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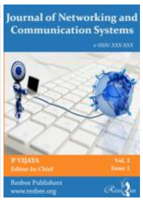

# Improved Salp Swarm Algorithm for Network Connectivity in Mobile Sensor Network

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**Abstract:** At present, the most significant point in the model of Wireless Sensor Networks (WSNs) is the network connectivity and sensor coverage point. Moreover, the important convenient problem in modeling the necessary WSN is the mobility of mobile sensors that utilizes high power thus minimizes the lifetime of the network considerably. To evade these issues, the Mobile Sensor Deployment (MSD) issue is examined, which consists of target coverage and network connectivity is solved by Euclidean Spanning Tree Model (ECST). Moreover, an Improved Salp Swarm Algorithm (ISSA) optimization algorithm is presented by attaining less movement of mobile sensors against the network. Moreover, the widespread experimentation analysis has presented the best hopeful solutions of Network Connectivity (NCON), to the MSD problem with less movement and presenting the enhanced lifespan of WSN. At last, the investigational outcomes examine the movement distance exhibited by the proposed method and that is compared with the conventional algorithms such as ECST-Particle Swarm Optimization (PSO), and ECST- Artificial Bee Colony (ABC).

**Keywords:** WSN; Coverage Sensor Nodes; MSD; ECST; Target Coverage

***Nomenclature***

| Abbreviations | Descriptions |
|---|---|
| KDE | Kernel Density Estimation |
| MWSN | Mobile WSN |
| NCON | Network CONnectivity |
| IoT | Internet of Things |
| SOP | Secure Outage Probability |
| MLE | Maximum Likelihood Estimation |
| ABC | Artificial Bee Colony |
| QoS | Quality of Service |
| MSN's | Mobile Sensor Networks |
| PSO | Particle Swarm Optimization |
| TAS | Transmits Antenna Selection |
| SN | Sensor Network |
| TCOV | Target COVerage |
| MST | Minimum Spanning Tree |

## 1. Introduction

WSN plays a significant role in numerous surveillance and monitoring technologies such as environmental sensing, structural health monitoring, and target tracking, and so on [1]. The inadequate battery ability impedes the large-scale deployment of WSNs since the conservative sensors are powered using the batteries. The wireless energy transport, which transforms energy provisions to WSNs, is done on the basis of the magnetic resonant coupling. In contrast with the sensor energy replacements via energy harvesting, which simply presents the spatially and temporally differing energy sources such as wind and solar energy? The use of mobile charging vehicles is the latest efficient technology in order to charge sensors wirelessly, which makes sure sensors have the ability to charge with maximum stable charging rates, thus they can function frequently [2].

Since the fast growth of sensor applications, besides data transmission and sensing capability, sensors, otherwise called as mobile sensors, it has the capability to pass to a few positions [4]. A WSN is a collection of mobile sensors, which is called an MWSN [20]. Due to the movement of the sensor needs considerably superior power utilization than that in communication and sensing reducing the total movement distance of mobile sensors turns out to be a significant problem in MWSNs. The scheduling mobile sensors issue is to cover all sustain network connectivity and targets; hence to the total movement distances of mobile sensors are reduced and it is referred as the MSD issues. Nevertheless, the difficulty of the MSD issue remnants unidentified as no precise confirmation has been presented earlier [6].

In WSNs, the coverage is considered as the most significant problems in present years. Moreover, the coverage is classified as the subsequent three types such as area coverage, barrier coverage, and target coverage. In reality, the three types of coverage are associated with each other. The sensors have the capability to communicate with each other for target coverage and carry out the data filtering and collection, which guarantees full filtering and monitoring of the preferred area [11]. To accomplish the entire area coverage or barrier coverage, the coverage issue appears. The complete WSN performance is related to area coverage. Hence, in area coverage, the primary and major problem in numerous applications is on the basis of the rule or arbitrary based sensors deployment [12]. A coverage model and a few fundamental ideas of coverage issues with uncertain properties and the appropriate techniques, for instance network techniques, deployment techniques and detection techniques, was stated to increase coverage QoS, to extend the lifetime of the network, and to reduce the number of deployed sensors [21] [22]. In WSNs, an enhanced system coverage performance clearly includes superior hardware costs for the system [4] [19].

In WSNs, the issue of barrier coverage enhancement using relocation of the SNs was broadly reported in the literature. In many algorithms, the centralized deployment methods were presented, and merely not many works have contemplated the distributed solutions [17] [18]. In addition, though these methods were used to enhance barrier coverage deployment, none of the algorithms concentrates on reducing the relocation cost in both communications and moving distance with the aim of increasing the number of barriers [13] [14].

The main objective of this paper is to propose the Hybridization of the improved metaheuristic optimization algorithm and ECST. In order to attain less movement of rest nodes and increasing the coverage area, and so Improved Salp Swarm technique is presented. As far as preserving the network connectivity among coverage sensors and sink, the NCON problem is included.

# 2. Literature Review

In 2019, Jifu Zhao and Clair J. Sullivan [1] presented the idea of mobile radiation SNs to resolve this issue. It was significant to increase competent algorithms to calculate the position and activity of possible radioactive sources for mobile sensor networks. Here, grid and KDE search were used with MLE to calculate the source position and intensity. Experimentation analysis and study were performed to analyze the efficiency of the proposed algorithm.

In 2018, Ngoc-Tu Nguyen and Bing-Hong Liu [2] addressed the issue of scheduling mobile sensors to cover-up all the targets and uphold network connectivity. Hence, the total movement distance was reduced, referred to as the MSD issue, which had encountered an immense pact of interest. Nevertheless, the complexity of the MSD issue remnants unidentified as no accurate evidence was presented earlier. Here, they had an exhibit that not merely the MSD issue, but and its unique case, referred to the target coverage problem, was NP-hard.

In 2018, Haiping Huang et al [3], discussed the virtual possible field among sensors and intruders. Subsequently, they had presented the formulation of the mobility model of the SN by exploiting the elastic collision method and that of intruder exploiting point charge method. Moreover, the point charge method explains a thus far-unexplored mobility model of empowered-intruders that can able to substitute on the virtual revolting forces from sensors to conceal them away from being recognized. Experimental outcomes and analytical expressions show that the proposed model attains a superior k-barrier coverage probability while comparing with the traditional models with the help of the two proposed methods in intrusion detection. Additionally, it was significant to state that these enhancements were attained with shorter average displacement distance.

In 2017, Wenzheng Xu et al [4] worked on the wireless charge sensors in a rechargeable SN with the utilization of a mobile charger. Hence, the summation of the lifetime of the sensor was enhanced when the travel distance of the mobile charger was reduced. Contrasting conventional reports the unspecified mobile charger should charge a sensor to its complete energy ability before moving to charge the subsequent sensor. Initially, dual novel optimization issues of scheduling a mobile charger to charge a set of sensors were presented.

In 2018, Tri Gia Nguyen and Chakchai So-In [5] studied a competent distributed deployment method for barrier coverage enhancements with mobile sensors, in that the Sensor Nodes can be relocated subsequently to the first deployment. A distributed method was presented to model k-barrier coverage using the relocation of the Sensor Nodes to attain a huge amount of barriers. Unlike conventional algorithms, a new clustering algorithm was presented on the basis of the network area to minimize the information exchange messages. Subsequently, a heuristic algorithm to allocate the Sensor Nodes consistently into each cluster by considering the necessary amount of Sensor Nodes on the basis of the Sensor Nodes clusters. Moreover, the major objective of this algorithm was to relocate the Sensor Nodes to model the utmost amount of barriers with the smallest amount of relocation cost, regarding sensor energy utilization of movement and communication.

In 2018, Chia-Hsu Kuo and Siou-Ci Syu [6], presented an adaptive method of trap coverage with a vigorous area coverage method that uses mobile sensors for IoT and in the MSNs applications. Numerous capable technologies such as the mobile sensing and target tracking were practically realized and enhanced subsequent to integrating the features of a trap coverage scheme based on adaptively adjusting the sensor mobility and trap size. In WSNs, all over the deployment of sensors the trap obviously subsists, in that the target had predictably mislaid or application service remains unnoticed. Moreover, a robust mechanism was presented for trap coverage such as the utilization of mobile sensors in target tracking for MSNs applications.

In 2019, Han Wang et al [7], presented on the basis of Wyner's wiretap framework, the privacy performance of the wireless MSN against 2-Nakagami fading channels was examined. Moreover, the precise SOP, and the probability of severely positive secrecy ability expressions for two TAS strategies, was derived. Additionally, the precise closed-form expressions exploiting the best TAS method for the smaller bound on the SOP were derived. Subsequently, using Monte Carlo experimentations the secrecy system performance was examined and evaluated in different circumstances.

In 2018, Zhijing Qin et al [8], worked on mobile converge cast, as a many-to-one communication model, that had lately searched in MSNs for the industrial IoT. Here, SN was typically in mobile status, and the description of the sensed data frequently else arbitrarily to one or more stationary sinks during multi-hop routing path. Moreover, a probabilistic method for mobile converges cast was presented and analyzed to detain path duration times, using in view of parameters such as SN capacity, mobility patterns and network models of network elements.

# 3. Problem formulation and System Model

## 3.1 System Model

Let us assume a network area of $n$ mobile sensors $MS = \{ms_1, ..., ms_n\}$ at first positioned on a stated position and set of $m$ targets $T = \{t_1, ..., t_m\}$ are positioned on identified positions to be covered. The function of the system model is stated as below:

a) Every mobile sensor node recognizes its own location in the network by the GPS unit. Additionally, the sensors position and transmits movement order information are collected through a control center named sink.

b) In the specified area, consider the movement of the sensor has no barriers. In the event of barriers available in the network, the sensor chooses an appropriate path to the target to keep away from the barriers to the chosen manner. In WSN, to confirm both network connectivity and target coverage, we concentrate on recognizing WHERE and WHICH the sensors must transmit.

c) Network model: To construct an effectual communication among different sensors possessing radius $r_c$ and sensing the target with radius $r_s$, Let us assume disk model [10] every sensor and target can be surrounded by more amount of targets and sensors correspondingly. If at any rate 1 sensor enclosed the target with the disk of radius $r_s$, the target is stated as covered. The target's coverage disk is stated as a disk, and the circle enclosed the coverage disk and it is referred to as target's coverage circle in disk model.

d) Mobility model: In [6], the free mobility representation is the model in that sensors are efficient to route or move interminability in any direction and stop anyplace. The energy utilization accomplished in the movement of the sensor is computed from the distance whereas it travels. The sensor distance $ms$ to cover target $t$ is $dist(ms, t) - r_s$, whereas $dist(ms, t)$ indicates the Euclidean distance among $ms$ and $t$. Likewise, the movement distance to the linked sensor $ms_i$ with the sensor $ms_j$ is $dist(ms_i, ms_j) - r_c$, whereas $dist(ms_i, ms_j)$ indicates the distance among different sensors $ms_i$ and $ms_j$. In an optimal condition of the barrier-free environment, the sensor must move beside the straight-line path to attain the coverage area of the target to communicate information among sink and coverage SNs.

### 3.2 NCON Problem

In WSN each target is wrapped by no lesser than 1 adaptable sensor node subsequent to resolving the TCOV issue. Additionally, another important constraint is the NCON issue for WSN those affirmations the data transmission using the established connection among a sink and coverage sensors. If the relation among coverage sensors and sink is chiefly established, subsequently the NCON issue is resolved. Conversely, if there is no connection among them, it is significant to examine the NCON issue. The NCON is an aspect of establishing connectivity among the sink nodes and the coverage sensors that have covered the targets, by relocating the rest nodes at minimum possible movement.

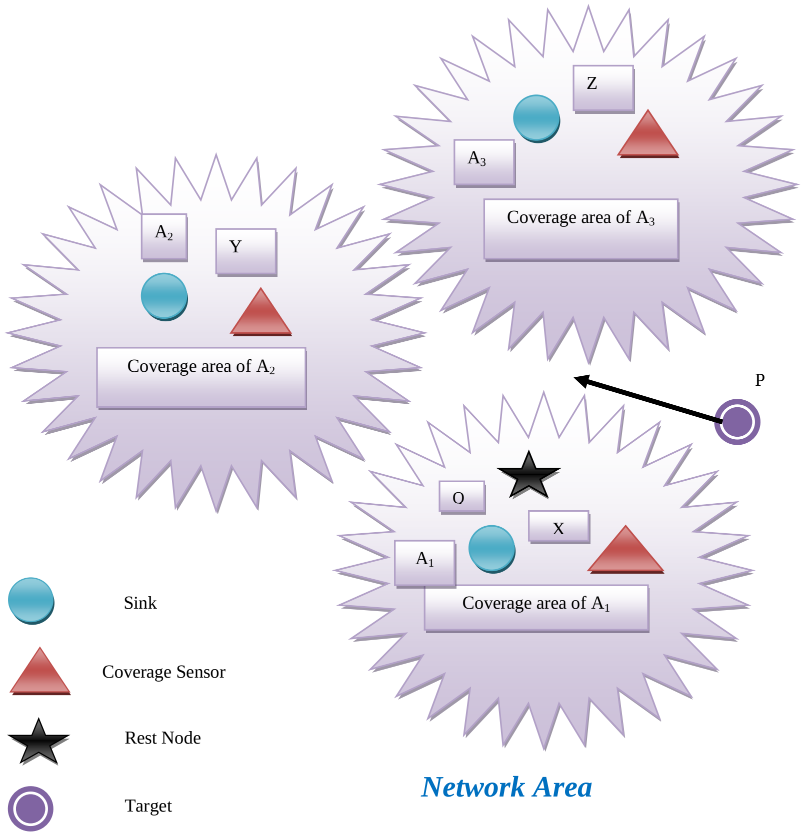


***Fig. 1.*** *Digarmattic representation of targets, coverage sensors, and sinks with no connection*

As exhibits in Fig. 1, the Target COVerage issue is solved with at least one coverage sensor node covers each target established in the WSN system. Because of the coverage area of sensor A1 encloses the sink; the connection among sink and a sensor A1 is created. Moreover, there is no association among sink and other two sensors such as A2 and A3. Hence, network CONnectivity issue emerges in WSN. To overwhelm the NCON issue, the random location remaining nodes have to be relocated with less movement hence which it can set up association among coverage sensors and sink in WSN. For example, let us consider the movement of 1 remaining node to a novel location in the manner of resolving the NCON issue. Fig. 2 exhibits the relocation of the remaining node to link all the coverage sensors with a sink and promise consistent transmission of data.

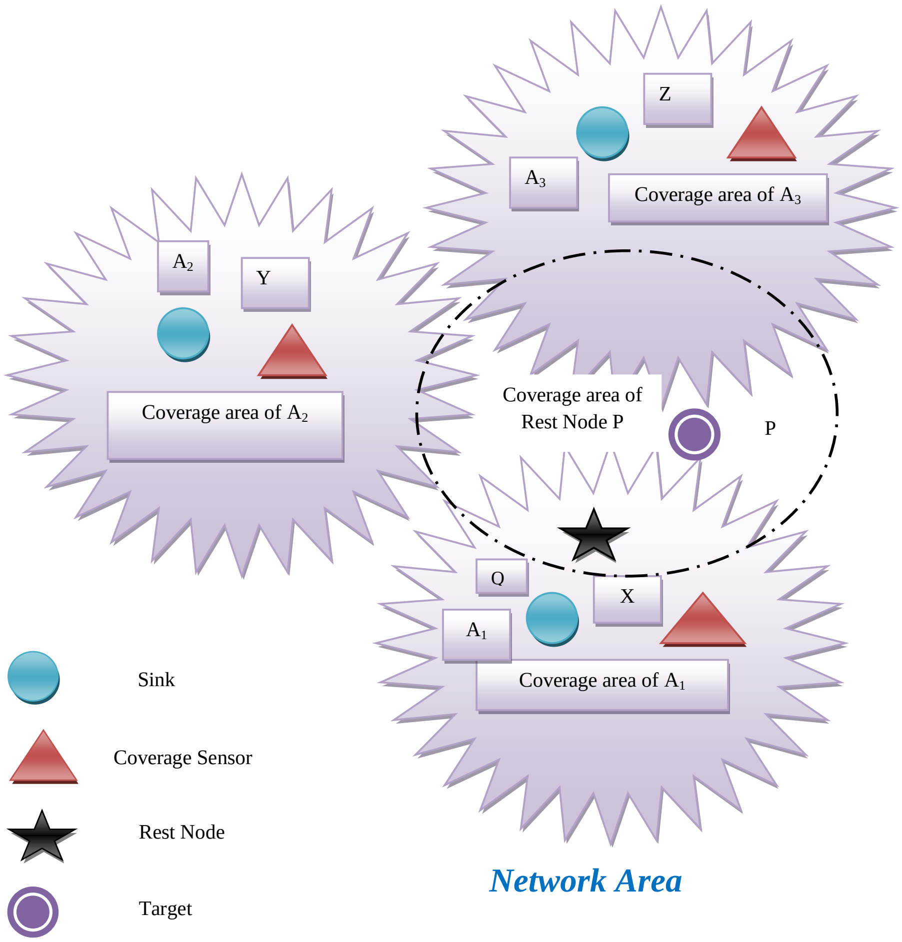


***Fig. 2.*** *Digarmattic representation of solution for a network connectivity problem*

## 4. Elucidation of the NCON Problem

The basic design for the connectivity of the network approach is to transferring the mobile SNs to the intended position from whereas it can link with the sink to communicate information. Let us assume the tree topology with sink as root node and the coverage sensor nodes as leaf nodes the contribution of NCON is to set up dependable connection among sink and coverage sensor nodes by moving the remaining nodes to novel positions as linking nodes in WSN and thus minimizes the cost movement. It can be resolved in two phases, as per the contribution of NCON.

Construct less edge length spanning-tree topology to that the edge length among sink and coverage sensors must be lesser than $r_c$ in the first phase. In general, the less distance spanning tree is important to less the movement of remaining nodes.

Let us connect the coverage sensor nodes and the sink by exploiting the remaining nodes as connecting nodes using relocating the remaining nodes to the produced Steiner points from the ECST approach in the second phase. Nevertheless, it is an exceptional case of TCOV, the Steiner points with 0 coverage radiuses are represented as target and the remaining nodes are covered to the Steiner points with less distance. Hence, we need to communicate an enthusiastic sensor efficiently for every target.

### 4.1 Formative Steiner Points for Connectivity

The key element to resolve the NCON issue is stated as below:

In WSN, create an edge length constrained spanning tree $T$ to connect the sink and coverage sensor nodes. As the Steiner tree issue is NP-hard, an estimated method for NCON issue is formulated such as a) Make a Euclidean MST, and b) Each consecutive edges of the spanning tree is unconnected with length lesser than the communication radius $r_c$. In ECST, as such the summation of all edge length is low, also the movement distance of remaining nodes to creating a link among sink and coverage sensor nodes is minimized. In Algorithm 1, the pseudo-code of the Euclidean MST algorithm is shown.

The subsequent step is to assign the remaining nodes 1-by-1 to every point in $sp$ produced from the ECST method output with the low-cost movement.

| **Pseudocode of the ECST method** | |
|---|---|
| **Input:** | $R = r_1, r_2, ......, r_n$ ; // The set of remaining nodes |
| | $MS_{cov\,rg}$ ; // Set of coverage SNs |
| | $Sink(x, y)$; // Sink Position |
| | $r_c$ ; // Communication radius |
| **Output:** | $sp$ ; // Set of Steiner points |
| 1 | $N = S_{cov\,rg}$ ; |
| 2 | Produce a complete graph $G = (N, E)$; |
| 3 | Generate a Euclidean MST $T_{ecms}$ with sink as the root of $G$ and coverage sensor nodes as a leaf ; |
| 4 | **for** each $n_i \in N$ and its parent $n_p^i$ **does** |
| 5 | Divide the edge $e(n_i, n_p^i)$ into $\left\lceil \frac{\lVert e(n_i, n_p^i) \rVert}{r_c} \right\rceil$ parts; |
| 6 | $sp(x_i, y_i) \leftarrow$ each dividing point; |
| 7 | return *sp* ; |

### 4.2 Objective Function

Subsequent to the determination of the target points of the remaining nodes, the remaining nodes are moved to relocate the target points. In WSN, to enhance the low movement of the remaining nodes to link the sink and coverage sensors and the improved SSA optimization approach is presented in this paper.

In eq. (1), the objective function is estimated regarding the cost values between the rest node and Steiner points

$$f_i = \sum_{j=1}^{N_{sp}} C_j \tag{1}$$

In eq. (1), $C[Y_{ij}, j]$ indicates the cost function to move $y_{ij}$ solution to $j^{th}$ Steiner's point.

## 5. Proposed Improved SSA approach for network connectivity

### 5.1 Conventional SSA

The conventional SSA is a new presented meta-heuristic approach and it is inspired by the swarming behavior of salp fishes, which survive in oceans, whereas they create a salp chain [15] [16]. In the water, salp fishes are translucent fishes move by pumping water using their bodies.

The Salp chain is designed by partitioning them into two types such as followers and leaders. The leader is at the front position of the chain and its location can be updated using eq. (2)

$$y_j^1 = \begin{cases} Fp_j + a_1((u_j - l_j) * a_2 + l_j) & \text{if } a_3 \le 0.5 \\ Fp_j - a_1((u_j - l_j) * a_2 + l_j) & \text{if } a_3 \le 0.5 \end{cases} \tag{2}$$

$$a_1 = 2e^{-\left(\frac{4c}{M}\right)^2} \tag{3}$$

In eq. (2), $Fp_j$ denotes the food position, $y_j^1$ denotes the leader position, $a_1$ denotes the value from 2 to 0, $a_2$ and $a_3$ denotes the random numbers between [0,1], $u_j$ states the upper bounds, $l_j$ states the lower bounds, $c$ denotes the current iteration, $M$ denotes the Maximum iterations. Using Newton's Law of motion as in eq. (4) the position of the followers can be transformed. In optimization, the time is the iteration step that equals to 1, $u_0$ is represented as 0 subsequently the follower location is updated using eq. (5).

$$y_j^i = \frac{1}{2} a_c t^2 + u_0 t \tag{4}$$

$$y_j^i = \frac{1}{2}\left(y_j^i + y_j^{i-1}\right) \tag{5}$$

In eq. (4), $a_c$ denotes the acceleration, $y_j^i$ denotes the follower's position for i>1, and $u_0$ denotes the velocity, $t$ denotes the time, where $t = 1$.

## 5.2 Improved SSA

In recent times, the SSA is available in its easy fundamental model that has the ability to be improved for superior convergence and best solutions. Here, the SSA is improved by balancing the exploitation and exploration phases. To discover food location $Fp_j$ the leaders are accountable as stated in eq. (2), subsequently, the leader will travel to the food location in accordance with the squared exponential covariance variable ($a_1$) which is stated in eq. (6).

The variable $a_1$ is the significant parameter that directs the leader agent to explore the food as similar to the Gaussian model. For the exploration phase, the followers are dependable regarding the food and assist the leaders for decision making, and subsequently the eq. (5) can be reformulated as in eq. (7).

$$a_1 = 2e^{-\left(\frac{4 * r_1 * c}{M}\right)^2} \tag{6}$$

$$y_j^i = r_2\left(y_j^i + y_j^{i-1}\right) \tag{7}$$

In eq. (7), $r_1$ represents an integer arbitrary number among [0, 50] and $r_2$ represents a real arbitrary number among [0,1]. The parameter performance $a_1$, whereas the higher the $r_1$ lesser $a_1$. The leader location is not primarily dependable in order to search subsequently it is superior for the variable $a_1$ to be approximately 0 most of the time. The optimization procedure for improved SSA is demonstrated in Fig. 3. A big oh notation of SSA is stated in eq. (8):

$$\eta\left(it * (Dm + Fit) * n\right) \tag{8}$$

In eq. (8), $it$ denotes the total iterations, $Dm$ denotes the dimension of the fitness model $Fit$, $n$ denotes the solution number. Fig 3 illustrates the flowchart of the proposed ISSA algorithm.

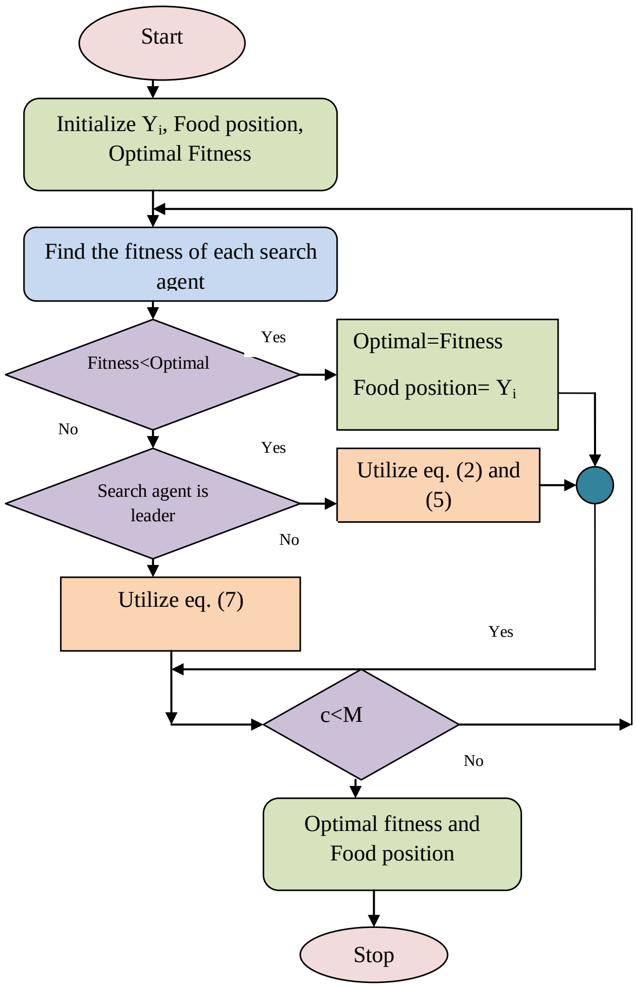


***Fig. 3.*** *Flow chart of the proposed ISSA algorithm*

# 6. Result and Discussions

## 6.1 Experimental Procedure

In this section, the TCOV problem to find out the movement of the sensor was discussed to the possible target as such it wraps the entire destination positioned in the network area and also it was explained in [9]. By means of the location, coverage sensors attained from the resolved target coverage issue, the connectivity among coverage sensors and sink were done by exploiting the less movement of remaining nodes (connecting nodes) for attaining the best solution to the MSD issue. The proposed ECST-ISSA method performance was evaluated and analyzed with conventional methods.

## 6.2 Performance Analysis

In Fig 4 and 5, the overall performance analysis of the parameters like standard deviation and the mean of proposed and conventional algorithms are demonstrated. In Fig 4, the mean values of the proposed algorithm regarding deviating communication radius are 21% and 26% superior to the conventional ECST-PSO and ECST-ABC algorithms. In some instances, the standard deviation of the proposed algorithm with conventional ECST-ABC and ECST-PSO and in the varying radius is established to be raised in Fig 5. Here, the proposed method is 13% better than the conventional ECST-PSO and 19% better than the conventional ECST-ABC algorithm. The overall performance analysis shows the proposed algorithm presents less deviation. Hence, the proposed algorithm can be declared as consistent and reliable on attaining the less movement distance when resolving the NCON issue.

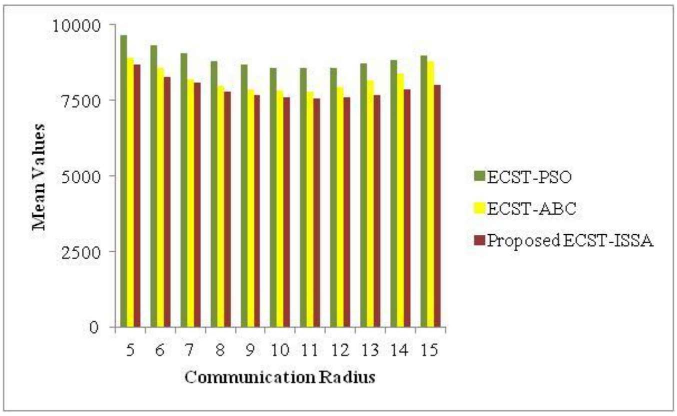


***Fig. 4.*** *Mean value of the proposed algorithm for the movement distance*

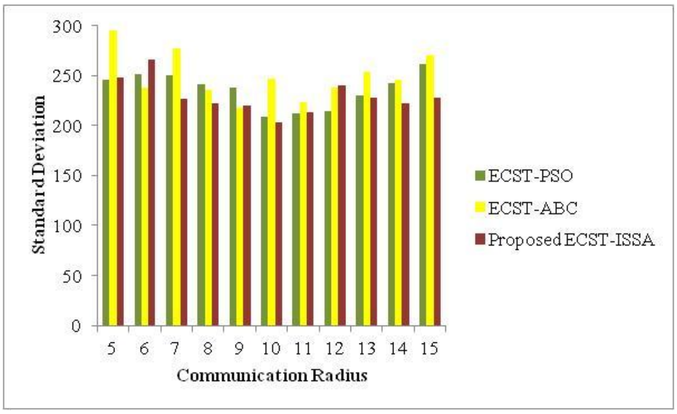


***Fig. 5.*** *Standard Deviation of the proposed algorithm for the movement distance*

# 7. Conclusion

In WSN, the coverage problem can be usually stated as a measure of how efficiently a network field is monitored by its sensor nodes. Moreover, this issue has attracted a lot of attention over the years and as a result, many coverage protocols were proposed. In this paper, a novel optimization algorithm called improved SSA algorithm was proposed to improve the network connectivity and the MWSN lifetime in this paper. Additionally, the NCON problems were solved using the ECST-ISSA algorithm. The proposed technique performance regarding the important features of reducing movement and dissolute energy when on mobility in MWSN was effectively analyzed with conventional techniques and enhances the network connectivity. Experimental results exhibit that the ECST-ISSA approach performance was better than the conventional method regarding NCON and energy saving.

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