



Research paper

Depuration based Efficient Coverage Mechanism for Wireless Sensor Network

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Abstract

Background and Objectives: The quick response time and the coverage range are the crucial factors by which the quality service of a wireless sensor network can be acknowledged. In some cases, even networks possess sufficient available bandwidth but due to coverage tribulations, the customer satisfaction gets down suddenly. The increasing number of nodes directly is neither a canny solution to overcome the coverage problem nor a cost-effective. In fact, by changing the positions of the deployed node sagaciously can resolve the coverage issue and seems a cost-effective solution. Therefore, keeping all circumstances, a Depuration based Efficient Coverage Mechanism (DECM) has been developed. This algorithm suggests the new shifting positions for previously deployed sensor nodes to fill the coverage gap.

Methods: It is a redeployment process and accomplished in two rounds. The first round avails the Dissimilitude Enhancement Scheme (DES), which searches the node to be shifted at new positions. The second round controls the unnecessary movement of the sensor nodes by the Depuration mechanism thereby the distance between previous and new positions is reduced.

Results: The factors like loudness, pulse emission rate, maximum frequency, and sensing radius are meticulously explored during simulation rounds conducted by MATLAB. The performance of DECM has been compared with superlative algorithms i.e., Fruit Fly Optimization Algorithm (FOA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO) in terms of mean coverage range, computation time, standard deviation, and network energy diminution.

Conclusion: According to the simulation results, the DECM has achieved more than 98% coverage range, with a trivial computation time of nearly 0.016 seconds as compared to FOA, PSO, and ACO.

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Introduction

Usually, wireless sensor networks (WSNs) are incorporating with small-sized self-governing

wireless sensor device, which is generally placed in aggressive and vulnerable environments to monitor and collect the data. However, in spite of widespread

adaptation, WSNs are given to multiple restrictions associated with processing abilities, thin wireless bandwidths, random sensor node deployment, limited storage spaces, and limited battery power. The fundamental issue in observing such environments is the area coverage which reflects how well the region is monitored. Coverage is usually defined as a measure of how well and how long the sensors are able to observe the physical space [1].

The quality of coverage in static sensor is significantly affected by the initial deployment location of the sensors. Unfortunately, sensor deployment cannot be performed manually in most applications [2], for instance, the deployment in disaster areas, harsh environments, and toxic regions. Most of the previous studies showed that, sensors were usually deployed by scattering from an aircraft; however, the actual landing position cannot be uniform due to the existence of obstacles for instance, buildings, trees and wind causing some areas of the sensing region to be denser than others. Therefore, even if a large number of redundant nodes are deployed, the desired level of coverage still cannot be achieved. Therefore, it is essential to make use of sensors, which can move iteratively to a better location that can give the required coverage [3].

In order to address the sensing coverage area, it is important to understand the mobility control attribute [4], of the sensor nodes. Indeed, sensor nodes have two type of mobility control attributes i.e., centralized and distributed [5]. Regarding centralized attribute, the bunch of nodes are centrally monitored by a sink node that overhears the sensing data from neighbouring nodes while in distributed networks, the sensors are self-controlled.

All sensor nodes have limited sensing and communication abilities [6], which make the sensor nodes unable to obtain the entire network information. Due to which sensors are deployed randomly and allowed to move and communicate with their neighbours by exchanging information between them [7]. The miniaturized robotics have overcome some hurdles regarding sensors mobility. Thereby, mobile sensors have the same sensing capability as static sensors [8], and can move freely to correct locations for providing the required coverage. On the other hand, it is not a cost-effective solution.

Keeping all aforementioned challenges, it is motivated to design a sagacious sensor node deployment strategy which should enhance the coverage area by consuming just confine energy metrics. Considering the pattern of a hybrid sensor network [9], which composed of mobile and static sensors we have proposed a Depuration based Coverage

Mechanism for Wireless Sensor Network (DECM). For this purpose, a DECM algorithm has been designed which focus how to redeploy the sensor nodes to improve network area coverage in hybrid WSNs environment. It is indeed a cost-effective solution towards improving coverage with unevenly deployed sensors.

Initially, algorithm aims to determine where the sensor nodes should be moved while incurring the trivial moving cost. This will result only a confine moving cost including the accumulated moving distance, total number of moves, and communication rounds. The proposed DECM mechanism ultimately can maintain a balance between coverage with confine resource consumption during node redeployment process.

A. Working mechanism of proposed DECM

Initially, the nodes are deployed with some random positions, with certain velocities [10], to search the shrewd target positions in network coverage area. The minimum distance value and related coordinates are being recorded. After getting best minimum distance value the intended positions are crosschecked otherwise process will be repeat the same step. The further proceedings are explained stage by stage through Flow chart shown as Fig. 1.

Stage 1: Initialize all the parameters including the group size (n), the maximum number of iterations and the initial positions of sensor node group ($X_{initial}$, $Y_{initial}$), step length [11], number of area range points, loudness and pulse rate, minimum and maximum frequency, upper and lower bounds [12]. All these parameters are being calculated through (1), (2), where i varies from 1 to n , LB and UB is lower and upper bounds, and n is the size of sensor node group.

$$X_{initial}(i) = LB + (UB - LB) * \text{Random value} \quad (1)$$

$$Y_{initial}(i) = LB + (UB - LB) * \text{Random value} \quad (2)$$

Stage 2: The essential parameters of the sensor nodes like positions (x_{it}), velocities (v_{it}) and frequencies for time t are updated as expressed in (3)-(5),

$$f_i = f_{min} + (f_{max} - f_{min})\beta \quad (3)$$

$$V_i^t = V_i^{t-1} + (x_i^t - x^*)f_i \quad (4)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (5)$$

where β is an arbitrary vector whose value is lies between 0 and 1, the f_{max} represents maximum frequency and x^* indicate the Shrewd solution.

Stage 3: The distance of all the sensor nodes from the current area position (Distn*m) [13], is being computed by the (6)

$$Dist_{n*m} = \sqrt{(X_{n*m} - x_j)^2 + (Y_{n*m} - y_j)^2} \quad (6)$$

where X_{n*m} and Y_{n*m} are initial positions of $n*m$ sensor nodes x_j and y_j are coordinates of j area range.

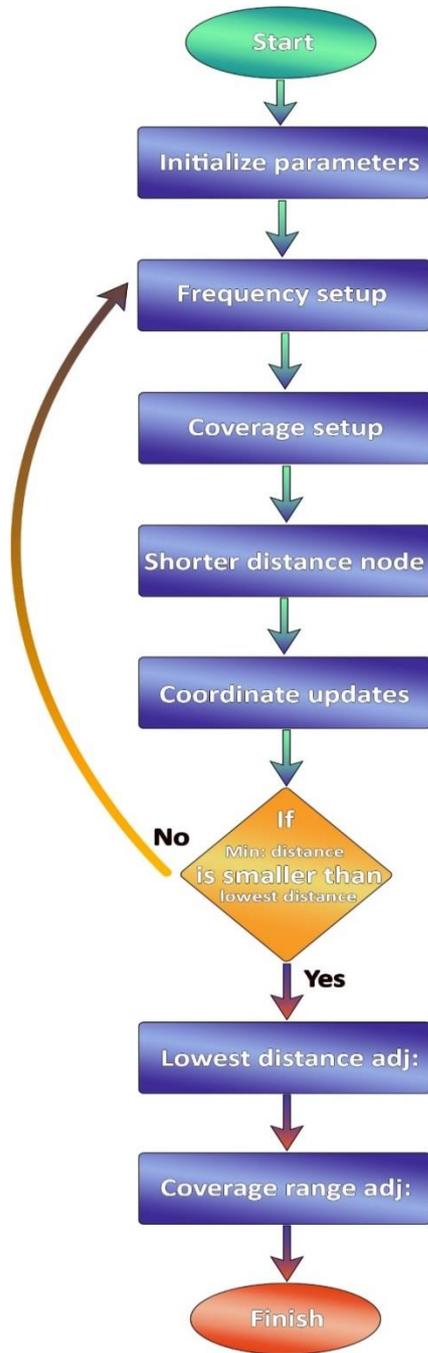


Fig. 1: DECM information flow chart.

Stage 4: Any sensor node having minimum distance value to the intended node positions are compared and this moving distance is selected.

Stage 5: The lowest distance value and related coordinates are recorded in corpus Table.

Stage 6: The lowest and shrewd distance value is compared with other distance value during

every iteration. If no other shrewd distance value is found then this lowest and shrewd value and its coordinates are updated and sensor node shift its position to the intended target in accordance to the condition defined in DECM algorithm otherwise, repeats step from 2 to 5.

Stage 7: The overall network Coverage Range (CR) [14], has been computed through (7).

$$CR = \frac{N_{m*n}}{M*N} \quad (7)$$

The $M*N$ is the network coverage area, $m*n$ represents total summation points of each sensor node.

Further explanation is given in the third section. Our unique contributions have been summarized as:

- The proposed DECM algorithm tends to overcome related issues with the network coverage range by shifting already deployed sensor nodes from previous to new positions.
- In some cases, it makes substitution of nodes to adjust the coverage hole.
- The unnecessary sensor movement is also being monitor to reduce the movement distance between nodes which prevents the wastage of the energy resource.
- The simulation results generated through Matlab has vouched the succulent performance of DECM when compared with previous work FOA, PSO and ACO.
- The proposed DECM algorithm accomplished the operation in two junctures, during first juncture the intended target positions of the sensor node is computed through Dissimilitude Enhancement Scheme (DES). The second juncture is referred as Depuration, where the moving distance between node is sagaciously reduced, thereby the target positions are achieved.

The rest of the manuscript is structured as: The previous work has been rummaged out in the second section, the proposed methodology has been explained in the third section, while in the fourth section renders the output performance and the result discussion. Finally, overall achievements have been summarized in the form of conclusion in the next section.

Literature Review

Usually sensor nodes are deployed to cover the area between distinct boundaries. However, selection of most suitable area is ever remained a challenge [15]. In order to achieve the sufficient coverage area, the distributed deployment strategy is commonly used to improve the area coverage by moving the sensor nodes from one location to another. For this purpose, the distributed movement algorithms are being used wherein the coverage area is allocated in multiple segments. If any sensor node was unable to detect the

event happenings within the deployed segment, no other sensor node can detect it. Eventually, the monitoring of each segment area for coverage gap (hole) and calculation of new location is the prime liability of the deployed sensor node. All distributed movement algorithms are facing numerous tribulations regarding new position calculation within the segment area while relocating the new location. No researcher could ever address to overcome the nodes position reallocation challenge in hybrid environment. Therefore, no wireless network having coverage holes, can successfully carry out its monitoring operation [16]. The researcher tried to incorporate more iterations in their designed model to address the new allocation issue but it drastically increased the implications and causing higher energy consumption. To some extent, overcome these issues the numerous researchers have made substantial contributions. For example, the motion capability of sensor nodes with relocating ability and dealing with sensor failure have been identified by Qingguo *et al.* [17], They suggested a two-phase sensor relocation solution. The redundant sensors are first identified and then relocated to the target location. They proposed a grid-quorum solution to locate the closest redundant sensor, and proposed to use cascaded movement to relocate the redundant sensor. In fact, their suggested model could not control the exorbitant energy drainage and thereby whole network might die after few transmission rounds. On the other hand, Li Jun *et al.* [18], tried to address the coverage and load balancing issues by minimizing the moving distance and argued a centralized movement solution, based on the Hungarian method. However, the centralized movement technique revealed those sensor nodes having already appropriate positions when impelled to leave the position creating energy holes. Wang *et al.* [19], proposed three different distributed movement assisted sensor deployment algorithms, VEC, VOR, and Minimax, to improve the total area coverage. Thereby they used the Voronoi diagram to partition the monitoring area into n convex polygons where every polygon enclosed one sensor node only. This method utilizes the local polygon information to calculate the new position location to move sensor node. The VEC approach uses virtual force between two nodes to push them away from each other at a certain distance. Minimax and VOR algorithms are greedy, and try to fix the largest coverage hole by moving sensor node towards the farthest polygon vertex. The nodes approaching to the polygon do not need to move towards the farthest vertex.

As a result, this movement may not reduce coverage hole, but might increase the complications. The identification of new node location and its relative computation has been calculated through four local

displacement conditions by the H. Mahboubi *et al.* [20], taking into account the circles having centered position within the respective polygons. Some centers might lie out of the polygon and thereby sensor nodes locating around those circles may not have movement. Consequently, this issue demands more rounds to overcome the coverage tribulation. The more the rounds it demands, the more the resources are being consumed; As a result, the sensor nodes will cause the network to confine the lifespan before the specified time. In order to increase the coverage rate of sensor nodes, various researchers have proposed different optimization techniques. A sensing and perception-based Fruit Fly Optimization Algorithm (FOA) was applied by Wen-Tsao Pan [21], to address the position issue of the sensor node which aims to enhance the coverage matter in ideal and obstacle environment. As the fruit flies can reach the food source by using their smell and vision organs. Initially, they use olfactory organs to find all kinds of scents in the air. Then they fly toward to food. When they get close to the food, they use their vision organs to get closer. Similar action is adopted for relocating the sensors positions. Despite its advantages, there are critical issues for instance, the first pointing location remains poor. Further, the algorithm significantly traps into local optimum and the update strategy is limited.

An Edge Based Centroid (EBC) algorithm is proposed by Muhammad Sirajo *et al.* [22], and author claims about enhanced area coverage of monitoring field with minimal energy consumption.

In fact, this algorithm is based on Voronoi diagram that partitions the sensing field into polygons with one sensor node each to monitor any event in its respective subregion. The sensor node moves to new location at the center of each polygon from location, which improves area coverage. This algorithm depends on certain group of rules that ensures about the center of each polygon before the movement and thereupon the ratio of energy consumption can be lowered. Though this algorithm works smooth but no control over the uncouth movement of the node is addressed due to that sometime a node can make unusual and large displacement which might cause the energy wastage. In pursuit of a better coverage technique, a majority of scholars have tried to use intelligent algorithms like, Genetic Algorithm (GA) [23], and Particle Swarm Optimization (PSO) [24], to solve the issue. Though, fruit fly algorithm is simple and practicable than GA and PSO but due to unavoidable limitations the researcher is still exerting their efforts to develop shrewder algorithm. Table 1, exhibits various comparison among such algorithms and shows a significant improvement by the proposed algorithm.

Table 1: Comparison of proposed DECM with in-practice algorithms

Algorithm	Working ground	Expediency	Impairments	Comparison with proposed DECM
Genetic Algorithm (GA)	Stochastic search methodology through generic system, withing a population it impels the recombination and mutation.	It is faster and have ability to find best quality solution in trivial time, possessed parallel capabilities. Easily discovers the global optimum.	Never guarantee for optimal solution. Hard to choose parameters like number of generations, population size. It is expensive.	It functions in hybrid environment, ensures about relocating the intended nodes position within the coverage area therefore energy consumption remains confined.
Particle Swarm Optimization (PSO)	Inspired by bird flocking and fish schooling. The particles move in a multidimensional search space and single intersection of all dimensions forms a particle.	It can overcome the unconstrained minimization issue. Provides the derivative free technique, it is less sensitivity, less dependent of a set of initial points. It can generate high-quality solutions.	It can easily fall into local optimum in high-dimensional space and has a low convergence rate in the iterative process. Difficult to adopt the best topology.	At the beginning it rummages where the sensor nodes should be moved therefore local minima can easily be avoided.
Bacterial Foraging Algorithm (BFA)	It works on search and optimal foraging decision making capabilities, problems, movement take place either in clockwise or counter clockwise direction	Used for unconstrained numerical optimization, having dual movement i.e., swimming and tumbling called chemotaxis,	Having weak ability to perceive the environment and vulnerable to perception of local extreme, hard to deal with complex optimization problems	As it operates in two stages, thereupon no vulnerabilities can slow down the performance, each stage performs independently.
Ant Colony Optimization (ACO)	Based on social behaviour of the insects, the optimization process is initialized by random solutions	Rapid discovery of good solutions with guaranteed convergence,	Dependent sequences of random decisions, having complicated theoretical analysis, uncertain time to convergence	The Depuration technique in second stage reduce the moving distance and there exists no uncertainty.
Artificial Bee Colony (ABC)	Search optimization consists of three essential components: employed and unemployed foraging bees, and food sources.	It minimizes the expense of deploying nodes inside the monitoring regiondeals with local solution, havingbroad applicability, complex functions	Slow process, higher number of objective function evaluation, number of dimensions might change	It maintains the network dimension by reducing the moving distance between the nodes.
Jenga-inspired optimization algorithm (JOA)	Based on greedy fast convergence, select minimum cost node subset through the roulette method, bridge between optimal solution and short computation time.	Address the Energy-Efficient Coverage issues, having stochastic approach to conduct random exploration, if sensor node cannot cover an area the other node take avail the chance	The detection probability decreases exponentially as the distance becomes greater	Have shrewd control over moving distance therefore no uncouth movement can degrade the overall communication.

Coverage Model

A coverage model explains the possible coverage range by the sensor nodes in coverage area.

All sensor nodes have various coverage range characterized by area where these sensors are being deployed, the accuracy, the environment factors and resolution. The coverage area depends on various

factors such as the signal strength generated from the source, distance between the sensor node and source and the rate of attenuation in propagation. For example, an acoustic sensor network establishing the coverage range to detect the mobile vehicles, the sensor nearer to a vehicle can detect higher acoustic signal strength than the one farther away from the vehicle due to signal attenuation, and as a result there is higher confidence of detecting vehicles.

A. Problem Formulation

For proposed coverage model, a two-dimensional coverage area has been considered. Further, the coverage area is divided into various segments each having unit size. When n number of sensor nodes have been deployed in targeted area m, thereby a full couplet of sensor node can be defined as given in (8),

$$S = \{S_1, S_2, \dots, S_n\} \quad (8)$$

the position of ith node is defined as $S_i = (x_i, y_i)$ where $i = (1, 2, \dots, n)$. The coverage range of sensor S_i can be expressed as a circle centered at its coordinates (x_i, y_i) with the radius of the sensing range R_s . Let E_i , being a random variable for an event that a sensor node S_i covers an area of segment $A(xA, yA)$. The Presage factor for event E_i can be written as $P\{E_i\}$ which is equal to the coverage presage i.e., $P(S_i, xA, yA)$. Thereupon, the happening of an event presage can be defined by the discrete coverage model expressed in (9).

$$P(S_i, xA, yA) = \begin{cases} 1, & d(S_i, xA, yA) \leq R_s \\ 0, & \text{other case} \end{cases} \quad (9)$$

The Euclidean distance [25], of i^{th} sensor node from segment area $A(x, y)$ can be computed by (10).

$$P(S_i, xA, yA) = \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (10)$$

All coverage pints within the coverage range are measured as unity covered [26], by the particular sensor whereas, the points outside of this coverage range is regarded as 0. The shrewd objective of coverage optimization issue is to provide sufficient Coverage Range (CR), by using a smaller number of sensor nodes. The CR is used to estimate the performance of sensor network. Generally, it is assumed that segment area point can be covered by any sensor node only once.

B. The proposed DECM Model

At present, among all optimization algorithms the DES [27], is considered as a fasted optimization scheme therefore we found it sagacious and motivated to take full advantage for our proposed DECM algorithm. Thus, the coverage range tribulations in WSN is being resolved by redeployment of sensor nodes through DES strategies and therefore the stages of DECM design model are being explained one by one.

Stage 1. Locating intended target positions of the node:

The depuration based efficient coverage mechanism (DECM) is an investigative search technique that utilizes the shrewd coverage mechanism. It exploits the position of the sensor node for potential solutions, individuals, to probe the search range. It initializes the parameters while addressing the coverage area issue as depicted in (11),

$$X_s = (x_{s1}, \dots, x_{s2}, \dots, x_{s3}) \quad (11)$$

considering $1 \leq s$, as the area range and $x_{s2} \in [a_s, b_s]$, where " a_s " and " b_s " denotes the lower and upper bound of the s^{th} node, respectively. After every transmission round t , the corresponding re-allocation round presages the intended position of the bodacious node which is expressed as (12),

$$V_s(t + 1) = X_{bodacious} + F(X_{r2}(t) - X_{r3}(t)) + F(X_{r4}(t) - X_{r5}(t)) \quad (12)$$

The $X_{bodacious}$ indicates the appropriate position of the node while r represents the transmission round and F points a scaling factor that is a distance control parameter between initial and the new node position. To increase the sensing range, the position parameter $V_s(t + 1)$ is incorporate the value of predicted node $X_s(t)$, thereby yields a temporal position $Q_s(t + 1)$ as expressed in (13),

$$Q_{s,j}(t + 1) = \begin{cases} V_{s,j}(t + 1), & \text{if } (rand[0,1] < FCR \text{ or } j = J_{rand}) \\ X_{s,j}(t), & \text{for other case} \end{cases} \quad (13)$$

The $rand(0,1)$ represents a uniformly distributed random positions, while J_{rand} exhibits randomly predicted positions within the range $[1, D]$. The FCR came up as a Fractional Control Parameter $\in [0, 1]$, which shows the inherited characters of previous node position.

Proceeding towards final position, the temporal position $Q_s(t + 1)$ is being compared with predicted node $X_s(t)$. The newly generated position that possessed greater fitness metric among rest of the positions is our intended position of the node given in (14),

$$X_s(t + 1) = \begin{cases} Q_s(t + 1), & \text{if } (f(Q_s(t + 1)) \geq f(X_s(t))) \\ X_s(t), & \text{other case} \end{cases} \quad (14)$$

here $f(X)$ represnets the intended target position of the node. In fact, the sensor network performs the virtual movement and as long it achieves the intended position of the sensor node in accordance to the (14), physical displacement has been performed accordingly.

Stage 2. Depuration process:

The depuration process is performed to reduce the moving distance of the node. This will reduce

the number of sensor nodes that need to move, as well as reduce the average moving distance; however, it does not affect the network coverage. The moving distance reduction strategy can be understood as: Consider the initial positions of the deployed sensor nodes illustrated in Fig. 2. Sensor node s_1 is lying at position-1, s_2 with position-2, s_3 with position-3, s_4 with position-4, and s_5 with position-5. The sensor node s_1 is trying to move at new intended position i.e., intended-SP1. At the same time, another sensor node s_2 also trying to capture the same position but DECM algorithm systematically controls the movement of sensor node that are needed to be moved. The sensing range may even be fully overlapped by other nodes, these nodes are called redundant nodes. If coverage range $R_{area}(S)$ presages no substantial change to position of a sensor node is required when a node with smaller distance has already accessed the intended position thereby node s_2 can be removed from the queue which eventually decreases the distance. In Fig. 3, the positions of sensor node are being updated thereby at initial state, the moving distance of s_1 and s_2 is $d_1 + d_2$ and after the displacement, it will be updated to $d_3 + d_4$ as depicted in Fig. 4. It is worth mentioning that $d_1 + d_2 > d_3 + d_4$, therefore achieving the intended positions, the moving distance of s_1 and s_2 can be confined but no change will be occurred in coverage area but the area coverage distance rate will be extended. The sensor nodes that eager to update their moving position will be substitute with the moving position of the nodes which are stationary and does not require to move further. This step can prevent the nodes to make unnecessary and longer movement. In case the node does not possess sufficient energy while reaching at intended position, the other surrounding node will surrogate the liability. Initially, the node s_1 and s_2 tries to shift their positions with Intended-SP1 and thereupon establishes the desired link.

In fact, the distance between node s_1 and SP1 is greater than that one of its neighbouring node. Similarly, node s_2 has a longer path to access the intended-SP1 position and meanwhile there appears another node in its surrounding which is much closer.

Both sensor nodes s_1 and s_2 will be hiatus to shift their positions depicted by the Fig. 3, but will change their positions according to the Fig. 4, i.e., s_1 will avail the new intended-sp1 position with distance d_3 , and s_2 will be shifted to surrounding node position (intended-sp3) under distance d_4 .

All this happens because $d_3 < d_1$ and $d_4 < d_2$ therefore the proposed DECM algorithm shrewdly decides which sensor node should be moved to what positions in accordance to the distance metric. This change will not affect the coverage range of the network and does not impel the rest of the nodes to move in the queue. Eventually, an average moving distance of the node node are reduced which enhance the coverage area distance range.

C. Affective parameters

The DECM, explains the impact of some effective elements such as, loudness, pulse emission rate and maximum frequency and wavelength which directly influence the performance and diversity the sensor coverage range.

- Loudness: It is a relative quality of sound or the characteristics that characterizes noises varying from silent to strong [28]. The sensing coverage range of the nodes are directly affected by the ambient forms of varying loudest. The proposed DECM algorithm handles the loudness by adjusting radius of the sensing range in the coverage area. It is also called a perceptual effect of the intensity of the sound. There are several models for this parameter estimation that aim to process numerically a loudness degree approximation dependent on the sound's objective characteristics.

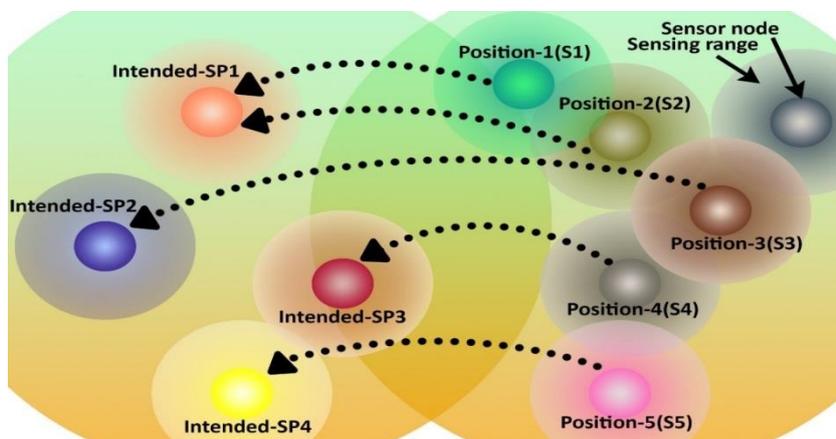


Fig. 2: DECM network topology.

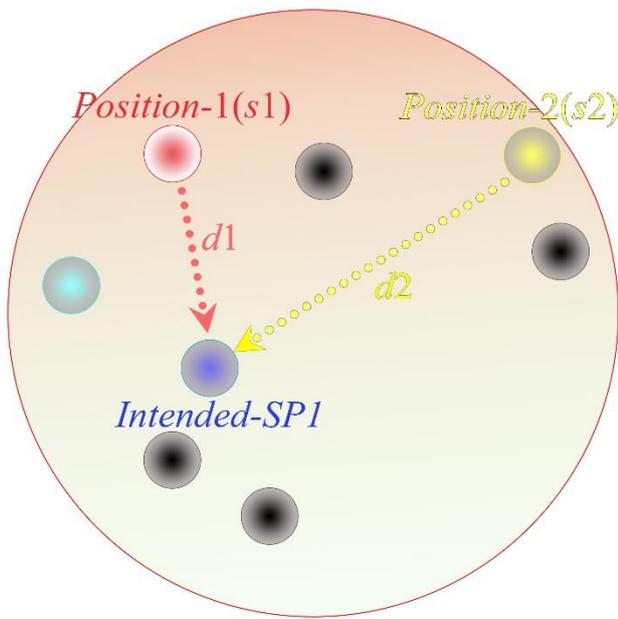


Fig. 3: Locating intended position mechanism.

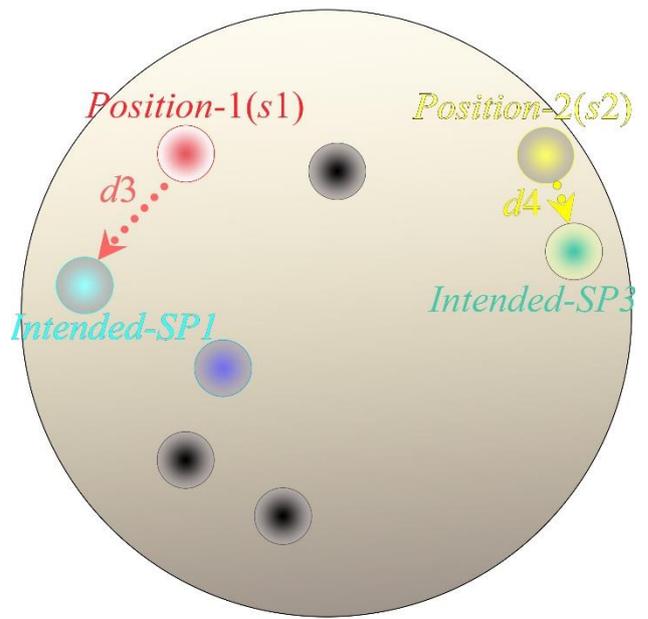


Fig. 4: Sensor nodes reaching at target position.

Algorithm 1. DECM position displacement mechanism

- 1: **Input** distance(d_1, d_2, d_3, d_4) // distance metrics
 - 2: **Procedure** InitialPositions(S_1, S_2, S_3, S_4, S_5) // sensor nodes deployed at initial positions
 - 3: **Procedure** IntendedPositions(SP_1, SP_2, SP_3, SP_4) // sensor nodes accessing new positions
 - 4: **for** $F(s) = \{S_1, S_2, S_3, \dots, S_n\}$
 - 5: $\forall F(s)$, if $d_3 > d_1$ AND $d_4 > d_2$ // distance metric computation
 - 6: **Compute** distance using Eq. (14)
 - 7: $S_1 \leftarrow sp_1, S_2 \leftarrow sp_3$, // changing positions according to the displacement criteria
 - 8: **if** (Rarea(S) reduces) $S_1 =$ Position; moved[S] = false;
 - 9: **if** ($S_1 \neq SP_1$) and (moved[S_1]) and (moved[S_2]) and ($d_1 + d_2 > d_3 + d_4$)
 - 10: $S_1 \leftrightarrow SP_1, S_2 \leftrightarrow SP_3$
 - 11: **endfor**
 - 12: **endif**
 - 13: **end Procedure**
-

- Pulse emission rate: A pulse is a bit of disturbance emitted by any transmission source and travels through a medium [29]. The free end and fixed end pulses sometimes collide with other pulses which may narrow down the performance of the system. The DECM control the pulse emission rate by predicting the distance between sensing range of the nodes. The pulse emission rate for each sensor nodes is calculated as the total number of pulses detected divided by

total duration of the number of individuals in the coverage area.

- Frequency and wavelength: In order to locate the intended target position, the shrewd adjustment in frequency and wavelength is often made by the DECM. Sometimes, for a shorter distance the frequency level might be shrinker from previous level.

- Group size(n): The number of sensor node appears in a couplet are referred as group size [30]. These nodes

leys at varying positions and communicate simultaneously with surrounding nodes to access the intended position. In fact, DECM makes shrewd decision in selection of the intended position from initial position by considering the distance metric between the sensor nodes at new position.

- Maximum iteration: The number of times the transmission rounds take place to achieve the desired position is known as iterations [31]. For a denser network, this might possible within a few iterations the target position can be achieved [32], but in case a sparse condition [33], the DECM decides about the number of iterations to be needed to complete the task.
- Step length estimation: A point indicates the initial position of sensor node and the number of total points going to record till reaching at the intended position is known as length of the steps [34]. The most common example of step length from real experience is a pedestrian positioning.

Simulation Results

In order to validate the performance of sensor nodes based on DECM algorithm, the simulation trials are conducted using MATALAB R2016a [12]. The performance among DECM, FOA, PSO and ACO are carried out using simulation setup parameters given in Table 2, in term of coverage range, computation time, standard deviation and network energy diminution. Continuing, nearbout 65 sensor nodes were deployed randomly in the monitoring area of size 60 × 60 m². The initial and final sensor node deployment is illustrated in Fig. 6 and 7. As the transmission begins, it can be clearly understanding that node deployment based on (DECM) has minimum redundancy and is utmost uniform as compared to node deployment by the FOA mechanism.

Table 2: Simulation setup

Contents	Setting value
Deployment area	60 x 60 m ²
Number of sensor nodes	65
Grid point	0.4 m*0.4 m
Group size	20
Sensing radius,	5 m
Maximum iterations	25
Loudness	0.5
Pulse emission rate	0.5
f_{min}	0
f_{max}	2

Table 3 signifies the influence of pulse emission rate (r) on coverage of sensor nodes.

The value of r changes from 0.1 to 1 whereas value of other parameters such as loudness, maximum frequency and sensing radius is kept constant to 0.5, 2 and 5 respectively. To beat the effect of arbitrariness [35],

the node mechanism is simulated 50 times and greatest value of coverage is picked every time. The maximum value of coverage after performing DECM is attained 93.54% at pulse emission rate of 0.9. As node moves towards respective target, they emit a greater number of pulses, therefore, the pulse emission rate will be high when sensor nodes move close to the range points [36].

Thereupon, value of pulse emission rate is kept to 0.9. Further to analyze the effect of loudness of the mechanism on the coverage rate of sensor nodes, the value of loudness (A_o) is varied from 0.1 to 1 while pulse emission rate (r) is set to 0.9 and value of other parameters such as is 0.5, sensing radius (r_s) is fixed to 5 meters.

Table 4, shows the variations of loudness, initial and final coverage rate of nodes after implementing DECM. The DECM runs 50 times and best value of initial and final coverage range is selected. The coverage range after executing DECM has obtained highest 93.1% at 0.2 value of loudness. When sensor nodes getting near to the range point the intensity of emitted pulses is low, therefore loudness parameter should be kept low. Thereupon, the value of loudness parameter is fixed to 0.2. In addition to this Table 5, demonstrates the effect of maximum frequency (f_{max}) [37], on coverage; its value has been changed from 0.1 to 2. The constraints of the mechanism for instance the pulse emission rate, loudness and sensing radius are kept constant to 0.9, 0.2 and 5 respectively. For each variation of maximum frequency the proposed mechanism has been executed 50 times and supreme values of coverage before and after execution of the mechanism has been chosen.

The best value of coverage after implementing DECM is 93.31% when f_{max} is 1.3. Thus, the value of f_{max} is set to 1.3. To observe the impact of range points on coverage rate of nodes, value of range point has varied from 0.1 m*0.1 m to 1 m*1 m. The various simulation factors such as pulse emission rate, maximum frequency, sensing radius and loudness are kept constant to 0.9, 1.3, 5 and 0.2 respectively. In Table 6, for every value of coverage point DECM runs 50 time and uppermost values of coverage rate has been taken. The highest value of coverage rate of nodes is obtained after running DECM is 93.41% when range points are set to 0.6 m*0.6 m. Consequently; the range points have been kept constant to 0.6 m*0.6 m. Further, the sensing radius is varied from 1 m to 10 m.

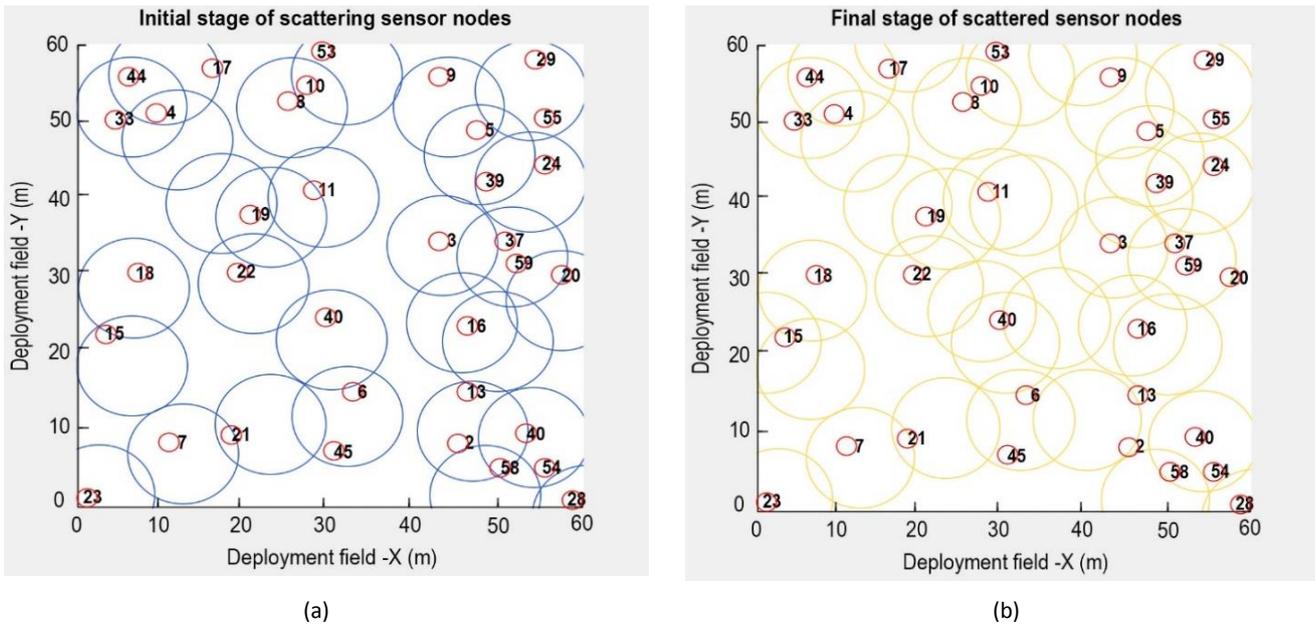


Fig. 6: (a) Initial and (b) final FOA node deployment mechanism.

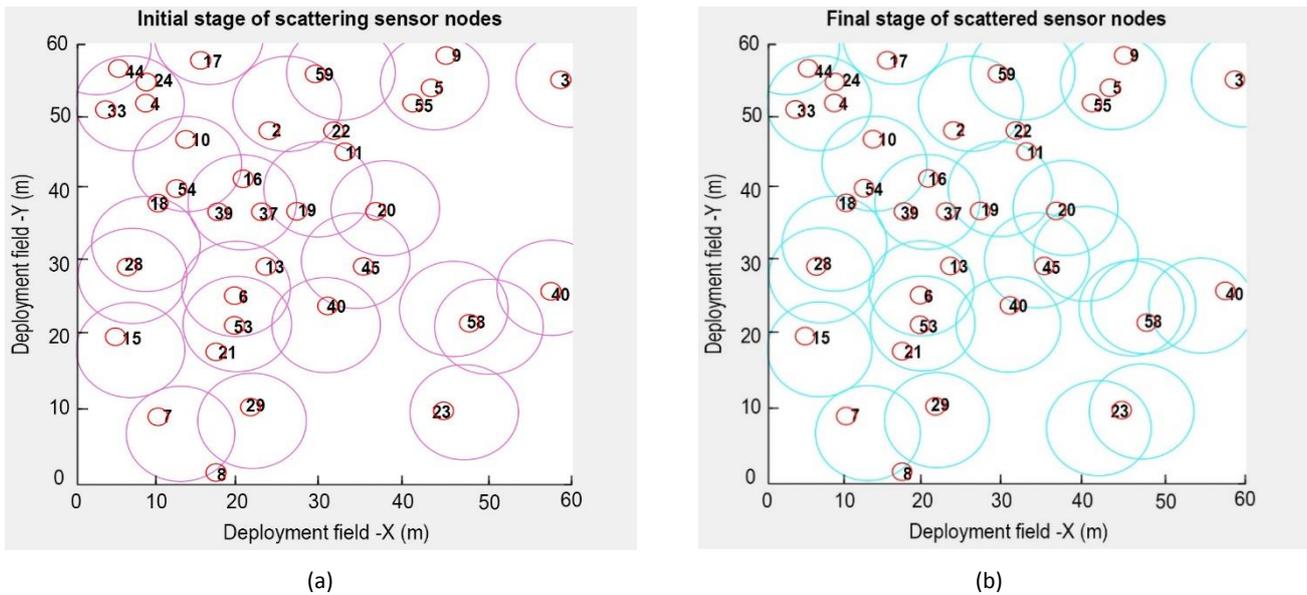


Fig. 7: (a) Start and (b) end of the node deployment process for DECM.

Fig. 8, signifies the variations of coverage range after applying DECM w.r.t. changes in the sensing radius of node. The parameters of DECM for example range points, loudness, pulse emission rate and maximum frequency are set as 0.6 m*0.6 m, 0.2, 0.9 and 1.3 respectively. It is clear from Fig. 8, as the sensing radius has increased, thereby coverage rate of sensor nodes is also increased and its value is 100% when the sensing radius is increased beyond 7 m, but there is trade-off between the sensing radius and cost, while sensing radius of node is increased the cost of sensor nodes also increased. The value of various constraints of DECM such as loudness, maximum frequency, sensing radius, pulse emission rate and range points are 0.2, 1.3, 6,

0.9 and 0.6 m*0.6 m respectively. To validate the performance of node deployment based PSO after setting above constraints values, the initial and final node deployment after executing are shown in Fig. 9. Thereupon, it can obviously be seen that node deployment based on DECM has lowest redundancy than PSO and FOA. To further demonstrates the effectiveness of coverage range curve for DECM compare to FOA for various iterations shown in Fig. 10. The iterations are varied from 0 to 500. The convergence speed of DECM is exorbitant as compared to FOA. The PSO converged arounds are 150 iterations whereas FOA converges around reached 350 iterations due to exploitation characteristics of the sensor nodes.

Table 3: Influence of pulse emission rate on coverage range

Pulse Emission (Hz)	Initial Coverage Range (%)	Final Coverage Range (%)
0.1	0.8	0.8929
0.2	0.8124	0.905
0.3	0.787	0.9077
0.4	0.8281	0.9041
0.5	0.8097	0.908
0.6	0.8202	0.9025
0.7	0.8208	0.9218
0.8	0.8167	0.9108
0.9	0.8537	0.9354
1	0.8314	0.9153

Table 4: Effect of loudness on coverage range

Loudness (A _o) db	Initial Coverage Range (%)	Final Coverage Range (%)
0.1	0.8052	0.8931
0.2	0.8375	0.9291
0.3	0.8491	0.9056
0.4	0.8281	0.9107
0.5	0.8276	0.9167
0.6	0.828	0.9219
0.7	0.8273	0.9048
0.8	0.8308	0.9259
0.9	0.8343	0.9281
1	0.8169	0.9179

Table 5: Effect of f_{max} on coverage range

f_{max} (Hz)	Initial Coverage Range (%)	Final Coverage Range (%)
0.1	0.8492	0.8698
0.2	0.819	0.8433
0.3	0.8135	0.8359
0.4	0.8115	0.8327
0.5	0.831	0.8602
0.6	0.8186	0.8507
0.7	0.8196	0.8414
0.8	0.8211	0.8417
0.9	0.8499	0.8712
1	0.8369	0.8549
1.1	0.8298	0.8888
1.2	0.822	0.9053
1.3	0.8134	0.9331
1.4	0.7965	0.898
1.5	0.8116	0.91
1.6	0.8367	0.9279
1.7	0.8145	0.9169
1.8	0.8267	0.9132
1.9	0.8296	0.9147
2	0.8127	0.9078

Table 6: The impact of range on network coverage

Range points (m*m)	Initial Coverage Range (%)	Final Coverage Range (%)
0.1*0.1	0.8306	0.9203
0.2*0.2	0.7975	0.9006
0.3*0.3	0.8006	0.9106
0.4*0.4	0.8342	0.9132
0.5*0.5	0.8012	0.9056
0.6*0.6	0.8451	0.9341
0.7*0.7	0.8052	0.9125
0.8*0.8	0.8135	0.9181
0.9*0.9	0.8142	0.9200
1*1	0.8240	0.9212

The DECM has achieved more coverage rate about 99.46% as compared to 93.37%, 88.33% of PSO and FOA. In order to overwhelm the effect of randomness DECM, mechanism optimization and fruit fly algorithm runs 15 times respectively.

The deployment results in terms of average coverage rate, standard deviation, best and worst coverage values for DECM, PSO and FOA are presented in Fig.11 to 13.

It can be seen that DECM has achieved the average coverage range about 98.29% as compared to 91.91%, 85.16% of PSO and fruit fly algorithm. Further the standard deviation of DECM is lower, therefore DECM is more stable as compared to FOA and PSO.

The best and worst coverage value for DECM are 99.46% and 97.31% as compared to 94.30% and 90.02%, 87.49% and 78.20% for PSO and FOA based on node deployment.

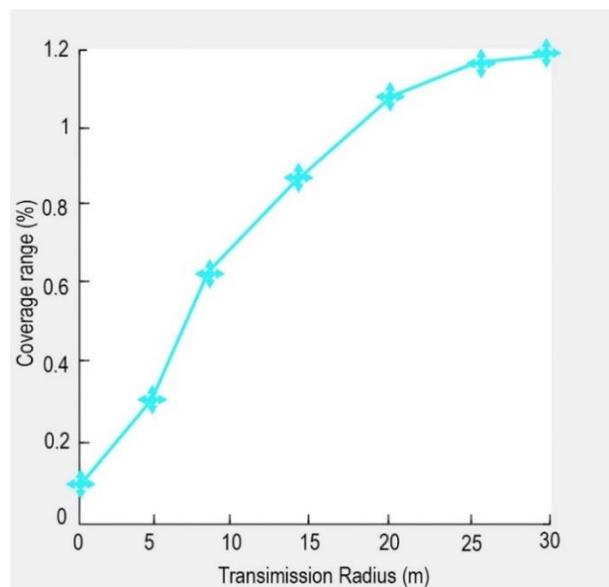


Fig. 8: DECM coverage range at various sensing radius .

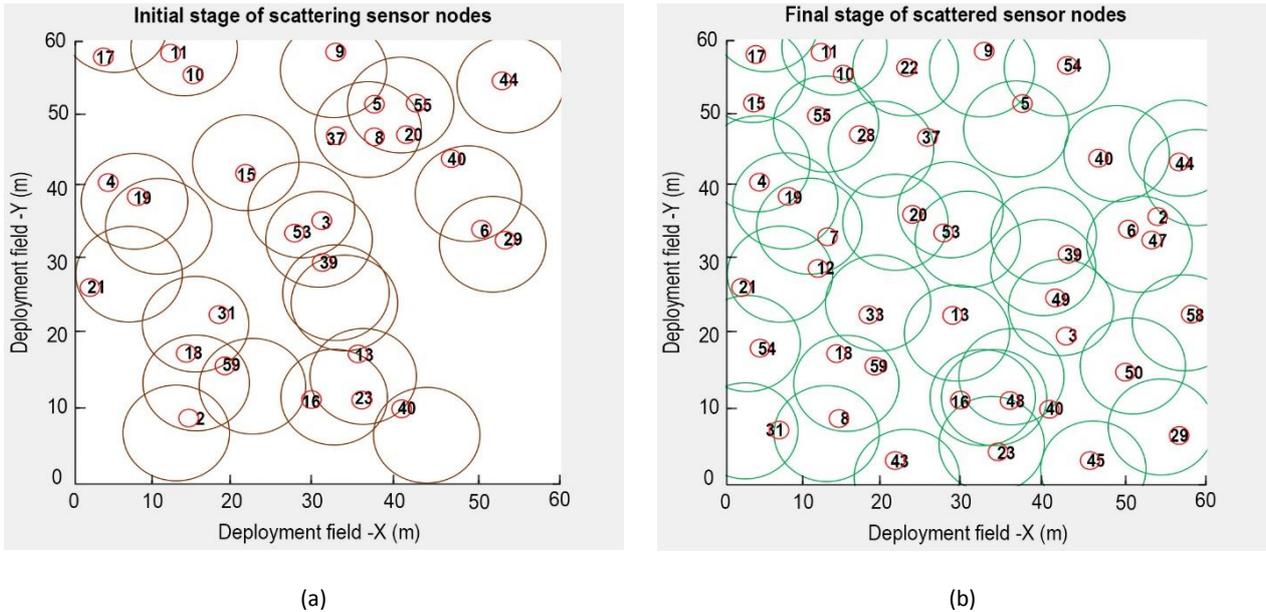


Fig. 9: (a) Initial deployment of sensor nodes for PSO (b) Final deployment of sensor nodes for PSO.

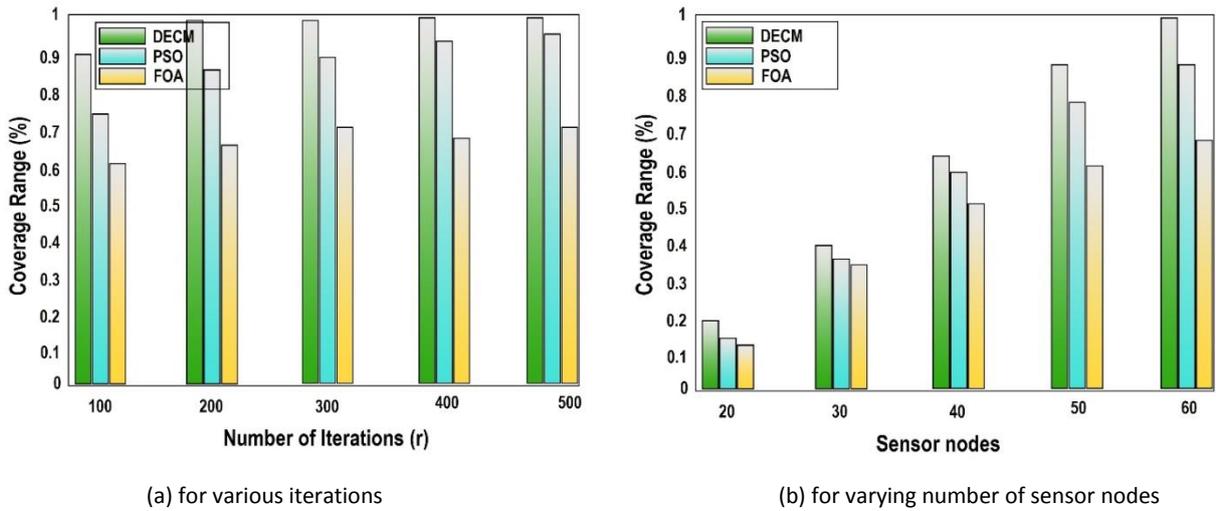


Fig. 10: Coverage range comparative analysis for DECM, FOA and PSO.

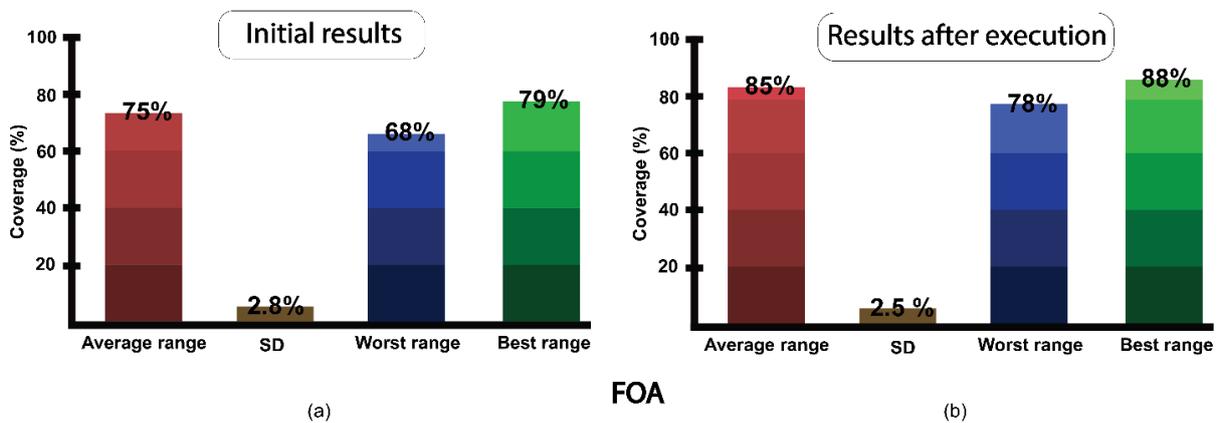


Fig. 11: The coverage range statistics achieved by FOA (a) before and (b) after the execution process with significant changes in standard deviations.

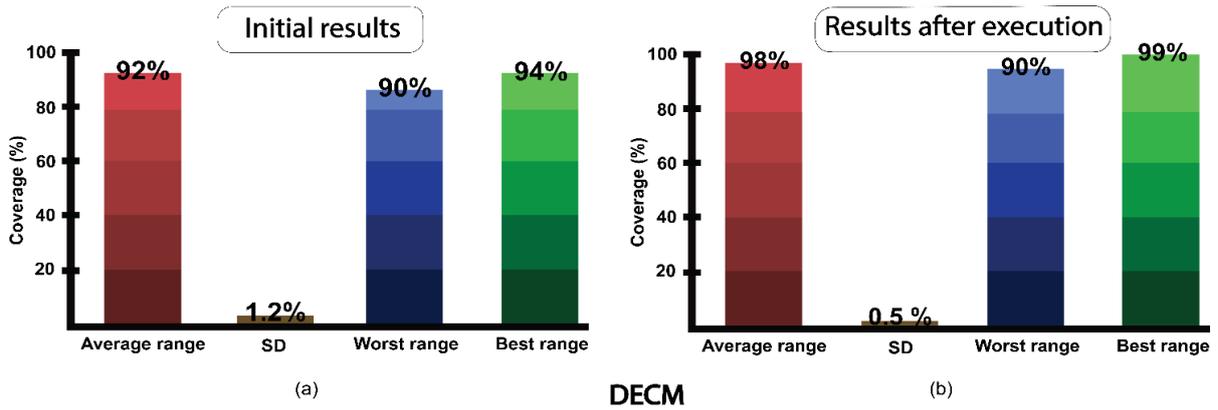


Fig. 12: The coverage range statistics achieved by PSO (a) before and (b) after the execution process with improved standard deviations.

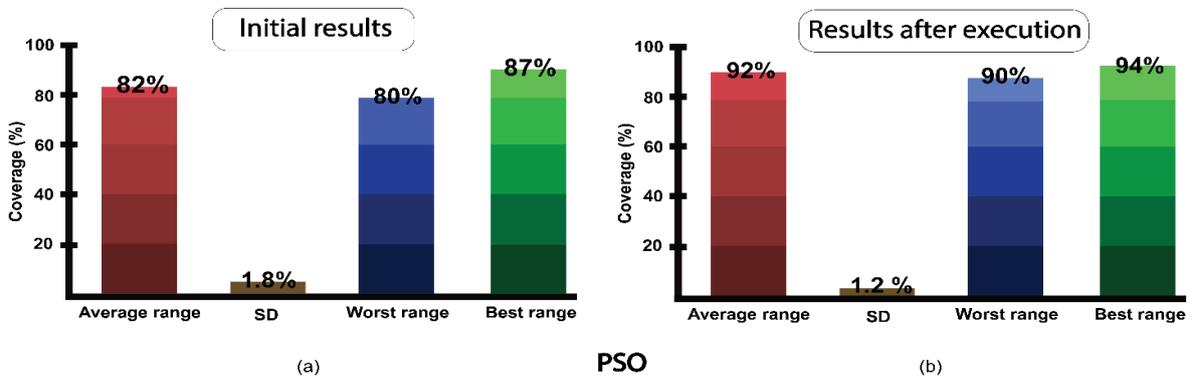


Fig. 13: The coverage range statistics achieved by DECM (a) before and (b) after the execution process with trivial standard deviations.

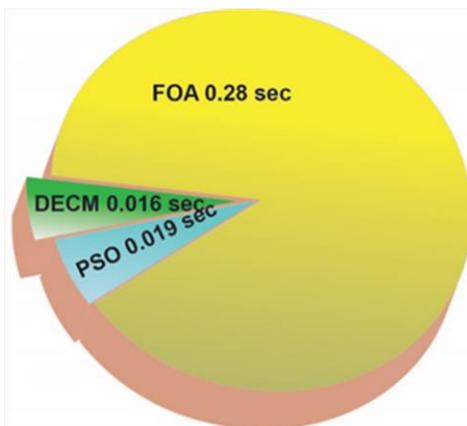


Fig. 14: The computation time statistics of FOA, PSO and DECM.

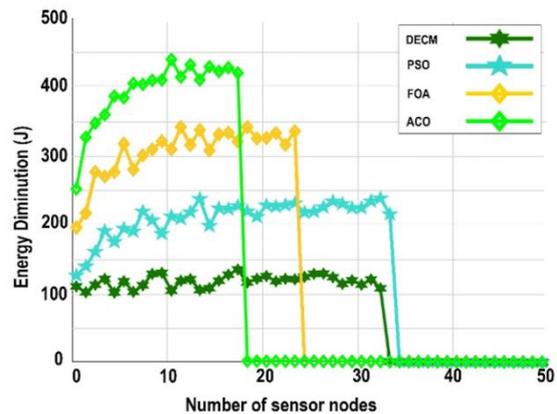


Fig. 15: Overall energy consumption by all algorithms.

Further the comparison of DECM, PSO and FOA in terms of computation time is illustrated in Fig. 14. The computation time for DECM is lesser i.e. 0.016 seconds as compared to 0.019 seconds, 0.28 seconds for PSO and FOA. The DECM and PSO converges at 25

iterations whereas FOA converged at 500 iterations, therefore the speed of DECM and PSO is more and converges faster at earlier stage because of its exploitation feature as compared to fruit fly algorithm. During each transmission round, the overall energy diminution analysis is illustrated in Fig. 15. It can

be seen that between 20 and 32 nodes all algorithms going to die. The proposed DECM has consumed only 100 to 150 Jule of energy approaching to relative position as compare to PSO, FOA and Ant Colony Optimization ACO. The consumed energy increases when the coverage degrees required increase, since the sensor nodes require more energy to cover target positions and therefore it takes more energy for sensing and communication tasks.

Conclusion

Wireless sensor networks are severely facing the coverage issues therefore a shrewd coverage mechanism is presented in this study. The proposed algorithm Node Redeployment Shrewd Mechanism (DECM) has been designed to overcome the tribulations occurred due to the uncouth deployment of the sensor node which ultimately has great impact over network coverage range. The DECM functions in two phases, in first phase it searches the new intended node positions through Dissimilitude Enhancement Scheme (DES) and moves the node to new position. For second phase, the distance measurement between moving sensor node and the intended position is reduced and number of sensor movements are also being controlled sagaciously. This process is called Depuration. The analysis of various factors of DECM such as loudness, range points, emission rate and radius of nodes, and frequency have also been identified. The performance metrics of DECM has been obtained by conducting simulation test through MATLAB and meticulously compared with previous well-known algorithms FOA, PSO and ACO. The simulation results vouched that DECM has attained mean coverage range about 98.29% which is higher as compared to rest of the algorithms. The proposed DECM algorithm has appeared with higher coverage range and less computation time compared to all.

In future the various evolutionary optimization algorithms can be applied to solve the node deployment issues to enhance the coverage range phenomenon.

Author Contributions

Every author has equally contributed to accomplish the targeted results.

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Conflict of Interest

All authors declare that there is no conflict of interests regarding the publication of this manuscript.

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