Smart Agriculture System Towards Iot Based Wireless Sensor Network

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Abstract—WSN is being hugely preferred in diverse application like the military, surveillance, agriculture, industry as well. Nowadays, huge research is being carried out in the WSN exploitation, more particularly in the field of irrigation management. A serious concern need to be raised in the growing water demand, as it is the fundamental source for the growth of crops. The traditional irrigation system are not good in managing the water resources, they provide unnecessary water to one part of land, while letting the other part to pass away. Further, this irrigation system also helps the weeds to grow wealthier along with the crops. In this research work a novel smart agriculture system is developed based on IoT. In the Target coverage phase, the critical TCOV and NCON issues are resolved using an Improved Euclidean Spanning Tree Model (IECST) with hybrid optimization model (LFUM). The hybrid optimization model (LFUM) is the hybridized form of LA and FF. In the Sensor deployment phase, the crops (target) are identified and sensors are deployed to crops alone using threshold method. Thus, the crop alone gets irrigated and the weeds are not. Finally, the implemented model is assessed over the traditional tactics in terms of movement distance.

Keywords—*WSN; TCOV; NCON; IEST; Irrigation management; LFUM model*

Nomecnlature

Abbreviation	Description
WSN	Wireless Sensor Network
TCOV	Target Coverage
SGG	Square Grid Graphs
NCON	Network Connectivity
LA	Lion Algorithm
IECST	Improved Euclidean Spanning Tree Model
SSO	Social Spider Optimization
FF	Firefly Algorithm
C-PSO	Cooperative PSO
ACO	Colony Optimization
FL	Fuzzy Logic
BA	Bat Algorithm
ARS	Adaptive Rotation Scheduling Method
PSO	Particle Swarm Optimization
SN	Sink Node
ABC	Artificial Bee Colony
MCkC	Minimum Connected K-Coverage
VABC	Velocity Added Abc
RG	Random Graphs
FSM	Free Space Model
AVABC	Adaptive VABC

IC-PSO	Improved Cooperative PSO
LFUM	Lion with Firefly Update Mechanism

I. Introduction

In the present era of advanced technology, there has a wireless or wired link between each and everything in the world [9] [10] [11] [12] [13]. WSN are highly renewed when compared to wired sensor networks due to their enhanced infrastructure [47] [48] [49] [50]. it is a huge network of wirelessly linked nodes that gathers extensive types of environmental information like motion capture, pressure, and temperature [14][15] [16]. WSN's can be deployed to collect information from the surroundings, which assists scientists and researchers for further analysis or study [42] [43] [44]. It is a network comprises of large number of heterogeneous data such as images, sound, distance, SNs, and each node is equipped with a acceleration, and perhaps smell, taste, etc. [17] [18] [19] [20].

Recently, WSN is indulged in a wide range of applications like surveillance of the battlefield, monitoring the environment, biological detection, smart spaces and industrial diagnostics. The lifespan of the network is a major bottleneck problem in WSN [21] [22] [23] [24] [25]. There may be a chance for the network topology to get altered due to the draining of the energy in the SN. Further, the coverage in wireless network portrays about the area that has to be enclosed by each nodes of sensor. The coverage provides essential information on areas that are monitored by the SNs and the quantity of the sensing. Further, when the SNs are present in the centre of the sensor area, then it resembles a disk [31] [32]. The sensing range of the disk is the radius of the disk. The active sensors in the area coverage are designed with aspire of covering each of ROI by at least one SN [45] [46] [47]. A WSN is seems connected only when a minimum number of SNs are linked together by consecutive wireless communication links and they keep transmitting the data in a single-hop or multi-hop communication path. The connectivity of WSN is also related to the deployment of sensors in specific locations and communication ranges [26] [27] [28] [29] [30]. As mentioned above, both the "coverage and connectivity" are important issues in the field of WSNs. Currently, in the designing of the WSNs, the sensor coverage point and network connectivity are considered as the vital key point. Even though, number of deployment models have been worked on from the past years, still more issues are there to be concerned in various applications [33][34] [35]. In context to this, some of the research work has studied the issue of optimizing consumed energy with ensuring coverage in WSN. The mobility of mobile sensors is the major practical problem in modelling the WSN that consumes more power and hence the network lifetime reduces considerably. Therefore, these issues can be overcome by investigating the MSD problem that includes the NCON and TCOV.

Currently, there is an increase in the deployment of WSNs, mainly in the irrigation management systems. In the agriculture, WSN provides solution to multiple problems like

- ✓ Smart Irrigation - Through Multiple Sensors like Moisture, Temperature, Humidity and rain measurement with integration of weather forecast we can create smart irrigation system.
- ✓ Insects and disease prediction - with leaf and stem analysis with sensors we can predict few insects and diereses
- ✓ Nutrition analysis in agriculture -with few sensors we can monitor what Nutrients required by plants Potassium.

Smart agriculture is the term used to signify the application of Internet of Things devices/solutions in agriculture. Although agriculture is smart IOT, as well as the IOT industry in general, are not as popular as in consumer devices; but still the market is very dynamic. The mobile application can remotely control a moisture sensor based irrigation system on a large agricultural land [33] [34] [35]. This technique consumes more cost, but it will save a lot of water and labor time as well. The machine learning models with optimization concept [38] [39] [40] [41] can be solution for the aforementioned issues.

The major contribution of this research work is:

- ✓ TCOV and NCON are established to be the most vital issues and it is resolved in this research work with the aid of an IECST with hybrid optimization model.
- ✓ The hybrid optimization model named LFUM, which is the hybridized form of LA and FF.

- ✓ In the Sensor deployment phase, the target is identified and deployment of the sensors for irrigation takes place based on the computed threshold value.

The left behind areas of the research work is ordered as: Section II addresses the most recent work sin WSN coverage as well as connectivity. Section III tells about the proposed smart agriculture system based on IOT-WSN: an overview. In addition, the target localization is depicted in Section IV. The proposed IECST model is manifested in Section V. In addition, the results acquired with the proposed work are discussed in Section VI. Finally, this paper is concluded in Section VII.

II. Literature review

A. Related works

In 2018, Song *et al*. [1] have projected a new SN deployment scheme on the basis of the evidence theory, and this technique caters for 3D underwater wireless sensor networks. In the D–S evidence theory, the probability deployment was improved by implementing the enhanced data fusion model and the sonar probability perception model. the results of the multiple simulation experiments exhibited the performance of the proposed work in terms of consumption of energy consumption and higher detection potential in large coverage area.

In 2018, Zhou *et al*. [2] have established a novel sensor deployment scheme on the basis of the SSO algorithm in order to enhance the WSNs coverage. The WSN placement problem was solved by means of reducing the blind areas with SSO algorithm. Thereby, the coverage of WSN was improved. The experimental results had exhibited the enhancement of the proposed work in terms of coverage performance.

In 2017, Krishnan *et al*. [3] have developed a new heuristic algorithm to boost up the network's lifespan. The proposed new heuristic algorithm was constructed by blending the concepts of standard ant ACO and the PSO and the ABC algorithm. The extensive experiments have revealed that the proposed heuristic algorithm along with the modifiable radius of sensing was good in increasing the life time of the network, by significantly increasing the sensor deployment.

In 2018, Xu *et al*. [4] have proffered a node optimization deployment model for increasing the coverage of the wireless sensor network. The routing of the data in the network was accomplished via the adaptive rotation scheduling method. Moreover, the sensor gird point's credibility was quantified by using the sensor quantization fusion tracking method. The simulation results have revealed that the constructed proposed method increasing the reliability of the network with minimum energy cost.

In 2020, Arivudainambi *et al*. [5] have introduced a "vertex coloring based sensor deployment algorithm" for WSN in 3D terrain in order to identify the requirements of WSN as well as to determine the spot of 100% of target coverage. The Breadth first search algorithm was utilized for enhancing the connectivity of sensors in the WSN. Further, the acquired results had exhibited the efficiency of the proposed work in providing "efficient coverage and connectivity".

In 2018, Elloumi *et al*. [6] have solved the MCkC problem by proposing two mathematical programming formulations on SGG and RG. The diverse instances were solved using the standard mixed integer linear programming. The proposed work has exhibited higher performance in terms of total CPU time.

In 2020, Mohar *et al*. [7] have projected a new node deployment approach on the basis of the BA in order to improve the network coverage. The SN's coverage rate was further improved by optimizing the bat algorithm's parameters like the "loudness, pulse emission rate, maximum frequency, grid points and sensing radius". The results demonstrate that the proposed algorithm shows higher coverage rate.

In 2020, Yarinezhad and Hashemi [8] have introduced two improved versions of the most renowned PSO algorithm, namely IC-PSO using FL and C-PSO to solve the sensor deployment problem. The simulation results had exhibited that the proposed model had solved the target coverage problem with expansion in the network life span.

B. Review

The most fascination works done in WSN are discussed in the literature section. The advantages and drawbacks of those techniques are tabulated in Table I. In evidence theory, the network life span is higher and detection range of network is also higher. But, it suffers from lower coverage. The Social Spider Optimization Algorithm in [2] produces higher Coverage rates. This technique is more accurate and robust. But, it consumes higher power and so it is not preferred in large scale. The heuristic model [3] (ACO, ABC and PSO) is good in increasing the lifetime of the network. It also ensures the target monitoring. This technique also consumes higher power. Further, the adaptive rotation scheduling method introduced in [4] improve the reliability of the network. Apart from this advantage, the energy cost of the network is lower and hence consumes more cost. Further, the vertex coloring in [5] provides efficient coverage as well as connectivity. Here, the power consumption is higher and time for processing is also higher. In addition, the Mixed integer linear programming ·in [6] considers multiple coverage of targets and hence suggested to be more useful. Apart from this advantage, it suffers from lower connectivity. The BA utilized in [7] consumes lower power and here the coverage rate is lower. As a contrast to this, the life span of the network seems to be lower. The cooperative PSO and improved cooperative PSO using fuzzy logic introduced in [8] expands the network life span and here only less resources are required. But, here the coverage as well as connectivity is lower.

TABLE I. ADVANTAGES AND DRAWBACKS OF STATE-OF-ART MODELS

Author [Citation]	methodology	Advantages	Drawbacks
Song *et al*. [1]	evidence theory	✓ Higher network life span ✓ Higher detection performance ✓ Expands the detection range of network	❖ Lower node coverage efficiency ❖ Slower
Zhou *et al*. [2]	SSO Algorithm	✓ Higher Coverage rates ✓ Higher accuracy and the robustness ✓ quick and unwavering technique	❖ Higher power consumption
Krishnan *et al*. [3]	ACO, ABC and PSO	✓ Expands the network lifetime ✓ ensure target monitoring ✓ higher connectivity and QoS	❖ Higher energy consumption ❖ Lower reliability ❖ Consumes more resources
Xu *et al*. [4]	ARS method	✓ improve the reliability of the network ✓ minimum energy cost ✓ improve the connectivity of network ✓ higher data forwarding accuracy	❖ Higher energy cost ❖ Reduces the network life span.
Arivudainambi *et al*. [5]	vertex coloring	✓ provides efficient coverage as well as connectivity ✓ decipher the target coverage problem in 3D terrain ✓ increase the network lifespan	❖ Lower consistency ❖ Higher computation time
Elloumi *et al*. [6]	Mixed integer linear programming ·	✓ Considers multiple coverage of targets ✓ Lower total CPU time	❖ Consumes more power ❖ Lower connectivity
Mohar *et al*. [7]	BA	✓ Lower computation time ✓ Higher coverage rate	❖ Reduces the network lifespan

Yarinezhad and Hashemi [8]	C-PSO, and IC-PSO using FL	✓ longer network lifetime ✓ solve the target coverage problem ✓ requires less resources	◆ Less coverage and connectivity

III. PROPOSED SMART AGRICULTURE SYSTEM BASED ON IOT-WSN: AN OVERVIEW

A. *Architectural Description*

In this research work a novel smart agriculture system is developed based on IoT. The proposed model will include two major phases: Target coverage and localization and SN deployment for irrigation

The steps that will be followed in the proposed work are depicted below:

Phase 1: Target coverage and localization: The target is fixed as the crops, such that the crop alone gets the adequate amount of water and the weeds are not wetted. This reduced the growth of weeds in the agriculture field. TCOV and NCON seems to be the most crucial issue, which need to be resolved to acquire better communication and environmental sensing in WSN based agriculture. Therefore, the IECST with hybrid optimization model (LFUM) is introduced in this research work. The LFUM model is the hybridized form of LA and FF.

Phase 2: Sensor deployment for irrigation:

- Identify the crops (targets) and deploy the SNs are irrigation, if the target is crop. This identification of the crops is based on the computed threshold value.
- Irrigation is applied via deployed senor only to crop targets, while the weeds are not wetted.

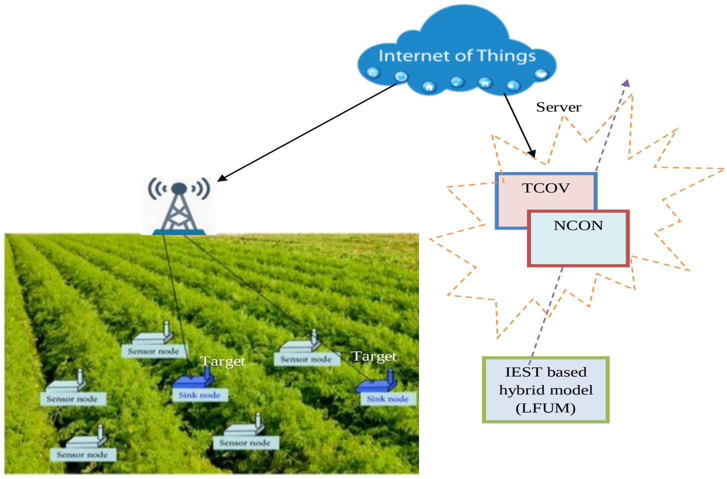

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Fig. 1. Overall architecture of the proposed work

IV. TARGET LOCALIZATION

In the precision agriculture, there is a dramatic variation in the soil type and temperature constraints as well. These significant parameters vary from place to place and from region to region. The WSN being the cost-effective processes is utilized in monitoring the climatic condition (like temperature and humidity), required nutrient level; forecast the physical condition of crops as well. Smart farming and sustainable agriculture rely on the availability of these data. Therefore, is crucial of any irrigation system to adapt to these changes in a flexible manner. However, it is practically complex to deploy the SNs in the harsh environment like the agricultural fields**,** owing to its battery life. Moreover, the TCOV and NCON are established to be the most fundamental problem that has to be determined to accomplish successful data communication and ecological sensing in WSN. In this research work, an IEST model is introduced to tackle the TCOV and NCON problems. As a resultant, the WSN technology makes it possible to monitor the target (crops) making it cost effective and at the same time permits the watering the crops alone and neglecting the weeds from getting the water.

A. TCOV Problems

In this research work, let's consider an agriculture field, in which the weed too grows along with the crops. In general, the weeds look alike the crops and consume more nutrients as well as the water. The presence of weeds in the field affects the growth and performance of target crops. It is essential to control to the weeds before and soon after, they start sprouting. In general, the weed control is labour-intensive and consumes huge cost. Despite a huge advancement in the weed control techniques, farmers still find it challenging to effectively control the weeds. As a solution to this, the crops in the concern field is fixed as the target and only these target region is irrigated, while the non-target regions are not. In the considered husbandry region G, there is N count of targets (crops) $Target = \{target_1,...,target_N\}$ and M count of SNs $Sensor = \{sensor_1,...,sensor_M\}$. All these $Sensor = \{sensor_1,...,sensor_M\}$ are localized in the specific region $G = \{g_1,...,g_N\}$.

The upcoming explanation itemise the operation of the system model.

✓ Each of the mobile SNs is embedded with a GPS unit that aids in localizing the position of the targets (crops) in the concern agriculture field. Further, the information regarding the migration of the SN is broadcasted, and it is collected by the sink nodes (control centre) in the network.

✓ In this research work, it is assumed that the sensor is free to move with no obstacles along its path. However, in certain complex cases, there is possibility for the obstacles to move towards the trajectory of the SN. In such circumstance, an appropriate path is chosen Thereby, from this precisely localization of the movement of sensors; both the NCON and TCON problems can be resolved.

✓ Network model: In this research work, the disk model is utilized for constructing the network model for powerful communiqué among the SNs with radius $(radius_C)$ and target SN with radius $(radius_S)$. Every SN and target may perhaps be enclosed by abundant targets and SNs, respectively. Further, if a target is covered by at least one SN with the radius of the disk $radius_S$, the corresponding target is said to be enclosed. In disk model, the disk is nothing but the "coverage disk of the target and the region surrounding the coverage disk is referred as the target's "coverage circle".

(4)FMS: Here, the SNs are independent and they can move anywhere uninterruptedly in any direction, and can halt anywhere. On the basis of the travel distance, the power consumed by the SN is computed. The distance of SN $sensor$ to wrap-up $target$ is indicated by $dist(sensor, target) - radius_s$. Here, $dist(sensor, target)$ is the Euclidean distance between $sensor$ and $target$. The movement distance to connect $sensor_i$ and $sensor_j$ is computed as $dist(sensor_i, sensor_j) - radius_c$. In the obstacle-free environment, it would be ideal, if the senor move in a straight line path to reach the TCOV are thereby makes the information communication more precise among sink nodes and coverage SNs.

B. Problems on NCON

Once, the TCOV problem is solved, and then each of the target nodes is surrounding by at least one adaptable SN. In WSN, the other major issue is NCON, which guarantees the data transmission between the coverage SNs and sink nodes, by means of introducing an association between them. On the other hand, if there exist no connection between the coverage SNs and sink nodes, then NCON problem exist, and so it is vital to evaluate the NCON issue.

Definition 1: The phenomena of introducing linkage among the coverage SNs and the sink nodes that have enclosed $target$ by means of rearranging the rest nodes at least practicable movement are referred as NCON. Since, the TCOV issue solved with a bare minimum of at-least one coverage SN that surround each $target$ there in WSN system. Such that, the problem of NCON is resolved in this research work by randomly locating the rest nodes with a insignificant movement and therefore it might locate an organization amongst coverage SNs and sink.

V. PROPOSED IMPROVED IECST

The foremost initiative behind NCON is to relocate the mobile SNs to an idle position from which the connection is established to sink nodes for efficient information exchange. In this research work an improved IECST model is introduced. In EST, a spanning tree is constructed based on the Euclidean distance between the edges.

A. *IECST model*

A tree topology is constructed in this research work, in which each of the leaf nodes and the root nodes are the coverage and sink SNs, respectively. The fundamental initiative behind the NCON is to institute a reliable linkage between the coverage SNs and sink SNs. This can be accomplished by assembling the left over to randomly shift to a newer location as connecting nodes, and thereby lessen the expenditure incurred for movement. As per the NCON objective, it could be resolved in two stages:

Stage 1: Construct a "minimum edge length spanning tree topology", where the edge measurement lengthwise between the sink and coverage SNs need to be lower than $radius_c$. Usually, the "minimum distance Spanning tree" diminish the migrations of the rest nodes.

Stage 2: The rest nodes are considered as the connecting nodes for linking the sink and coverage SNs by repositioning the "rest nodes" to the "produced Steiner point"s from IECST model. On the other hand, in the exceptional case of TCOV, the targets are the "Steiner points with coverage radius=0" and the rest node with minimum distance are covered by the Steiner points. Therefore, there is a requirement for effectual communication for every target with its dedicated SN.

Identification of the Steiner points of connectivity: The major intention behind the determination of the Steiner points of connectivity is to resolve the NCON problem. The steps followed are depicted below:

- Construct a spanning tree T with constrained edge length in order to associate the coverage SN and sink nodes.
- The construction of the spanning tree is with weighted Gaussian function based Euclidean distance.
- The mathematical formula for weighted Gaussian function $Weight_{Gau}$ based Euclidean distance is shown in Eq. (1)

  $$Weight_{Gau} = \frac{1}{Norm} e^{\left(-d^2/h^2\right)} \qquad (1)$$

  Where, d is the weighted position distance from centre and h controls the exponential function decay speed. In addition, $Norm$ is the normalizing factor. The mathematical formula for computing d is shown in Eq. (2).

  $$d = Weight_{Gau} \times \sqrt{\sum_{i=1}^{n} \left(X_i - Y_i\right)^2} \qquad (2)$$

- The Steiner tree problem is being the NP-hard and so an approximate algorithm is formulated for NCON problem, and this includes

  a) For length lesser< $radius_c$ (communication radius), separate the spanning tree's edges.

- The rest node's movement distance to establish association among SNs and the sink is minimized as per the reduction in the summation of IECST's entire edge length.

The pseudo code of the IECST algorithm is given by Algorithm 1.

Algorithm 1.	The IECST Algorithm
Input:	$Rest = rest_1, rest_2, ..., rest_P$ //group of rest nodes, where P is the count of rest nodes
	S_{covrg} // group of coverage SNs
	$Sink(X,Y)$ // sink position

	$radius_c$ // radius of communication
Output:	sp // group of Steiner point
1	$N = S_{\mathrm{cov}\,rg}$
2	Produce a whole graph $J = (N, E)$
3	Generate a Euclidian minimum spanning tree T using the sink as the root of J and coverage SNs as leaf
4	Compute the weighted Gaussian function $Weight_{Gau}$ based Euclidean distance using Eq. (1)
5	For each $p_i \in P$ and its parent p^i_{parent} do
6	Divide the edge $e(p_i, p^i_{parent})$ into $\left\lceil \frac{\|e(p_i, p^i_{parent})\|}{radius_c} \right\rceil$ parts
7	$sp(x_i, Y_i) \leftarrow$ every dividing point
8	Return sp

Subsequently, the rest nodes are assigned to each of the point in sp that are produced from the resultant of IECST. with decreased movement cost. The algorithm of IECST-LFUM is is used to resolve the allocation issue in the aforesaid issue. The pseudo code of IECST-LFUM approach is explicated in Algorithm 2.

Algorithm 2.	The IECST-LFUM Algorithm
Input:	$\mathrm{Re}\,st = rest_1, rest_2, \ldots\ldots, rest_P$ // count of rest nodes
1	$S_{\mathrm{cov}\,rg}$ // count of coverage SNs
2	$Sink(X, Y)$ // sink position
3	$radius_c$ // radius of communication
4	IECST($\mathrm{Re}\,st, S_{\mathrm{cov}\,rg}, Sink(X, Y) radius_c$)
5	AVABC($sp, \mathrm{Re}\,st / S_{\mathrm{cov}\,rg}$)// moving of rest nodes to the Steiner points
6	Return movement cost and deployment order

B. Relocation of Rest Nodess

Once the target points corresponding to the target points are identified, then the destination points are relocated by the rest node's movement. Therefore, An LFUM optimization algorithm is developed for connecting the node and sink thereby enhances the movement reduction of rest nodes. The pseudo code of proposed technique is portrayed in Algorithm 3.

C. Solution Encoding

Assume, the rest nodes $\mathrm{Re}\,st = rest_1, rest_2, \ldots\ldots, rest_P$ with randomly initialized numbers as N_{bees}. The count of Steiner points acquired from IECST is represented as N_{sp}. In addition, $\mathrm{Re}\,st_{ij}$ represent the solution to be encoded, in which $i = 1,2,\ldots\ldots, N_{bees}$ and $j = 1,2,\ldots, N_{sp}$ .the notation $\mathrm{Re}\,st_{ij}$ is the encoded solution within the search area to the Steiner points that can be randomly produced by the rest node movement. The encoded solution has to be certainly a real number in search space $\mathrm{Re}\,st^{N_{\mathrm{Re}\,st} \times N_{\mathrm{Re}\,st}}$ and has been defined as $\mathrm{Re}\,st_{ij} \in [1, N_{\mathrm{Re}\,st}]$. Further, $\mathrm{Re}\,st_{ij}$ element remains as a unique one and is demonstrated as per the Eq. (3)

$$\mathrm{Re}\,st_{i1} \neq \mathrm{Re}\,st_{i2} \neq \ldots\ldots \neq \mathrm{Re}\,st_{iN_{sp}} \quad \forall i \qquad (3)$$

D. Fitness Function

The fitness is made with respect to the value cost amongst the Steiner points and rest node, and is illustrated in Eq. (3). In this, $C[\mathrm{Re}\,st_{ij}, j]$ denotes the cost function to shift $\mathrm{Re}\,st_{ij}$ solution to j^{th} Steiner point. In Fig 2, the Steiner point is referred using the square block and the rest nodes movement is represented by circles

$$fit_i = \sum_{j=1}^{N_{sp}} C_j \qquad (4)$$

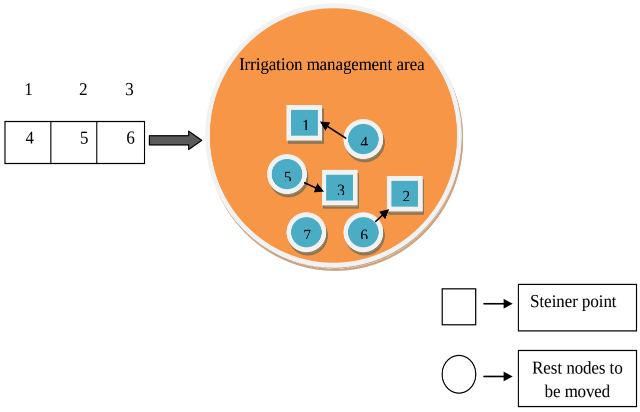


Fig. 2. Solution Encoding

E. LFUM

The standard LA was introduced with the inspiration acquired acquired from the fireflies.. Typically, FF has an inborn capability of dealing with the complex problems related to the non-linear, multi-modal optimization in an optimal as well as efficient way. But, it suffers from lower convergence. In association with this, the fireflies lack the behaviour of random migration and they are capable of moving in a peculiar direction, where there is improvement in the brightness value. So, with aspire of overriding these complex nature of FF, they are linked with LA algorithm. LA was introduced on the basis of the inspiration got from the unique social behaviour of the lions. The terrestrial defence and territorial takeover are the two major lions behaviours that were utilized to get solution to the problem. The hybridized algorithm enhances the quality of the optimal solution and hence solves the issues related to the formation of the objective function. Since, LA and FF are amalgamated; the proposed algorithm is referred as LFUM. Hybrid optimization algorithms have been reported to be promising for certain search problems. The steps followed in the proposed LFUM model is depicted below:

Step 1: The initialization of the male territorial lion K^{male}, female territorial lion K^{female} and the nomadic lion $K^{nomadic}$ takes place.

Step 2: Evaluate the fitness of K^{male}, K^{female} and $K^{nomadic}$ using Eq. (4). The corresponding fitness computed solutions is denoted as $fit(K^{male})$, $fit(K^{female})$ and $fit(K^{nomadic})$.

Step 3: Assign fitness of the search agent $fit^{FIT} = fit(K^{male})$ and set the current generation value as $Ct_{gen} = 0$

Step 4: Perform fertility evaluation. In general, the female terrestrial lion K^{female} as well as the male terrestrial lion K^{male} are said to reach the value of the global optima or local optima, only when there fitness value is said to be saturated. The fertility assessment is mainly undergone to neglect the local optimal solutions. After the elimination of the local optimal solutions, the female best solution K_{best}^{female} and the male best solution K_{best}^{male} are updated. The updating of K_{best}^{female} with K^{female} and $y*$ takes place as per Eq. (5).

$$K_{best}^{female} = \min\left[K_{y*}^{\max}, \max\left(K_{y*}^{\min}, \lambda_{y*}\right)\right] \qquad (5)$$

In which,

$$\lambda_{y*} = \left\{K_{y*}^{female} + \left[0.1ra_2 - 0.05\left(K_{y*}^{male} - ra_1 K_{y*}^{female}\right)\right]\right\} \quad (6)$$

Here, $y*$ represent the random integer that resides in the range $[1,Y]$. In addition, female renewal function is denoted using the symbol λ, and the random integers symbolized as ra_1 and ra_2 are generated within the interval [0, 1]. The sterility rate $S(r)$ ensures the fertility of K^{female} and at the end of the crossover operation $S(r)$ is raised by one.

Step 5: Carry out mating and gain cubpool. The process of mating is accomplished by the newly formulated K^{male} and K^{female} by means of undergoing the process of mutation as well as crossover. The cubs $k_{21}^{cub}, k_{22}^{cub}$ are formulated by performing the crossover initially, and then the mutation process is undergone, where the two cubs $k_{21}^{cub}, k_{22}^{cub}$ are produced with the FF's position update K_{best}. The mathematical formula for position update in FF is shown in Eq. (7).

$$K_{best} = K_g + \rho_0^{-\gamma x_{gh}^2}(K_h - K_g) + \omega\left(rand - \frac{1}{2}\right) \qquad (7)$$

In which, the "maximum attractiveness" is indicated as ρ_0 and it is the "light absorption coefficient". In addition, two FF are denoted as g and h and the position of these two FF are depicted as K_g and K_h, respectively.

Step 6: Then, once the cubs are formed, they fill the pool and then the "gender grouping" takes place in the pool. Then, at the end of the clustering operation K^{z-cubs} and K^{s-cubs} are generated.

Step 7: If age of cubs is less than the maximal age $\hat{A}_{cub} < \hat{A}_{\max}$. Then, perform of the operations corresponding to the territorial takeover and gain updated K^{male} and K^{female}.The mechanism of terrestrial takeover happens, when the cub's age is equivalent ot greater than the maturity age. The appending of the male terrestrial lion K^{male} is accomplished to get K_{pride}^{male} and K_{pride}^{female}. Further, in K_{pride}^{female} the formation of K^{z-cubs} and K^{s_cubs} are done by appending K_{pride}^{male} and K^{female}. The mathematical equation constraints corresponding to the for the formation of K_{best}^{female} and K_{best}^{male} are depicted in Eq. (8) and (9).

$$f\left(K_{best}^{female}\right) < f\left(K_{best}^{female}(c)\right); K_{best}^{female}(c) \neq K_{best}^{female} \qquad (8)$$

$$f\left(K_{best}^{female}\right) < f\left(K_{best}^{female}(c)\right); K_{best}^{female}(c) \neq K_{best}^{female} \qquad (9)$$

Step 8: increase generation count by 1

Step 9: Further, the termination of the lion procedure takes place, when one of the upcoming condition from Eq. (10) or Eq. (11) gets satisfied.

$$Max_e > Max_e^{\max} \qquad (10)$$

$$\left\lfloor f\left(K^{male}\right) - f\left(K^{optimal}\right)\right\rfloor \leq T_e \qquad (11)$$

Here, T_e (error threshold) , and Max_e (maximal generation count). The pseudo-code of the LFUM model is shown in Algorithm 3.

Algorithm 3: LFUM model	
Step 1	Initiate K^{male}, K^{female} and $K^{nomadic}$
Step 2	Evaluate $fit(K^{male})$, $fit(K^{female})$ and $fit(K^{nomadic})$
Step 3	Assign $fit^{FIT} = fit(K^{male})$ and $Ct_{gen} = 0$
Step 4	Store K^{male} and $fit(K^{male})$
Step 5	fertility evaluation is performed
Step 6	Mating is undergone and cup pools are formualted

Step 7	In cup pool formation, the cross over cubs is produced with traditional LA and the mutated cubs are produced via the FF's positional update shown in Eq. (7).	
Step 7	Carry out gender clustering and gain K^{male_cub} and K^{female_cub}	
Step 8	Initiate $\hat{A}_{\max}$ as zero	
Step 9	Implement the cub growth function	
Step 10	territorial defence is carried out; if the result of defence is 0 move to step 4	
Step 11	If $\hat{A}_{cub} < \hat{A}_{\max}$ the move to step 9	
Step 12		Territorial takeover is performed and gain is updated K^{male} and K^{female}
Step 13		Increment generation count Ct_{gen} by one
Step 14	If termination criteria is not met, then move back to step 4	
Step 15	else	
Step 16	Terminate the process	

VI. PHASE-2: SENSOR DEPLOYMENT

Initially, the sensors are identified and irrigation is done if and only if the target is crop. The threshold is computed based on the coverage, energy and uniformity constraints.

The mathematical formula for computing threshold is shown in Eq. (12).

$$Threshold = \frac{Convergence + Uniformity + Energy}{2} \quad (12)$$

Mathematically, the convergence is computed as per Eq. (13).

$$Convergence = \frac{\bigcup_{i=1,\dots,N} A_i}{ROI} \quad (13)$$

Here, A_i is the area covered by i^{th} node and N is the overall count of nodes. In addition, the area of region of interest is denoted as ROI .

In addition, the uniformity is computed as per Eq. (14).

$$Uniformity = \frac{1}{N}\sum_{i=1}^{N} U_i \quad (14)$$

In which,

$$U_i = \left(\frac{1}{K_i}\sum_{j=1}^{K_i}(D_{i,j} - m_i)^2\right)^{1/2} \quad (15)$$

Here, K_i denotes the count of neighbouring nodes of i^{th} node and $D_{i,j}$ is the distance between the i^{th} node and j^{th} node. In addition, m_i is the mean of the intermodal distance between i^{th} node and its neighbour.

- ✓ Is coverage energy>threshold- then SNs is deployed for irrigation mechanism.
- ✓ Is coverage energy>threshold- then it is a weed and it is not irrigated.

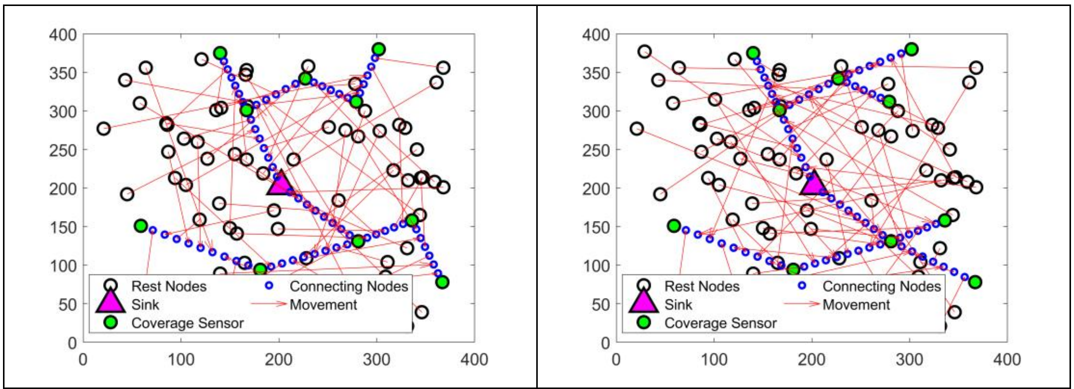
VII. RESULTS AND DISCUSSION

A. Simulation procedure

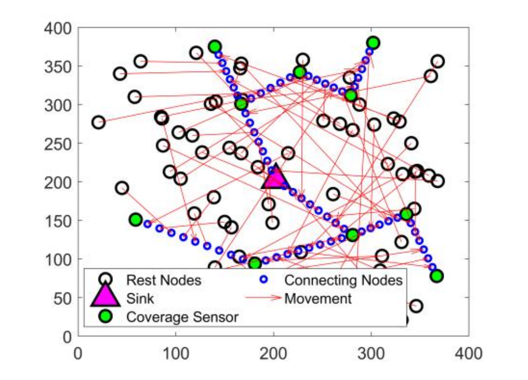
The presented approach using FI-WOA scheme was implemented in "MATLAB", and the outcomes were examined. After implementation, the adopted IESCT- LFUM scheme was compared over IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA and schemes. The evaluation of the movement distance was accomplished by means of varying the sensor radius and the count of the target/ sensors as well. The manually collected data for evaluation are shown in Table II. Fig. 3 demonstrate the results of optimum movement of rest nodes to act as the connecting nodes under diverse schemes.

TABLE II. COLLECTED DATA FOR EVALUATION

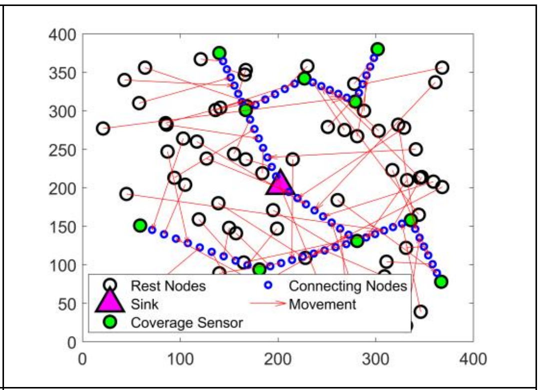
Date	IECST-ABC	IECST-VABC	IECST-AVABC	IECST-FF	IECST-LA	IECST-LFUM
01-Jan	9207.971	9079.903	8045.993	8784.214	9173.453	6116.555
01-Feb	7642.318	7711.194	7041.708	7927.235	7839.64	5311.984
01-Mar	7471.626	7637.581	6658.904	8188.128	7823.459	5134.841
02-Jan	13077.01	11651.87	10421.03	11917.26	11722.46	7904.051
02-Feb	15486.18	15175.72	13423.6	15469	13715.11	10763.29
02-Mar	15223.49	14239.91	13279.83	14755.65	15384.25	10267.46
03-Jan	17472.81	16647.8	15318.11	17753.66	16930.13	12134.09
03-Feb	18092.27	14978.86	14035.36	15306.36	15252.48	10580.59
03-Mar	21112.36	17741.45	16542.16	18902.29	18096.34	12987.03
04-Jan	22754.06	17543.02	16350.91	18291.72	18627.13	13831.26
04-Feb	22878.22	20016.24	18239.16	20824.61	19639.01	14523.98
04-Mar	23300.51	19337.2	18048.35	20391.74	20463.72	14313.6
05-Jan	27861.03	22568.56	21350.6	22959.06	23525.6	16630.77
05-Feb	29467.83	23995.62	23069.31	24952.94	25610.14	17666.3
05-Mar	25072.96	21084.89	19543.84	20779.06	20317.31	15359.74



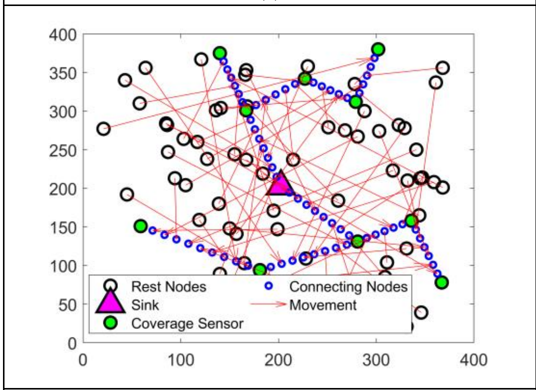
(a) (b)



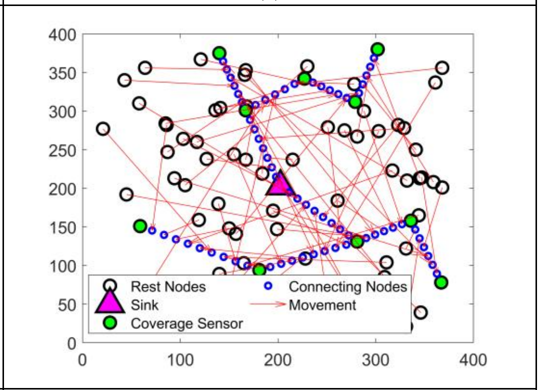
(c)



(d)



(e)



(f)

Fig. 3. Optimal movement of rest nodes using (a) IECST-LFUM, (b)IECST-ABC, (c)IECST-VABC, (d)IECST-AVABC, (e)IECST-FF and (f)IECST-LA

B. Impact of varying sensing radius

Fig 4 portrays resultant of the the analysis on IECST-LFUM method over the other classical methods like IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA in terms of movement distance. Here, the evaluation is carried out by varying the sensing radius from 5m, 10m and 15m, respectively. Here, the communication radius is fixed as 1m (in Fig,4 (a)), 2m (in Fig. 4(b),3m(in Fig. 4(c), 4m (in Fig. 4(d) and 5m (in Fig. 4(b), respectively. Fig. 4 shows that under the inversely proportional to the radius of communication. As a result, a conclusion can be derived that, there is an increase in the interlinking sensor's communication radius, and then the rest node's decreased movement is obtained. The implemented IECST-LFUM algorithms show betterment over the other standard IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA algorithms in terms of huge margin attainment. Therefore, the performance of IECST-AVABC reveals the lowest movement distance, and it is 37.5%, 36%, 35%, 28.5% and 25% better than the benchmark IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA at radius sensing radius=15m in Fig. 4(b). Thus, the proposed work is said to be much sufficient for solving the TCON and NCON problems.

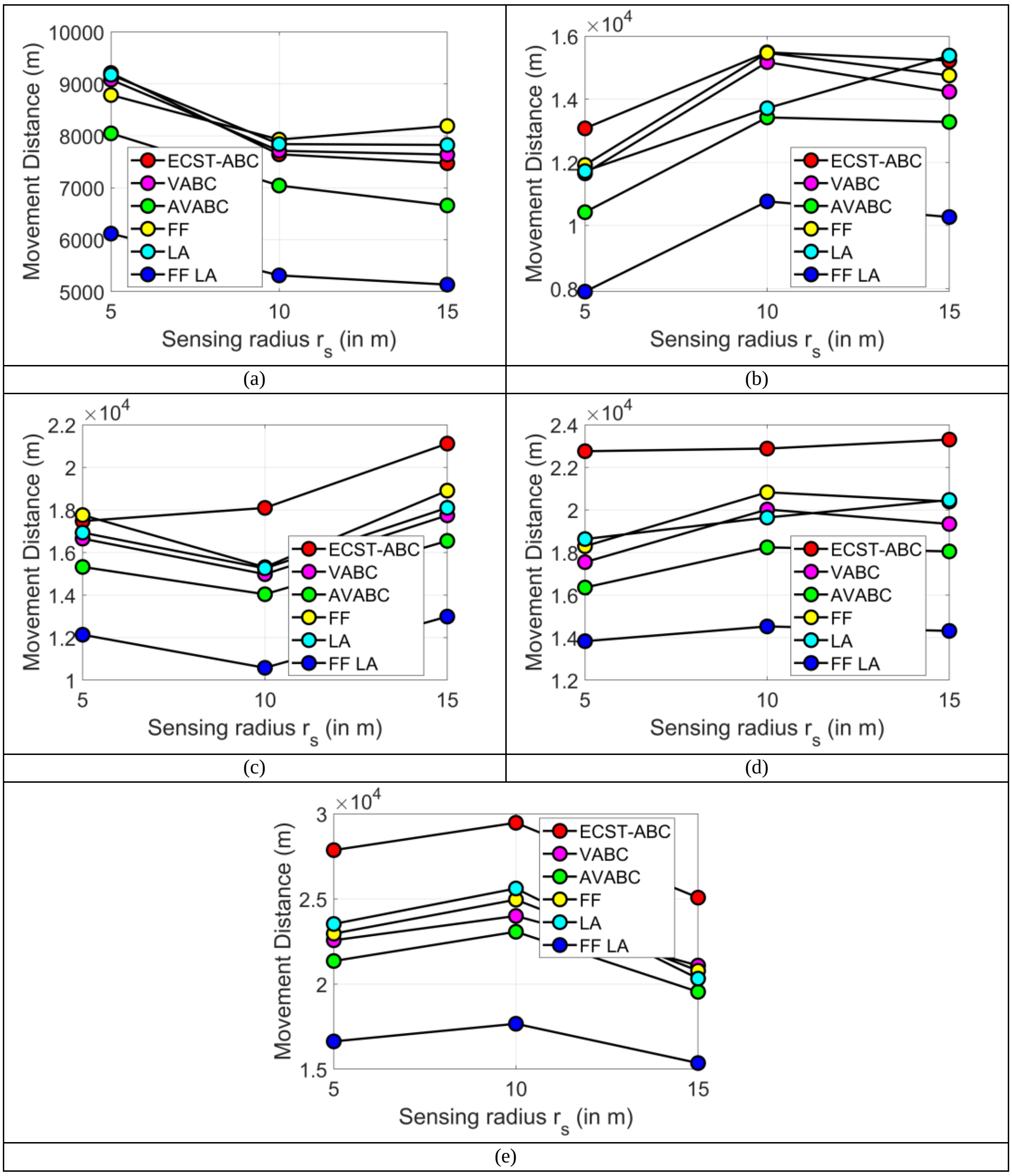
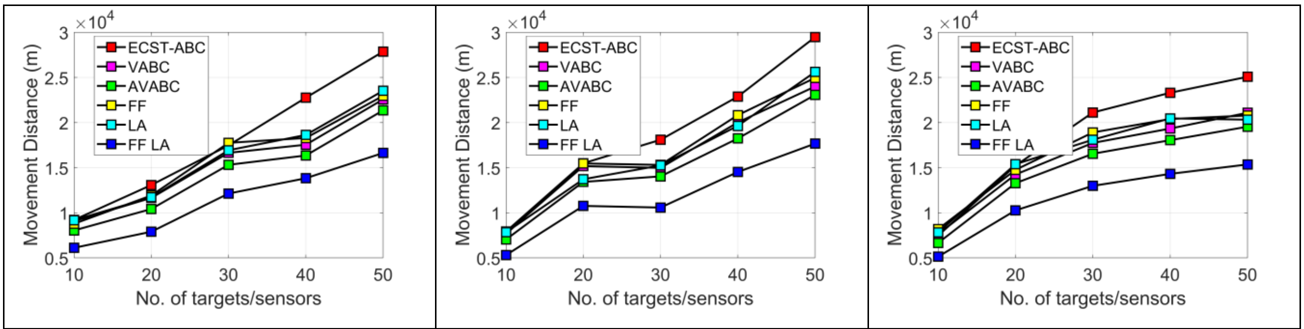


Fig. 4. Relative analysis on rest node that movemnt for sensing radius as 5, 10 and 15 by assigning the variable targets/sensors amount like (a) 10, (b) 20, (c) 30, (d) 40, (e) 50

C. Impact of the count of target

The relative evaluation of movement distance with a count of targets/sensors existed on the WSN by differs the communication radius as 5m, 10m and 15m are demonstrated in Fig. 5. The proposed IECST-LFUM algorithms have better performance than other conventional models regarding attaining decreased movement of rest nodes over count of targets/sensors. Moreover, the rest node's movement distance is directly comparative to the count of available targets/sensors. It is further explained as the movement distance of rest node gets increased as per the increase in the amount of target/sensor. Further, the proposed method has attained a better performance of 66.6%, 50%, 20%, 30.4%, 21.43% and 26.5% over the existed IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA count of targets/sensors =40 given in Fig. 4.4 (a). Similar evaluation is carried out for the rest of the target nodes and the results are analyzed. Thus, from the overall evaluation it is clear that the proposed work exhibits lower movement distance and hence said to be good in resolving the TCOV and NCON problems.



(a) (b) (c)

Fig. 5. Relative analysis on the movemnt distance of the proposed as well as existing works for varyting count of sensors or targets for (a) communication radius=5, (b) communication radius=10, (c) communication radius=15

D. Performance Analysis

The analysis on standard deviation (σ) and mean(μ) for changing sensing radius for the proposed method and the conventional models is given in Table III. From the obtained outcomes μ and σ of the implemented scheme is less for all varying sensing radius. The mean of the implemented IECST- with respect to the sensing radius= 5 gains the lowest value as 6141, while compared to IECST-ABC=9133.2, IECST-VABC=9139.5, IECST-AVABC=8023, IECST-FF=8698.3 and IECST-LA=9196.1. Further, the implemented IECST-AVABC model in terms of std-dev achieves 26.5%, 26.3%, 23.5%, 26.6% and 27.2% better than IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA, respectively. From the result, it is obvious that the proposed model provides better mean and standard deviation value when compared over the other conventional methods. Hence, the enhancement of the presented IECST-LFUM model was effectively confirmed from the analysis.

TABLE III. MOVEMENT DISTANCE ANALYSIS IN TERMS OF MEAN AND STANDARD DEVIATION FOR PROPOSED AND EXISTING MODEL

Sensing radius	IECST-ABC		IECST-VABC		IECST-AVABC		IECST-FF		IECST-LA		IECST-LFUM	
	μ	S.D	μ	S.D	μ	S.D	μ	S.D	μ	S.D	μ	S.D
5	9133.2	277.64	9139.5	250.24	8023	221.69	8698.3	261.85	9196.1	240.12	6141	194.02
6	8754.5	240.09	8743.7	258.84	7771.6	219.44	8515.4	237.08	8822.7	253.56	5894.8	153.33
7	8459.8	254.67	8386.7	267.91	7535.6	207.51	8289.6	222.01	8534.7	215.91	5737.6	180.23
8	8131	260.87	8115.6	237.14	7365.6	203.64	8081	254.92	8223.1	231.51	5540.5	179.62
9	7835.8	204.85	7887.6	272.2	7169.8	202.24	8009	239.02	8011.6	234.87	5436.2	145.77
10	7674.7	220.37	7691.1	219.89	7033	211.79	7940.1	220.66	7877.6	222.4	5335	161.89
11	7555.2	204.57	7596.9	209.59	6901.9	215.19	7904.9	206.63	7763.4	228.63	5220.2	136.77
12	7423.7	215.58	7537	217.77	6785.7	212.4	7892.6	188.77	7686.6	241.31	5103	122.84
13	7379.6	219.81	7493.9	217.46	6736.3	186.65	7957	218.35	7655.6	215.03	5101.4	149.65
14	7381.4	201.94	7540.5	208.89	6633.3	175.42	8053.5	250.41	7731.1	230.98	5148.3	171.66
15	7451.6	193.32	7649.8	209.77	6591.1	172.47	8178.6	227.34	7743.3	193.18	5085.8	131.98

VIII. CONCLUSION

In this research work a novel smart agriculture system was developed based on IoT. The proposed model encompassed two major phases: Target coverage and localization and Sensor deployment for irrigation. In the Target coverage and localization, the target is fixed as the crops, such that the crop alone gets the adequate amount of water and the weeds are not wetted. This reduced the growth of weeds in the agriculture field. Further, IECST was introduced to resolve the TCOV and NCON problem in WSN based agriculture. The LFUM model was introduced to assist the IECTS model in solving the comprised NCON and TCOV. In the Sensor deployment phase, the crops (target) are identified and sensors are deployed using threshold method. Further, the implemented IECST-AVABC model in terms of std-dev achieves 26.5%, 26.3%, 23.5%, 26.6% and 27.2% better than IECST-ABC, IECST-VABC, IECST-AVABC, IECST-FF and IECST-LA, respectively. Hence, the enhancement of the presented IECST-LFUM model was effectively confirmed from the analysis.

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