



Solving the Problem of Target k-Coverage in WSNs Using Fuzzy Clustering Algorithm

Mohammad Hossein Shafiabadi ^{1*}, Zohre Ahmadi ², Mohammad Reza Esfandyari ³

¹ Department of Computer Engineering, IslamShahr Branch, Islamic Azad University, IslamShahr, Iran

*Corresponding author's Email: shafiabadi@iiu.ac.ir

² Department of Computer Engineering, Adiban Institute of Higher Education, Garmsar, Semnan, Iran

Email: zahamadi102@gmail.com

³ Department of Computer Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

Email: 777.re28@gmail.com

Abstract

The purpose of the present research was to introduce an algorithm to solve the coverage problem in wireless multimedia networks that can be used to optimize energy consumption and network lifetime. In this regard, the problem of target k-coverage in WSNs was solved by dividing the environment into the proportional area and random selection. This can be done using a fuzzy clustering algorithm. It is worth noting that the results of the proposed algorithm were compared with previous methods such as genetic and annealing algorithm. The simulation results and comparison with other algorithms show a 27% superiority of the proposed algorithm. It is hoped that this method can be used in networks with larger dimensions in the future

Keywords: Multimedia Networks, Wireless Sensor, Fuzzy Clustering, Increased Network Lifetime, Throughput, and Network Variability.

1. Introduction

Wireless sensor networks (WSNs) consist of sensor nodes that can communicate with each other by wireless and Ad-hoc. Each sensor can receive data such as humidity, pressure, temperature, and so on from its surroundings. Also, the sensors can communicate and exchange data wirelessly with other sensors within their communication radius. In addition to sensors, there is another item called sink (or base station) in WSNs. One of the main tasks of a sink is to collect data from sensors. After collecting data from their surroundings, the sensors send data packets to the sink in a single hop or the multi-hop. Also, the sink can play the role of the network administrator [1].

A sensor node consists of several main sections, including the sensing unit, processor and memory unit, the transfer unit, and the power unit. Sensing unit: This unit consists of one or more sensors depending on the type of application. For example, sensors such as light, temperature, heat, acceleration, infrared, so on can be mentioned. The values and signals generated by the sensors must be digitized so that they can be processed by the processor and stored in memory. By using an analog-to-digital converter, the value generated by the sensors is converted to digital values. Processor and memory unit: This unit is responsible for receiving data from the sensing unit, processing it, and managing and executing functions and procedures. This unit sends the data to the transfer unit after processing. This unit usually uses a microcontroller or microprocessor. In addition to being cheap, the microprocessor usually also has memory.

Power unit: This unit must provide the necessary power for the other units. Transfer unit: In this unit, data is usually transferred wirelessly, although, in some applications, there are also wired communications. Wireless communication can be done through radio waves, optical waves, and ultrasonic waves. Radio frequencies require circuits for modulation, filtering, so on, which make them complicated and expensive. The advantages of using these networks include quick setup in emergencies, avoidance of dangerous and challenging environment for repeated studies, and an economical and cost-effective way to collect data over the long term.

WSNs have various sensors such as seismic, motion, thermal, gas, deformation, optical, infrared, audio, so on sensors that can monitor the different environments and collect and process different types of data.

The research aims to determine the best working direction for a sensor node, with minimal overlap and sharing. Therefore, by doing so, the sensor node can serve in that direction with high efficiency. On the other hand, just setting the direction of work is not enough. To extend the lifetime of the network, it is necessary to put several plugin nodes in the environment.

Some scheduling algorithms are used to sleep the nodes to save energy by targeting plugin nodes. Among the challenges in sensor networks are issues such as target-based coverage, area-based coverage, coverage with guaranteeing connection, and increased network lifetime [2]. In this article, it is tried to solve the k-coverage using the proposed algorithm to the problem of energy consumption optimization, the process of using an innovative fuzzy clustering method based on four criteria including distance from targets, data collection location, battery level, energy consumption process, considering the most optimal area and calculating the cost of moving a sensor to that area.

The structure of the article is as follows. Section 2 reviews previous related work. Section 3 introduces the network model and assumptions, the targets of the problem. In Section 4, the proposed algorithm will be stated. Section 5 presents the evaluation results of the proposed algorithm and its comparison with the algorithm. Section 6 presents the conclusions.

2. Previous Works

The fuzzy set theory has been proposed by Professor Lotfi Asgarzadeh, an Iranian scientist and professor at Berkeley University in the United States in 1965.

Kalogeraki et al. [2] mentioned that the fuzzy theory was introduced by Professor Lotfi Asgarzadeh in 1965 in an article called Fuzzy Sets. Before working on the fuzzy theory, he was a prominent professor of control theory. He developed the concept of the state, which forms the basis of modern control theory. Asgarzadeh wrote something about biological systems in 1962: We need a fundamentally new kind of mathematics, the mathematics of ambiguous

or fuzzy values that cannot be described by probability distributions. He embodied his works in fuzzy theory in an article entitled Fuzzy Sets.

Sambhoos et al. [3] expressed the first international conference on fuzzy systems was held by the most significant engineering organization, the IEEE, in 1992. Many advances in fuzzy systems have been conducted in the 1990s, but despite the fuzzy systems becoming more explicit, there is still much work to be done, and many solutions and methods are still at the beginning of their path.

Fuzzy clustering has another application in integrated detection and image analysis, requiring different algorithms. Various forms of FCM and PCM have been proposed to determine lines, circles, and ellipses on data set corresponding to complex infrastructure, called shell clustering algorithms. One of the algorithms in this category is FCV, which has been developed to determine lines, planes, and *hyperplanes*. The AFCE algorithm that which is a modified form of FCM and PCM, assigns distinct line components in different clusters. Circular alignments can be found using Fuzzy C-Shells and Fuzzy C-Spherical Shells. These algorithms extract samples with different natures from other data and need to replace the Euclidean meter with a modified meter to measure the distance between data and samples. The FCQS algorithm is capable of detecting parabolic, hyperbolic, and linear clusters. Other shell clustering techniques have also been developed for uneven structures such as triangles and other polygons.

Ma et al. [4] mentioned, in short, sensor networks consist of several interconnected electronic devices. If these networks are connected to the camera, new algorithms and solutions should exist to retrieve and process images. Also, the problem of coverage is another challenge in such networks.

Costa and Guedes [5] proposed that the target of this class is to define more robust fuzzy clustering algorithms which results do not depend on the presence of scattered or off-center data in the data set. There are three approaches to this category. The first is noise clustering, which introduces a specific cluster called the noise cluster to display *outlier* data. The second method is based on the use of robust estimators, and the third reduces the effect of outlier data by defining weight.

Wang and Cao [6] stated that since WSN is used in various fields, the deployment of these networks is one of its most fundamental challenges, and there is almost no precise mechanism for its systematic analysis. Deployment mechanisms are usually divided into two categories, including determinism and non-conventional.

Aznoli and Navimipour [7] believed in the issue of coverage when the view of the cameras is not considered in this type of network has been investigated because, in the typical case, the view of the cameras is directional. As a result, the proposed methods for non-directional coverage are different from the existing methods for directional coverage. Much research has also been done on barriers to the environment and their effect.

Cardei et al. [8] stated the barriers affect the data received from the environment by the cameras. As a result, distributed methods for camera sensor networks have been proposed using a large number of inexpensive video sensors. The proposed methods for receiving images are used when the direct distance should have existed between the camera and the object, and there should be no barriers.

Si et al. [9] suggested the most coverage problems focus on 2D) and 3D environments. In the real world, a complex 3D surface is present. Network segmentation algorithms and optimization ideas can be used to improve coverage at coordinates and deviation angles of the nodes. The proposed method, which is, in fact, the same as the self-rotation algorithm, increases the coverage in the environment and reduces the overlap. The cameras automatically update their angle of view according to the condition of the neighboring nodes.

Ping Shih et al. [11] stated that mobile camera sensors had been used to increase coverage in the monitored area. In this project, the camera sensors are randomly placed in a connected lattice location. Then a weighted and oriented graph is constructed that indicates the areas are completely covered, and the areas are connected. After the graph is formed, using the shortest path algorithm of the new path, the path of the camera's barriers, connected to the full coverage areas, is revealed. By using this algorithm, the map of the desired area covered with the least number of cameras is determined in the form of a minimum coverage tree.

Rahimi et al. [12] proposed a new SL-based distributed algorithm to activate the camera sensors to cover the desired geographical space. In this algorithm, the SLs are selected in a hierarchical node, so that each small location is placed at least twice the depth of the node fields and prevents possible overlap between the camera scenes.

Bibhuprada et al. [13] suggested a new algorithm for calculating multimedia coverage. This algorithm starts exchanging messages between neighbors to gather neighborhood data. All sensors emit a HELLO-MSG message to identify the corresponding sensor IDs, and to introduce their spatial coordinates. Early messaging ensures that each sensor is aware of its neighbors and their locations. In this algorithm, there are two main phases that field of view detection and self-direction algorithm. This algorithm uses local data, and as a result, overhead occurs only between neighboring nodes with complexity $O(n)$. This algorithm is also sufficiently distributed, which can operate after initial placement and updates the direction of multimedia sensors. This algorithm can also increase coverage.

Tezcan and Wang [14] used a genetic algorithm to solve the coverage problem in multimedia sensor networks. In this method, 50 nodes are considered. The initial population is considered to be the same number and is repeated 50 times in the environment. Since each environment contains camera nodes, then the rotation angle of each node is genes. This algorithm consists of 8 steps. The results of this algorithm show that with increasing the number of nodes, the percentage of coverage also increases, and it reaches 100% with 200 nodes.

Luo et al. [15] mentioned that one of the classic algorithms is the link tree with first depth search (ASM-ST-DFS). However, its temporal complexity is sensitive to string length, and a pruning strategy can solve this problem.

Hu et al. [16] stated there are challenges such as the scope of work, the type of antennas and targets, as well as the type of memory technology and electrical energy and the user interface in WSNs.

Potdar et al. [17] proposed a new observation model with camera network reliability that optimizes coverage rate and reliability of multi-camera networks. In this method, a directional sensor model is first designed. In order to do this, a Boolean 2D model is used, which can be defined as a parametric array. The perimeter of the sensor is a vector, and by changing the direction of the sensor, the camera can cover a circle. Continuous observations of camera nodes are used to extract the signal needed to create an environmental model. Here is a network of cameras in which each camera node can perform local calculations and extract some discrete symbolic observations. Discrete observations are then used to construct a model of the environment.

Guo et al. [18] expressed that open schemas are a tool for analyzing useful coded genetic algorithms (GAs). By using several different cross-operators, failure points can be predicted for coded GAs (Eshelman and chaffer, 19).

Rossi et al. tried to solve the problem by using meta-innovative methods and a combination of genetic algorithm and linear programming. In the problem, two models are considered for sensor directions. In the first model, the directions are fixed and predetermined, and in the second model, the directions are considered to be adjustable so that these adjustments are made at the beginning of the network and according to the geographical location of the targets. However, the sensor directions in both models are assumed to be uniform and without overlap, which is not very consistent with the realities of camera networks and affects the performance of the algorithm in achieving the optimal solution.

Rossi et al. [20] proposed a greedy heuristic algorithm and genetic metaheuristic algorithm to solve the coverage problem. Greedy algorithms usually work faster to find the response than other algorithms, but due to the nature of the local search, the response may fall into the local optimal point, so the authors in this article use the evolutionary global search technique (genetic algorithm) to find the optimal response. The genetic algorithm uses a 2D and matrix representation of coverage sets in the form of chromosomes, then tries to adjust the orientation of the sensors in the next generations with two operations of fertilization and genetic mutation, and finally applying a fit function will lead to finding the maximum possible coverage set. This will continue until the remaining energy of the sensors is wholly depleted or where not all targets can be covered [21].

Xiao et al. investigated the 3D coverage of uneven grounds in directional sensor networks. They then presented algorithms to improve the area coverage area using lattice splitting, simulated refrigeration, and local optimal point methods. First, they simplified the 3D model of directional sensors. They then proposed algorithms to optimize the surface coverage by shifting the position of the sensors and changing their angle of view (from above) to the uneven

surface. This improvement is achieved only by covering cavities caused by natural surface irregularities, and the authors do not cover the area during operation and increase the lifetime of the network. However, as far as the study is addressed, this is one of the few studies in sensor network coverage that has been simulated using refrigeration's evolutionary method in recent years. Barrier coverage is an essential issue in WSNs. In wireless camera sensor networks, the position and angle of the camera sensor effect in a specific range to capture images or videos of objects. Therefore, the problem of barrier coverage in the camera sensor network is different from the scalar sensor network.

Min Gil and Han [22], according to the full definition of coverage, focused on the minimum camera barrier coverage in wireless camera sensor networks where the camera sensors are randomly targeted in a field. First, the target field is divided into several areas, including areas fully covered or areas not fully observed. The target areas and their relations are then modeled as a weighted guided graph. Based on the graph, an algorithm is proposed to solve the problem of minimum camera barrier coverage to prove the solution's correctness. In addition to the above, another optimal algorithm is proposed for the problem. The simulation results in this article shows acceptable performance.

Funk [23] mentioned that HSLs EC-based distributed method is proposed in wireless multimedia sensor networks. A new approach to HSLs-EC has been suggested. Initially, all cameras and scalars are randomly used in the area to be tracked. Cameras and scalar players all broadcast the camera sensor information message (CSIM) and the scalar sensor information message (SSIM), respectively. CSIM and SSIM are messages transferred by a camera and scalar sensors, respectively, that include the ID and location of the sensors. There is also a list called the activation list that stores the active cameras' IDs, which is initially empty. Additionally, the IDs of all cameras are stored in a list called my waiting list. After receiving the SSIM and CSIM messages, the sensors calculate the Euclidean distance from each other. If the calculated distance between a camera and a scalar is less than the depth of the camera field, it can be concluded that the scalar is inside the depth of the camera field. The proposed method activates the minimum number of cameras that cover an area to reduce data transfer.

Elhoseny et al. [24] used Newton's gravitational algorithm to cover the area and reduce energy consumption optimally. This article uses four parameters to evaluate the performance, including the minimum number of nodes in the coverage area, network lifetime, including the time interval from the start of the first node to the time of the shutdown of the first node and network power. The results of repeated simulations show that the proposed algorithm performs better than the previous two methods in terms of performance parameters.

Serik and Kaddour [25] stated that one way to increase the performance and lifetime of the sensor network is to arrange the nodes so that they cover the entire target area. However, in some areas, such as mountainous environment, nodes may spread through the aircraft, and coverage of the area becomes a challenge. Therefore, researchers believe that solving the coverage problem is very complicated.

Elhabyan et al. [26] used BA to select the optimal sensor and the resulting path to reduce energy consumption. The primary purpose was to increase the lifetime of the network by increasing the life of operational sensors, and the data collected by the above node is sent to the sink. Due to the simplicity and flexibility of simple BA execution, this algorithm was chosen. The results of the proposed algorithm with different values of the parameters were presented. The results show that the algorithm is scalable. That is, the algorithm responds well not only to a particular state but also to different network states. Finally, the results of the proposed algorithm were compared with MSS, MSGSA, MSACO, EEDG, GSA, and EDTC methods. The simulation results and comparison with other algorithms show a 27% superiority of the proposed algorithm.

Sangaiah et al. [27] believed the proposed activity scheduling algorithm provides an approach that enables any MSN in WMSN and takes advantage of the network energy by observing the essential points. By prioritizing each volume set, they introduce a new way to select the most appropriate MSN coverage set based on the correlation of visual data from camera observations. The work of simulating them and comparing the results with the existing approaches shows that their proposed method exceeds the current results in terms of network lifetime, recording rate, and percentage of inactive and active nodes.

AlNuaimi et al. [28] stated that a new and efficient design is presented in the form of a genetic algorithm, which overcomes several existing metaphorical weaknesses, along with an accurate method for calculating performance. The proposed genetic algorithm includes an innovative heuristic population method, the calculation of the exact integral

area for fitness performance, and a combination of the Laplace Crossover and Arithmetic Crossover operators. The results show that this algorithm provides the best performance in terms of solution quality and stability in most cases tested.

Hanh et al. [29] stated that to achieve the desired target, the SL's selection to activate the camera is done in a hierarchical manner, as shown in Figure (3). Selecting SL activates cameras that have the least overlap in the depth of field, thus reducing redundancy in data transfer.

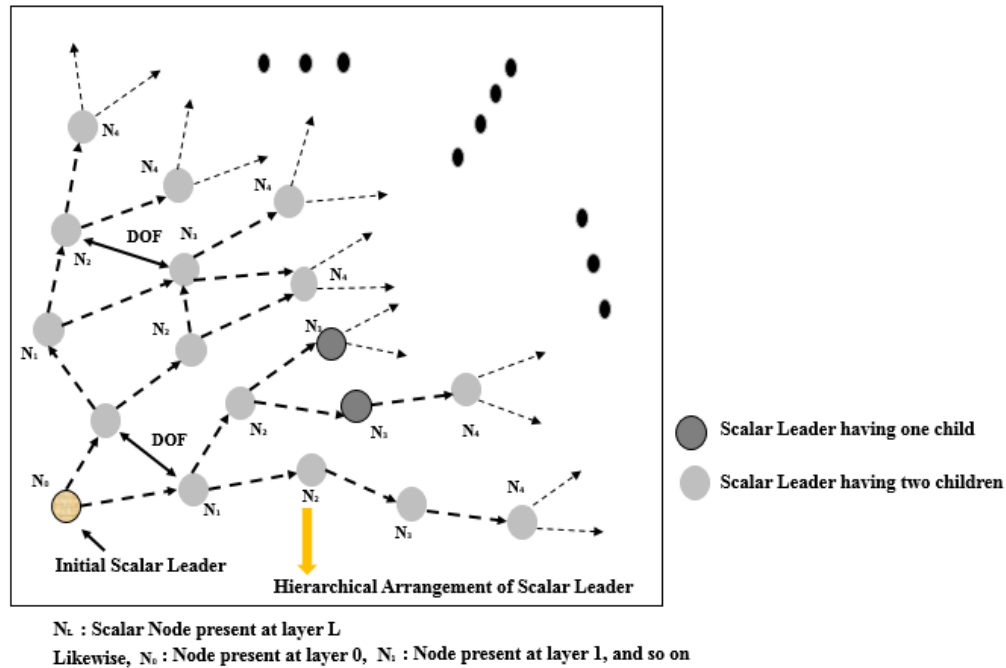


Fig. 1. The hierarchical arrangement of SL [15]

Finally, the subject of coverage in the scientific research network can be seen in the diagram of Fig. (2). This diagram has been compiled and prepared according to the amount of research done in the IEEE scientific database. According to the researchers' research on the previous studies, two challenges were posed as a common subject in this regard.

- By focusing on one aspect of problem-solving factors of network coverage, this problem has different aspects.
- Extensive cost of implementing some of the proposed methods in terms of time, hardware required, memory costs, so on

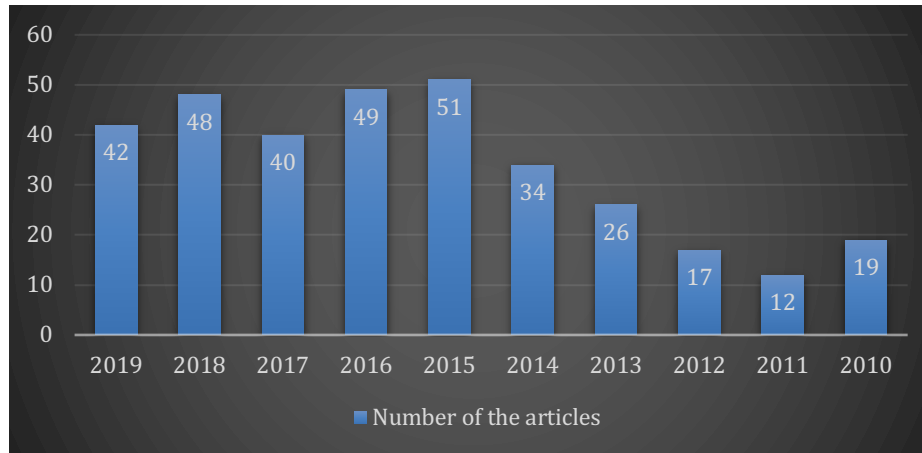


Fig. 2. Review of the number of research done in the valid IEEE database on the subject of network coverage of existing references

2. Proposed Method

In the proposed method, by default, a node must have the following characteristics in order to be an appropriate option for covering a target:

1- Distance from targets, other nodes, and location of data collection, 2- Battery level, 3- Energy consumption process

In the proposed method, the process of variable energy consumption is influenced by five factors:

1- Number of stored bits, 2- Number of bits in the receiving queue, 3- Number of bits being processed, 4- Number of bits in the sending queue, 5- Cost of moving from point x to point y.

To solve the problem of covering the processed environment, targets are divided into several areas based on the density. To select an appropriate sensor in an area of the proposed method, a fitting function is required based on the three variables of distance, battery level, and power consumption process. This function must be able to determine the suitability of each category of sensors to cover all the targets in each section.

After selecting the most appropriate category of sensors in that area, the best point for the existence of a cluster head sensor is selected based on the distance from the targets, and the sensors will be arranged based on the amount of fit and the cost of energy consumed to move to that area. The one with the highest rank will be selected as the cluster head, and all the collected data from the targets will be transferred to the desired sensor, and through it will be transferred to the data collection center. The proposed method is in modeled mode and includes the following steps:

2.1. Dividing the environment into the proportional area with the number of targets

In the proposed method for dividing the areas, the total number of targets is calculated first, then the ratio of targets to the area is determined using Equation 3-3:

Equation 3-3

$$r_A = \frac{T}{A}$$

In this equation, T and A are the total numbers of targets and the surface area, respectively. The environment will be divided into r_A sections. If the density of targets in one area exceeds the standard value for sensors, each area is subdivided into other areas using Equation 1.

2.1.1. Identifying all appropriate subsets

Identifying all subsets of sensors capable of covering all nodes in the area. This set can be displayed as Equation 3-4.

Equation 3-4

In this regard, each c_i is a subset of sensors that can include distance from the target, energy level, and energy consumption process. In other words, each node in the c_i set must be able to meet the following two conditions:

$$C = \{c_1, c_2, \dots, c_n\}$$

- Its distance from at least one target is less than the range of the node.
- The node's battery level is higher than the estimated energy for collecting and sending data to the cluster center or data collection center.

Estimating the amount of energy consumed to perform the task of the target k-coverage state available to a sensor node is calculated using Equation 3-5:

Equation 3-5

$$E_a = E_r + E_{sa} + E_p + E_{se}$$

In Equation 3-5:

1. E_r : The amount of energy required to receive n bits of the k-target set under coverage
2. E_{sa} : The amount of energy required to store n bits of the k-target set under coverage
3. E_p : The amount of energy required to process n bits of the k-target set under coverage
4. E_{se} : The amount of energy required to send n bits of the k-target set under coverage

2.1.2. Selection of the best subset

The best subset of all identified responses is c_i , which has the highest value in Equation 3-6.

Equation 3-6

$$T_{ci} = \frac{\sum_{j=1}^b (E_j - E_{aj})}{\sum_{j=1}^b dist_j}$$

In Equation 3-6, E_j , E_{aj} , $dist_j$ are the battery level of j^{th} node, the amount of power consumed to perform the operations related to the target k-coverage in j^{th} node, and the sum of the distances of the targets covered by the j^{th} sensor node.

2.1.3. Identifying the cluster head for each area

In the proposed method, each area will contain a cluster head. The cluster head is selected from the top subcategory and is responsible for sending and receiving data to other cluster heads and the data center. In addition to the amount of energy needed to do the work, the cluster head must also have the energy to send and receive data. The best point (ideal point) of each area is calculated according to the targets' location and the relationship with the nodes. The node with the highest value in Equation 3-7 will be selected as the cluster head node.

Equation 3-7

$$S_j = \frac{\sum_{j=1}^b (E_j - E_{aj} - E_{mj})}{dist_g}$$

In Equation 3-7, E_{mj} and $dist_g$ are the energy required to move the j^{th} sensor to the ideal point and the distance from the ideal point to all targets that can be covered by the j^{th} sensor. Fig. 3 shows an overview of the proposed method. After determining the appropriate cluster head for each subset, data is collected from the targets and sent to the data collection center, and then the network performance will be calculated with Equation 3-2. If the network does not

improve compared to before, the location of the sensors will change. In this section, the proposed method was reviewed, and by stating the desired point, which is to increase the amount of EN, the problems in achieving this target were examined. Existing targets are obviously not completely achievable, so it needs a method that can obtain the best results in general by creating a balance in achieving the targets. The proposed method by fuzzy clustering tries to provide a way to increase the performance of networks in the optimal identification of targets.

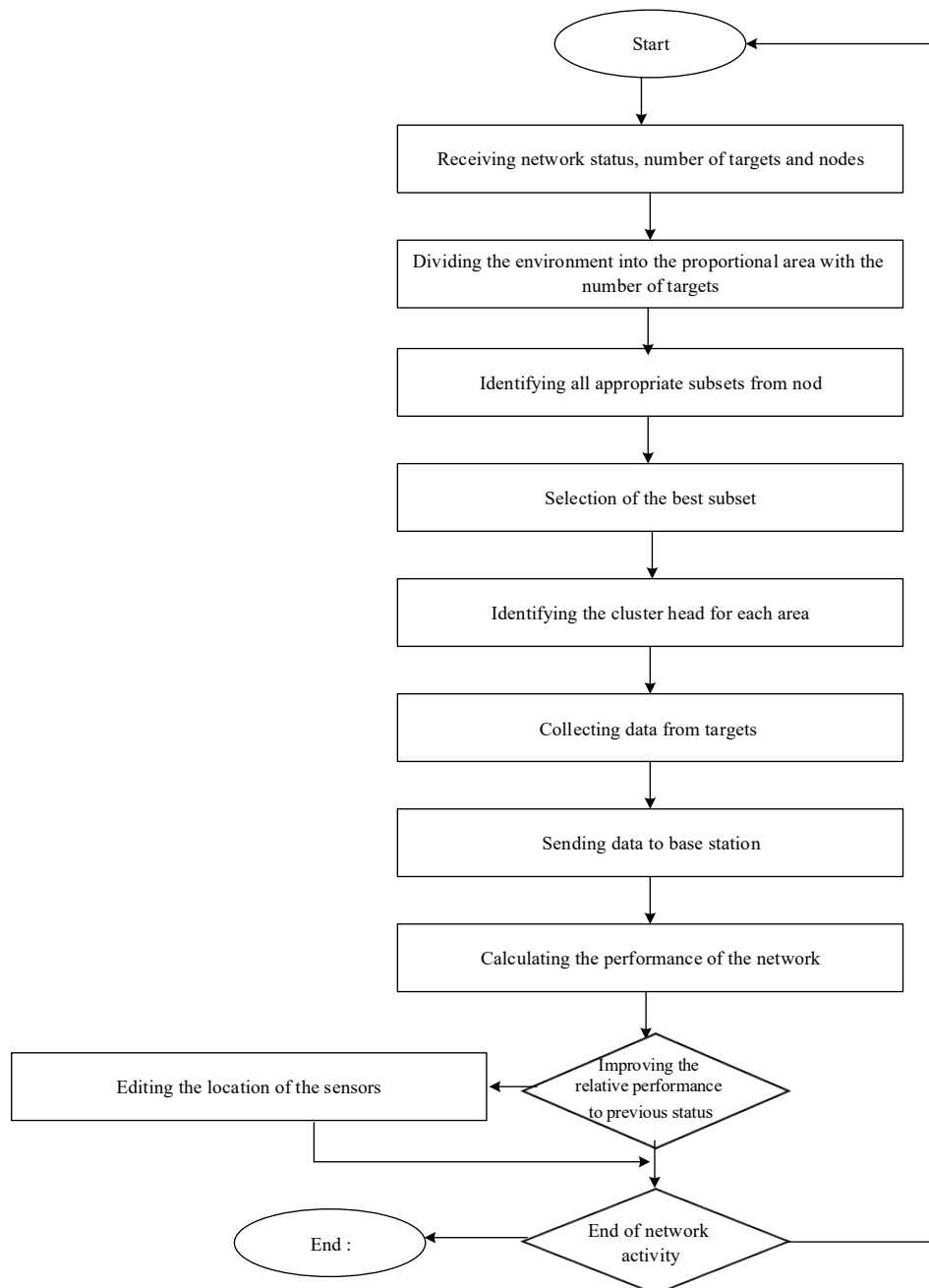


Fig. 3. Flowchart of the proposed method

2.2. Challenges in the proposed method

Based on the structure and type of sensor nodes, the set of nodes selected for sensor networks can be of the homogeneous or heterogeneous type. A homogeneous group is a set of sensor nodes that are entirely similar in terms of energy, communication power, and other such parameters. However, in the heterogeneous group, there are usually more robust nodes (in terms of communication power, radio radius, energy storage, and fault tolerance) that are called cluster head and can categorize and collect data obtained by weaker nodes to process and send this data to the base station or sink according to the desired program.

Various structures of homogeneous nodes have been introduced, which stated to improve their use, several strategies, and solutions for each of the applications. In most of these solutions, the need to know the exact distance between nodes is considered, which depends on the measurement of each node in the same state. In this article, the nodes are assumed to be homogeneous, but by changing the measurement of nodes to prove the effectiveness, a special algorithm has been stated. Perhaps the most essential factor in developing coverage models is considering energy consumption limitations. Sensor nodes typically use a battery to supply energy, which in most cases, is not rechargeable or replaceable. Therefore, it is essential to carry out operations to reduce energy consumption and increase the sensor node's lifetime. There are several ways to access this. One way is to put a number of extra nodes to sleep, which is a popular and efficient method. The second method is to adjust the transfer range to the neighboring node's size so that only the distance of the neighboring node is needed to feel and transfer data.

When sensor nodes are in a hierarchical structure, cluster head nodes can collect data and transfer it to the sink, respectively. This will remove the burden of routing and data transfer from the interface nodes and will last longer. The productivity of data collection and routing can also play an essential role in reducing energy consumption. If several nodes start collecting the same data, of course, energy consumption increases. Elimination of redundancy is one of the most essential issues in WSNs.

2.2.1. Network model and problem statement

The issue of coverage in WSNs depends on several factors that must be considered when distributing sensor nodes at the desired location. Many of these factors have a software aspect that must be considered in the ability of sensor nodes. Most researchers have focused on a single model. This article tries to introduce an algorithm that can be used in many different cases. The proposed method is described below. In order to solve the coverage problem in WSNs, this problem is first formulated. Then, the theoretical aspects of the proposed method and the reasons for its effectiveness have been examined.

2.2.2. Problem formulation

The first step in the development of WSNs is to identify essential targets and parameters for monitoring. Typically, the entire area for identifying multiple targets or for a defect in a border area has been searched. The problem of coverage in this article is defined as follows:

When the coverage takes place in an area where every point in the area is detected by at least one category of sensors. An appropriate solution to the target coverage problem should include an optimal selection for the following three factors:

- A. It increases network life (NI) as much as possible. This means that nodes can collect data from all targets and send them to the base station over a more extended period of time.

- B. It maximizes network throughput (N_t). This means that the maximum targets can be covered at each stage of the network, and the data of those targets can be sent to the base station.
- C. It increases the ability to change network structure (N_a) as much as possible. This variable indicates that if the network targets change, it can change its structure accordingly.

If the optimality of a solution to solve the maximum coverage problem is shown in Equation 3-1.

$$\text{Equation 3-1} \quad E_N \propto N_l + N_t + N_a$$

In order to convert Equation 3-1 into an equal equation, the coefficients should be added to the desired factors. These coefficients were displayed as w_1 , w_2 , and w_3 .

$$\text{Equation 3-2} \quad E_N = w_1 N_l + w_2 N_t + w_3 N_a$$

The coefficients w_1 , w_2 , and w_3 according to the conditions and the importance of each of the variables in the problem explicitly initialized for each problem of target coverage. These coefficients will be equal to 1. In other words, the values of these three factors are considered equally. Obviously, the purpose of the proposed method will be to increase the amount of E_N in Equation 3-2

$$E_N = w_1 N_l + w_2 N_t + w_3 N_a$$

2.3. Simulation and numerical results

The architecture of existing wireless networks is not designed to meet all users' current needs, including telecommunications service providers, customers, and companies. In other words, wireless network structure designers at the time of design due to limitations such as design complexity, conflicting policies in the use of network resources, lack of scalability and dependence on a particular node, lack of coordination between market economic needs and capabilities in the wireless network and lack of accountability to meet all the needs of the IT science and technology network has led to deviations. In an ideal wireless network, packets enter and exit routers through ports. Routing and network topology tables are made up of several sections and layers. The connection between two nodes in a wireless network does not necessarily require a physical connection between the two nodes. Also, in this network, requests from all sections of the network are covered and responded to it.

In this section, the results of testing hypotheses in a wireless network with a randomized structure are compared in terms of three variables, including network lifetime, the response rate to requests sent to the network, and network compatibility with targets. These three factors ultimately indicate the performance of the proposed method in maximizing the load. To implement, the studied network was examined in two structures, which include the wireless node structure and the wireless network topology. Also, using three scenarios (network life, response to send requests, and network compatibility with targets), the network is evaluated. The results are calculated to eliminate the effect of random results in the test, after performing ten simulations (and removing the best and worst results) as well as taking the average of these results. The range of requests in the network environment is 100 by 100. In this article, 0.1 seconds is considered for the final measurement of each step of the network's studied variables. To compare the performance of the proposed method, this method compared with two methods of random state change and the method used in reference [29].

2.3.1. Test environment

To create the same conditions for comparing results, it needs to limit the environment to build a similar environment for tests. Therefore, in the present article, to clarify the conditions of the test, this section has been explained. The OMNET ++ software was used to simulate the mentioned hypotheses. OMNET ++ simulator is an extensible, module-based simulator software with C++ programming language that uses the libraries and framework of this language. The hardware and conditions defined for wireless network simulation are shown in Table 1. The main tasks of this simulator include the following tasks:

- 1- Construction and design of wireless network structure,
- 2- Observing the implementation process of the proposed wireless network's proposed method,
- 3- Observing the change of variables in the wireless network environment,
- 4- Observing the results by considering the variables.

Table 1. Hardware and conditions defined for wireless network simulation

CPU	RAM	Software version	Number of the node	OS
5-core processor with a frequency of up to 2 MHz	6GB	OMNET++ 4.5.1	5-50	Windows 10

2.3.2. The structure of a node

A member of the network in the wireless network, which will be called a node from now on, will consist of 3 layers of data transfer and connections, control, and application. There are two types of nodes in the target network, including ordinary nodes and base station nodes. In terms of structure and hardware, these nodes are no different. It is assumed that this node is connected to the energy source only in the base station node, and its energy is never reduced or finished.

Data transfer layer: Each node that operates in the tested wireless network has three properties in this layer. These properties are:

1. Node ID value: The node ID is the node name and is a unique number.
2. Gate: This gate has 2 data entry and exit gates. All wireless exchanges of a node are done this way.
3. The energy capacity of a node: This capacity is defined as the total capacity and the remaining energy capacity in each node. This property generally indicates the network lifetime according to the amount of processing performed on the node.

Control layer: In the control layer of the wireless network, there are five sections, these sections include:

1. Node starter: In this part, initialization will be done for the required properties of the nodes. The data that is uploaded at this stage includes:

A- The node's number of connections with its adjacent nodes, B- The amount of energy capacity of each node, C- The ID of each node, and like. This data will be sent to the base station at the beginning of the network operation.

2. Message maker: This section aims to create a message (by the standard 802.11) with the following features. These features are:

A. The title and content of the message can be the level of energy in the node.

B. A source node (message sender)

C. Destination node (next recipient of the message)

D. Message type (a message can be identified from message type or an ordinary message)

These features will be initialized when creating a message.

3. The receiver of the message: This section will be activated when a message enters the node gate through the communication channel. Packet validation is also done in this section.
4. Network starter: This section's task is to check if all nodes have been able to introduce themselves to the base station. In order to perform this task, a probe-like message must be sent to all nodes as a broadcast when the network starts. If the base station node in the response sent by each node realizes the type of connections and the capacity of each node, this section will finish its work. Otherwise, this message will be broadcast again in the same way as mentioned.
5. Routing: This section specifies the policy for sending messages to adjacent nodes. In other words, this section specifies to which of the current packet should be delivered to the adjacent packets. This section contains three other parts:

A- An appropriate node selector, B- An appropriate output gate selector, C- Sending packet

In the studied network, it is evident that these sections' tasks are different in two types of base station nodes and ordinary nodes. To reduce the available variables, the data processing at the application layer will be neglected. In-network implementation, the effect of the processes in this layer is aggregated as a constant number with the packet transfer delay in each node.

2.3.3. Network topology

The nodes' final *interlock* of the desired wireless network is made through the connections of their gates. This *interlock* will be a random *interlock*. Also, requests in the network are created in this way with the feature of random location in each area. To create a request, it is assumed that a change has occurred in one area of the network and a data receiver (this device can be a camera, voice recorder or any node with the ability to receive data and send it with wireless technology based on standard 802.11) should report this change to the base station. The graphical structure of the implemented network called k-coverage LTA is shown in Fig. 5.

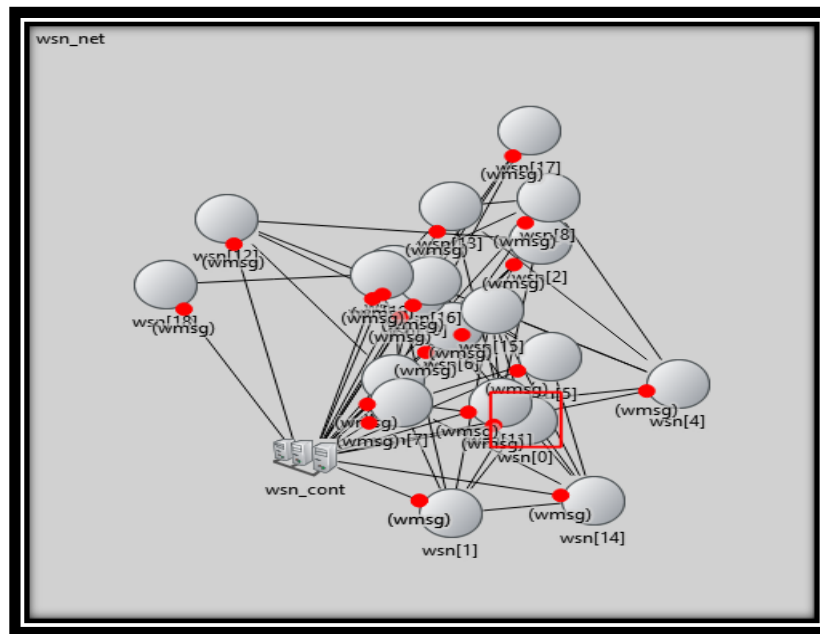


Fig. 5. Graphic structure of the implemented network called k-coverage LTA (simulation view)

2.4. Scenario 1

In this scenario, the lifetime of the network was examined. Network lifetime in this scenario is when it takes for the first network node to reach zero energy level called network lifetime. This variable is measured by the t/s unit. In Tables 2 and 3, the studied algorithms were tested for the variable of network lifetime affected by the number of nodes and also the network with 20 nodes affected by the number of requests.

Table 2. The average lifetime of the network affected by the variable of number of nodes

Number of the node	10	20	30	40	50
Proposed method	22	32	50	50	50
Random selection	14	19	38	50	50

K-Coverage	19	28	47	50	50
------------	----	----	----	----	----

Table 3. The average lifetime of the network affected by the number of requests for 20 nodes

Number of the request	10	20	30	40	50
Proposed method	10	20	30	32	32
Random selection	10	19	19	19	19
K-Coverage	10	20	28	28	28

The results obtained from the simulations show that increasing the number of nodes will increase the lifetime of the network. Also, these results show that increasing the number of requests in the network's average lifetime will have a ratio of 12%. In fact, the average rate of reduction of network lifetime in the proposed method is 40% less than random selection and 7% less than reference [29]. Figs. 6 and 7 compare these results visually. These changes are more evident than the compared methods.

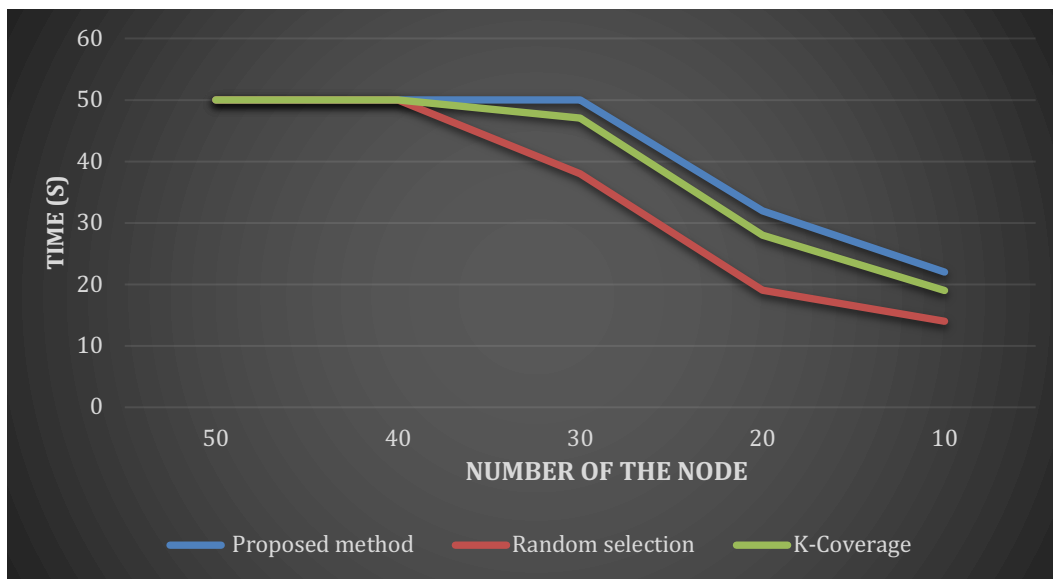


Fig. 6. The average lifetime of the network affected by the variable of number of nodes

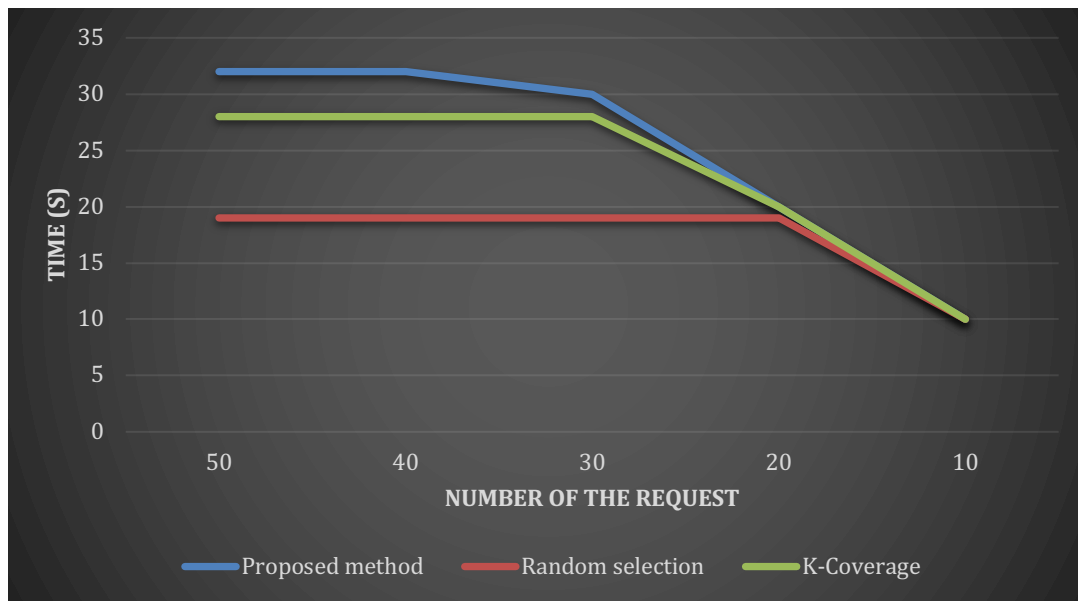


Fig. 7. The average lifetime of the network affected by the number of requests for 20 nodes

2.4.1. Scenario 2

In this scenario, the response to the sent requests includes the number of requests from the network that are responded correctly. This means that the request is recorded from the location created by the first wireless receiver and sent to the base station. Three studied methods were examined as the variable before the response rate to the sent requests affected by two variables, increase the number of nodes, and increase the number of requests. The results can be shown in Tables 4 and 5. In general, it can be said that in the proposed method, the best improvements have been achieved over time, as well as the worst results have been obtained in the early times. From Figs. 8 and 9, it can be concluded that the proposed method responds to the requests on average, 2% more than the method in the reference [29], and average 16% more than the random selection.

Table 4. Comparison of response rate to send requests affected by the increase in the number of nodes

Number of the node	10	20	30	40	50
Proposed method	42	50	50	50	50
Random selection	31	39	44	48	50
K-Coverage	40	47	49	50	50

Table 5. Comparison of response rate to send requests affected by the increase in the number of requests in 20 nodes

Number of the node	10	20	30	40	50
Proposed method	10	20	30	40	50
Random selection	10	19	27	34	39
K-Coverage	10	20	30	39	47

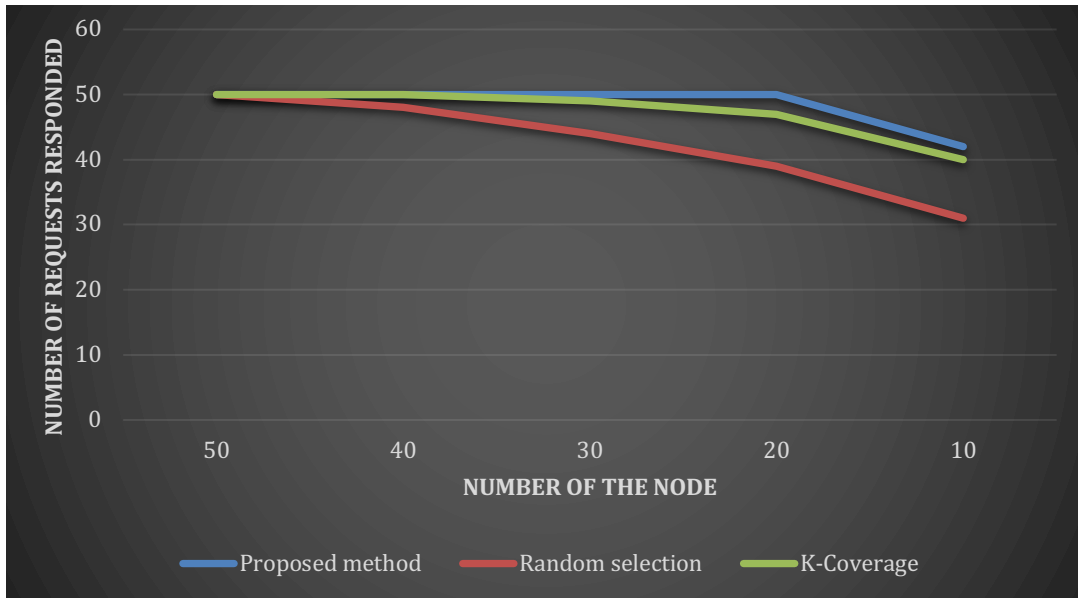


Fig. 8. Comparison of response rate to send requests affected by the increase in the number of nodes

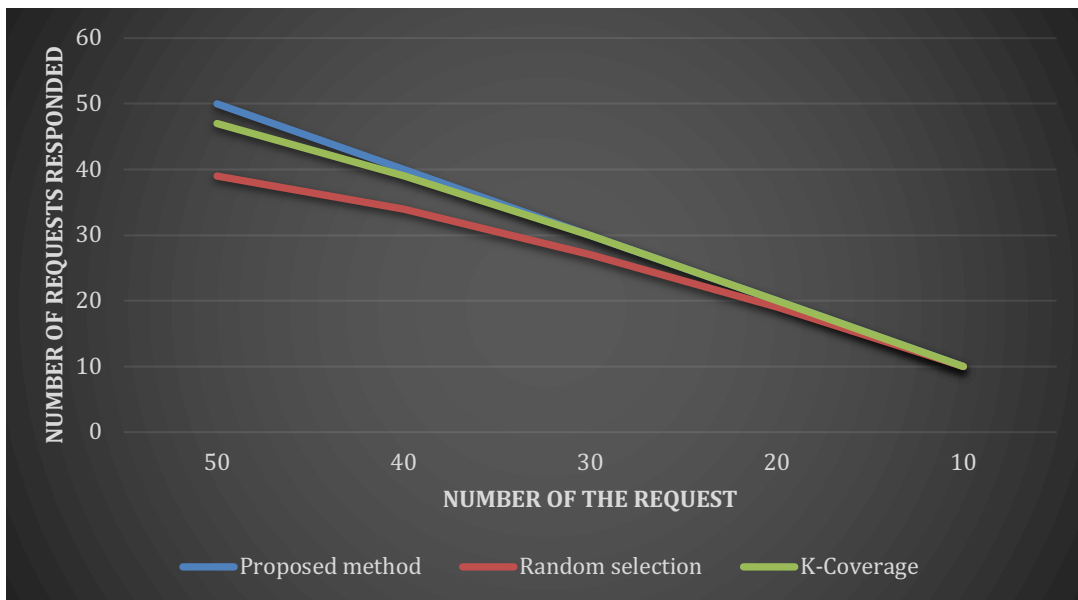


Fig. 9. Comparison of response rate to send requests affected by the increase in the number of requests in 20 nodes

2.4.3. Scenario 3

In this scenario, the compatibility of the network with the targets of this variable is determined by measuring the average Euclidean distance between the locations of the responded requests in the network. In fact, this variable is

formulated to measure the ability to change the network's structure or compatibility with requests. In this section, three methods studied in the style of previous variables in terms of network compatibility rate with the targets affected by two variables, increasing the number of nodes and increasing the number of requests, were examined. These results are shown in Tables 6 and 7. If it is intended to extract a general conclusion that the changes in this variable can be expressed according to its two independent variables, namely the number of nodes and the number of requests, it should be said that the proposed method was able to respond to more different requests in terms of spatial dimension than the methods in reference [29] and random selection. In other words, the average distance of responded requests is 46% more than random selection and 2.5% more than the reference [29], respectively. These changes can be seen in Figs. 10 and 11.

Table 6. Comparison of network compatibility rate with targets affected by the increase in the number of nodes

Number of the request	10	20	30	40	50
Proposed method	1420	1605	1780	1788	1814
Random selection	954	1109	1012	1186	1140
K-Coverage	1365	1480	1564	1702	1754

Table 7. Comparison of network compatibility rates with targets affected by the increase in the number of requests in 20 nodes

Number of the request	10	20	30	40	50
Proposed method	210	419	828	1292	1605
Random selection	196	208	588	920	1109
K-Coverage	232	406	782	1240	1480

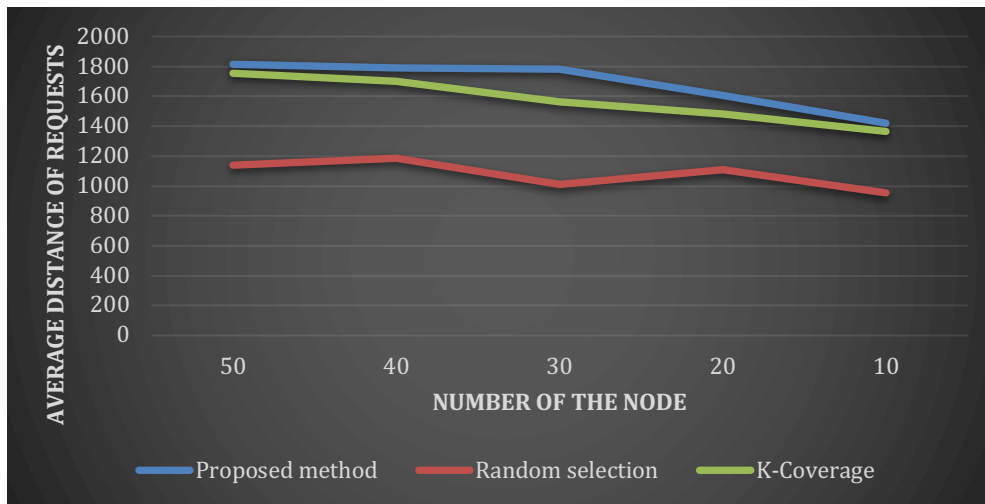


Fig. 10. Comparison of network compatibility rate with targets affected by the increase in the number of nodes

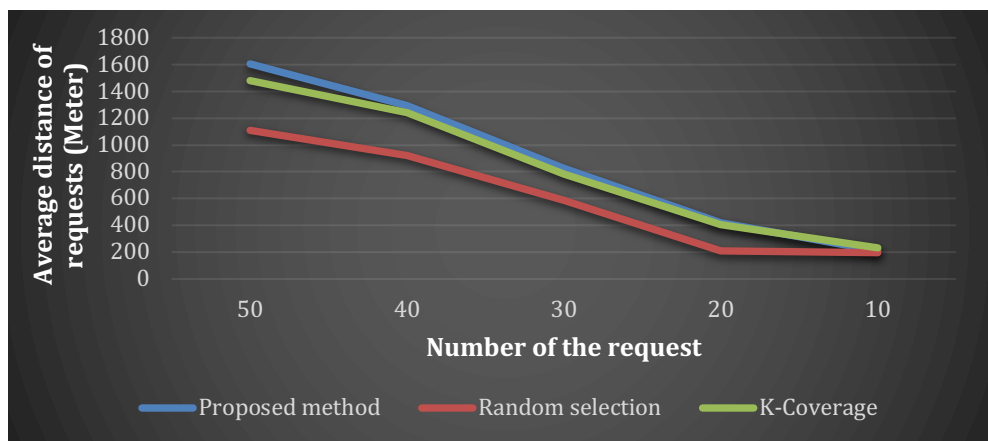
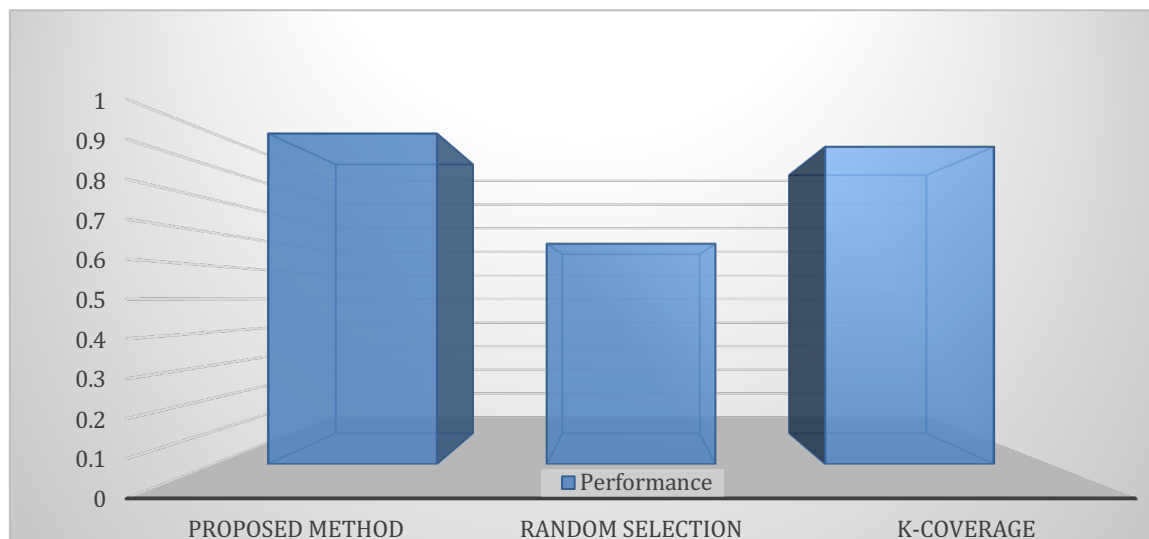


Fig. 11. Comparison of network compatibility rate with targets affected by the increase in the number of requests in 20 nodes

Verification

In order to analyze and simulate this idea, three scenarios have been proposed. In the first scenario, the network lifetime is compared with another article in reference (29) and the random selection, the results shown in Tables 2 and 3. In the second scenario, the response rates to the submitted requests, which include the number of requests from the network that are responded correctly, have been reviewed. The proposed method responded to the requests by an average of 2% compared to the reference (29) method and 16% more than the random selection method. Also, in the third scenario, the compatibility of the network with the targets of this variable is determined

Fig. 12. Comparison of the performance of the proposed method with the two methods of Ki-coverage and random selection



by measuring the average Euclidean distance between the location of the responded requests in the network, which is shown in Tables 6 and 7. Finally, a diagram shows the improvement of the ideas compared to the previous works.

3. Discussion

In order to increase the coverage in WSNs, previous works in this field have been reviewed. In previous works, in order to increase the lifetime of the network, in some sending periods, some nodes that used a lower percentage fall asleep to save their energy for subsequent sending. In this article, the method of categorizing data and helping neighboring nodes have been used in such a way that after collecting data, it is delivered to a neighboring node that its distance is less than the range of the primary node. There are also nodes called sinks that have an inexhaustible energy source, for example, connected to a solar energy source. So far, sensors have been used to collect data in the military, environmental, commercial, so on fields. For example, sensors can be used to build a hospital or a prominent place. The results of previous work are compared with the idea of this article. Existing sensors have the ability to collect data from the surrounding environment and transfer it to the nearest neighbor and the central node. Its achievements are increasing the lifetime of the network and storing the amount of energy of each sensor after the steps are performed. The best advantage of sensor networks is its fast setup, and one of its disadvantages is the short battery life of each sensor.

The main limitation of this article is the data amount and the lack of access to the real environment of wireless multimedia networks. In other words, there is no practical access to data from various networks according to the existing rules on administrative structure (as owners of such networks) and security limitations in this area. Another limitation is the high cost of laboratory hardware equipment for testing physical networks.

4. Conclusion

The purpose of this research was to increase the coverage in WSNs. Thus, the sensors were placed in an environment sequentially or randomly. The method is that first, the environment is divided into different areas, then for the sensors were placed in each section, and an appropriate cluster head is identified for each section. All sensors collect data from the surrounding environment and deliver it to the cluster head, and it sends the data to the collection center. Then the network efficiency is measured by three variables, including network lifetime, responsiveness rate to requests sent to the network, and network compatibility with the targets. If this process does not optimize the previous process, the location of the sensors will change.

The advantages of this method are as follows:

- The proposed method, considering the amount of weight used in Equation 3-2 for each of the variables measured by 1.3, has better efficiency than the two methods compared.
- Increasing the network lifetime
- Increasing the responsiveness rate to requests sent to the network
- Increasing the compatibility of more sensors

References

- [1] M. Amac Guvensan and A. Gokhan Yavuz, On coverage issues in directional sensor networks: A survey, *Ad Hoc Networks*, vol. 9, no. 7, pp. 1238–1255, 2011, doi: 10.1016/j.adhoc.2011.02.003.
- [2] V. Kalogeraki, D. Gunopulos, and D. Zeinalipour-Yazti, A local search mechanism for peer-to-peer networks, *Int. Conf. Inf. Knowl. Manag. Proc.*, pp. 300–307, A 2002, doi: 10.1145/584838.584842.
- [3] P. Sambhoos, A. B. Hasan, R. Han, T. Lookabaugh, and J. Mulligan, WeebleVideo. Comprehensive Angle Field-of-View Video Sensor Networks, *Comput. Sci. Tech. Reports*, p. 5, 2006.

- [4] B. Xu, Y. Zhu, D. Li, D. Kim, and W. Wu, Minimum (k, ω) -angle barrier coverage in wireless camera sensor networks, *Int. J. Sens. Networks*, vol. 21, no. 3, pp. 179–188, 2016, doi: 10.1504/IJSNET.2016.078321.
- [5] D. G. Costa and L. A. Guedes, The coverage problem in video-based WSNs: A survey, *Sensors*, vol. 10, no. 9, pp. 8215–8247, 2010, doi: 10.3390/s100908215.
- [6] Y. Wang and G. Cao, On full-view coverage in camera sensor networks, *Proc. - IEEE INFOCOM*, pp. 1781–1789, 2011, doi: 10.1109/INFCOM.2011.5934977.
- [7] F. Aznoli and N. J. Navimipour, Deployment Strategies in the WSNs: Systematic Literature Review, Classification, and Current Trends, *Wirel. Pers. Commun.*, vol. 95, no. 2, pp. 819–846, 2017, doi: 10.1007/s11277-016-3800-0.
- [8] M. Cardei, M. T. Thai, Y. Li, and W. Wu, Energy-efficient target coverage in WSNs, *Proc. - IEEE INFOCOM*, vol. 3, no. C, pp. 1976–1984, 2005, doi: 10.1109/incom.2005.1498475.
- [9] P. Si, C. Wu, Y. Zhang, Z. Jia, P. Ji, and H. Chu, Barrier coverage for 3D camera sensor networks, *Sensors (Switzerland)*, vol. 17, no. 8, pp. 1–17, 2017, doi: 10.3390/s17081771.
- [10] F. Xiao, X. Yang, M. Yang, L. Sun, R. Wang, and P. Yang, Surface coverage algorithm in directional sensor networks for 3D complex terrains, *Tsinghua Sci. Technol.*, vol. 21, no. 4, pp. 397–406, 2016, doi: 10.1109/TST.2016.7536717.
- [11] K. P. Shih, C. M. Chou, I. H. Liu, and C. C. Li, On barrier coverage in wireless camera sensor networks, *Proc. - Int. Conf. Adv. Inf. Netw. Appl. AINA*, pp. 873–879, 2010, doi: 10.1109/AINA.2010.77.
- [12] M. Rahimi, S. Ahmadian, D. Zats, R. Laufer, and D. Estrin, Magic of numbers in networks of wireless image sensors, 2006.
- [13] S. B. B. Priyadarshini and S. Panigrahi, A distributed approach based on Hierarchical Scalar Leader Selection for Enhanced Event Coverage in wireless multimedia sensor networks, *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 10109 LNCS, pp. 3–14, 2017, doi: 10.1007/978-3-319-50472-8_1.
- [14] N. Tezcan and W. Wang, Self-orienting wireless multimedia sensor networks for maximizing multimedia coverage, *IEEE Int. Conf. Commun.*, pp. 2206–2210, 2008, doi: 10.1109/ICC.2008.421.
- [15] W. Luo, Q. Lu, and J. Xiao, Distributed collaborative camera actuation scheme based on sensing-region management for wireless multimedia sensor networks, *Int. J. Distrib. Sens. Networks*, vol. 2012, 2012, doi: 10.1155/2012/486163.
- [16] H. Hu, H. Wang, J. Li, and H. Gao, An efficient pruning strategy for approximate string matching over suffix tree, *Knowl. Inf. Syst.*, vol. 49, no. 1, pp. 121–141, 2016, doi: 10.1007/s10115-015-0896-6.
- [17] V. Potdar, A. Sharif, and E. Chang, WSNs: A survey, *Proc. - Int. Conf. Adv. Inf. Netw. Appl. AINA*, pp. 636–641, 2009, doi: 10.1109/WAINA.2009.192.
- [18] L. Guo, L. Lei, Z. C. Zeng, P. Zou, D. Liu, and B. Zhang, Evaluation of spatio-temporal variogram models for mapping Xco2 using satellite observations: A case study in China, *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 8, no. 1, pp. 376–385, 2015, doi: 10.1109/JSTARS.2014.2363019.
- [19] L. J. Eshelman and J. D. Schaffer, *Real-Coded Genetic Algorithms and Interval-Schemata*, vol. 2. Morgan Kaufmann Publishers, Inc., 1993.
- [20] A. Iross, A. Singh, and M. Sevaux, Lifetime maximization in wireless directional sensor network, *Eur. J. Oper. Res.*, vol. 231, no. 1, pp. 229–241, 2013, doi: 10.1016/j.ejor.2013.05.033.
- [21] S. K.- Cerne, Construction and Analysis of Bibliographic Networks, *Networks*, pp. 24–30, 2006.
- [22] J. M. Gil and Y. H. Han, A target coverage scheduling scheme based on genetic algorithms in directional sensor networks, *Sensors*, vol. 11, no. 2, pp. 1888–1906, 2011, doi: 10.3390/s110201888.

- [23] M. Funk, Problem solving skills in young yellow-crowned parakeets (*Cyanoramphus auriceps*), *Anim. Cogn.*, vol. 5, no. 3, pp. 167–176, 2002, doi: 10.1007/s10071-002-0149-4.
- [24] M. Elhoseny, A. Tharwat, X. Yuan, and A. E. Hassanien, Optimizing K-coverage of mobile WSNs, *Expert Syst. Appl.*, vol. 92, pp. 142–153, 2018, doi: 10.1016/j.eswa.2017.09.008.
- [25] A. Amine, E. J. Neuhold, L. Bellatreche, Z. Elberrichi, and R. Wrembel, Computer Science and Its Applications: 5th IFIP TC 5 International Conference, CIIA 2015 Saida, Algeria, May 20-21, 2015 Proceedings, *IFIP Adv. Inf. Commun. Technol.*, vol. 456, pp. 454–464, 2015, doi: 10.1007/978-3-319-19578-0.
- [26] R. Elhabyan, W. Shi, and M. St-Hilaire, Coverage protocols for WSNs: Review and future directions, *J. Commun. Networks*, vol. 21, no. 1, pp. 45–60, 2019, doi: 10.1109/JCN.2019.000005.
- [27] A. K. Sangaiah, M. Sadeghilalimi, A. A. R. Hosseinabadi, and W. Zhang, Energy Consumption in Point-Coverage WSNs via Bat Algorithm, *IEEE Access*, vol. 7, pp. 180258–180269, 2019, doi: 10.1109/ACCESS.2019.2952644.
- [28] M. AlNuaimi, F. Sallabi, and K. Shuaib, A survey of wireless multimedia sensor networks: Challenges and solutions, *2011 Int. Conf. Innov. Inf. Technol. IIT 2011*, pp. 191–196, 2011, doi: 10.1109/INNOVATIONS.2011.5893815.
- [29] N. T. Hanh, H. T. T. Binh, N. X. Hoai, and M. S. Palaniswami, An efficient genetic algorithm for maximizing area coverage in WSNs, *Inf. Sci. (Ny)*, vol. 488, pp. 58–75, 2019, doi: 10.1016/j.ins.2019.02.059.