Using the Cuckoo Optimization Algorithm to Solve the Point Coverage Problem with Moving Targets in Wireless Sensor Networks

Fen He
Guangzhou Nanyang Polytechnic College
Zhihao Peng
Dalian Neusoft University of Information
Seyedsaeid Mirkamali (s.mirkamali@pnu.ac.ir)
Payame Noor University https://orcid.org/0000-0002-8340-7003

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Using the Cuckoo Optimization Algorithm to Solve the Point Coverage Problem with Moving Targets in Wireless Sensor Networks

[1]Fen He, [2]Zhihao Peng, *[3]Seyedsaeid Mirkamali

[1]School of Information Engineering, Guangzhou Nanyang Polytechnic College, Guangdong, China.
hefen0500@163.com

[2]School of Software, Dalian Neusoft University of Information, Dalian, China.
pengzhihao@neusoft.edu.cn

[3]Department of Computer Engineering and IT, Payame Noor University (PNU), Tehran, Iran
s.mirkamali@pnu.ac.ir

Abstract

Wireless Sensor Networks (WSNs) have been used in many sectors in recent years. Easy deployment and low prices are the main reasons for using WSN. On the other hand, power source limitations and unstructured overlay networks are the major concerns in these kinds of networks. Region coverage is one of the problems that should be solved smartly in order to maximize the productivity of the network. Appropriate sensor selection and efficient energy usage are essential in region coverage. Pointwise coverage is a well-known version of the coverage problem. Since this is an NP-complete problem, many approaches have already been designed to solve it. The main shortcoming in previous works is the short network lifetime due to high energy consumption. In this paper, an enhanced method has been proposed based on the Cuckoo Optimization Algorithm (COA). By means of an adjusted version of the cuckoo search and a heuristic fitness function, it has been possible to expand the lifespan of the network. The proposed algorithm is composed of three phases: the first phase is setting up, the second phase is the selection, and the third phase is stable status. Simulation results show that the proposed method in comparison with recent works has achieved a sensible optimization in energy consumption, lifetime, and coverage quality.

Keywords: Cuckoo Search, Wireless Sensor Network, Pointwise Coverage, Target Monitoring, Network Lifetime

1. Introduction

In recent years, the capabilities of Wireless Sensor Networks (WSN) in various fields, including military, medical services, environmental monitoring, and the high speed of sensors in processing and exchanging information with their neighbors, have attracted the attention of researchers [13, 10]. Due to the smallness and cheapness of the sensors, there are various limitations in equipment such as memory, battery, and processing power [18]. Also, due to the impossibility of recharging the battery in most cases, optimal energy consumption is considered one of the main challenges of sensor networks. Much research has been done to increase the lifetime of sensor networks. The results of this research, the presentation of different protocols and different algorithms aware of energy, in the fields of selecting monitoring sensors [22], maximizing cover categories [11], sensor timing [23], routing [24], data aggregation [25], clustering [26] and etc. has been.

The issue of coverage in sensor networks is one of the parameters of service quality and is one of the significant matters in network performance analysis. This describes how and with what quality the monitored area or targets are monitored [17, 9]. This is discussed in three models:

1. Regional coverage,
2. Border coverage,
3. Point coverage.

In general, the issue of coverage and selection of monitoring sensors is an NP-hard issue [1, 2].

The application of point coverage, on which this paper focuses, is to monitor specific areas of the environment whose location is already known and called the target and should be kept under observation by at least one sensor node [1]. In point coverage, the issue of optimal selection of monitoring sensors in each phase with the aim of increasing network life is an important issue, and many studies have been conducted in this field [1, 6].

The lifetime of a network covering a deployment sensor is said to be until all targets on the network are monitored by at least one node. Accidental placement of sensors in the environment causes the monitoring node density for the monitor to be insufficient for some purposes [8, 6]. Sensors are often exposed to harsh environmental conditions and may be subject to energy depletion or destructive attacks.

Sensors are able to cover the target until their residual energy is greater than one threshold, and nodes whose residual energy is less than the threshold are excluded from the set of active nodes, and the remaining existing sensors must be able to cover the targets [8]. The selected cover nodes are sent to the main station after receiving the information and then provided to the end-user [3]. To increase the lifetime, monitoring energy consumption must also be minimized. Other solutions that can be proposed to extend the existence of the network include scheduling the activity of nodes between sleep and active mode, topological control, energy-conscious routing, etc. [19, 6].

In general, sensors have four modes of data transmission, data reception, idle, and sleep [4, 3]. Nodes in sleep mode have the lowest energy consumption; therefore, when they need to send and monitor the environment, they switch from sleep mode to active mode with a schedule. This process continues until the first target is removed from the monitor. Transfer, receive, and idle modes can be categorized as active because they consume more energy than sleep mode. Nodes change their status to active mode only when they need to send, receive, or monitor the environment, and stay asleep in the rest of the situation [8]. There are three basic requirements for point coverage [10]:

- For each target, it must be specified which sensors can be viewed. These sensors are called target monitor sensors.
- In each period, for each target, a sensor is selected from among the monitoring sensors and is activated and assumes the task of monitoring the target during the period.
- In the case of point coverage in all conditions, even in critical situations where the energy suddenly decreases, all targets must always be monitored by at least one monitoring sensor.

Different solutions are provided to solve the problem of point coverage. In order to use energy efficiently in the matter of point coverage, the following solutions are presented [3].

- Schedule node activities,

- Power control by calibrating the transmission range of wireless nodes,
- Data collection,
- Reduce data transfer and prevent useless activity.

Various papers have tried to improve and enhance the quality of network energy efficiency by using different algorithms, as well as various functions for selecting a monitor sensor.

One way to solve NP-hard problems is to use optimization methods. One of the most useful and effective solutions in optimization methods is the use of metaheuristic algorithms such as the Cuckoo Optimization Algorithm (COA) [20]. Here, a cuckoo-based algorithm scheduling mechanism is used to select active sensors [21]. The aim of this algorithm is to fully meet the required conditions in a point coverage network along with increasing the network lifetime.

This paper provides an algorithm for selecting target monitoring sensors in each round. The purpose of the algorithm presented in this paper is to find the best candidate sensors to cover the targets using the COA. Depending on the characteristics of the candidate nodes around each target, the COA selects the optimal node in respect of remaining energy, distance, and the number of target targets as the active node. By optimizing the active nodes, energy consumption will be decreased, and the network life will be maximized.

In the following, the structure of the paper is organized as follows: In Section 2, energy efficiency and coverage work are presented. The issue of point coverage is described in Section 3. The proposed method and explanation of the algorithm are presented in Section 4. Sections 5 and 6 show the simulation and conclusion results, respectively.

2. Related Works

In recent years, the issue of point coverage has been widely studied. The issue of coverage can be categorized in terms of various aspects: static or mobile (aims or nodes), symmetrical and asymmetric network, centralized or distributed network.

In the case of stationary point coverage, all sensors are static and stationary after deployment and cannot be moved. In moving point coverage, some sensors have the ability to shift some of their energy to better coverage, maintain connectivity, and maintain service quality standards [17, 14].

In symmetrical sensor networks, all sensors are similar and have the same ability to sense, process, and transmit sensed data. In asymmetric sensor networks, the sensors have different capabilities, and the sensors have different capabilities in terms of sensor radius, energy, CPU power, memory, etc., so that a sensor may have several sensor radii. Or the radial characteristics of the sensors are different from each other [19, 5]. In the distributed point coverage network, all coverage operations are performed locally and distributed [12].

In the case of k-coverage, each target must be precisely monitored and covered by the k-sensor from the set of cover sensors. The aim of this method is to minimize the number of active sensors in order to minimize energy consumption [1]. Presents a method for energy optimization in k-coverage in which Dijkstra's algorithm is utilized to discover the shortest path between interface nodes.

Underwater sensor networks are one of the important emerging technologies. In [2], a combined approach is proposed that uses the Depth-first search (DFS) algorithm and the Genetic Algorithm (GA) to solve the problem of spot coverage of underwater sensor networks. The proposed algorithm uses the DFS algorithm to maintain the connection and energy consumption, and the GA is used to monitor the targets and optimally select the active nodes.

In [3], in order to increase the lifetime of the network, the nodes are divided into several cover sets so that the nodes in coverage are set to cover all the goals in the network. In this study, a method based on maximizing the number of cover sets is presented, and the nodes are categorized by linear programming and greedily in the cover sets.

A new greedy exploration method that prioritizes energy-based monitoring sensors has been proposed in [4]. The results presented in the above paper show that the proposed algorithm performed better than previous methods.

A method called Energy-Efficient Distributed Target Coverage Algorithm (EDTC) is presented in [5] that prioritizes target monitoring nodes. Each node is assigned a priority based on its sensory ability, node capability, including location, and the number of targets monitored, and the remaining energy.

In [6], the Energy Efficient Data Gathering (EEDG) method for selecting sensor nodes is presented. The EEDG algorithm prioritizes each node based on the number of targets and the energy of the nodes.

A technique has been presented for point coverage and connection preservation in [7]. The point coverage method provides a process for computing the waiting time that lessens the number of active sensors, which utilizes the Virtual Robust Spanning Tree (VRST) and Modified Virtual Robust Spanning Tree (MVRST) to maintain the connection.

In [8] addresses the issue of maximum coverage for the directional sensor network. The sensors in the Directional Sensor Networks (DSN) have a limited sensor range. Point coverage in these networks is determined by the location and direction of the sensor. The aim of this algorithm is to maximize network life by allocating different schedules for each coverage set. This paper uses a GA-based scheduling mechanism to solve the NP-complete problem of maximum coverage.

In [9] presents another method in which active monitoring nodes are tried to minimize targets in each round using the modified Ant Colony Optimization (ACO) algorithm. The results of the proposed algorithm in comparison with other algorithms compared in the same study show a relative increase in a network lifetime.

A Euclidean approach based on greedy algorithms for selecting overlays in solving point coverage problems is presented in [10]. The proposed solution, with the aim of maximizing network life, introduces a function that selects the active set of unused nodes. In this algorithm, each target can be monitored by two sensors. The sensor that has the most residual energy is chosen as the active sensor.

In the case of Connected Point Coverage (CTC), the aim is to maximize network life so that each set can maintain both coverage and connection between active sensors and the sink. In [11], this has been done using sensors scheduling for multiple sets, and the CTC problem is modeled as a Minimum Cover Tree (MCT). In this proposed algorithm, a high bound for the lifetime of the network is considered to solve it using one of the meta-algorithmic algorithms called Communication Weighted Greedy Cover (CWGC) [11].

In [12], a distributed design called Distributed Lifetime-Maximizing Scheme (DLMS) is proposed for the CTC point coverage problem. In this algorithm, a number of nodes are first selected as the source node to cover all targets by these nodes. Then an optimal path and efficient energy are generated from the source node to the sink so that the source node information is sent to the sink with minimal energy consumption.

In WSN, sensors that can be deployed to monitor targets can be scheduled to improve network life. A learning-based automation method has been proposed in [13] in which each node is equipped with a learning machine, which selects the appropriate state of the node (active or sleep). The proposed timing method prolongs the life of the network compared to its compared sources.

In [14], the optimal selection of active monitor sensors in a connected point coverage network using the Simulated Annealing (SA) algorithm is discussed. The simulation results show the superiority of the proposed method over the studies compared in it.

In [15] and [16] suggest ways to categorize nodes and select nodes for the monitor sensor, which increases the lifetime of a point coverage network by reducing energy consumption. By reducing the number of active sensors using the genetic algorithm while maintaining connectivity, it has reduced energy consumption during a period of sensor network activity.

According to the applications of a sensor network, it can be said that the general aims in a sensor network are accuracy coverage in sending information, reliability, and maximum energy storage according to the user. Achieving these aims requires a network structure with minimal energy consumption. The proposed method in this paper is an attempt to meet this need.

3. System Specification

The system specification is as follows:

- The provided coverage network has a diverse structure in which two classifications of sensors are used. The less capable group is called the ordinary nodes, and the other group that is more capable is called the supernodes.
- The desired network includes *n* sensors. The distribution of all nodes is random.
- All administrator nodes are connected, meaning there is at least one path from the administrator nodes.
- The sensor node has an *E* initial energy, a communication range, and a sensor range.
- Sensors can be in touch with each other and with administrator nodes.
- Each node can be an interface, a monitor sensor, or both.
- Each active sensor node must send its information to at least one interface node by the interface nodes.
- The network is timed and rounded.

3.1 Network Model

The network model is as follows:

-Each node has a distinctive ID.

-Nodes are not conscious of their location and coordinates.

-The number of supernodes is much less than ordinary nodes.

-The energy of the supernodes is considered more than ordinary nodes and is multiplied by the scale.

-All supernodes have the ability to communicate with each other.

-The synchronization of supernodes is done through the central station, and then the synchronization of other nodes is done through the administrator nodes.

-Nodes have the ability to alter the transmitted power and adjust the transmitter power due to increasing and decreasing distance. The nodes are also able to detect the distance based on the received signal energy.

-The number of *i* target is covered by a fixed position in the environment. The desired network is a combination of administrator nodes, sensor nodes, and targets.

3.2 Energy Model

In the proposed model, the network is considered as a graph of *G(N, E)*. *E* is a set of links and *N* is a set of sensor nodes that are randomly distributed. *d* is the distance from the sensor node to the destination, l is the packet length and *Eelec* is the energy wasted in the circuit. Also, the two radio models are considered as energy models based on the distance between the transmitter and the receiver, which include the open space model (*Fs*) and the multi-path model (*Mp*). The parameters of the open space channel with ε_{fs} and the multi-routing channel parameters with $\varepsilon_{mp}$are shown.

For example, the energy consumption of the S_i is calculated to send data directly based on Equation (1).

$$E_1(S_i, CH_{S_i}) = \begin{cases} lE_{elec} + l\varepsilon_{fs} d(S_i, CH_{S_i})^2 & , d < d_0 \\ lE_{elec} + l\varepsilon_{fs} d(S_i, CH_{S_i})^4 & , d \geq d_0 \end{cases} \quad (1)$$

In this case, the S_i uses an intermediate node such as S_j and multi-step routing to send data to save energy. As a result, the S_i uses energy to deliver a packet of length l to the Cluster Head (CH) through multi-step routing based on Equation (2).

$$E_2(S_i, S_j, CH_{S_i}) = E_{TX}\left(l, d(S_i, S_j)\right) + E_{RX}(l) + E_{TX}\left(l, d(S_j, CH_{S_i})\right) \quad (2)$$

Finally, a node is selected that has the least value related to Equation (2) because, in order to select the relay node, it is necessary to establish Equation (3) at the beginning.

$$E_2(S_i, CH_{S_i}) = \text{Min}\left(E_2(S_i, S_j, CH_{S_i})\right) \quad (3)$$

Then the Equation (1) and (3) are examined and finally, the lowest value is selected based on Equation (4).

$$E(S_i, CH_{S_i}) = \text{Min}(E_1(S_i, CH_{S_i}), E_2(S_i, CH_{S_i}) \quad (4)$$

In the proposed model, due to the mobility of the targets, some nodes may use up less energy to forward data to the nearest target, therefore in this study, each sensor node must first calculate the cost of sending the data before sending the data and then transfer through the shortest route based on the Equation (5).

$$\text{Min}(E(S_i, CH_{S_i}), E(S_i, BS)) \quad (5)$$

4. The Proposed Algorithm

Due to the efficient time division of life expectancy in different studies, the basis of the proposed algorithm (COAMS) is based on scheduling. The scheduling protocol means that the existence of the network in the algorithm is divided into equal executable phases. This division is in the sense of dividing the time of network activity into specific and fixed time periods. Scheduling protocols are one of the most popular classification protocols in sensor networks. Typically, these protocols use a two-phase mechanism. The two phases mentioned are under the headings of the establishment phase and the steady-state phase. The first part selects the required sensor nodes with network activity and the second part runs a network round. In these protocols, according to some special parameters and the fulfillment of the goal of the node network, nodes are divided into two categories, active and inactive.

In the under reviewed network, a number of aims are identified with an unspecified position that requires to be controlled. Plenty of sensors are scattered near targets by chance. These sensors transmit the information to the supernodes using interface nodes. At any given moment, each target must be controlled by at least one sensor. In this network, lifetime is defined in such a way that the network is considered alive as long as all the aims covered are monitored. The network life is over when only one point on the monitor is removed from the cover. It should be noted that the activation of monitor nodes is not enough to cover, and the existence of a route for sending data is one of the main conditions. Therefore even when all the targets are covered, but there is no way to send the data to the monitoring sensors, the network life is over.

The goal of this paper is to increase the lifetime of the whole sensor network and to optimally place the nodes in the network so that they cover the weaknesses of the network to maximize the lifetime of the total sensor network.

4.1 Select Active Monitoring Nodes Using COA

To select monitoring nodes (sensor), the proposed algorithm first checks the ability and functionality of the sensors using the fit function. In order to measure the ability of each node for the sensor to be monitored, the remaining energy of the sensor must be more than a threshold. This condition is used to check the minimum capability of the sensors. Nodes that do not meet the required conditions are not suitable candidates for selection as monitoring nodes.

After the random placement of the nodes in the desired coverage network, the setup phase begins, in which each node identifies its communication nodes of the single-hop neighbors. All nodes whose distance from the mentioned node is less than the telecommunication radius of the node are considered to be single-hop neighbors of the node, and this identification of neighbors requires the cost of some energy, which is directly related to the distance between nodes.

In the next step, after identifying the single-hop neighbors, the two-hop neighbors are determined by the nodes. After establishing the nodes and determining the neighbors, the first phase is completed, and the selection phase begins. In this phase, network nodes are categorized for monitoring activity, and it is determined which nodes will be active and which will be inactive in each round. This fitting is done in the proposed algorithm using the COA algorithm.

Many parameters affect the choice or non-selection of a node. The most important parameters are the residual energy of each node, the number of targets monitored by each node, and the distance from each node to the target. Since the activation of each node constitutes the energy consumption of that node, the selected node must have the required amount of energy. Therefore, the remaining energy of each node has a direct effect on whether the node is activated or not.

A node that meets more targets around it can be responsible for monitoring all or part of them, and since most of the energy is used to transmit the monitored data, this results in saving a lot of energy. As a result, a node that meets more targets is a better candidate for activation.

The last involved parameter in the activation of a node is the distance between the node and the target. As mentioned, most of the energy consumption in the network is spent on transmission, and the energy consumption of the transmission has direct and exponential relation related to the transmission distance. The longer the transmission distances, the higher the energy consumption. Therefore, nodes that are closer to the target are more suitable candidates for activation.

The importance and involvement of the mentioned parameters are different from each other, therefore, in the fit function of the COA, the importance of each of these parameters has been determined.

The process and how this decision is made by COA are described below. In the next step, based on the proposed objective function, considering some of the main factors such as the residual energy of each node and the number of goals covered by each node, the average energy, the distance of each node to the target, and the coefficients considered to optimize the function, nodes compete for activation. In Equation (6) the objective function is described.

$$(6)\ Cost(i) = \alpha\left(\frac{Eremaind_i}{E_{ave}}\right) * \beta(target_i) * \gamma\left(\frac{1}{S_i}\right)$$

In this Equation, the $target_i$ is the target covered by each sensor, $Eremaind_i$ is the energy of each node, $Eave$ is the average energy in each round, S_i is the distance between each node and the target. After running the COA algorithm, the active sensor is selected, and the other nodes go to sleep mode.

After running the various rounds, all of these steps should take so that the node that has the least measure of ability also tries to be activated, but does not have the necessary conditions to be activated, and therefore the lack of target coverage message is sent, and the categorizing and execution of the round is stopped, which means the end of the network life. At this time, a message is sent stating that the supernodes are not completely covered, and the network sends the non-coverage announcement to the final destination of the monitoring network.

4.2 Point Coverage Algorithm with Moving Targets Based on COA

The COA is one of the metaheuristic algorithms inspired by nature that is used to solve heuristic problems. In the case of coverage, the use of this algorithm helps to cover the nodes in the network optimally.

Swarm Intelligence Algorithms (SIA) has advantages over other optimization algorithms, which makes their use in the matter of point coverage with moving targets. These advantages include the following:

- They are strong and resilient in the face of dynamic change. Traditional optimization methods are not robust in the face of dynamic environmental changes and need to be restarted to provide solutions. In contrast, SIA is used to adapt the solution to changes in conditions.
- One of the advantages of SIA is that they are able to solve and deal with issues that human knowledge and experience cannot solve.
- SIA can be applied to any problem that can be formulated as an optimization function.
- SIA can be blended with classical optimization techniques.

4.2.1 The Process of COA

This algorithm runs in three phases: the setup phase, which determines the sensory ranges for each target. The selection phase in which the appropriate active node is selected. Stable phase in which data is sent from the target to the monitoring node and from the monitoring node to the central station. The phase of forming the sensor range is performed only once, but the phase of selecting the monitoring node and the steady-state are repeated in each cycle.

4.2.1.1 Setup Phase

The COA is based on the life of a bird called the cuckoo. The unique spawning and breeding of cuckoos set up the basis of this state-of-the-art, optimization algorithm. The cuckoo used in this model is in two types the adult cuckoo and cuckoo egg. The adult cuckoo lays eggs in the nests of other birds, and if the host birds recognize the cuckoo's eggs and do not destroy them, the cuckoo's eggs will grow, and the cuckoo will mature. Environmental characteristics and migration of cuckoos lead to convergence and finding the best environment for breeding cuckoos.

The purpose of using the COA in point coverage is to find the coordinates of the monitoring node so that the distance, energy, and targets covered by the selected node are the most optimal. The COA, like all population search algorithms, begins with an initial population. The aim is to find habitats where the cuckoo's eggs are most likely to survive. In the case of point coverage, the position of the nodes around the target is considered as the habitat of the cuckoos. Once the algorithm is complete and the best habitats are found, the location of the best active node is determined.

To begin the algorithm, a candidate matrix of habitats is generated by the number of cuckoos in the space. In nature, each cuckoo lays between 5 and 20 eggs, and these values are used as the upper and lower constraints of the cuckoo's spawning in different repetitions. Cuckoos lay their eggs in the nests of other birds within their spawning range. After all the cuckoo eggs have been placed in the nests of other birds, those that are less almost identical to the host bird's eggs will be identified and destroyed by the host bird, the rest of the eggs will feed and grow in the host bird's nest.

To find the most suitable habitat, each cuckoo calculates the profitability of each habitat by the objective function. In this case, each habitat includes the location of the nodes around the target. By receiving these nodes and the location of these nodes in the environment, the target function calculates the energy of the nodes and the number of targets covered by each node, the distance between each node and the target, and the profitability of each cuckoo's habitat. In this way, each cuckoo calculates the profit of its habitat, and the habitat that has the most profit is selected as the target point for the migration of other cuckoos.

Cuckoos do not travel all the way when migrating to the target point but pass through part of the path at a deviant angle. As a result, more opportunities for search space are being explored by each cuckoo. This greatly reduces the possibility of local extremism. In fact, the COA, in addition to the general search, also performs the local search. After completing this algorithm, the active node that had the most benefit in the fitness function is selected, and the other nodes are put to sleep.

4.2.1.2 Selection Phase

In each sensory range, not all nodes have the same chance of being activated. The node distance criteria to the target, and the remaining energy of the node, the number of targets monitored by each node are the parameters that are involved in selecting the active node. In this algorithm, there are a number of candidate nodes per activation. In each range, the node that has the most residual energy and the least distance to the target and the number of targets monitored by each node is the first candidate to be activated.

4.2.1.3 Phase Stable Mode

Once all the active nodes have been identified, each target gives its information to the selected active node, and the rest of the nodes are put to sleep or idle.

After the active nodes receive the target data, it sends the received data to the supernode and then to the central station. After all the supernodes have sent their data to the central station, that round ends.

The energy consumption model in this algorithm is similar to the Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm. Figure 1 shows the flowchart of the proposed algorithm.

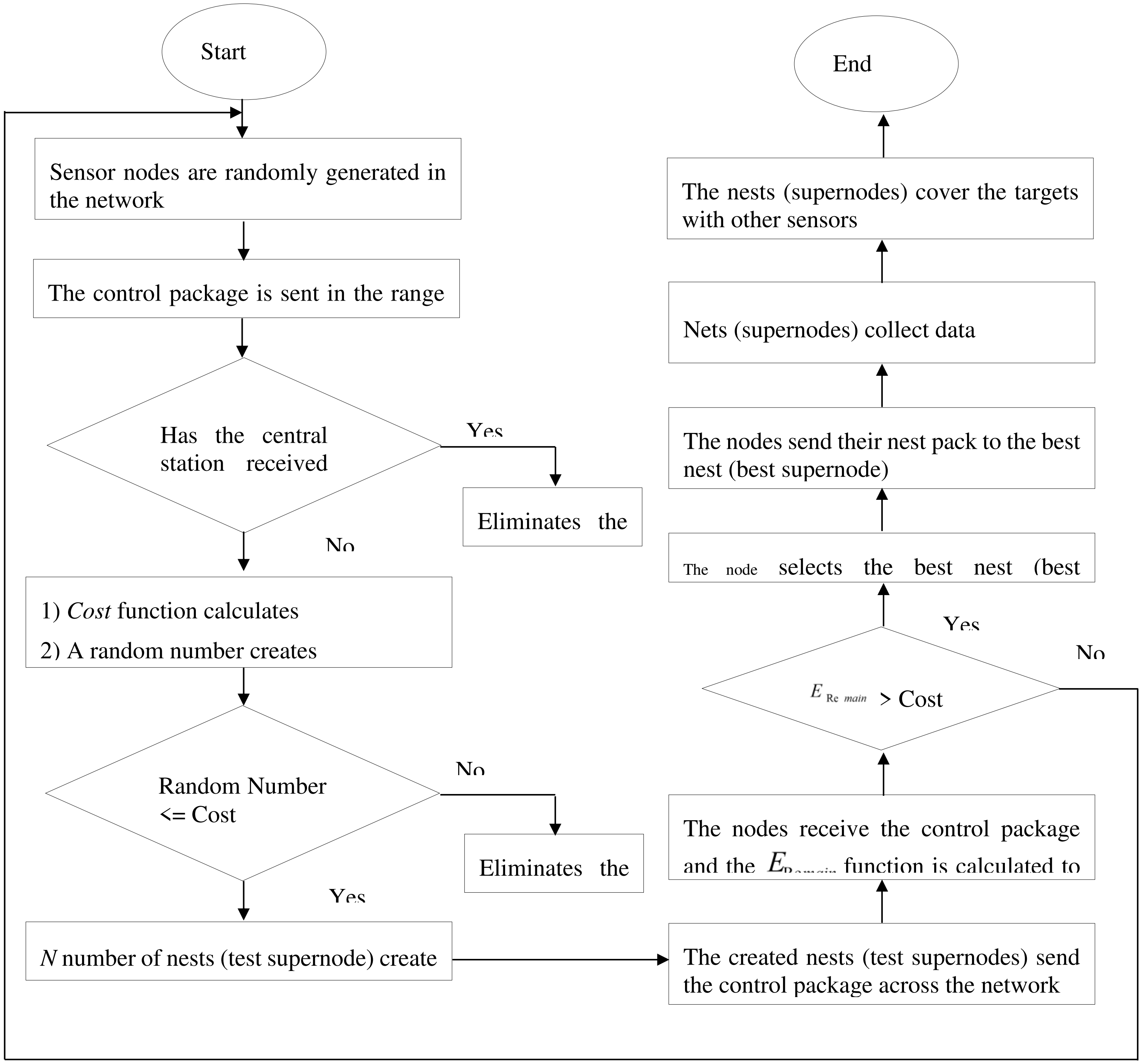

Fig. 1. Flowchart of the proposed algorithm

Figure 2 shows the pseudo-code of the proposed algorithm for solving the point coverage problem in WSN.

Input:

- Given a set *N* of *n* sensor node and a set *T* of t target and a set s of *S* supernode
- iters: total number of iterations
- dS_i: euclidean distance between sensor *i* and target
- $target_i$: number of targets which are seen by the sensor *i*
- $eremaind_i$: remain energy of sensor *i*
- Eave: average energy of all sensors per round

Output:

A converged network`s targets that has monitor all targets

```
BEGIN
sensor nodes and the manager nodes and the target randomly placed on the page
// INITIAL PHASE
For (each target  in Nework())
senseEnvironmetn()
End-For
While (All Targets Could Cover)
// SELECTION PHASE
For (each target in Nework())
For (sensor around the target in the network())
If  E_n>E_astane
Sensor enter to COA
ELSE
The sensor can be removed from the competition
End IF
If  (E_n<E_astane  for all sensor around the target)
network lifetime is over()
End IF
END FOR
END FOR
For (each target  in COA())
Select active node
```

```
END FOR

// STABLE  PHASE
For (active node())
Find the best route from each active node to the sink()
END FOR
End While
END
```

Fig. 2. Pseudo-code of the proposed algorithm to solve the problem of point coverage in WSN

5. Simulation Results

In this section, the performance of the scheduling mechanism provided in asymmetric and symmetrical sensor networks is evaluated in which all sensor nodes and targets are randomly deployed. MATLAB software is used to simulate the network environment. The energy model used in these simulations is the energy model described in [29].

The COA, like all population search algorithms, starts with an initial population and converges after repeated sequences. Figure 3 shows the convergence velocity of the COA.

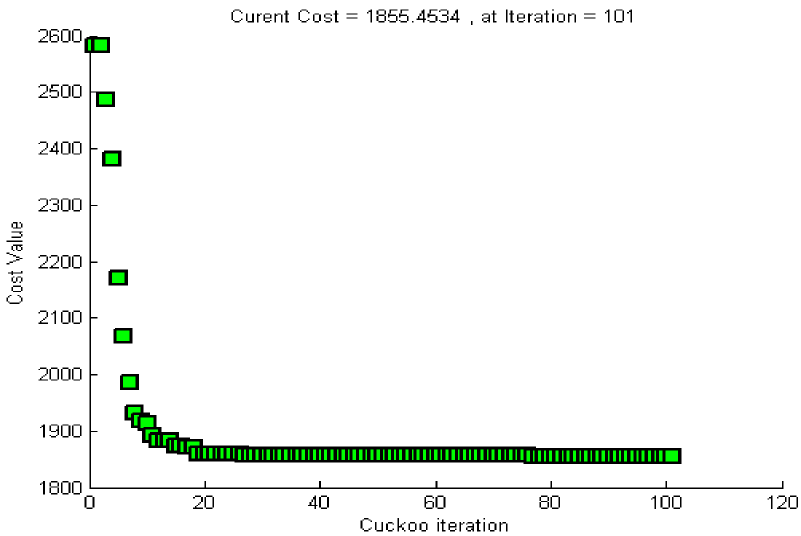

Fig. 3. Convergence velocity in the COA

In COA, energy efficiency has been optimized, and lifetime has been increased by implementing appropriate policies in selecting active nodes. The results of comparing this algorithm with other previous algorithms are shown in the following diagrams.

The following parameters are considered for the COA are given in Table 1.

Table 1. Parameters of the COA

Parameters	Value
The number of cuckoos	5
Minimize the number of eggs in each cuckoo	2
The maximum number of eggs per cuckoo	4
Maximum number of cuckoos	200
Moving coefficient	2
The number of repetitions	20

First, the evaluation of the scheduling mechanism provided in the asymmetric sensor network has been evaluated, and the performance of the scheduling mechanism presented has been compared with the results of the EEDG [6], EDTC [5], SA [14], MSS [16] algorithms. The simulation parameters are given in Table 2.

Table 2. Parameters used in the first simulation [30]

Parameter	Value
Network size	500*500m
SNods location	Random
Nods location	Random
Nods Initial location	0.1J
SuperNods Initial Energy	0.5J
Communication range	90m
Sensing range	60m
Number of nods	300
Number of Snod	25
Number of targets	20
E_{elec}	50 nj/bit

5.1 The Effectiveness of Proposed Algorithm in Asymmetric Network

As can be seen in Figure 4, assuming the same conditions apply to all the compared algorithms, it is observed that in most rounds the energy consumption in the proposed algorithm (COAMS) is less than the compared algorithms EEDG [6], EDTC [5], SA [14], MSS [16] which increases the lifetime of the proposed algorithm by about 6 to 12 percent compared to the maximum lifetime of the studied algorithms. The final residual energy in the proposed algorithm is more than the other four algorithms. Compared to the proposed algorithms, the COAMS algorithm has, in the same way, increased the average network lifetime from 66 rounds to 78 rounds. It should be noted that the value obtained and displayed is the average execution of the algorithm for 10 executions.

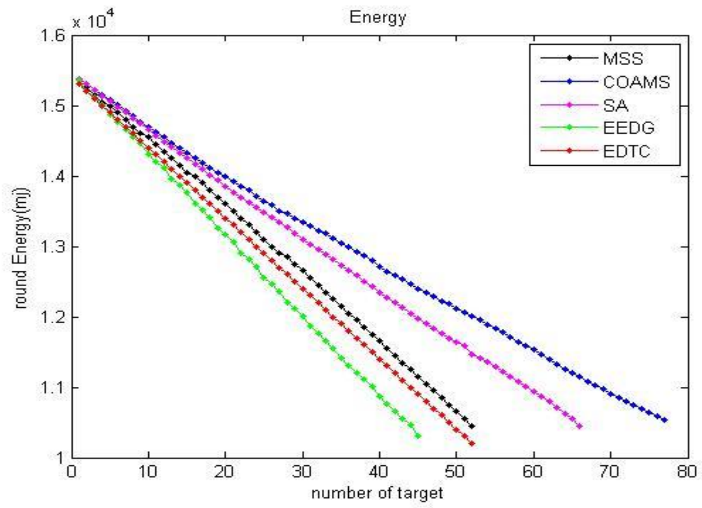

Fig. 4. Comparison of the lifetime of the proposed algorithm network with the compared algorithms

Figure 5 shows the changes in network lifetime as the number of targets changes. As expected, as the number of targets increases, the lifetime of the network is declining. The reason for the deviation of the graph and the non-uniformity of the downward trend is the change in the topology of the network and the instability of the node position for increasing the number of targets. As can be seen in Figure 5, on average, the COAMS algorithm has a longer lifetime than the other four algorithms.

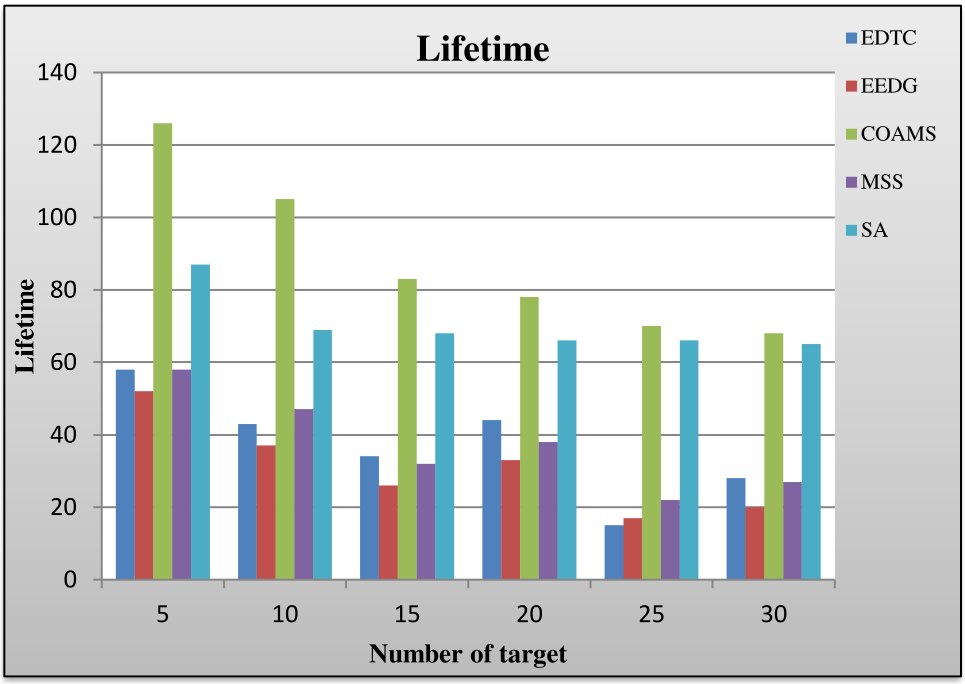

Fig. 5. The rate of change of network lifetime per increase in targets with rearrangement

Figure 6 shows the change in the lifetime of the network for increasing the number of network nodes from 100 to 300 nodes with a fixed number and the same position of the targets and supernodes.

As the number of nodes increases, the nodes around each target increase, and the probability that a node will be selected as an active node in successive cycles decreases, meaning that the role of the active node in the network rotates, and this results in balancing the energy consumption of our entire network and storing more energy in the network. Consequently, it should be eliminated in higher periods of the network.

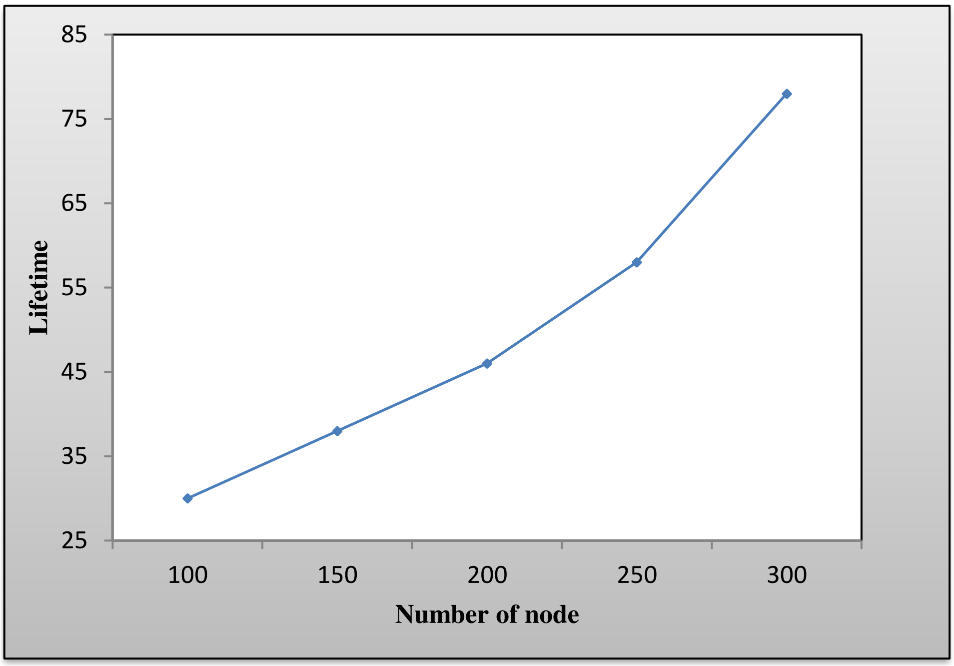

Fig. 6. The rate of change in a network lifetime per increase in the number of network nodes with a fixed arrangement of targets and supernodes

Figure 7 shows the change in the lifetime of the network in terms of increasing the supernodes in the network with a fixed number and the same position of the targets and supernodes.

As supernodes increase, the lifetime of the network increases. The only energy consumption of a supernode is in transfers. The transmission of power is related to distance, and the greater the distance, the greater the power consumption of our energy exponentially, therefore if the number of our supernodes are greater, the distance decreases, and the distance between the transmission of supernodes decrease, the distance of transmission decreases, the energy consumption decreases. Eventually, the energy consumption of the entire network decreases, and the network dies at later intervals, increasing the life of our network.

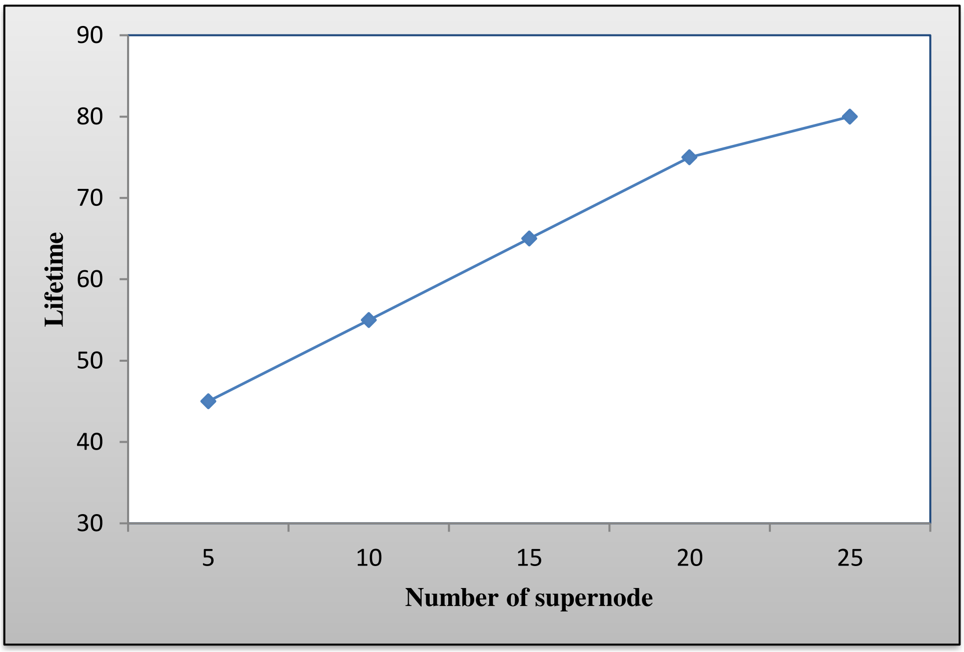

Fig. 7. The rate of change in network lifetime as a result of the increase in supernodes

One of the most important parameters in increasing network life is energy efficiency. Figure 8 shows the energy consumption per round separately. As can be seen, the energy consumption in the COAMS algorithm is less than the other two compared algorithms, which indicates the optimal selection of active nodes in each period.

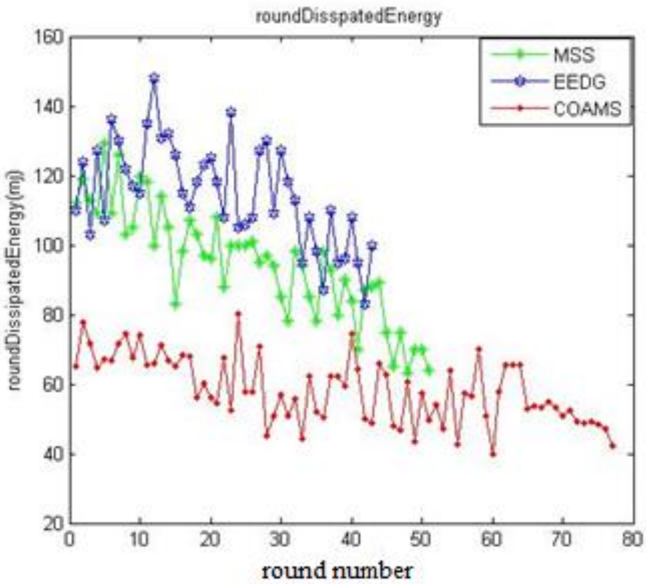

Fig. 8. The rate of change in energy consumption per all three algorithms

Figure 9 shows the number of live nodes per round in the proposed algorithm.

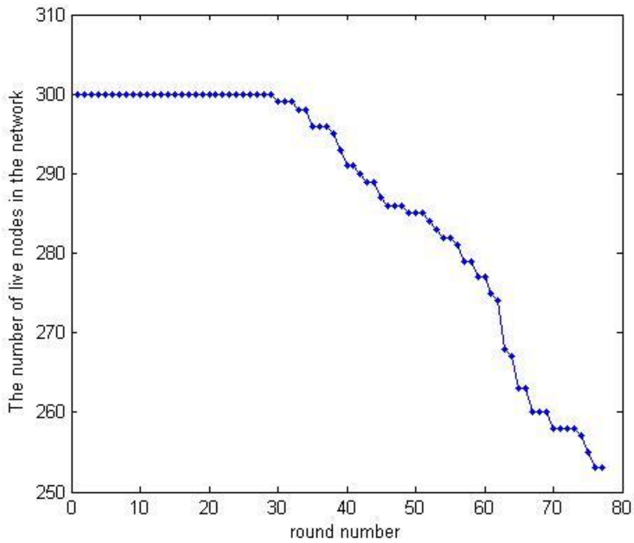

Fig. 9. Number of living nodes per round

5.2 The Implementation of Symmetric Network

We assess the performance results of the proposed scheduling mechanism in the symmetric sensor network. The simulation parameters in Table 3 are as follows:

Table 3. Parameters used in the second simulation

Number of nods	100-300
Number of targets	5-55
Communication range	100-600m

The energy required to transform a sleep node into an active state is negligible. The results are obtained from an average of 20 runs.

In this experiment, the proposed algorithm is compared with the LADSC [13] algorithm. In Figure 10, the two algorithms are compared in terms of lifetime. As you can see in the Figure, the lifetime increases with the number of sensors. COAMS has a longer lifetime than LADSC in all cases.

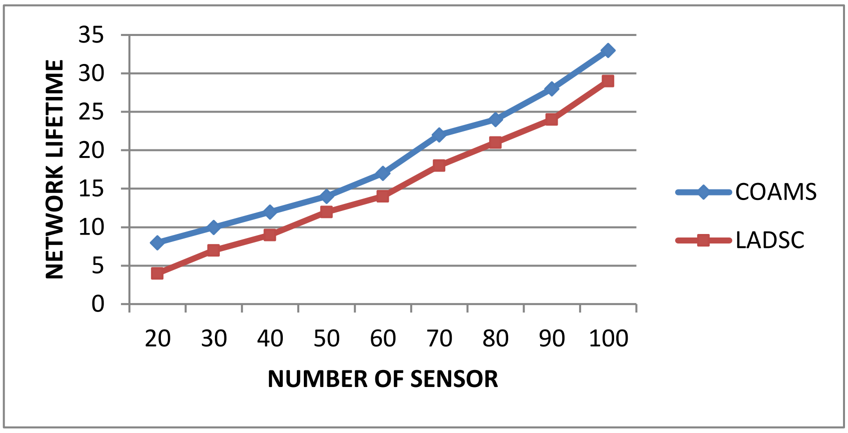

Fig. 10. Increasing the number of sensors from 20 to 100 with a constant sensor range R = 300m and a target number of 50

Figure 11 shows a comparison of network lifetime based on the sensory range of two algorithms. It is observed that by increasing the sensor range, the proposed COMAS algorithm has a longer lifetime than the LADSC algorithm [13].

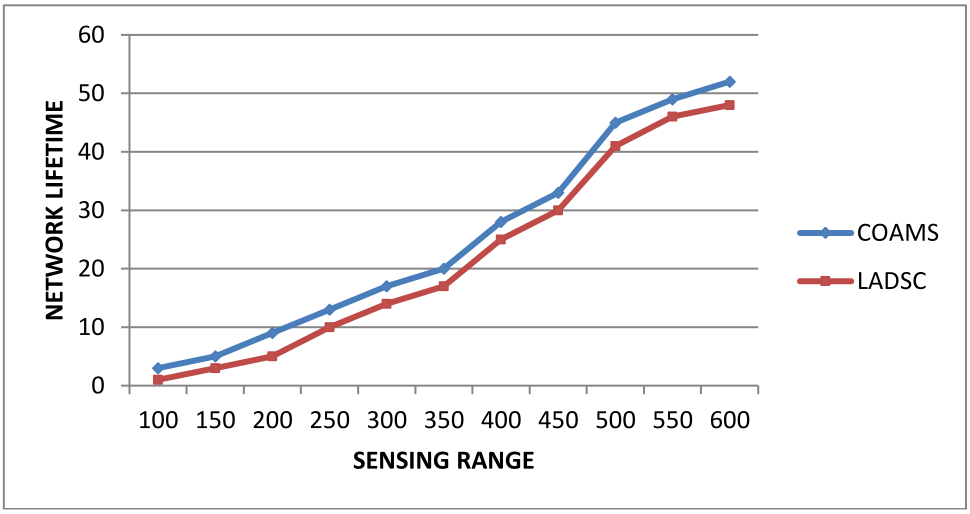

Fig. 11. Increase sensor range from 100 to 600m with 50 sensors and 50 targets

In this experiment, the increase in sensor range over the lifetime of the network is investigated. In Table 4 for 90 sensor nodes and 10 targets, the proposed COAMS algorithm is compared with MCMIP [28], Slijepcevic [27] and LADSC [13]. It is observed that the COAMS algorithm continuously covers the areas better, and therefore more energy is stored.

Table 4. Increase sensor sensitivity for 90 sensors and 10 targets randomly distributed in the environment

Sensing range(m)	COAMS			LADSC [13]			MCMIP [28]			Slijepcevic [27]		
	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
100	2	4.6	12	2	3.7	8	0	2.4	4	0	2.4	4
120	2	6.2	14	3	5.7	10	3	5.4	7	3	5	7
140	3	8.1	12	4	7.7	10	4	6.6	8	4	6	8
160	4	10.3	19	5	9.43	16	8	8.6	11	6	7.6	9
180	6	13.1	24	7	12.6	22	6	11.6	15	6	10.2	13
200	7	18.1	25	7	16.9	27	13	15	17	11	12.6	15
220	13	22.4	28	14	20.7	25	16	18.4	21	13	16.8	21
240	16	24.6	32	15	21.4	29	13	19.6	23	13	18.2	21
260	20	29.1	37	25	27.8	34	15	22.2	26	15	20.4	23
280	24	33.7	42	23	30.3	36	21	27	30	21	24.4	27
300	28	38.8	49	26	35.6	44	27	31.4	33	27	29.2	31

In this experiment, the network lifetime is compared with the COAMS algorithm when COAMS, LADSC, MCMIP, and Slijepcevic use a scheduling mechanism. For this experimentation, the number of targets was changed from 15 to 55 targets with 5 steps, and the results were evaluated. The number of sensor nodes is 90, and the sensor range is 250 meters.

Table 5 shows the maximum, average, and minimum coverage by COAMS, LADSC, MCMIP, and Slijepcevic. COAMS has been shown to provide better results than existing methods.

Table 5. Increase the number of targets for 90 sensors with a sensor range of 250

Number of targets	COAMS			LADSC [13]			MCMIP [28]			Slijepcevic [27]		
	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
15	18	38.6	49	17	26.95	37	17	20.8	27	16	20.8	23
20	13	36.2	46	14	22.95	32	17	18.2	22	16	18.2	21
25	15	34.3	44	17	22.8	29	18	18.2	23	16	18.2	19
30	17	34.1	41	19	23.4	30	18	18	24	16	18	19
35	19	33.12	40	13	21.8	30	11	16.6	23	11	16.6	19
40	17	32.5	38	15	21.35	29	16	16.8	22	16	16.8	18
45	16	31.4	36	16	20.35	28	17	16	20	15	16	17
50	15	30.52	34	15	20.35	27	18	17.2	23	15	17.2	20
55	18	29.95	33	16	21.5	26	14	16	21	14	16	18

6. Conclusion

This paper addresses the issue of point coverage in Wireless Sensor Networks (WSN) and provides a scheduling mechanism based on the Cuckoo Optimization Algorithm (COA). In the proposed scheduling mechanism, the selection of active nodes was to monitor the targets based on the COA. By examining the results of simulating the proposed algorithm and comparing it with the presented sources, in both symmetrical and asymmetric networks, it is observed that this algorithm solves the problem of optimal selection of monitoring sensors in a WSN. It works well on a large scale and is able to provide a good and feasible response to network design, and by organizing and categorizing network nodes, more energy can be achieved that leads to increased network lifetime. Creating balance and uniformity in the energy consumption of nodes and subsequently prolonging the life of the network is one of the results of implementing the proposed algorithm.

Declarations

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Conflicts of interest/Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Availability of data and material

Not applicable

Code availability

Codes would be available on Github repository after the publication.

References

[1] T. Han, S. M. Bozorgi, A. V. Orang, A. R. Hosseinabadi, A. K. Sangaiah, M. Y. Chen, "A Hybrid Unequal Clustering Based on Density with Energy Conservation in Wireless Nodes", sustainability, Vol. 11, 1-26, 2019.

[2] M. Yadav, Y. Mulge, "A DFS Improved Genetic Approach to Optimize Target Coverage Problem in Underwater Wireless Sensor Network, International journal of advanced research in computer science and software engineering, Vol. 3, Issue 6, 247-256, 2013.

[3] A. Rauniyar, J. Kunwar, H. Haugerud, A. Yazidi, P. Engelstad, "Energy Efficient Target Coverage in Wireless Sensor Networks Using Adaptive Learning", International Workshop on Distributed Computing for Emerging Smart Networks, 133-147, 2019.

[4] Manju, and A. K Pujari, "High-Energy-First (HEF) Heuristic for Energy-Efficient Target Coverage Problem", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC), Vol. 2, No.1, 48-58, 2011.

[5] Z. Liu, "Maximizing Network Lifetime for Target Coverage Problem in Heterogeneous Wireless Sensor Networks", International Conference on Mobile Ad-Hoc and Sensor Networks, 457-468, 2007.

[6] Y. Han, C. Kim, J. Gil, "A Greedy Algorithm for Target Coverage Scheduling inDirectional Sensor Networks ", Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, Vol. 1, No. 2/3, 96-106, 2010.

[7] P. Ostovari, M. Dehghan, J. Wu, "Connected Point Coverage in Wireless Sensor Networks Using Robust Spanning Trees", 31st International Conference on Distributed Computing Systems Workshops, 287-293, 2011.

[8] G. JM, H. YH, "A target coverage scheduling scheme based on genetic algorithms in directional sensor networks", Sensors, Vol. 11, 1888-1906, 2011.

[9] S. Begum, N. Tara, S. Sultana, " Energy-Efficient Target Coverage in Wireless Sensor Networks Based on Modified Ant Colony Algorithm", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC), Vol.1, No.4, 29-36, 2010.

[10] D. P. Singh, B. Pant, "An approach to solve the target coverage problem by efficient deployment and scheduling of sensor nodes in WSN", International Journal of System Assurance Engineering and Management Vol. 8, 493-514, 2017.

[11] Q. Zhao, M. Gurusamy, "Maximizing Network Lifetime for Connected Target Coverage in Wireless Sensor Networks", IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, Vol. 16, No. 6, 1378-1391, 2008.

[12] D. T. Le, T. L. Duc, H. Choo, "A Distributed Lifetime-Maximizing Scheme for Connected Target Coverage in WSNs", International Conference on Computational Science and Its Applications, 259-271, 2012.

[13] H. Mostafaei, M. Meybodi, "Maximizing Lifetime of Target Coverage in Wireless Sensor Networks Using Learning Automata", Wireless Personal Communications, Vol. 71, 1461-1477, 2013.

[14] M. Azami, M. ranjbar, A. S. Rostami, A. M. amiri, "Increasing the network lifetime by simulated annealing algoritm in WSN with point". International journal of Ad Hoc, sensor & ubiquitous computing (ijasuc), Vol.4, No.2, 1-8, 2013

[15] A. S. Rostami, K. Nosrati, H. M Bernety, "Optimizing the parameters of active sensor selection and using GA to decrease energy consumption in point coverage wireless sensor networks", Sixth International conference on Wireless Communication and Sensor Networks, 1-6, 2010.

[16] A. S. Rostami, M. R. Tanhatalab, H. M. Berenty, S. E. naghibi, "Decreasing the Energy Consumption by a New Algorithm in Choosing the Best Sensor Node in Wireless Sensor Network with Point Coverage", International Conference on Computational Intelligence and Communication Networks, 269-274, 2010.

[17] D. Zorbas, T. Razafindralambo, "Prolonging network lifetime under probabilistic target coverage in wireless mobile sensor networks", Computer Communications, Vol. 36, Issue 9, 1039-1053, 2013.

[18] A. S. Rostami, H. M. Bernety and A. R. Hosseinabadi, "A Novel and Optimized Algorithm to Select Monitoring Sensors by GSA", IEEE International Conference on Control, Instrumentation and Automation (ICCIA), 829-834, 2011.

[19] K. P. Shih, D. J. Deng, R. S. Chang, H. C. Chen, "On connected target coverage for wireless heterogeneous sensor network with multiple sensing unit", Sensors, 2009; Vol. 9, 5173-5200, 2009.

[20] Melika Khabiri, Ali Ghaffari, "Energy-Aware Clustering-Based Routing in Wireless Sensor Networks Using Cuckoo Optimization Algorithm", Wireless Personal Communications, Vol. 98, 2473-2495, 2018.

[21] R. Rajabioun, "Cuckoo Optimization Algorithm", Applied Soft Computing, Vol. 11, 5508-5518, 2011.

[22] F. Castaño, A. Rossi, M. Sevaux, N. Velasco, "A column generation approach to extend lifetime in wireless sensor networks with coverage and connectivity constraints", Computers & Operations Research, Vol. 25, 220-230, 2014.

[23] M. Keskin, I. K. Altınel, N. Aras, C. Ersoy, "Wireless sensor network lifetime maximization by optimal sensor deployment, activity scheduling, data routing and sink mobility", Ad Hoc Networks, Vol. 17, 18-36, 2014.

[24] S. Tanwara, N. Kumarb, J. P. C. Joel, "A systematic review on heterogeneous routing protocols for wireless sensor network", Journal of Network and Computer Applications, Vol.63, 39-56, 2015.

[25] S. Xiaoa, B. Lia, X. Yuan, "Maximizing precision for energy-efficient data aggregation in wireless sensor networks with lossy links", Ad Hoc Networks, Vol. 26, 103-113, 2015.

[26] M. Azharuddin, P. Kuila, K. Prasanta, "Energy efficient fault tolerant clustering and routing algorithms for wireless sensor networks", Computers & Electrical Engineering, Vol. 41, 177-190, 2015.

[27] S. Slijepcevic, M. Potkonjak, "Power Efficient Organization of Wireless Sensor Networks", EEE International Conference on Communications, 472-476, 2001.

[28] M. Cardei, J. Wu, "Energy-efficient coverage problems in wireless ad hoc sensor networks", Computer Communications, Vol. 29, 413-420, 2006.

[29] J. Kay, J. Frolik, "Quality of service analysis and control for wireless sensor networks", IEEE International Conference on Mobile Ad-hoc and Sensor Systems, 359-368, 2004.

[30] A. K. Sangaiah, M. Sadeghilalimi, A. R. Hosseinabadi, W. Zhang, "Energy Consumption in Point-Coverage Wireless Sensor Networks via Bat Algorithm", IEEE Access, Vol. 7, 180258-180269, 2019.