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Optimal Coverage in Wireless Sensor Network using Augmented Nature-Inspired Algorithm

Prof. Parvaneh Basaligheh
University of Tech and Management Malaysia
pbasaligeh@utmcc.my

Abstract

One of the difficult problems that must be carefully considered before any network configuration is getting the best possible network coverage. The amount of redundant information that is sensed is decreased due to optimal network coverage, which also reduces the restricted energy consumption of battery-powered sensors. WSN sensors can sense, receive, and send data concurrently. Along with the energy limitation, accurate sensors and non-redundant data are a crucial challenge for WSNs. To maximize the ideal coverage and reduce the waste of the constrained sensor battery lifespan, all these actions must be accomplished. Augmented Nature-inspired algorithm is showing promise as a solution to the crucial problems in "Wireless Sensor Networks" (WSNs), particularly those related to the reduced sensor lifetime. For "Wireless Sensor Networks" (WSNs) to provide the best coverage, we focus on algorithms that are inspired by Augmented Nature in this research. In wireless sensor networks, the cluster head is chosen using the Diversity-Driven Multi-Parent Evolutionary Algorithm. For Data encryption Improved Identity Based Encryption (IIBE) is used. For centralized optimization and reducing coverage gaps in WSNs Time variant Particle Swarm Optimization (PSO) is used. The suggested model's metrics are examined and compared to various traditional algorithms. This model solves the reduced sensor lifetime and redundant information in Wireless Sensor Networks (WSNs) as well as will give real and effective optimum coverage to the Wireless Sensor Networks (WSNs).

Keywords: Augmented Nature-inspired algorithms, wireless sensor network, Improved Identity Based Encryption, optimum coverage, reduced lifetime, time-variant particle swarm optimization, Multi-Parent Evolutionary Algorithm.

I. INTRODUCTION

Several sensor nodes make create a "wireless sensor network"(WSN) which is capable of communicating both with base station and with other sensor nodes. Depending on the architecture and application, the WSN routing protocol could change. The routing protocol will be difficult because of the sensor nodes' constraints, topological shifts, and unexpected changes in node status. The protocol will fall into one of several categories depending on the network design, such as location-based, hierarchical, or flat-based routing (Anand (2020)). Making sure that the target region can be adequately covered by sensor nodes is vital to increase the monitoring quality and network dependability. A WSN is a network that is often made up of inexpensive, small sensors that have limited storage, processing, and communication power. The massive ad hoc deployment of sensors into the target region by an aircraft is one of the key characteristics of WSNs. Since this enables the suitable construction of the required degree of coverage over a considerable amount of time (Attea et al. (2019)). A wireless sensor network's (WSN) fundamental design is shown in Figure 1.

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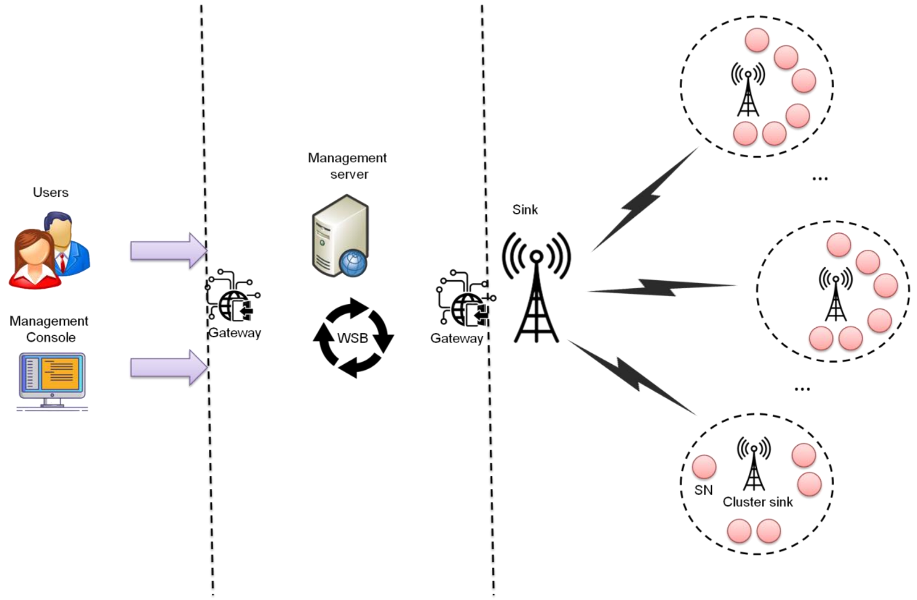

Figure 1: Basic architecture of Wireless Sensor Network (WSN)

WSNs are used in a variety of applications, including item tracking, traffic management, monitoring the environment, identifying and responding to disasters, and practicing accurate and intelligent agriculture, medicine, and health care. When compared to wired networks, WSNs are more affordable to install. They could actively respond to changes in the topology of the network and update their deployment environment to accommodate these alterations (Ketshabetswe et al. (2019)). The use of wireless sensor networks (WSNs) in several applications, such as environmental monitoring, intelligent traffic, and military surveillance, has increased significantly in recent years. Other common uses of WSNs include smart home systems, automated parking distance warnings, and monitoring forest fires. For many applications in WSNs, the gathering of node position data is essential. Only a few anchor nodes in WSNs typically can obtain their locations via loading GPS, etc. because of the limitations of node energy, deployment circumstances, and cost constraints (Wang and Tu (2020)).

WSN is a collection of sensor nodes used for tracking and monitoring that are dispersed around the region of interest (ROI). The main goal of the WSNs is to record noteworthy occurrences occurring in the ROI and transmit this data to the central unit. For the network to run more smoothly, sensor coverage is essential. When sensors are not placed properly, they may provide the least amount of coverage while using the most energy. WSNs are a new breed of versatile sensors that can record various environmental and physical variables. They stand out because of their compact size, limited battery life, limited data processing power, mobility, and potential to organize into networks. WSNs were prompted by military and civilian uses and made feasible by developments in "intelligent systems", "distributed signal processing", and "wireless communication technologies" (Zagrouba and Kardi (2021)).

Since utilizing only a few mobile nodes may significantly enhance network performance, mobile sensor nodes have recently drawn a lot of interest. They categorize three typical mobile node application situations, and we describe the challenges and goals of using mobile nodes to expand network coverage. The model of nodes' mobility strategy is also surveyed recently to maximize network coverage for each application scenario (Wang et al. (2009)). Data collection and transmission to the relevant places in WSNs need the use of routing, which is a crucial duty. The WSN task component that is needed to build up communication and carry out data transfer between sensor nodes and cluster head (CHs) and base station (BS) is the routing mechanism. The development of routing protocols is crucial for resolving these issues; it will also contribute to energy conservation and network longevity. Routing systems are defined in terms of their network architecture, and clustering strategies, among other things; node distribution, coverage, and security are some of the unique characteristics of sensor nodes (Yalçın and Erdem (2019)). To overcome this issue, we use an augmented nature-inspired algorithm (ANIA) in wireless sensor networks.

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The remaining part of the article includes II. Related works, III. Proposed work, IV. Result and Discussion and V. Conclusion.

II. RELATED WORKS

(Alarifi and Tolba (2019)) makes an effort to recommend an ‘energy-efficient reinforcement-based learning’ approach called “Adaptive Q-Learning” (AQL) to enhance network performance in a CIoT supported by sensor networks. Cluster head and forwarder selection are handled by AQL in two separate steps. Nodes are qualified by the decision-making mechanism based on their past transmission behavior. Utilizing adaptive forwarder and header selection criteria, AQL enhances “inter-and intra-cluster communication optimization”. (Daanoune et al. (2021)) categorized LEACH-based routing protocols for the first time in terms of the approaches utilized for ‘CH selection’, ‘data transmission’, and both CH selection and data transmission. They consider a lot of variables while assessing these protocols, including the ‘CH selection’ procedure, communication method, scalability, energy efficiency, mobility, node positioning, and others. In light of these criteria, they suggest comparing various clustered routing techniques. The advantages and disadvantages of each LEACH-variant technique are also included in this survey. (Zhu et al. (2012)) categorized the coverage problem from several perspectives, review research difficulties and current issues in the field, present assessment criteria for coverage management algorithms, and examine the connection between ‘coverage and connectivity’. (Binh et al. (2018)) concentrated on enhancing the area coverage, one of the most important factors that seem to have a significant influence on the performance of the WSNs. The recommended method improves the amount of ground coverage by deploying sensor nodes. (Wen et al. (2020)) proposes a TENG-based direct sensory transmission (TDST) -based “short-range self-powered wireless sensor network” (SS-WSN). The ‘TENG’ signal's output and frequency were increased by quickly discharging using a mechanical switch or a diode-switch combination. This made it possible to transmit signals directly without the use of extra wireless modules or other power sources. Unlike earlier studies, the force-sensing function is carried out with great sensitivity (434.7 Hz.N1) using a steady resonant frequency, and the result is a wireless real-time electronic scale. (Karimi Bidhendi (2022)) aim to determine the optimum cell partitioning, data routing, and deployment techniques for these networks to lower the power consumption of wireless communication. They do this by drawing comparisons between network nodes/cells and quantization points/regions. They specifically considered the effects of both small-scale signal fading and large-scale path-loss signal attenuation. They viewed the node deployment issue as an optimization problem, with the cost function being the network's total power consumption. (Saba et al. (2020)) offers a graph clustering and intelligent routing (EGCIR) approach that balances load distribution and energy consumption using a supervised system for WSNs. The suggested method also includes a secure and effective key distribution in a hierarchy-based mechanism to enhance the network's efficacy in terms of routes and connection integrity. (Tian et al. (2019)) proposed the node optimal coverage approach for wireless sensor networks (WSNs) that is based on the binary ant colony algorithm and an improved genetic algorithm. This approach considers two practical aspects: the wireless sensor networks' high distribution node density and the nodes' requirement for energy conservation.

Problem statement

The initial challenge with WSNs is how to fully cover a monitoring zone. Two of the most basic problems with WSNs are coverage and connection, both of which have a significant effect on how well they work. The network lifespan may be increased by using an optimized deployment method, sleep scheduling system, and coverage radius. Therefore, while designing systems based on WSNs, energy saving is a crucial consideration. We must use the sensors carefully to expand the life of the network since each sensor node has a finite amount of energy. The main concerns confronting WSNs, particularly during routing, are security, privacy, computational and energy limits, and reliability issues. The connected coverage challenge in WSNs is important because sensitive WSN applications need both high levels of connection and coverage.

III. PROPOSED WORK

Area coverage problems and target coverage problems are the two categories under which coverage issues fall. The goal of the area coverage problem is to gather data on an entire region of interest. The target coverage issue, on the other hand, relates to the monitoring of a group of localized areas. This paper proposes a novel algorithm for optimal coverage in WSNs. Figure 2 shows the representation of our suggested methodology.

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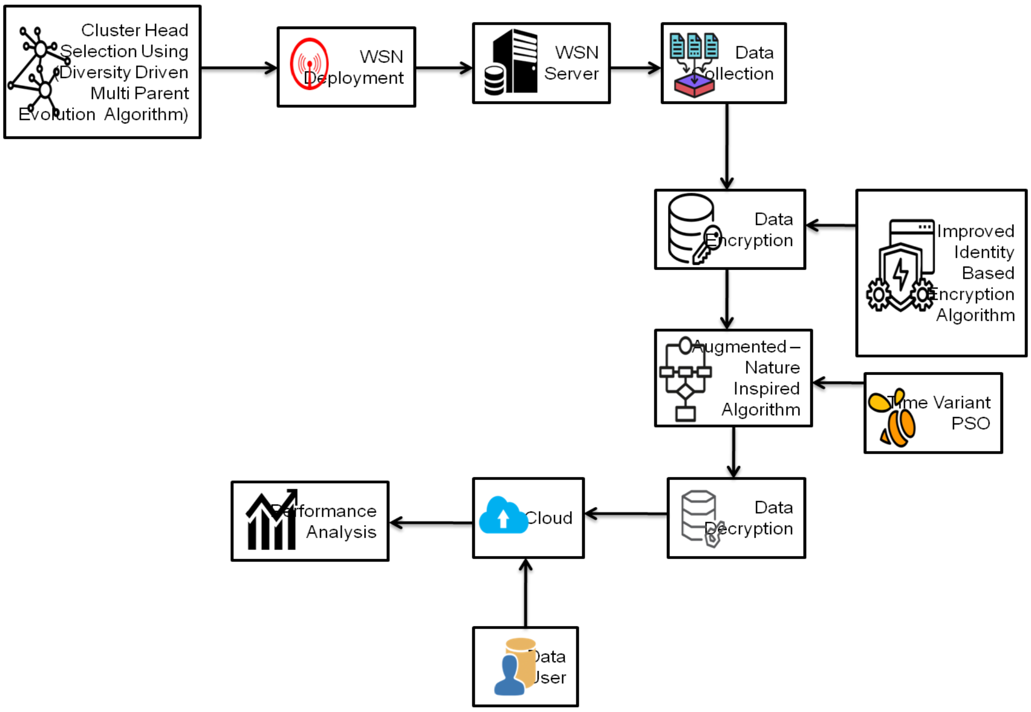

Figure 2: Representation of our suggested methodology

a. Cluster Head Selection using Diversity Driven Multi parent Evolution Algorithm

In a multi-parent crossover, three parents carry out a crossover to give birth to offspring. To create a pool of mating parents, the population's best P percent is selected. Three people are picked at random from this group (z_{g1}, z_{g2}, and z_{g3}) to take part in the crossover procedure and give birth to a child using the calculation below.

$$J_{qo}^{a} = z_{g1.o}^{a} + t_{qo}\left(z_{g1.o}^{a} - z_{g3.o}^{a}\right); \left(q = 1,2,\ldots,\frac{1}{3}.BS.\frac{S}{100}; o = 1,2,\ldots,F\right) \quad (1)$$

Where t_{qo} is a weighting factor, a is the iteration index, and is a 'random number with a mean of 0.7 and a variation of 0.1 from a normal distribution'. Once a participant in the crossover has been selected, an effort is made to ensure that they are not chosen again in the same iteration.

Because it uses more than two parents to produce children, the multi-parent DE crossover is also known as a multi-parent crossover. The three parents' usual distribution is used in the multi-parent crossover to create children. By fusing the power and process of Differential evolution with EA crossover operation.

The off-limit offspring are fixed using the equation below; the multi-parent crossover is present in this method.

$$J_{qo}^{a} = \begin{cases} \frac{z_o^{min} + J_{qo}^{a}}{2}, qdJ_{q.}^{a} < z_o^{min} \\ \frac{z_o^{min} + J_{qo}^{a}}{2}, qdJ_{q.}^{a} < z_o^{min} \end{cases} \quad (2)$$

After "multi-parent crossover operation", the objective description of the issue is used to evaluate the fitness value of newly generated offspring.

b. Data collection

We have taken the Pima aboriginals diabetes dataset that was originally donated by "Vincent Sigillito of the Johns Hopkins University's" Applied Physics Laboratory and the "National Institute of Diabetes and Digestive and Kidney Diseases"(Nilashi et al. (2017)).

c. Data encryption

The security of all currently employed data encryptions in WSNs is based on a large-size pair-wise shared key. A block of large-size data is encrypted using a single large-size key. A link is encrypted by each node, including hardware and network switches. At these points, the whole set of data, including the header and routing data, goes through this process. Integrity and authenticity are the goals of digital signatures, which serve to confirm the sender of communication and show that the content has not been altered.

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Improved identity-based encryption (IBE) algorithm

In an "IBE" system, any string may be used as a public key in this type of public-key encryption. For further information, let's say that a setup procedure is used to produce the "master" public and private keys. The "personal secret key" SK_{ID} may be derived from the master secret key and any string ID 0 or 1. By using the master public key and the string ID, any transmitter may encrypt a message for an "identity" ID. Even though the message is hidden from an unaware opponent SK_{ID}, even if that foe is shown SK_{ID}' for multiple IDs $ID \neq ID$, the resulting secret key may be used to decode the encrypted text that results in SK_{ID}.

d. Augmented-Nature Inspired algorithm

This section has examined the underlying mathematics of algorithms drawn from nature. Any optimization strategy may be theoretically analyzed in computer science. Any naturalistic k-parameter approach for a "single-agent trajectory-based system", s = (s1... sc), and m random variables, = (1,..., u), may be written mathematic.

$$z^{a=1} = \emptyset\left(z^{a}, s(z), \epsilon(z)\right) \quad (3)$$

Where the imperfect solution's non-linear mapping (at+1) to the ideal solution (at + a+ 1) is represented by the symbol as

$$\begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_b \end{bmatrix} = \emptyset\left((z_1^a, z_2^a, \dots, z_b^a); (s_1, s_2, \dots, s_c); (\epsilon_1, \epsilon_2, \dots, \epsilon_u)\right) \begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_b \end{bmatrix} \quad (4)$$

Where (1, 2,..., u) denotes the random variables needed to implement the randomization in the method and (s_1, s_2,..., s_c) denotes algorithm-dependent parameters. All of the above natural inspiration/meta-heuristic algorithms may be included in this mathematical model.

e. Time variant PSO

A simulation of a unique guided, controlled motion of a flock of flying birds served as the basis for the creation of the first PSO. These birds are envisioned as particles, each of which regulates the flight information of its neighbors as well as itself. After a random initialization, multiple iterations are performed, with each cycle ending with an updated particle location (z) and velocity (v), as seen below: The particle number q identifies each particle, such as the bird. Each particle has a location determined by its n-dimensional coordinates and velocity, which indicates how close it is to the ideal position.

$$z^q(c+1) = z^q(c) + \upsilon^q(c+1) \quad (5)$$

$$\upsilon^q(c+1) = y^q \upsilon^q(c) + k_1 g_1\left(z_{best}^q - z^q(c)\right) + k_2 g_2\left(z_{best} z^q(c)\right) \quad (6)$$

q = 1,2,...,N_S; N_S is the swarm's dimensions, c =1,2,... y^q = the mass of each particle's inertia q,

z_{best}^q Is the ideal place for the particle to be, z_{rbest} best position in the swarm of particles overall, k_1 denotes a confidence factor, which symbolizes the particle's inner thoughts; given toz_{best}^q, k_2 represents a confidence factor (given toz_{rbest}), which depicts the cooperation between the particles. g_1, g_2 denotes a random values between [0, 1]. Later, various updated PSO versions with extra characteristics like confidence factors appeared (k_1,k_2) and inertia weight (y) were included.

IV. RESULT AND DISCUSSION

Wormhole resistant hybrid technology (WRHT), Neuro-fuzzy based routing algorithm (NFBRA), Cuckoo optimization algorithm (COA), and "Hybrid Metaheuristic algorithm-based Clustering with Multihop routing" protocol is the currently used techniques (HMA-CMHR). Our suggested approach uses an enhanced algorithm inspired by nature (ANIA).

The augmented-nature inspired algorithm (ANIA) method outperforms other techniques in terms of coverage performance and sustains a level of coverage greater than 80% over an extended number of cycles. Due to ANIA's significant energy savings throughout the early rounds, coverage performance improved. Figure 2 shows the comparison of the coverage ratio with other existing methods.

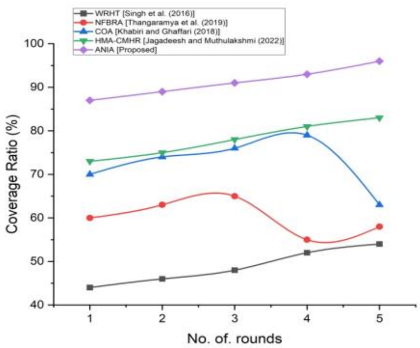

Figure 2: Coverage ratio for 200 deployed nodes

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Decreasing the number of active nodes in each cycle to conserve a significant amount of power and, as a result, lengthen the lifespan of the WSN. Compared to WRHT (Singh et al. (2016)), NFBRA (Thangaramya et al. (2019)), and COA (Khabiri and Ghaffari (2018)), the ANIA (Proposed) protocol activates a greater number of nodes as the number of rounds rises to give a better degree of coverage, as seen in Figure 3. Figure 3 shows the comparison of the active sensor network with other existing methods.

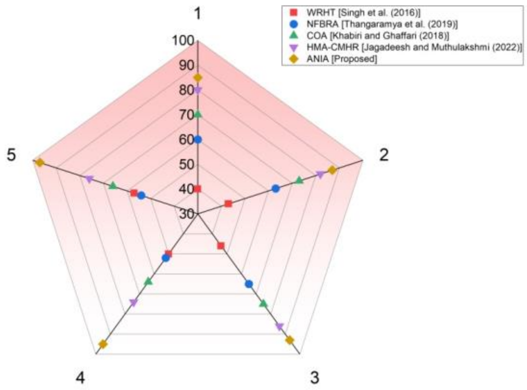

Figure 3: Active sensor ratio for 200 deployed nodes

The influence of network energy consumption on the various sensor node states, for various WSN sizes, is shown in figure 4 along with a comparison to other methods. The comparison demonstrates ANIA supremacy in terms of power conservation. The two figures demonstrate how ANIA uses less energy in comparison to other strategies.

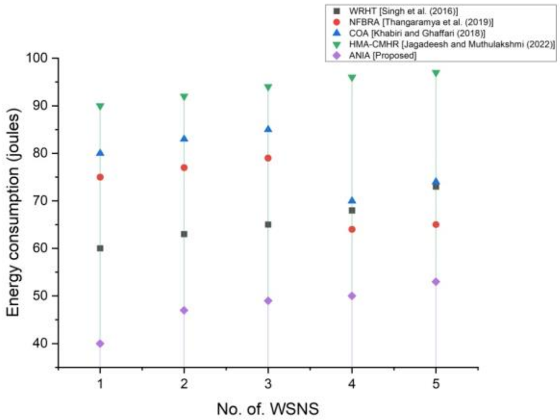

Figure 4: Comparison of Energy consumption per round with suggested methodology

In reality, certain applications may not always need a complete coverage level. For example, a forest fire application only needs an 80 percent coverage level during the wet seasons, but a full coverage level throughout the summer. For all levels of coverage, ANIA consistently outperforms. Furthermore, when the network size grows, the improvement grows as well. The comparison of network lifespan with various approaches is shown in Figure 5.

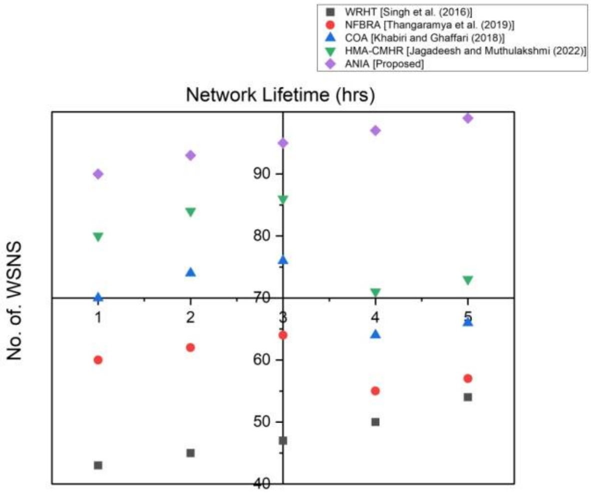

Figure 5: Comparison of network lifetime with other methods

Discussion

In comparison to current distributed approaches, this section discusses how our protocol might work better in a real wireless sensor with restricted resources. For a variety of techniques and various network sizes, the typical amount of time required to resolve our suggested coverage optimization problem is provided. When compared to other existing methods, our proposed method provides a high degree of coverage ratio. The capacity of the network to monitor an area of interest is expressed by area coverage, which denotes that all locations within this area are always being watched. The suggested technique, when compared to other current methods, offers a high level of an active sensor network. One of the most prevalent issues with wireless sensor networks that do not exist in more conventional cable sensor networks is energy consumption. A “wireless sensor network” is heavily dependent on the batteries of each sensor node since they are all battery-operated. When compared to other existing methods, ANIA provides a low degree of energy consumption. A significant performance indicator for WSNs is the network lifespan, which is calculated as the period of time until the energy of the first sensor runs out. Every sensor node in typical WSNs is

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configured to multihop communicate data collected to the sink. When compared to other existing methods, ANIA provides a better lifetime period for the network. The research demonstrates that the ANIA regimen outperforms other strategies in terms of lifespan, degree of coverage, the ratio of active nodes, and the amount of energy used.

V. CONCLUSION

The connected coverage issue is significant for WSNs because sensitive WSN applications need both high levels of connection and coverage. A new era in next-generation computing has begun with the usage of algorithms that are inspired by nature. Multi-objective optimization issues may be solved with the help of these algorithms. Natural-inspired algorithms have several characteristics that make them suitable for solving optimization issues in the real world, including acceptable processing time, finding global optimum, and applicability. We have proposed an augmented nature-inspired algorithm to overcome the issue of optimal coverage in a "wireless sensor network". In the future, our research expands the optimization algorithm and offers a timetable for numerous sensing rounds.

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