An Inclusive Study of Coverage Optimization in Wireless Sensor Network with Intelligence-Inspired Algorithms

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ABSTRACT
Wireless Sensor Network (WSN) has gained more attention of researchers as it is having issues which has to be addressed in an efficient way. Energy-efficient network, Clustering, Network lifetime, Effective Routing, Fault-tolerance, Coverage maximization, Connectivity among sensor nodes, etc. are various issues which require effective solutions for better utilization of WSN in real-time scenario. Coverage is one of the important factors in wireless sensor network which describes covering quality of sensor nodes in particular deployed area. It is defined as how well the sensor nodes cover the particular region and monitor the events or any triggered action in that region. Coverage Optimization is an approach to maximize the covering of monitoring area or target points using sensor nodes. The motive of the proposed work is to explore coverage optimization using different paradigms of intelligence-inspired algorithm under various factors and construct the comparative assessment of these algorithms based on different criteria.

Keywords
Coverage, Connectivity, Deployment, Sensing, Intelligence, Optimization

1. INTRODUCTION
In the era of IoT where collection and organization of data is much more controlled with the help of sensor network which facilitates the process of data generation through event detection using sensor nodes and communicate to target location. Wireless sensor network has many diverse applications in different areas like in healthcare, smart cities, agriculture, defence, inventory tracking system, various automated systems etc [1]. which motivates the researchers to look out the various issues in WSN and provide the optimal solutions regarding that. Wireless sensor network includes thousands to millions sensor nodes which are having the capability to sense the surrounding area and detecting the particular event like environmental data temperature, humidity etc [2], followed by processing and transmission of data to base station (sink node). Sensor nodes are deployed in an area called Field of Interest (FoI), to monitor the event [3] and collect the information about it when it is happened. It becomes very important to deploy sensor nodes in FoI effectively so that whole deployment region or all target locations should be monitored by at least one sensor node defined as Coverage. Coverage is Quality of service (QoS) parameter to indicate the effectiveness of monitoring abilities and preciseness of collected information that incorporate reliability and quality in WSN design. Coverage can be of different category based on the nature and surveillance requirement of application [4] , for instance predicting the environmental conditions require the whole area to be covered or some application require some target points to be covered by sensor node or some critical applications require only the border of monitoring area to be covered by sensor nodes for detection of any movement or intrusion as all this is classified as types of coverage.

Nodes deployment in WSN effects the sensing ability of nodes which is in direct relation with coverage. Effective node deployment approach aims for better monitoring of the sensing region. Different Situations in deployment scenario can arise specially when a field segment is not covered by single sensor node are termed as coverage hole, whereas similar set of target points are covered by multiple sensor nodes are characterized as coverage redundancy [5]. The occurrence of coverage hole is indication of degradation of QoS of WSN as any event in uncovered segment of FoI is not detected which tends to degrade the quality of information. Coverage overlapping can be promising or discouraging for WSN based on the nature and application. The occurrence of coverage overlapping is considerable with respect to fault-tolerant WSN as in case of failure of any sensor node, coverage is performed by the redundant nodes. The effective use of redundant nodes in the regular intervals enhances the network lifetime and make WSN energy efficient as sensor nodes are not required to perform the sensing of identical target points which prevents the quick energy depletion of nodes. On the other side, some applications require cost-effective coverage with deployment of minimal number of sensor nodes which motivates the elimination of redundant nodes and to achieve the minimum coverage overlapping. Coverage optimization is performed in various research work to maximize the covering of monitoring field with the multiple objectives and deliver the balance between them.

Sensor node needs to be connected to base station for smooth transmission of processed data i.e. wireless sensor network should be connected. WSN is connected if there are single or multi communication paths among sensor nodes [6] and base station. Connectivity is another QoS parameter which assures the delivery of data to the base station. Once the sensor nodes collect the information where they are deployed, then it becomes very important that all the information should be reached to base station for further processing. Sensor node communicates to sink node via single-hop or multi-hop path. Single-hop involves the direct communication while multi-hop involves intermediary sensor nodes or relay nodes [7] for forwarding the data. Integration of coverage maximization with connectivity has been proposed and discussed in some research works using different methodology.

Intelligence-inspired computing is inspired from intelligence behaviour of different creatures to perform their regular duties and expressed as mathematical model. Intelligence-inspired computing helps to derive near-optimal solutions of optimization problems. The problem of coverage optimization in WSN is addressed using intelligence-inspired algorithms under different parameters. The contribution of this paper is as follows: -

1. Intelligence-inspired computing based various coverage optimization techniques are studied under different conditions and scenarios.
2. Comparative analysis is also performed on various parameters for exploring the need of research on uncovered ideas in coverage optimization.

The structure of this paper has been put out in sections. The first section gives the introduction about WSN and coverage optimization followed by idea of various terminologies associated with it, which will be discussed in Section II. Study of different methodologies for coverage optimization based on various intelligence-inspired algorithms, have been done in Section III. The comparative analysis of various methodologies has been put out based on various parameters in Section IV. At last, the paper is concluded with Discussions and future scope in Section V.

2. BASIC CONCEPTS AND TERMINOLOGIES

Understanding of basic terms and different parameters is required for getting the basic idea about the identified problem, is discussed. The Surveillance field (FoI) has been considered in rectangular shape in graphical explanations. Simulation is carried out in MATLAB R2021A to demonstrate the graphical illustrations of various concepts in this section.

2.1 Sensor Node

Sensor node is considered as disk or circular shape perceptively [8] as shown in figure 1. A sensor node S_i is described as disk with centre (x_i, y_i) and radius R_s and R_c. (x_i, y_i) represents the position of sensor node in field, while R_s (R_s>0) and R_c (R_c>0) are sensing and communication range respectively.

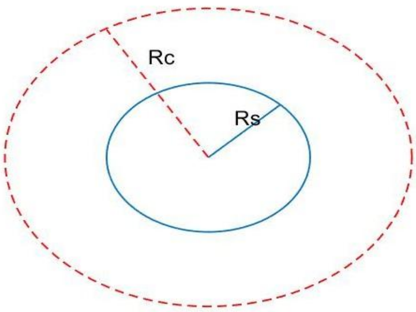


Figure 1: Sensor Node

2.2 Homogenous vs Heterogenous WSN

In homogenous WSN, all sensor nodes are uniform in terms of energy, computation, sensing abilities etc., while in heterogenous WSN, nodes are organized into K different types, where each type is having different resource ability. Both types of WSN is displayed in figure 2.

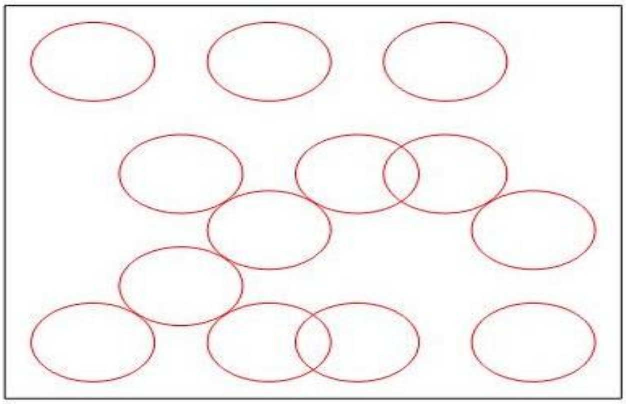


Figure 2: (i) Homogenous WSN with R_s=7m

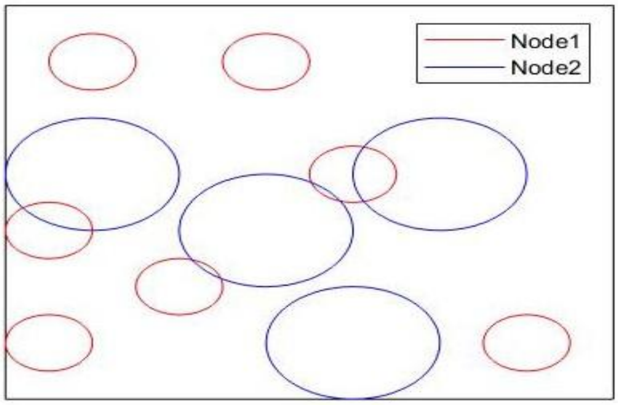


Figure 2: (ii) Heterogenous WSN having two different types of nodes with Rs1=5m, Rs2=10m

2.3 Node Deployment Model

Sensor nodes are deployed using deterministic or randomized approach [9]. Deterministic approach involves the computing of location of sensor nodes using mathematical model and randomized one applies random distribution for placement of nodes. Deterministic model is applicable in monitoring areas where the knowledge about area is known [10]. Deterministic model takes the details of surveillance field to minimize the occurrence of coverage hole and coverage overlapping by determining the positions of sensor nodes precisely. In figure 3, sensor nodes are deployed in rectangular field with sensing range of 10m using both models.

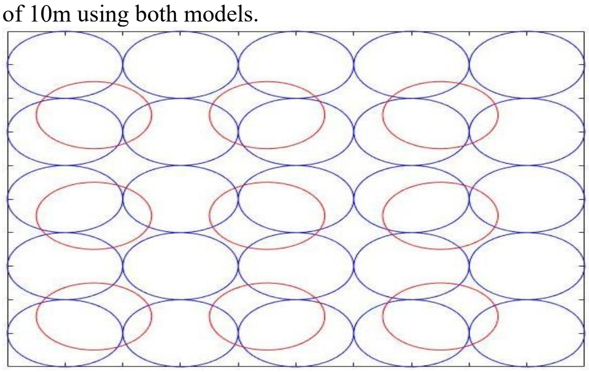


Figure 3: (i) Deterministic Deployment

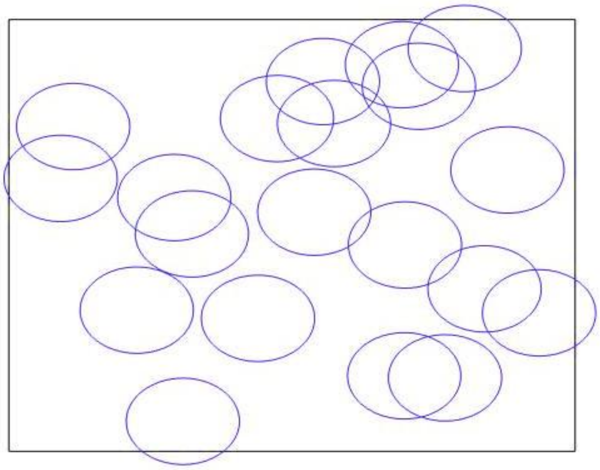


Figure 3: (ii) Random Deployment

2.4 Coverage Classification

Coverage is broadly categorized into area, point and border coverage [11]. Area coverage is systematic distribution of sensor nodes to cover the entire field of interest while point (also called target) coverage implements the covering of specific target points in monitoring field. Border coverage (also called barrier) is based on the covering the movement across the barrier of sensors [12]. It is mostly applicable in border areas of surveillance area. Area coverage is perceptively illustrated in figure 4(i), where the monitoring field is divided into grid area with placement of grid point in each area and sensors nodes are deterministically deployed to cover each of the grid (target) point as this is represented as full coverage, while some specific target points are covered in figure 4(ii) to display target coverage. The different forms of barrier coverage is demonstrated in figure 4(iii) as right side one shows the undetected movement across the fencing of sensors.

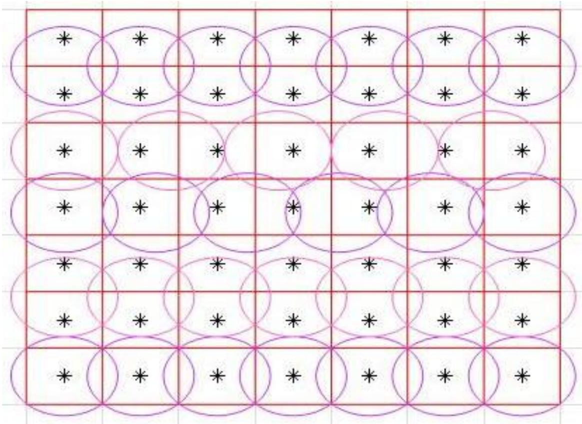


Figure 4: (i) Area Coverage

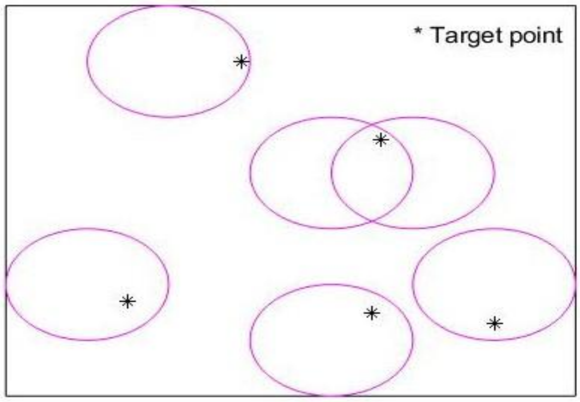


Figure 4: (ii) Target Coverage

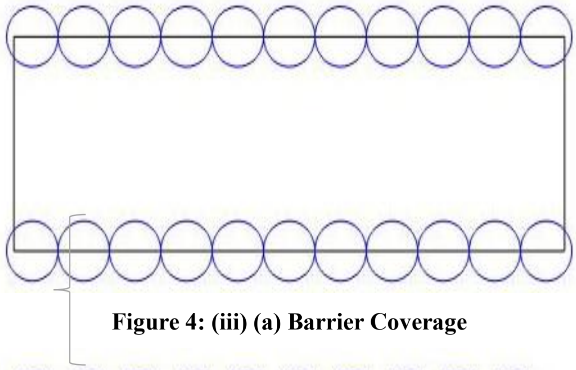


Figure 4: (iii) (a) Barrier Coverage

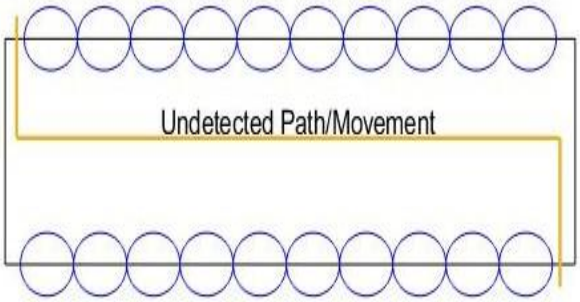


Figure 4: (iii) (b) Barrier Coverage with undetected sensing area

2.6 Sensing Model

Sensing behaviour of sensor nodes is characterized as mathematical model, which defines the sensivity of target locations. A sensor node with a shape of disk is situated at its centre coordinates and sensivity of target points is dependent on distance from sensor node as sensivity will decrease if points are located far away from sensor node. Bianry and Probabilistic sensing model [14] are utilized for this purpose. In binary sensing model, event is detected if they occur within the sensing range of sensor node otherwise not. The deployment of WSN suffers from surrounding environmental conditions or obstacles placed in monitoring area which affects the sensing, so in probabilistic sensing model, factor of uncertainty is considered and derived for determining the sensivity in terms of probability ranges from 0 to 1. In the Probabilistic sensing model, uncertainty factor R_u is taken ($R_u < R_s$) and event is monitored with probability 1 and 0 if it occurs within the range of (R_s - R_u) and outside the range of (R_s + R_u). The probability for detection of an event between (R_s - R_u) and (R_s + R_u) lies between 0 and 1. Both sensing models are illustrated in figure 6.

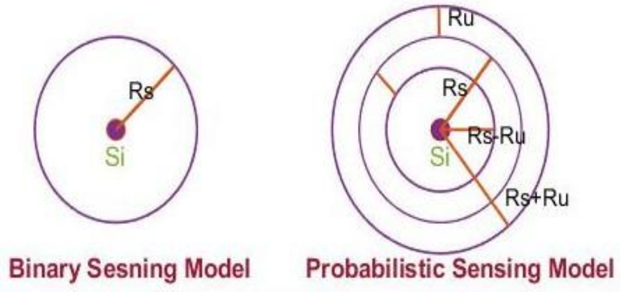


Figure 6: Sensing Model

2.7 Coverage Model

It is described as mathematical model for determing the coverage. Coverage of target is derived from the sensing as two coverage models are used i.e. binary and probabilistic. Binary coverage model yields coverage probability as 1 if target point of surveillance region lie within the sensing range of node, otherwise 0. It is determined by computing the Euclidean distance from the target point and sensor node and comparing with sensing range of node. The coverage probability based on probabilistic sensing model is as follows in eq. 1 [14].

$$C_P(S_i)= \begin{cases} 0, & d(S_i, p) > (R_s + R_u) \\ e^{-\Upsilon k} & (R_s + R_u) <= d(S_i, p) <= (R_s + R_u) \\ 1 & d(S_i, p) < (R_s - R_u) \end{cases} \quad (1)$$

where $k=a^{\beta}$ and $a= d(S_i, p) – (R_s - R_u)$. Υ and β are the detection probabilities when monitored object is some distance away from the location of sensor node. $C_P(S_i)$ is the coverage probability of a point p (x_p,y_p) by sensor node S_i (x_i,y_i) and $d(S_i, p)$ is the euclidean distance between sensor node S_i and point p which is computed as given in eq. 2.

$$d(S_i, p) = \sqrt{(x_i – x_p)^2 + (y_i – y_p)^2} \quad (2)$$

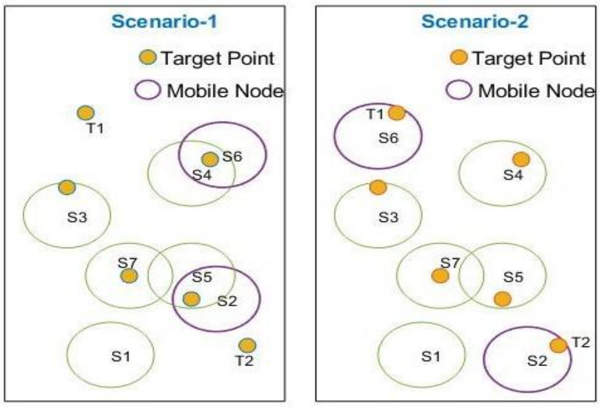
Coverage probability is evaluated collectively when target point is covered by more than one sensor node and computed as sum of coverage probabilities of sensor nodes covering the point.

2.8 WSN Classification Based on Mobility Criteria of Sensor Nodes

Sensor nodes are categorized into static and mobile on the basis of mobility criteria. Static nodes do not have the movement ability, while mobile nodes perform the movement. In order to optimize the coverage, it is required for sensor nodes move to another location but suffers from rapid energy consumption. Deployment of mobile nodes incurs the cost as these nodes are placed several times during their movement. Wireless sensor networks are defined as static, mobile or hybrid on this basis. Hybrid WSN includes the both static and mobile nodes which tries to balance between energy-efficiency and effective coverage along with the maintenance of deployment cost of WSN.

2.9 Deployment Scenario

Effective node deployment is the key issue for coverage enhancement in WSN. Nodes should be deployed on the desired locations to achieve optimum coverage. On nature, deployment can be static or dynamic based on the application. Node deployment is remained unchanged in static, once nodes are deployed. Dynamic deployment involves changes in deployment after initial one. Sensor nodes are deployed randomly in initial phase as there is no information about region of interest which is followed by performing the deterministic approach for determing the desired location of nodes w.r.t the objective and movement is performed subsequently. Nodes are dynamically adopted to their position for desired output. The sensor nodes are randomly deployed in figure 7(i), where target points T1 and T2 are left uncovered and create coverage hole. Mobile nodes S2 and S6 are moved to their optimized positions to cover T1 & T2 in next scenario without affecting the coverage as displayed in figure 7(ii).



(i) **(ii)**

Figure 7: Dynamic Deployment

2.10 Connectivity

This parameter mathematically models the communication path from each of the sensor node to base station. It ensures the presence of communication path among the sensor nodes. It becomes important that sensor nodes should be connected to sink node for communicating the data. Node communication is performed via communication range R_c which defines the maximum area for transmission [15]. Two nodes are connected if they are located within their communication ranges. k-Connectivity is also addressed for solving the fault-tolerance issue as each sensor node having the different communication routes to k number of different sensor nodes, ensures WSN connected even after failure of k-1 sensor nodes [16]. Connectivity among sensor nodes and connected WSN (1-Connectivity) is illustrated in figure 8.

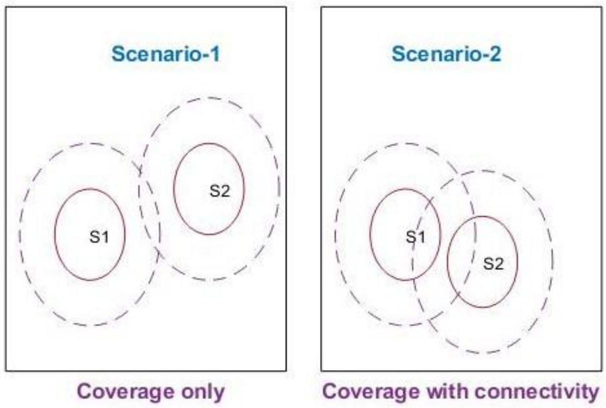


Figure 8: (i) Coverage & Connectivity

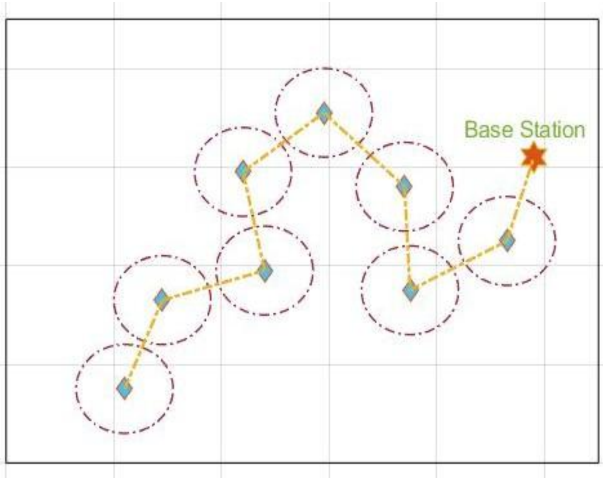


Figure 8: (ii) Connected WSN

2.11 Evaluation Criteria

A number of different methodologies have been adopted to improvising the coverage and tried to achieve optimal coverage. Subsequently, comparative analysis has been made based on the evaluating criteria. Coverage ratio/rate is the performance metrics for evaluating the coverage. Coverage ratio is described as total no of points covered by all the deployed sensor nodes collectively to total number of points/target locations in the detection area. Another metric is optimum number of sensor nodes required to achieve desire coverage which results in reduction of deployment cost of WSN.

2.12 Intelligence-Inspired Algorithm's (IIA) Paradigm

A number of different techniques based on this computing have been evolved to achieve near optimal solution of coverage optimization. No-free lunch theorem [17] states that No universal optimization computing is able to solve all problems. Different paradigm has been adopted by IIA as original, improved or modified and hybrid. Original approach reflects the no modification is derived in computing as it proposed by author. Improved approach experiences the addition of strategies in the existing or original one for betterment. Hybrid involves the integration of two or more IIA to take out the best of their computing and try to achieve optimal results.

3. INTELLIGENCE-INSPIRED ALGORITHM BASED COVERAGE OPTIMIZATION IN WSN

Different techniques based on intelligence-inspired algorithm to achieve optimized coverage has been proposed in research works and is studied and analysed with various factors.

H. Zhao et al. [18] introduced node deployment based on intelligence behaviour of fruit fly with the objective of uniform node deployment and enhancement of coverage rate in WSN. Author took the inspiration from food searching habit of fruit fly group with their smell and vision abilities. Binary coverage model is used for determing the coverage. The effectiveness of node deployment is evaluated by placing the obstacles in the circular and rectangular shape in the field. The performance of this approach is comparatively evaluated with PSO and GSO based one.

R. Ozdag et al. [19] presented the balanced effective node deployment with the aim of prolonging the network lifetime based on whale optimization algorithm which is inspired from hunting behaviour of humpback whales. Author involved the mobile sensor nodes homogenous in nature for measuring the performance of proposed method by evaluating the node distribution and coverage in WSN. Binary sensing model is used for computing the coverage of target points.

L. Wang et al. [20] proposed the methodology based on improved form of whale swarm optimization to determine the maximum coverage. Author also included the issue of more energy consumption and derived the multi-objective fitness function combining the coverage ratio, utilization of sensor nodes and energy-consumption by all the deployed sensor nodes. The idea is to deploy the sensor nodes in such a way utilization of deployed sensor nodes should be done in energy efficient way by achieving the maximum coverage.

Cuckoo search coverage optimization is proposed by T. Xiang et al. [21] in the mixed WSN where objective is performed in two phases. In this research work, static nodes are taken for balancing the deployment cost of WSN and optimum positions are determined for mobile nodes based on cuckoo search to achieve the ideal coverage. Further, position optimization strategy is applied to enhance the network lifetime by minimizing the mobile nodes with the approach of eliminating the extra ones and reducing the movement of mobile nodes without affecting the optimal coverage.

B. Gorkemli et al. [22] proposed enhanced version of artificial bee colony named as qABC for node deployment approach in WSN to minimize the uncovered area. Authors considered both mobile WSN and hybrid WSN for evaluating the performance of the proposed technique. In this work, node deployment is updated after the random deployment in initial phase as mobile nodes move to their positions until the termination of specific condition as termed as dynamic deployment. Performance is measured in terms of coverage by varying the different parameters and number of mobile nodes.

S.S. Mohar et al. [23] presented bat inspired algorithm with the aim of obtaining the uniform node distribution in the given deployment area. This approach demonstrates the food searching and collection habit of bat. 1-coverage policy is strictly observed in this research paper as points inside the region is covered by exactly one node and then excluded for rest of the process, to eliminate the cost of overlapping and balancing the load of sensor nodes. Binary detection model is involved to computing the coverage. Apart from optimized coverage rate, load-balancing of sensor nodes is also achieved.

The optimizing issue of coverage along with the connectivity is addressed in the proposed research work by J. Chelliah et al. [24]. This research work adopts the hybrid paradigm of intelligence-inspired algorithm to discover the optimal position for sensor nodes for covering the target locations effectively. This approach is mainly cantered on point coverage where locations of target points and sensor nodes are given in the monitoring region and compute the minimum number of sensor nodes with their optimum locations to get the desired coverage and connectivity. Author applied the weighted sum approach for resolving the conflicts among objectives and derived the multi-objective function comprising of having minimum number of sensor nodes with good coverage with connectivity.

A hybridized approach of intelligence-inspired computing is proposed by H. Deghbouch et al. [25] for producing efficient node deployment to achieve optimal coverage. Apart from coverage rate, energy consumption of sensor nodes and overlapped area between sensor nodes is also considered as performance metrics for evaluating the node deployment. After determing the optimized positions for sensor nodes, the movement of sensor nodes is minimized by restricting the boundaries which tends to have less energy consumption. A mix of static and mobile sensor nodes has also been included for evaluating the deployment. This method performs better in terms of maximizing the coverage ratio and minimizing the energy consumption and coverage overlapping as compared to bat algorithm and improved grey wolf optimizer.

W. Chen et al. [26] proposed an approach for coverage maximization using efficient node deployment along with the purpose of reducing the deployment cost of WSN by minimizing the number of sensor nodes. Ant lion optimizer has been proposed in this work, is improvised with the integration of cuckoo search and differential evolution. Probabilistic coverage model is used for determining the coverage of target points. This approach performs better in coverage rate along with reduction in coverage hole and coverage overlapping.

Q. He et al. [27] presented marine predator algorithm's improved version for solving the coverage optimization problem which is inspired from hunting behaviour of marine predators. Author applied probabilistic coverage model to determine the coverage of points. The concept of joint coverage probability is applied as target points can be sensed by multiple sensors at same time. Performance is evaluated by computing the coverage rate.

The hunting behaviour of Cheetah is taken as inspiration for determining the uniform node deployment. and maximize the coverage in WSN. M. Basirnezhad et al. [28] improvised the Cheetah algorithm with addition of hunting behaviour of cheetah and implemented to optimize the coverage in WSN. Probabilistic coverage model is applied in this approach to compute the coverage ratio.

D.D. Yang et al. [29] constructed salp swarm optimizer based methodology for optimizing the coverage and ensures connectivity among sensor nodes. Effective node utilization and balanced energy consumption for improvement in network lifetime are the other objectives of this research work. The optimum deployment of nodes should be done to achieve load balancing among nodes to minimize the unbalanced energy consumption with enhanced coverage. The multi-objective function treated as fitness function is built based on weighted sum approach combining all these factors. The factor of obstacles in diamond and triangular shape, is also been considered in this work along with approach for handling these in the field for evaluating the coverage. Connectivity is addressed in the form of graph where connection among sensor nodes is defined w.r.t communication range and derive the transitive closure and check whether all the terms show the connectivity.

An improved version of PSO algorithm has been proposed by K.V.N.A. Bhargavi et al. [30] for deployment of sensor nodes to achieve the optimum coverage by covering the coverage hole and minimizing the coverage overlapping. The proposed method avoids the node deployment in neighbouring position as multiple nodes sense the same target location which tends to quick energy depletion of node and propose sleep-wake up scheduling for redundant nodes to make coverage energy-efficient. This approach integrates Delaunay triangulation with PSO which adopts the methodology to remove the hole at the boundary of deployed region followed by deploying nodes in optimal positions to cover the hole at minimum level.

A node placement technique based on Satin bower bird with reinforcement learning mechanism is introduced by S.M. Kusuma et al. [31]. This research emphasizes on the deployment of minimum number of nodes ensuring adequate coverage and maximize the network lifetime. The concept of reinforcement learning is adopted for sensor nodes to adjust to better position respective of considerable factors and surrounding environment. The concept of placing the relay nodes at the optimum position for forwarding the data, is also included for addressing the connectivity. Performance is measured by measuring the number of selected positions out of possible ones, number of placed sensor and relay nodes against different number of target positions.

V. Saravanan et al. [32] established coverage improvement scheme of homogenous sensor node based on walrus optimization algorithm inspired from the regular activities of walrus i.e. feeding, migration, breeding, escaping, etc. Area coverage is optimized using by determining the near ideal positions and placing the sensor nodes on these locations. Author computed function value for measuring the optimized coverage as well as the packet delivery ratio (PDR) and throughput for evaluating connectivity.

An improved version of grey wolf optimizer has been introduced by Y. Ou et al. [33] for enhancing the coverage rate. Multiple strategies such as Sobol sequence for initialization, search space strategy, integration of reverse learning and mirror mapping and levy flight simulation to avoid the local minimum are involved. The monitoring region is divided into equal sized grids for monitoring the target points. The simulation is carried out in python and performance is measured in terms of node deployment graph and evaluating the coverage rate against different parameters.

This section has covered various methodologies based on different intelligence-inspired algorithm which has been applied in the area of coverage optimization and analysed in brief.

4. COMPARATIVE STUDY OF IIA BASED DIFFERENT COVERAGE OPTIMIZATION TECHNIQUES

A comparative study of different coverage optimization approaches based on intelligence-inspired algorithms is carried out in this section by considering the various factors such as IIA model, objectives accompanied with coverage (coverage type, connectivity), coverage model etc.

Table 1: Comparative Assessment of IIA based different techniques for Coverage Optimization in WSN

Reference	Coverage	WSN type based on Mobility	Coverage Model	Connectivity	IIA's paradigm	Remarks
H. Zhao et. al [18]	Area	Mobile	Binary	×	Original	The presence of obstacles in the monitoring field is included for observing the effect on coverage of target points. Connectivity among sensor nodes is not addressed.
R. Ozdag et. al [19]	Area	Mobile	Binary	×	Original	Mobile nodes are moved to the sub-optimal locations for enhancement of area coverage. The factor of obstacle and connectivity is not addressed.
L. Wang et. al [20]	Area	Mobile	Binary	×	Improved	Balanced Energy consumption is addressed along with coverage and effective node utilization. No study on hybrid WSN is performed.
T. Xiang et. al [21]	Area	Hybrid	Binary	×	Original	Network lifetime is prolonged by efficient use of sensor nodes and redundant nodes are eliminated to reduce the wastage of resources and deployment value of network.
B. Gorkemli et. al [22]	Area	Mobile & Hybrid	Binary & Probabilistic	×	Improved	The objective is to maximize the coverage by minimizing the uncovered area. The dynamically arrangement of nodes is carried out using different scenarios and parameters.
S.S. Mohar et. al [23]	Area	Mobile	Binary	×	Original	The uniform node distribution is performed for improvising the coverage. Coverage degree of 1 is strictly obeyed for balancing the load factor of nodes.
J. Chelliah et. al [24]	Point	Mobile	-	✓	Hybrid	Minimum no. of sensor nodes are deployed on optimum among the possible positions to ensure coverage of target locations. Obstacle factor is not studied in this work.
H. Deghbouch et. al [25]	Area	Mobile & Hybrid	Binary	×	Hybrid	Coverage is enhanced comparatively by optimizing the distribution of nodes. Energy-efficiency is motivated by minimizing the movement distance of sensor nodes.
W. Chen et. al [26]	Area	Mobile	Probabilistic	×	Hybrid	Coverage is optimized using deploying the minimum number of sensor nodes to reduce the coverage overlapping and deployment cost. Connectivity is not ensured in the proposed work.
Q. He et. al [27]	Area	Mobile	Probabilistic	×	Improved	Coverage is determined in the homogenous WSN. Apart from coverage, no other objectives are addressed for making the network more reliable.

M. Basirnezhad et. al [28]	Area	Mobile	Probabilistic	×	Original	Performs relatively better than TSA, MPA algorithms in terms of coverage rate.
D.D. Yang et. al [29]	Area	Mobile	Probabilistic	✓	Improved	Coverage optimization is performed with presence of obstacles in the FoI along with the mechanism to handle. Connectivity is also ensured for transmission of data to base station. The proposed approach on heterogenous WSN is not studied.
K.V.N.A. Bhargavi et. al [30]	Area	Mobile	Probabilistic	×	Improved	Distribution of nodes at neighbouring positions is avoided to minimize energy consumption of nodes and number of redundant nodes. Obstacles effect on coverage is not included.
S.M. Kusuma et. al [31]	Point	Mobile	-	✓	Improved	Sensor nodes are deployed in a way to achieve optimized point coverage with improvement in network lifetime. Relay nodes are also uniformly distributed for providing connectivity.
V. Saravanan et. al [32]	Area	Mobile	Binary	×	Original	Nodes are placed to achieve better coverage. Apart from coverage rate, packet delivery ratio and throughput is also measured.
Y. Ou et. al [33]	Area	Mobile	Binary	×	Improved	Effective node deployment is performed in order to get improved coverage rate. The presence of obstacles is not included in the monitoring area. Heterogenous WSN is also not covered in this methodology.

5. DISCUSSION & FUTURE SCOPE

Wireless sensor network is one of the major research domains in the area of networking, IoT, AI etc. having issues needs to be addressed and good number of research works is being carried out in this regard. A comparative analysis is established among the various techniques inspired from intelligence behaviour of various creatures for optimizing the coverage on the basis of different parameters. Coverage optimization is accompanied by multiple objectives like connectivity, improvement in network lifetime, load-balancing of sensor nodes which contributes in designing the reliable and qualitative WSN. Existing research works as discussed in section III & IV have been reviewed and the following observations have been made on this basis:-

I. Heterogenous WSN are not explored for optimizing the coverage along with addressing the energy-efficient framework along with connectivity. The nodes with relatively higher level of energy level and other resources can monitor the larger area efficiently and utilized as forwarding nodes to make network more energy efficient and enhance the connectivity.

II. In most of the research works, connectivity among the sensor nodes and base station is not addressed. Connectivity should be augmented with coverage more efficiently in the extensive work.

III. A real life environment has the presence of various interruptions including obstacles which affect the coverage ability of sensor nodes. This factor is considered in very few of the existing IIA based approaches. This requires to include the appearance of obstacles with uniform and non-uniform shapes in the surveillance area and implement IIA based techniques to maximize the coverage.

IV. Most of the research work has been carried out using original and improved computing of IIA. Hybrid intelligence computing techniques are not considered more with multi-objectives approach for solving the issue in more optimized way.

V. Coverage optimization should be balanced with other WSN objectives like fault tolerance, Energy efficiency, Deployment cost of sensor nodes to implement coverage in more effective way.

Consequently, these observations should be included and handled efficiently for optimizing the coverage in WSN using more intelligence inspired approaches in context of the future scope.

6. ETHICAL STATEMENT

This study does not contain any studies with human or animal subjects performed by any of the authors.

7. DECLARATIONS
All authors declare that they have no conflicts of interest.

8. DATA AVAILABILITY STATEMENT
Data sharing is not applicable to this article as no new data were created or analyzed in this study.

9. REFERENCES
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