Increasing Coverage in Wireless Sensor Networks by Minimizing Displacements Using a Greedy Method based on Nodes' Location and Neighborhood

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Received: January 2022 Revised: March 2022 Accepted: May 2022

ABSTRACT:
The successful operation of a wireless sensor network depends on the proper coverage of the environment, which in turn is affected by the number and location of sensors. In general, when the sensors are deployed randomly, the initial coverage is not high. One of the major challenges for network design is to determine the placement strategy of the sensors so that the deployed nodes can cover as many regions as possible. On the other hand, the power supply of each sensor node is a non-rechargeable battery. Therefore, the objective of this study is to solve the coverage problem in such a way that the energy consumption of the nodes is minimal, too. The proposed approach uses division and detection of uncovered regions. Then a greedy method based on the topology and properties of the nodes and the network deployment region is presented to select the optimal nodes and cover the region. The proposed approach is simulated and the evaluation results show a decrease in the displacement of the sensors for more coverage and a reduction in energy consumption compared to similar works.

KEYWORDS: Wireless Sensor Network, Coverage, Energy Consumption, Nodes' Displacement, Nodes' Neighborhood.

1. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of distributed and autonomous sensor nodes that are small in size, low power, low cost, and versatile. Sensor nodes often have the ability to sense, process, and transmit data from the environment to the base station called sink [1]. The main task of a WSN is to monitor the environment in which it is located, collect data from the environment, and then transfer the collected data to the sink. Data transfer is done directly or in several steps, and finally, the sink sends the collected data to the main control station. Due to the intrinsic nature of WSNs such as self-organization, low infrastructure, and local cooperation, nodes have many applications such as environmental monitoring, military applications, target tracking, environmental protection, and home automation [2].

Despite the advantages of this type of wireless network, WSNs have their limitations. These include processing and storage energy limitations. In a WSN, the lifetime of the network is the time it takes for the network to start operating until the desired coverage is lost or the length of time that the network covers the desired area. Network lifetime is a very important criterion for determining the performance of a WSN. Power consumption must be fully controlled to extend the lifetime because the sensors are battery-powered and may not be recharged or replaced due to the conditions of the environment [3].

Two methods are used to deploy nodes: random and deterministic. Random deployment is good for areas that are unknown or unavailable. In this type of deployment, a common way to extend the network lifetime, is to control the schedule of sensors, so that only a subset of them is used at any given time to cover the area [4]. In a deterministic deployment, the details of the area are known, and since the deployment of nodes in the environment is already available, there are two methods to maximize network lifetime. One in the deployment phase and the other in the node scheduling phase. The choice of network topology largely depends on the type, the application, and the environment in which the sensors work [5], [6].

Paper type: Research paper
DOI: https:// 10.30486/mjee.2022.696496
How to cite this paper: Y. Mehregan and K. Mohebbi," **Increasing Coverage in Wireless Sensor Networks by Minimizing Displacements Using a Greedy Method based on Nodes' Location and Neighborhood**", Majlesi Journal of Electrical Engineering, Vol. 16, No. 2, pp. 73-84, 2022.

An important challenge in WSNs is to maximize the coverage of the sensors. Coverage is one of the criteria for measuring the quality of service (QoS) in WSNs, which is closely related to energy consumption. Coverage in a WSN must ensure that the area is monitored with a certain degree of reliability. The location of nodes is the base input for the network coverage algorithms [1]. The total number of sensors and their placement determine the degree of network coverage. Depending on the application, a high degree of coverage may be required to increase the accuracy of the information received [7].

The coverage problem, in general, can be divided into two categories: Area coverage and Target coverage. The focus of the area coverage is on monitoring the entire target environment, while in the target coverage it is on monitoring specific points in the area [4]. Now consider a WSN where the sensors are randomly located in the area. In this network, multiple sensors can overlap. This will cause the network to not be fully covered. Assuming that the sensor nodes are movable, their arrangement can be changed after deployment in such a way that the overlap decreases and the coverage increases. On the other hand, displacement of the sensors consumes a lot of energy. Therefore, we need a solution that provides the most coverage in the network with the least movement of sensors [2].

One solution to the coverage problem is to use different computational geometry methods such as the Voronoi diagram and the Delaunay triangulation [8]. The Voronoi diagram is a way to divide space into several areas. In this diagram, each set of points (called domains, sites, or generators) is assigned a region. These areas are called Voronoi cells. For a set of points, the Voronoi diagram divides the surface into regions so that all points of a region are closer to its producer point. For example, as one of the prominent research works, [2] uses the Voronoi diagram. However, the method presented in this paper consumes a lot of energy to achieve maximum coverage. In fact, many of the proposed works to increase coverage have failed to make a tradeoff between this and the lifetime of WSNs. To solve this problem, the current study proposes a new approach to achieve the highest coverage with the least displacement of sensors. This approach is based on the nodes' neighborhood information. It defines a virtual infrastructure in the area, and each cell of this infrastructure, while consuming less energy, helps to identify areas that are not covered.

The rest of this paper is organized as follows. Section 2 reviews the related works. Section 3 explains the proposed approach in this research. Section 4 describes the simulation results and evaluation of this approach. Section 5 concludes the paper and suggests future works.

2. Related Works

In this section, some of the prominent research works to solve the coverage problem in WSNs are reviewed.

Data et al. (2009) used the bee colony algorithm to solve the problem of optimal deployment of sensors [9]. The purpose of this work is to reduce energy consumption by reducing the radio range of the sensors. This study has investigated both the problem of optimal deployment of sensors to increase the coverage and the placement of sensors in irregular ground segments. This method also can be used when the number of the covered target points is too much.

Al-Turjman et al. (2013) worked on the placement of sensors [10]. This research has tried to increase the lifetime of the network by optimally placing the sensors in a three-dimensional space. This method is suitable for the WSNs with large number of sensors.

Mahboubi et al. (2013), solved the coverage problem by finding the sensor nodes of uncovered areas in a Voronoi polygon [11]. Each sensor node tries to find the areas inside this polygon that are not covered. They then move in a suitable direction that minimizes uncovered areas. In this paper, the motion strategy for the nodes is based on the distance of each sensor node from the points inside the polygon and the vertices of the polygon.

Mansour and Jarray (2015) claimed that the issue of sensor coverage by maximizing network lifetime is an NP-hard problem, and to solve it, approximate methods such as metaheuristic or approximate algorithms must be used [12]. The proposed algorithm requires a lot of computation and is very difficult to implement.

Ray and De (2016) with the same assumption as the previous work, used the Firefly optimization algorithm to solve the problem of area coverage with the least movement of sensor nodes [13].

Roselin et al. (2017) proposed a routing method in WSNs that also considers the coverage problem [14]. The two parameters of coverage and topology of sensor nodes are defined which help the sensor nodes to solve the coverage problem, in addition to optimal routing. Similarly, Biswas et al. (2018) provided an algorithm for routing that increases network lifetime by considering the coverage problem [1].

Sun et al. (2018) proposed a method to solve the problem of overlap in WSNs to increase their lifetime [15]. In this method, when several overlapping nodes cover an area, only one of them remains active and the rest are put to sleep to save their energy consumption. When the residual energy of the active node reduces, it activates the closest node using the shortest path algorithm and the new node begins to cover the area. This increases the lifetime of the network.

Fang et al. (2018) solved the problem of maximum coverage using two new algorithms [2]. These algorithms search for the final position of the sensors to determine the location of each sensor node so that all the points are covered. Their goal in finding these points is that the sensors reach the maximum coverage with the least displacement. The sensors consider the Voronoi blind-zone polygons that are identified by their neighbors. Each sensor node then moves to the center of the polygon and moves to that point only if it increases coverage in the network.

Hanh et al. (2019) tried to solve the problem of coverage in WSNs by examining the weaknesses of the genetic algorithm and used an improved version of the this algorithm [16]. The main disadvantage of this method is that it is implemented centrally. The centralization of this method reduces the efficiency of the algorithm and causes high energy consumption and latency.

Chen et al. (2019) proposed a coverage method based on Borůvka's algorithm [17]. This algorithm is a method for finding the minimum spanning tree with the weight of individual edges in a graph. The minimum spanning tree contains all the vertices of a graph so that the total weight of its edges is the lowest. Using this method provides the most coverage, but has high energy consumption.

Wu et al. (2020) proposed a new position-based approach considering the direction of sensors [18]. In this approach, network lifetime is not optimal. In fact, it makes the lifetime of the WSN shorter than other methods.

Sateesh et al. (2021) proposed a method based on the initial deployment of sensors [19]. Although it provides more coverage than related methods, energy consumption is still not optimal and the network lifetime is shorter than other methods. Similarly, Wang et al. (2021) proposed an approach based on the distance of points that provides good coverage but overlooks the network lifetime [20].

Xu et al. (2022) focused on the WSNs and considered their important issues when used for complex environments such as social networks [21]. They introduced intelligent learning methods and swarm optimization algorithms to address reliability issues. Experimental evaluations were performed in industrial application environments and results showed the efficiency of the proposed model in terms of energy consumption and reliability.

Wu et al. (2022) proposed a data collection strategy to increase the lifetime of WSNs [22]. This end-to-end strategy uses an ant colony optimization algorithm to perform the collection point selection and the touring path planning simultaneously. The evaluation result showed the efficiency of this strategy, in particular in the unbalanced distribution scenario of sensors.

A summary of the reviewed articles is depicted in Table 1.

Table 1. Comparison of related works.

Reference	Approach	Advantages	Disadvantages
Udgata et al. (2009) [9]	Sensor deployment based on bee colony algorithm	- Reduces energy consumption - Suitable for a large number of target points	- Coverage is not optimal
Al-Turjman et al. (2013) [10]	Sensor deployment targeting environment monitoring applications	- Suitable for 3D spaces	- High energy consumption
Mahboubi et al. (2013) [11]	Distributed deployment based on the distance of the sensor	- High coverage	- Low lifetime
Mansour and Jarray (2015) [12]	Based on an iterative solution	- A precise answer to the coverage problem	- High computational complexity
Ray and De (2016) [13]	Sensor movement based on glowworm swarm optimization algorithm	- Efficient energy consumption	- Low coverage
Roselin et al. (2017) [14]	Maximizing lifeline through effective routing	- Low energy consumption - Good coverage	- Not a precise answer to coverage
Sun et al. (2018) [15]	Based on the topologic attributes of the network	- Considers both energy consumption and coverage	- Not optimal coverage as it focuses more on the routing
Biswas et al. (2018) [1]	Routing in multi-hop WSNs	- Energy efficiency and target coverage	- Not a precise answer to coverage
Fang et al. (2018) [2]	Considering the Voronoi blind-zone polygons	- High coverage	- Decrease in the lifetime

Hanh et al. (2019) [16]	Based on an improved genetic algorithm	- High coverage	- Centralized then high energy consumption
Chen et al. (2019) [17]	Based on the Borůvka's algorithm	- High coverage	- High energy consumption
Wu et al. (2020) [18]	Considering the direction of sensors via a position-based approach	- Good coverage	- Short lifeline
Sateesh et al. (2021) [19]	Based on the initial deployment of sensors	- Good coverage	- High energy consumption
Wang et al. (2021) [20]	Sensor deployment with distance-based coverage	- Good coverage	- Overlooks network lifetime
Xu et al. (2022) [21]	Based on intelligent learning and swarm optimization algorithms	- Good energy consumption and reliability	- Low coverage
Wu et al. (2022) [22]	Data collection based on ant colony optimization algorithm	- Increased lifeline	- Low coverage

To date, various approaches have been proposed to solve the problem of maximum coverage after the random deployment of sensors in WSNs. This review reveals that most of these research works ignore the issue of energy consumption. Therefore, increasing coverage as well as reducing energy consumption to increase the lifetime of WSNs is still a challenge that needs to be addressed.

3. PROPOSED APPROACH

In this section, first, the preliminaries of the proposed approach are described, then its algorithm is explained.

3.1. Assumptions and Network Model

In a WSN, it is assumed that all sensor nodes are randomly located in an area. The random placement of the sensors causes their overlapping that reduces the network coverage. To solve this problem, the sensor nodes must be relocated after deployment. The limited battery power of the sensors decreases due to receiving or sending data and moving. A connection between two nodes is established when they are in each other's radio range. All sensors have the same shape and are within the same radio range.

There is a sink in the area with unlimited power. Initially, the sink has information about all the sensors in the network, including the location of the nodes and their power. The proposed algorithm will be run in the sink. After a certain number of iterations or for a certain period, the sensors send their position and battery information back to the sink. If the coverage in one area is lost, meaning that a node is out of service or has too low energy, the sink reruns the algorithm and achieves the maximum network coverage again.

3.2. Overlapping Degree

The overlapping degree of a node is calculated based on its neighboring nodes. This degree for a particular node is equal to the number of nodes whose Euclidean distance from the node is less than $\sqrt{3}r$, where r represents the radio range of the sensors. Because for maximum coverage, the optimal distance between the two sensors is $\sqrt{3}r$ [2], if the Euclidean distance of two sensor nodes is less than $\sqrt{3}r$, then their overlap is one.

3.3. Energy Model

This paper uses a radio energy model, as in [23]. In this model, the free space and multi-path channels are used based on the distance between sender and receiver. When the distance is less than the threshold $d_0$then the free space model (fs) is used, otherwise the multi-path model (mp) will be used. Assume that E_{elec}, ε_{fs} and ε_{mp} are the requirements of electrical circuits in the free space and the multi-path models, then the required energy to send an *l*-bit message in distance d is as follows:

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

The required energy to receive an *l*-bit message is as:

$$E_R(l) = lE_{elec} \quad (2)$$

The E_{elec} parameter depends on several factors such as digital coding, modulation, filtering, and signal separation, while the amplifier energy depends on the distance between the sender and receiver. Amplifier energy is calculated using the following equation:

$$\varepsilon_{fs}(d^2)/\varepsilon_{mp}d^4 \quad (3)$$

Therefore, in this model, the energy consumption is directly related to the distance between the sender and receiver.

In this energy model, each node consumes only to receive or to send a message. But in this study, we assume that our sensor network is a moving one, and this movement consumes the energy, too. Therefore, the energy required to direct sensor *i* to sensor *k* is calculated by the following equation, in which $m_i$is the mass and $v_i$is the velocity of sensor *i* [13].

$$E_{ik} = \frac{1}{2}(m_i v_i^2) \quad (4)$$

3.4. Proposed Algorithm

The proposed algorithm uses information about nodes and network deployment region. It first creates a virtual infrastructure. This infrastructure is a grid or table that divides the network deployment region into several cells of equal size. The purpose of this cell structure is to identify uncovered points. Cells that are sparser are less likely to be covered, and more dense nodes overlap and have to cover more sparse regions. After the virtual structure is formed, each node determines which cell it belongs to. For each cell, a cell header is then identified whose main task is to calculate sparse regions and to determine which nodes should cover uncovered regions.

After identifying the cell headers, each node obtains its one- and two-step neighboring list using the beacon message. Each node then calculates its overlapping degree and sends this information to the header in the form of a "MyInfo_MSG" message. After receiving neighborhood information, the headers calculate which regions are not covered and which nodes have the highest overlapping degree. The headers then select the appropriate nodes with a high overlapping degree and send them to the uncovered points. This is done by sending a "Move_MSG" message to the node. Each time the algorithm is executed, a suitable node is selected to cover each region. This selection is performed locally and greedy because the best node is selected in a particular moment and situation, but in the whole flow of the algorithm, that it may not be optimal. The pseudo-code of the proposed algorithm is shown in Fig. 1.

1. Start //after deployment of the node
2. Construct the virtual grid infrastructure
3. Determine the cell headers
4. Send "beacon" messages by every node in the network
5. Collect neighbor node information in each node
6. Each node sends "MyInfo_MSG" to its cell header
7. Each cell header sends "Move_MSG" to some of the nodes
8. Nodes move and cover the region
9. If the network meets the end condition, go to step 11
10. After the death of some nodes go to step 3
11. End.

Fig. 1. Pseudo-code of the proposed algorithm.

The steps of this pseudo-code are described below.

3.4.1. Establishing Virtual Infrastructure and Cell Nodes

The algorithm establishes a virtual grid structure by dividing the network deployment region into several cells of the same size. For this purpose, similar to [24], we consider the number of cells as a function of the number of sensor nodes. Suppose that *N* sensor nodes are deployed in the region. Using Equation (5), the region is divided by *K* cells of the same size, where *K* is a square number.

$$K = \begin{cases} 4 & N \times 0.05 \le 6 \\ 9 & 6 < N \times 0.05 \le 12 \\ 16 & 12 < N \times 0.05 \le 20 \\ \dots & \dots \end{cases} \quad (5)$$

Fig. 2 shows the division of the region for 100, 200, and 300 nodes.

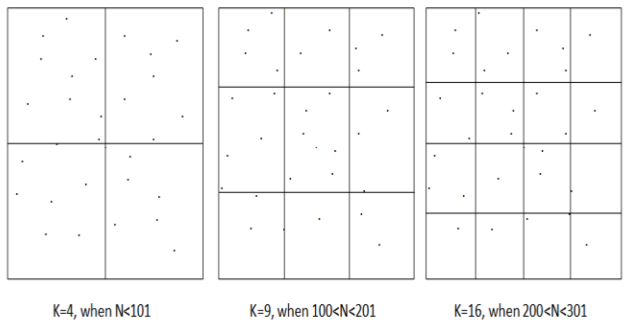

Fig. 2. Division of network deployment region.

After dividing the region into cells, a set of nodes is identified as header nodes. To do this, the nodes use the information about the dimensions of the deployment region and the total number of nodes to calculate the shared points of all four cells. A node is selected as the header if it is the closest one to the shared points.

To reduce the communication cost in selecting header nodes, a threshold can be considered, so that only nodes whose distances from the nearest shared point of four cells are less than the threshold participate in the selection process. If no sensor node is found in the threshold distance around such shared point, then the threshold limit increases. Fig. 3 shows the set of header nodes for a network with 200 sensors and *K* = 9.

After determining the header nodes, each of them broadcasts a notification message to the surrounding nodes. Because each header is close to the shared point of four cells, their nodes can receive this message. The nodes that receive notification messages from more than one header, select the node with the shortest distance as their header.

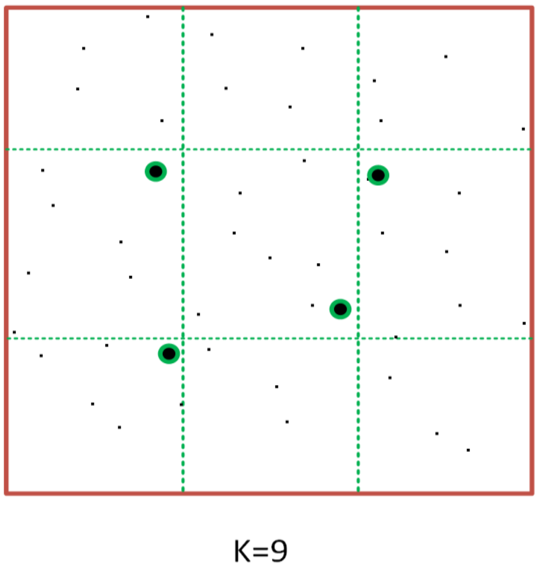

Fig. 3. Example of header nodes.

3.4.2. Gathering Neighborhood Information

Each sensor node periodically broadcasts a beacon message in the radio range by which it stores its list of one-step (one-hop) neighbors. Node neighborhood information is stored in a table called Table_OneHop. Each node also stores information about its one-hop neighbors and sends it to its neighbors inside the next beacon message. Thus, each node is aware of its list of two-hop neighbors. Two-hop neighbor information is stored in Table_TwoHop. Each node collects this information each time the algorithm is executed and sends it to its header or the nearest header node via the MyInfo_MSG message.

3.4.3. Identifying and Covering the Sparse Regions

After identifying and collecting information from the nodes, the header starts processing them. Each header is aware of the overlapping degree of its member nodes. This node specifies nine points for each neighboring cell. In fact, the coordinates of these points can be calculated based on the region size and the number of cells.

The headers check for their neighboring cells to see if each of these points is covered by a node of one- or two-hop neighboring nodes. If a point is not covered by at least one node i.e., the distance between the coordinates of that point and its nearest node is greater than $\sqrt{3}r$, then it must be covered by at least one node. In this case, the header selects an appropriate node and stores the coordinates of the destination point in a Move_MSG message, and sends it to the selected node.

The right node to move is selected by considering two conditions. The first condition is that the node should be closer to the destination point, which reduces energy consumption due to displacement. The second condition is that the node has the highest overlap degree, which allows us to achieve the lowest overlapping degree.

These are the points that the headers cover in the first stage and include the corners, the middle of the edges, and the center of the cell, as depicted in Fig. 4.

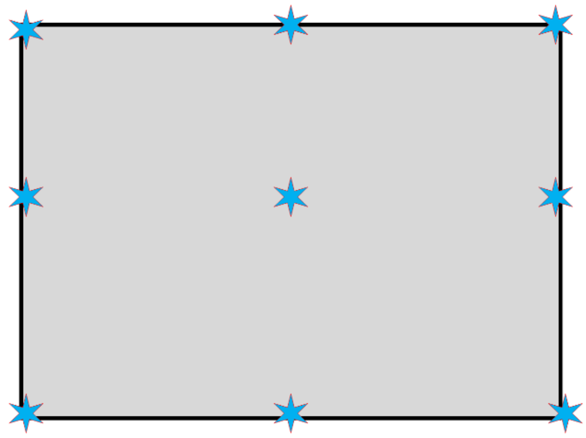

Fig. 4. Initial covered points of each cell.

For each node, the header calculates its distance to the uncovered point and for node i which $1 \leq i \leq N$, stores this value in $Dist_i$. Suppose the overlapping degree of node i is $DegCov_i$. Then, for the uncovered point, the header calculates the probability of movement using equation 6, where parameters a and b are determined experimentally.

$$Prob - Movement = a \times Dist_i + b \times DegCov_i \quad (6)$$

Each node that is most likely to move is selected as the appropriate one. The header then puts the coordinates of the destination point in a Move_MSG message and sends it to the selected node. The selected node, after receiving this message, moves to the destination point and covers that region.

4. EVALUATION

This section describes the simulation and evaluation of the proposed algorithm.

4.1. Simulation Settings

The proposed approach is simulated using MATLAB software. The simulation parameters and their values are shown in Table 2.

Table 2. Simulation settings.

Parameter	Description	Value
$x_m \times y_m$	Region dimension (case 1)	$100\ m\ \times 100\ m$
$x_m \times y_m$	Region dimension (case 2)	$200\ m\ \times 200\ m$
E_0	The initial energy of each node	1-5 J
E_{Tx}	Energy consumed to transmit information on a radio call	50 nJ/bit
E_{Rx}	Energy consumed by the radio to receive the massage	50 nJ/bit
E_{DA}	Energy used to collect information	5 nJ/bit/signal
E_{amp}	Energy consumed by the amplifier in multi-directional mode	0.0013 pJ/bit/m^4
E_{fs}	Energy consumed by the amplifier in open-space mode	10 pJ/bit/m^2
R	Radio range of each sensor node	10 m
N_n	Number of network nodes	50-100
l	Packet size	4000 bits

The number of sensors varies between 50 and 100 nodes that are randomly deployed in a region with dimensions of 50m × 50m or 100m × 100m. The initial energy of the sensors is randomly between 1 and 5 joules. The optimal values of parameters a and b in Equation 6 are determined by trial and error and are equal to 0.5.

4.2. Simulation Scenario

Assume that 100 sensor nodes are deployed using a uniform and random distribution in a region with the dimensions shown in Table 2. In one implementation of the algorithm, the sensors are randomly deployed as shown in Fig. 5. This figure shows the initial view of the network before running the algorithm.

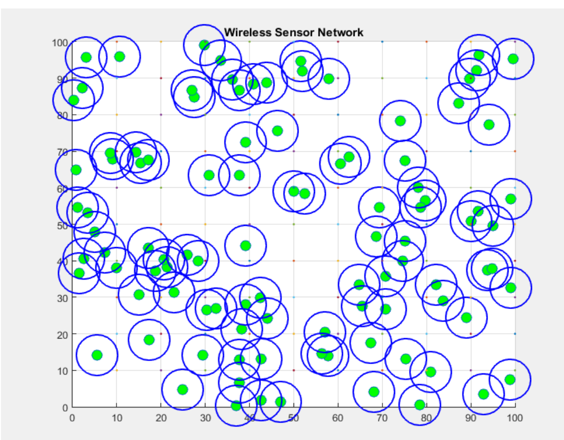

Fig. 5. Initial deployment of sensor nodes.

After running the algorithm, the position of the nodes changes as shown in Fig .6.

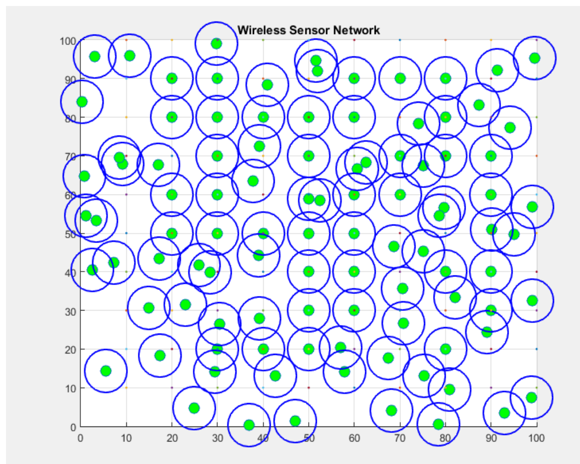

Fig. 6. Distribution of sensors after running the algorithm.

As can be seen, the amount of coverage in the network is higher, and also the sensor nodes have less overlap. Fig.7 shows another implementation of the algorithm.

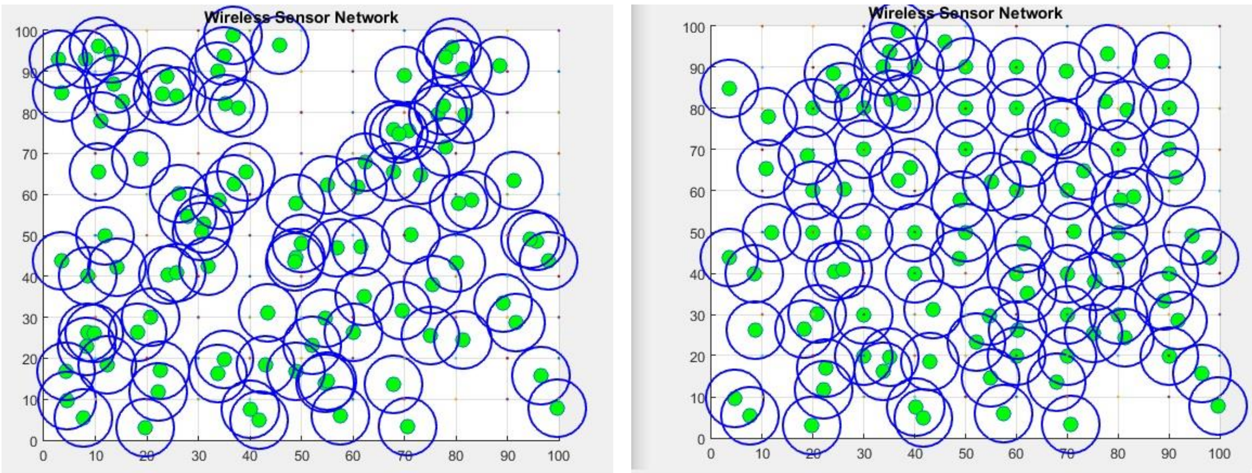

Fig. 7. Status of sensors before and after the execution of the algorithm.

The left and right graphs show the network status before and after the execution of the algorithm, respectively. Again, it can be seen that the coverage has increased and the overlap has decreased.

4.3. RESULTS

To evaluate the performance of the proposed approach, it is compared with some of the prominent related works. For this comparison, all of the works are implemented using the same settings as in Table 2.

In the first experiment, the proposed approach is compared with the works performed in Fang et al. (2018) [2] and Mahboubi et al. (2013) [11] with respect to energy consumption and sensor displacement criteria. Fig. 8 shows the energy consumption of these works to achieve maximum coverage per different number of sensor nodes.

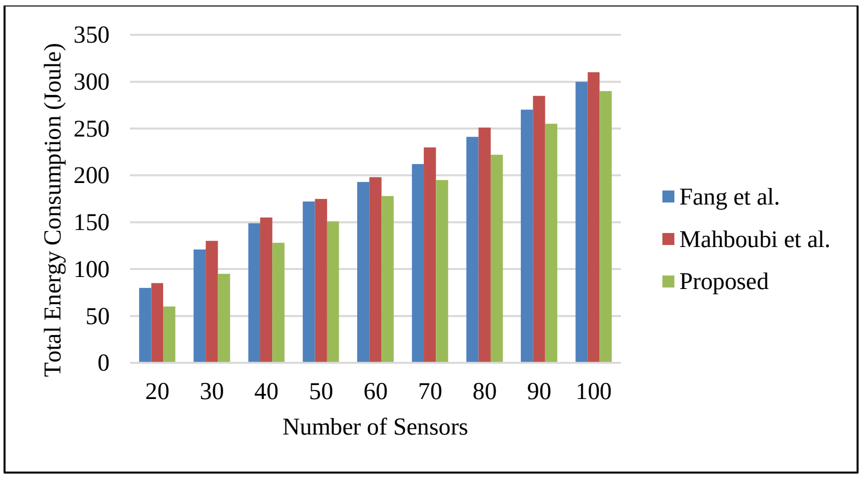

Fig. 8. Energy consumption for different number of sensors.

As can be seen, the proposed approach consumes less energy. The reason is that it creates the least displacement for the sensors. In fact, using the information such as the location and neighborhoods of the nodes, it finds an answer with a lower number of displacements, but the other two works require more displacements for the sensors to achieve maximum coverage.

In the next scenario, we consider the larger dimensions of 200m × 200m and run the approaches for different number of sensors. The results of energy consumption are shown in Fig. 9.

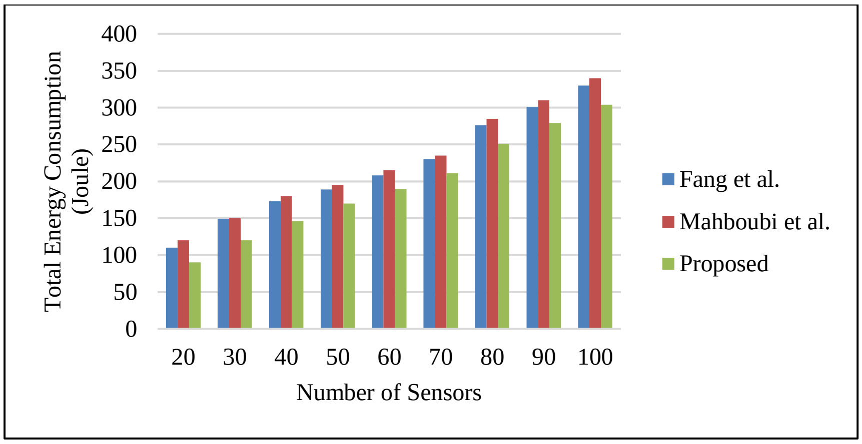

Fig. 9. Energy consumption for larger network.

Obviously, as the size of the deployment region increases, energy consumption increases in all approaches, because the sensors have to move longer distances to provide maximum coverage. However, the proposed approach also consumes less energy.

Fig. 10 shows the total displacement of the sensors to achieve maximum coverage in three approaches.

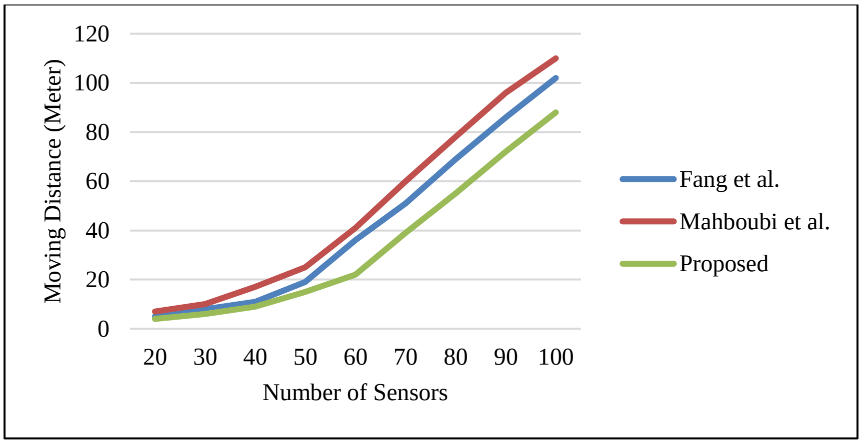

Fig. 10. The amount of displacement to achieve maximum coverage.

As can be seen, the proposed approach provides better coverage with less sensor displacement. Fig. 11 shows the displacement of the sensors in a larger scenario with dimensions of 200m × 200m.

In general, with increasing the dimensions of the network deployment area, the amount of displacement increases, but again, the proposed approach has better results. In all works, the network achieves a specific coverage, but they have different energy consumption and amount of movement to achieve this coverage.

In the second experiment, the proposed approach is compared with the works performed in Xu et al. [21] and Wu et al. [22] with respect to sensor displacement and coverage parameters. Whenever the deployment area of the network is expanded from several dimensions, the consumption of energy changes. As can be seen in Fig. 12, the changes of displacement in the proposed approach to achieve maximum coverage is much less than the related works. In other words, in this approach, the less displacement the sensors have, the better the coverage.

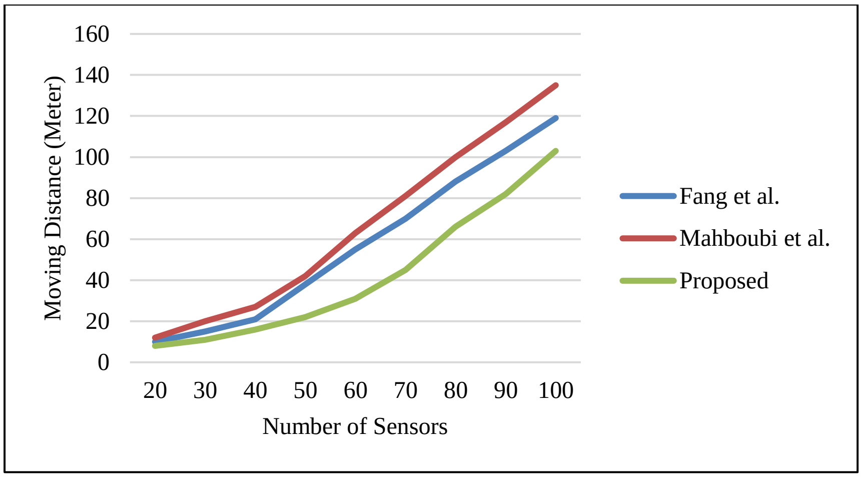

Fig. 11. Movement of the sensors to achieve maximum coverage in a larger network.

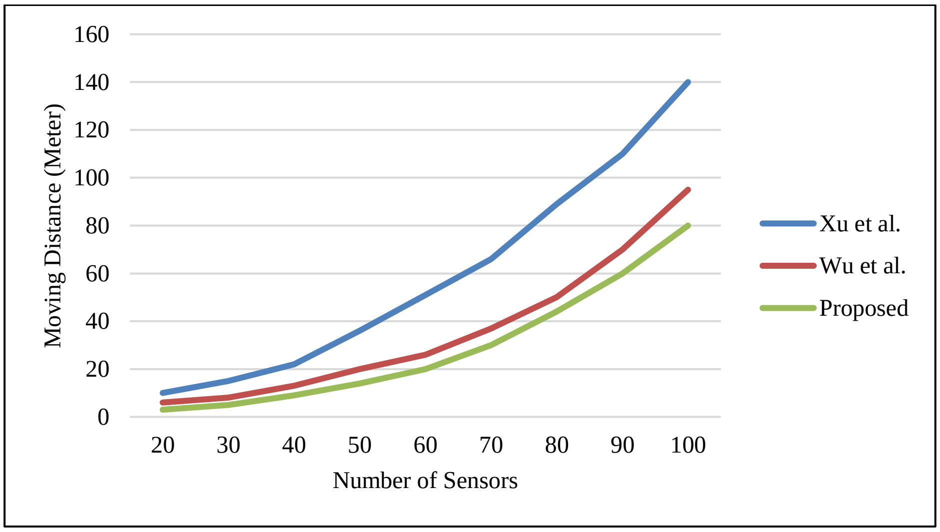

Figure 12. Movement of the sensors to achieve maximum coverage.

The evaluation results of the compared works are shown in Table 3.

Table 3. Comparative results of approaches.

Approach	**Height level (m)**	**Moving level (m/n)**	**Average number of nodes per unit of coverage**
Xu et al. [21]	1.3236	1521.05	35007.58
Wu et al. [22]	1.3212	1522.70	35028.35
Proposed	1.3247	1497.06	34465.34

These results show that our approach has better height and moving levels and is in the middle in terms of the average number of nodes per unit of coverage. In addition, the amount of energy consumption is examined by considering a larger space and the result is shown in Fig. 13.

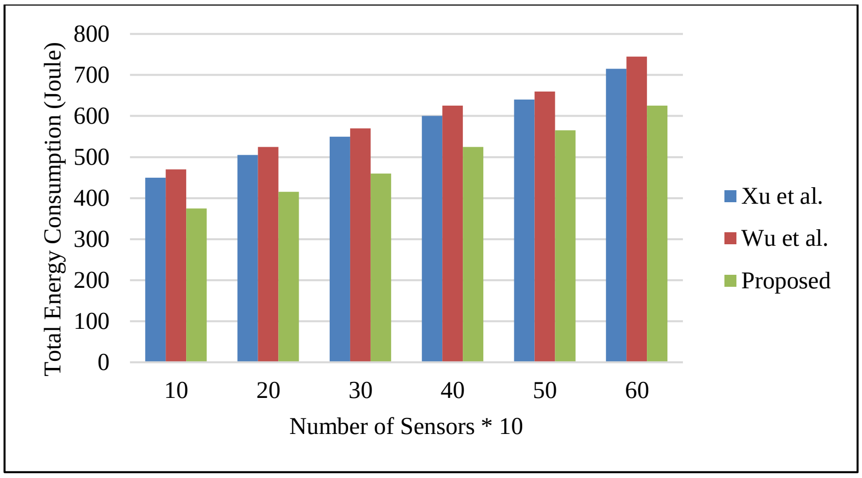

Fig. 13. Movement of the sensor in a larger space.

It shows that as the covered area becomes larger, the energy consumption increases. Because the sensors should travel long distances to provide more coverage. The proposed approach has the least energy consumption and the movement of sensors and provides better coverage than the similar works.

5. CONCLUSION AND FUTURE WORKS

In a WSN, due to the random placement of sensors, it is always possible for multiple sensors to cover the same area, and also for some areas not to be covered by any sensor. This will prevent maximum coverage in the network. In this paper, an approach to the problem of maximum coverage with the least displacement of sensors is presented. Since the displacement of a sensor consumes a lot of energy, the sensors move to the nearest position to get the most coverage, thus reducing the amount of power consumption in the network. The evaluation results of the proposed approach show its better efficiency concerning the displacement and energy consumption of sensors to achieve more coverage compared to similar works.

To extend this research, the problem of coverage can be solved in a distributed scenario. To do this, the network can be designed based on several sinks so that in each area, one sink can perform the task of managing and supporting sensors. In this case, the important issue is the topology of the sinks in the network because the position of the sinks is an important factor in the performance of such an algorithm.

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