.1%
30	15.6%	43.6%	47.8%	48.2%	50.7%
40	7.2%	37.4%	42.1%	43.4%	45.9%
50	10.3%	39.0%	43.3%	46.1%	46.5%
60	5.4%	35.7%	42.8%	40.0%	43.9%
70	5.9%	33.4%	38.1%	37.7%	41.9%
80	10.3%	31.2%	34.4%	35.1%	40.1%
Mean	11.0%	44.8%	50.1%	50.9%	54.2%

The results of the localization error vs the number of total sensor nodes between 200 to 450 sensor nodes were presented in Fig. 5 consequently, the proposed DGGDEA outperformed all other state-of-the-art algorithms.

Figure 6 shows the true localized position of the 20 anchor nodes. The localized node is represented with black small circles and the mobile sensor nodes are represented with the small open red circle while the cross symbols represent the mobile true locations at 0.5J energy for sensor nodes between 200 and 450.

In Table 3, we present the probability of error (PoE) during the simulation of the sensor nodes location detection, the presented data is evidenced that the best performance is attained from the proposed algorithm when compared to other state-of-the-art algorithms.

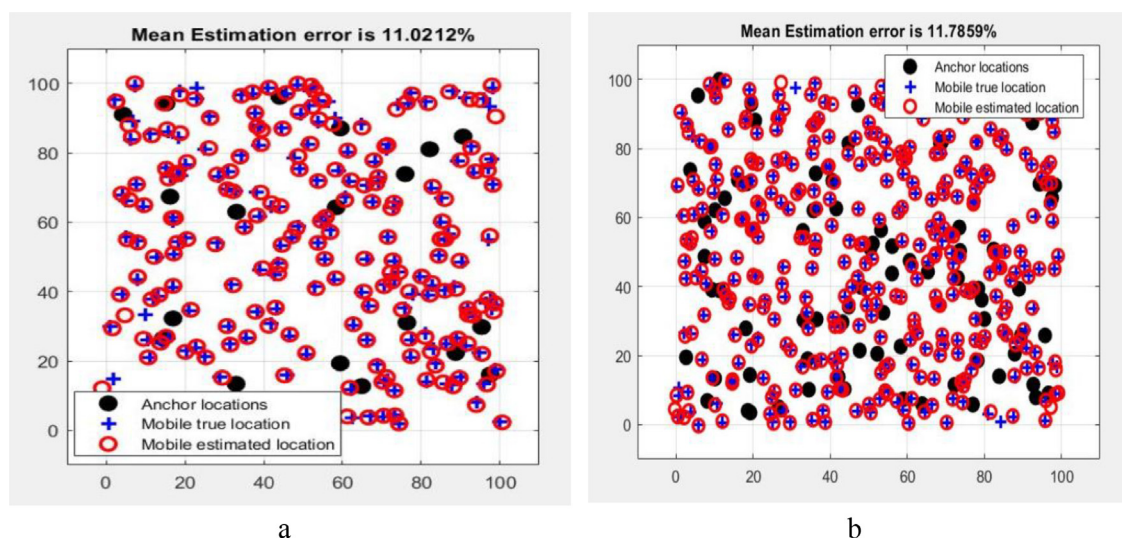


Fig. 6. The Localized 20 anchor nodes with a: 200 sensor nodes, b: 250 sensor nodes, c: 300 sensor nodes, d: 350 sensor nodes, e: 400 sensor nodes, f: 450 sensor nodes.

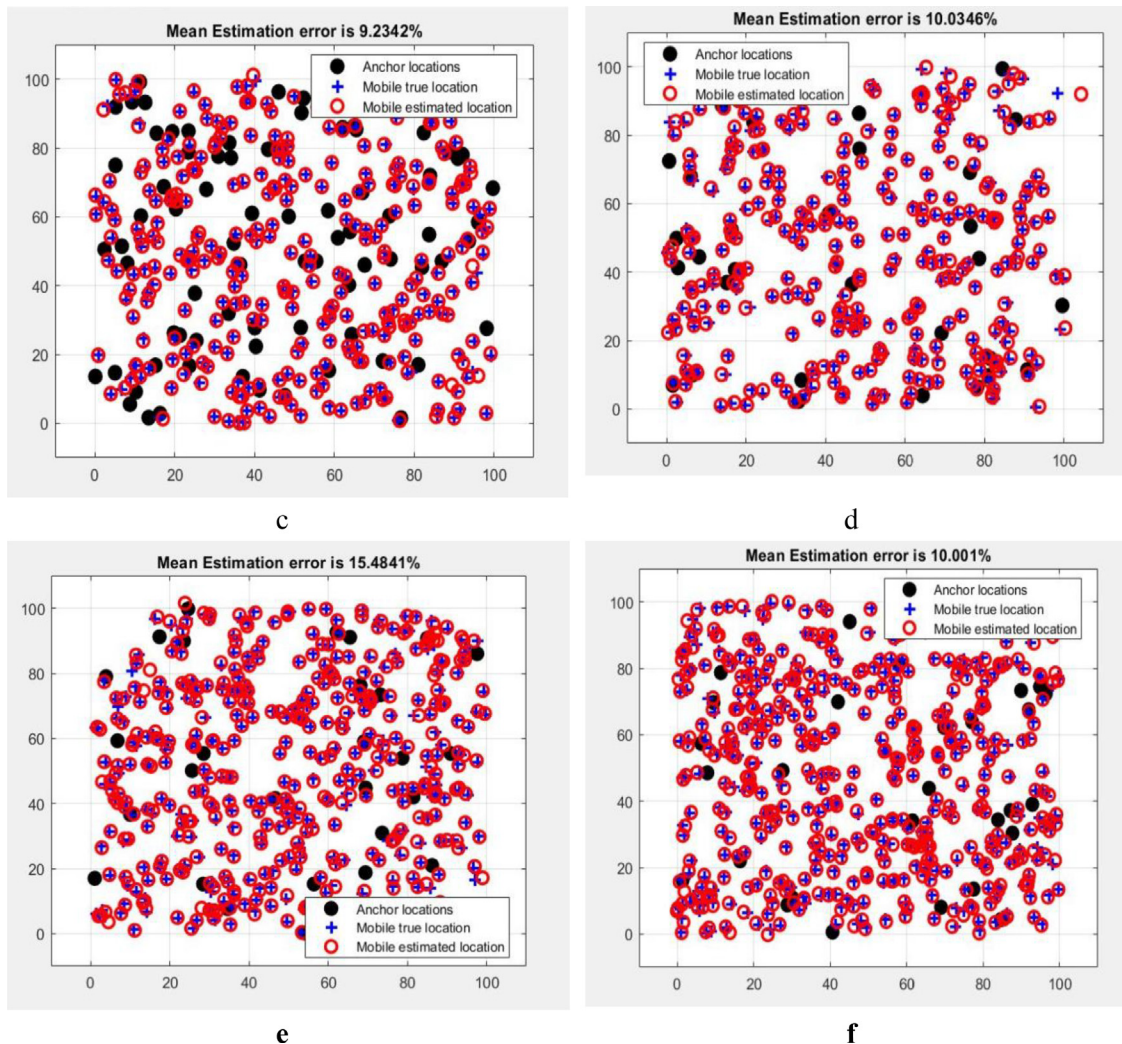


Fig. 6. Continued

**Table 4**  
The Localization Error vs the Number of Total Sensor Nodes

Total No. of Nodes	Proposed (DGGDEA)	WCL	CC	WH	DV-Hop
200	11.0%	37.2%	40.6%	42.1%	46.2%
250	11.8%	33.6%	40.2%	41.1%	42.6%
300	9.2%	29.7%	36.8%	39.6%	37.2%
350	10.0%	31.4%	35.8%	37.1%	39.2%
400	15.5%	30.6%	34.4%	35.6%	37.7%
450	10.0%	29.4%	33.7%	34.1%	36.9%
Mean	11.3%	32.0%	37.0%	38.3%	40.0%

Table 3 shows the localization error and the number of 20 to 80 anchor nodes used during the simulation performances. In Table 3 the DGGDEA was compared with four classical algorithms and the result presented shows that DGGDEA outperformed the other four algorithms. The lower the localization error, the better the performance of the algorithms, hence, the DGGDEA significantly optimized the node localization accuracy by reducing the localization error [74].

Table 4 shows the results of the localization error vs the number of total sensor nodes ranging from 200 to 450 sensor nodes.

Table 4 shows that the proposed algorithm outperformed all other algorithms for the total number of nodes from 200 to 450, while the second-best algorithm is WCL followed by the CC algorithm, and the worst algorithm is DV-Hop.

**Table 5**  
Node Localization Agenda 2063 and SDG Goal Major Contributions

Agenda 2063 Goals	Agenda 2063 Priority Areas	UN Sustainable Development Goals
First- All citizens have a high standard of living, a good quality of life, and are in good health [77,78].	Affordably priced, liveable housing, and good essential services [78,79].	SGD 9- Increase energy innovation, encourage global sustainable development, and build resilient energy infrastructure [78,79].
Fourth- Affordably priced, liveable housing, and good essential services [77,78].	Affordably priced, liveable housing, and good essential services [78,79].	SDG 7- Make ensuring that everyone has access to modern, affordable, dependable, and sustainable energy [78,79].
Sixth- Blue/ocean economies for quickening economic expansion [77,78].	Economic resilience and diversity [79,80].	Make ensuring that everyone has access to modern, affordable, dependable, and sustainable energy [78,79].

The DGGDEA can now address node localization and energy efficiency optimization challenges. Furthermore, the DGGDEA addresses the first, fourth, and sixth Africa Union Agenda Goals and priority region 2063, as well as the United Nations Sustainable Development Goals seven (SDG 7) and nine (SDG 9) as specified in Table 5:

Table 5 impact is in line with the Sustainable Development Goals of the United Nations, which are to "increase energy innovation, encourage global sustainable development, and build resilient energy infrastructure," in addition to "ensure that everyone has access to modern, reasonably priced, dependable, and sustainable energy." A high standard of living, a good quality of life, and excellent health are all goals of the AU Agenda 2063, as well as the achievement of blue-ocean economies for accelerating economic expansion, economic resilience, and diversity.

## Conclusions

The novel hyper-heuristic algorithm utilized three meta-heuristic algorithms, namely, Distributed Energy Efficiency Clustering algorithm (DEEC), Gaussian Elimination Algorithm (GAUSS) and Gradient Distance Elimination Algorithms to develop the hyper-heuristic optimization model for node localization in WSNs. The implementation of the novel hyper-heuristic DGGDEA for node localization showed the best performance in comparison to other state-of-the-art algorithms. During the simulation analysis using 20 to 80 sensor nodes and 200 to 450 sensor nodes with 20 static anchors the optimization node localization error and the probability of error (PoE) were determined, with the mean estimation for the locations of sensor nodes in WSNs. The comparative analysis was completed with state-of-the-art clustering algorithms to determine the performance evaluations using the number of data packets sent to the base station as well as the reduction of node localization error and the probability of error. It is evidenced that the performance of the range-free approach of the novel DGGDEA in contrast to traditional state-of-the-art algorithms such as WCL, CC, WH and DV-Hop in the application showed a reduction in the node localisation error for 20 to 80 sensor nodes and a reduction in node localisation error for 200 to 450 sensor nodes. Future work will focus on the performance of the DEEC-Gauss Gradient Elimination algorithm on larger sensor networks.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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