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Research Article

An Efficient Algorithm to Enhance Nonoverlapping Coverage Area with Less Energy Consumption in WSN

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Several chargeable sensor nodes are deployed randomly to cover the target points with an efficient heuristic approach for the mobility of sensor nodes in an area of interest (AoI). The heuristic approach generates the cover set that includes the targets for a prolonged time. The cover sets are the subset of the total sensor node area where each set is capable of representing all the targets. The functionality of the sensor nodes depends upon the network lifetime of the target points covering an AoI. The network lifetime would improve by reducing the consumption of battery power through heuristic process. The proposed heuristic process can do this by generating cover sets and selecting sensor nodes with the highest remaining battery power. These cover sets remove the redundant sensor node in an AoI that causes the overlapping issue and assign the maximum lifetime which is the minimum amount of battery power of the sensor node, participating in the cover set. The results show the improvement in the mobility of sensor nodes by coverage and attain maximum network lifetime as compared to the existing algorithms.

1. Introduction

Wireless sensor networks (WSNs) are a network of sensor nodes or sink nodes that are connected to detect movement, communicate, and perform a variety of other tasks [1]. The coverage area is one of the most challenging concerns during WSN deployment when the sensor nodes are not able to transmit data to their targets in specific coverage area. The key challenge of any wireless network is usually a coverage issue that needs to be handled efficiently. In case of WSN, the issue is not only coverage area rather an effective technique is required in which an appropriate number of sensor nodes are used for target coverage. The WSN deployed randomly or deterministically according to the requirement of sensor node functionalities [2]. The different numbers of sensor nodes are employed under the specific coverage area to overcome the issue of their network lifetime and battery consumption so that the coverage area can be efficiently utilized [3]. The sensor nodes operating in one coverage area can perform its activities under active or sleep mode. When a sensor node wants to do any function, it needs to be in active mode [4], whereas on the contrary, the sensor node can go into sleep mode when inactive and performing no task so that it can save its battery power and consumes less energy [5]. There are many application of WSN in which the sensor nodes can deploy in active or sleep mode as per application requirement such as indoor observation, environmental status, fire detection, and territory activity in the targeted coverage area [6]. The network lifetime and reliable connectivity depended on the area of coverage, and it is very challenging for the battery consumption of sensor nodes participating in WSNs [7].

The coverage area is maximized using an efficient heuristic approach by removing the overlapping areas of various sensor nodes that causes extra consumption of energy and eventually shuts down the network due to energy draining [6]. There are several ways described to maximize the lifespan of sensor network, but varying functionalities of sensor nodes are still demanding and need attention to adjust the coverage area [8]. The sensor node localization technique for coverage in a WSN is introduced which employs virtualized sensors using procedure to reduce the sensors while providing complete target coverage [9]. However, due to the limited battery, the network will die fast leading to very limited network lifetime. The sensor nodes are examined and scheduled for target coverage in order to guarantee the network lifetime in WSN [10]. It first places the sensor node in the best possible location and then schedules it to maximize its lifetime. The battery power of sensors is insufficient and died soon, which leaves the network into a standstill. The scheduling technique is used in order to maximize the network lifetime in a limited coverage area [11]. It is explored through the topic of critical location coverage scheduling and developed a computation approach for it which is based on a genetic algorithm to determine the operating time of each sensor node. However, it does not solve the problem of data duplication which minimizes the energy of every node. Hence, the problems of repetition, coverage, and network lifetime are the interrelated issues which need a special attention when deploying WSN. The chargeable sensor nodes are used to solve this issue by placing in an area where targets must be covered to ensure the least number of sensor nodes covering the entire targets so that the battery power can consume. This is achieved by creating the cover sets inside the deployed coverage area and is used to monitor all of the targets. The coverage is achieved by increasing the mobility of sensor node or shifting its position in case of any sensor node failure, and the target area is covered with one cover set consisting on operational sensors. This resulted in saving of battery power of sensor nodes, and due to this, the overall network lifetime can be enhanced as shown in Figure 1. The working time of a network is calculated by aggregating all cover sets operated under one WSN deployment. When a cover set node approaches to an end of its battery life, the rechargeable sensor nodes are recharged using solar energy. Hence, the network lifetime can be enhanced for a long time and have a reliable network connectivity than other techniques. Simulations and testing reveal that the proposed approach is superior to another algorithm for achieving the maximum network lifetime. The main contributions of this paper are as follows:

(1) An efficient heuristic algorithm is proposed for maximum coverage in WSN to solve the coverage problem

(2) The reduction in the overlapping issue that can cause extra consumption of energy in case of maximum coverage

(3) Detailed analysis and comparison of the proposed algorithm on varying parameter values with the latest maximum coverage small lifetime (MCSL) algorithm

Energy consumption depends on the coverage area, which plays a vital role in data packet transmission and clustering for transmission. The effective selection of cluster heads can directly reduce the end-to-end delay and achieves the highest scores of operating nodes. Network lifetime is one of the essential concerns for high-level performance achievement. The proposed technique can enhance the network lifetime to its maximum height by using the energy harvesting and, in this way, a reliable network connectivity, which is the major aspect, effects on alive rate of network. For large and complex network architecture, the effective selection of target nodes can reduce the overall cost and energy consumption, which results in the effective selection along appropriate usage of energy harvesting to reduce the cost and energy consumption.

The rest of the paper is organized as follows: a literature review is discussed in Section 2 which describes the related work according to the given proposed heuristic algorithm. Section 3 presents the coverage problems with their model consisting of motivational ideas of the proposed heuristic with proposed algorithm. In Section 4, the mathematical model of the proposed work is given enhancing the network lifetime using mathematical analysis explained in Section 5. Section 6 discusses the experimental results, and in the end, Section 7 concludes the paper with its future research directions.

2. Literature Review

In this section, the recent research work is discussed relevant to the proposed model. Many authors presented their work for target coverage and aim to enhance the network lifetime of WSNs. In [8, 12], the authors presented a heuristic function used for prolong network lifetime by generating the cover sets and reduced the consumption of energy which limited the coverage area of WSN. In [13], the authors used the directional sensor network for attaining maximum target coverage requirements and proved that the coverage problem was NP-complete problem. For this, a genetic-based algorithm was used for generating the subset of directional sensor network which consumed its maximum energy and the overall network lifetime was compromised.

In [4], the maximum lifetime target coverage (MLTC) algorithm had been proposed in which the network lifespan was calculated using the MLTC algorithm and compared to the greedy maximum set cover (MSC) approach. However, this approach has a longer network lifetime but the battery power consumption is still infancy. In [7], the authors generated a maximum number of cover set to achieve maximal network lifetime by solving MSC problem with two heuristic approaches as linear and greedy. It performed well for coverage issue; however, it reduced the power consumption and decreased network lifetime. Similarly, in [14, 15], the authors presented an efficient method that keeps track of all of the target sets using an optimized connected coverage heuristic (OCCH) algorithm for dealing with the interconnected targets in a coverage area. In this paper, an overlapping problem may arise and data duplication may result in creation of malicious data. For this purpose, in [16], the author

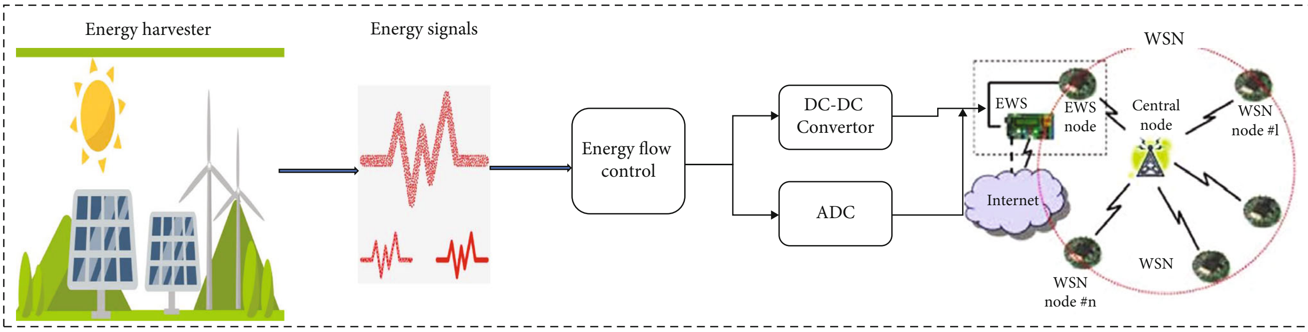

Figure 1: Energy harvesting to enhance coverage area in WSN.

presented a simple coverage technique generating disjoint and nondisjoint cover sets for maximal network lifetime. When the cover sets were generated, the optimal path from the cover set to the interconnected sink nodes is provided, yet the power consumption is not saved rather increases due to the functionality of disjoint and nondisjoint cover set differentiation.

In [17], to evaluate the coverage problem of 3D reign for power consumption reduction, a limited number of sensor nodes were used. The effective energy factor is used to compare the self-healing algorithm and measure the optimality in WSN. It generates the maximum number of sensor covers for improving network lifetime; even so, the coverage area is compromised. Later in [5], the authors presented a random full target coverage connectionist temporal classification (CTC) algorithm to obtain full complete target coverage. It is specifically designed for the selection of target coverage, but energy harvesting is still neglected which is essential for network lifetime.

The authors in [18] suggested a better immune fuzzy genetic model based on CH (channel) selection to attain the objective. A sensor may have a fixed battery or may be enhanced by harvesting; nevertheless, the restricted battery can only provide the maximum lifetime and all the sensors connected via base stations (BSs) perform their respective tasks. Another big achievement in the field of CH selection and energy harvesting was discussed in [19, 20], which used the power limitation and effective coverage with efficient selection of target nodes. The fire hole detection technique was employed in both of the studies, and authors tried to focus on hole detection with cell coverage in order to enhance the network lifetime, still not flexible and field protected.

The high-density wireless sensor network (HDWSN) is used to efficiently cover the targets for security and transportation with low power consumption and computation complexity. As a result, the author suggested elite adaptive particle swarm optimization (EAPSO) for HDWSN target coverage which lead to data duplication. In [21], the authors suggested three QoS criteria such as remaining energy, connection, and coverage to extend the network lifetime for an efficient interconnected coverage scheduling. But the sensor nodes not covering the targets are utilized as a relay node for sink node communication. In [22], an alpha-coverage was presented to increase the maximum network lifetime, in which no target was left uncovered. It provided partial coverage to maximize network lifetime by employing an efficient heuristic. In [23, 24], the authors proposed an exact column generation approach with the use of genetic algorithm which has a goal to enhance the network lifetime. Similarly in [25], an optimal schedule was used to perform a hybrid column generation to maximize the network lifetime. The limitations are the power consumption in case of network lifetime while covering the targets. In [6], the main aim of the authors was to enhance the network lifetime with a selection of specific sensors covering the maximum target area in WSN. The cover sets were used to attain the maximum lifetime, but at some point, the battery of sensor died and the network halted. Therefore, the main issue in coverage area of sensor deployment is the battery consumption which must be handled and managed so that the network connectivity and lifetime of a network can be improved. However, this technique is environmental specified; i.e., if we change the scenario, the overall performance will be affected. Moreover, this algorithm needs a lot of enchantment in terms of energy consumption. The coverage area is being a matter of concern for the analysts in order to predict the number of technical challenges of sensor networks.

In [19], routing protocols were incorporated to solve the balancing problem of network by using optimal path finding. The achievement of multipath routing is resulted in reducing the energy consumption of network. However, this approach is only beneficial for homogeneous WSNs. Some other techniques of coverage area with multipath are based upon data packet transmission and data centric algorithms [20]. However, the major drawback of these algorithms is their own sensing trust factor and reliability. In [26], the authors combined the primary user selection with multilevel transmission and enhanced the target scalability by harvesting the head nodes. The harvesting of cluster heads is not the efficient mechanism that is why the proposed algorithm of this study is based on harvesting of all the nodes.

3. Mathematical Model

In this section, the mathematical model of our proposed algorithm is presented to maximize coverage area for less energy consumption. The coverage challenges mostly occur during the deployment of the wireless network in terms of the consumption of battery power due to the abundant usage of WSN. To overcome these issues, some efficient heuristic techniques are required. Hence, to implement the proposed algorithm, assume that a specific region of size $L \times W$ has certain targets $T = \{t_1, t_2, t_3, \cdots, t_n\}$ and there are $Sj = \{s_1, s_2, s_3, \cdots, s_m\}$ number of sensor targets utilized in the location for target coverage. These sensors are deployed randomly with their detection range R and the initial battery powers E_i. A target t_i is in the monitoring reign which is covered by at least one sensor. The coverage problem has been explored by several researchers and categorized as NP-complete problem [12, 13]. The coverage area is represented as

$$P_{ij} = \begin{cases} 1, & \text{if sensor } S_i \in S_j \text{ (Cover)}, \\ 0, & \text{else}, \end{cases} \quad (1)$$

where P_{ij} is the coverage area of all nodes, S_i denotes the number of sensor nodes, and S_j is the cover set. Coverage problem can be described as

$$\begin{gathered} \text{Maximize} \sum_y B_y \\ \text{Subject to} \sum_y B_y < E_i \quad \forall s_i, B_y \geq 0, \end{gathered} \quad (2)$$

where B_y is the battery initial power and E_i is battery energy after harvesting.

To cover the given target, the linear programming problem (2) must be known ahead of time. The matrix output will be 1 if the sensor covers the target; otherwise, it will be 0. However, it is difficult to generate the covers ahead of time whenever a large network is deployed; thus, it must be calculated at that moment.

Another problem that can occur during the deployment of the sensor network is an overlapping issue. When network is deployed, there are more than two sensors sensing the same target. Due to overlapping problems, it causes fast dissipation of battery powers and data can be redundant. So, an effective optimization technique is needed to cover the maximum targets with less energy consumption in WSN. Hence, the parameters are calculated for comparison on the given mathematical notions and the results are analyzed in the next section.

3.1. Target Coverage Matrix. When sensor node s_i covers the target t_j, then it displays the output 1; otherwise, it displays 0. The relationship matrix of target coverage is formulated as

$$F_{ij} = \begin{cases} 1, & \text{if sensor } s_i \text{ Covering target } t_j, \\ 0, & \text{Not covering}, \end{cases} \quad (3)$$

where F_{ij} is the finite target coverage set and t_j is the target set.

3.2. K-Cover Set (S_k). The matrix F_{ij} in a K-cover set (S_k) represents a set of sensor nodes that cover the targets. If $F_{ij} = 1$, then the cover set is called as minimal K-cover set.

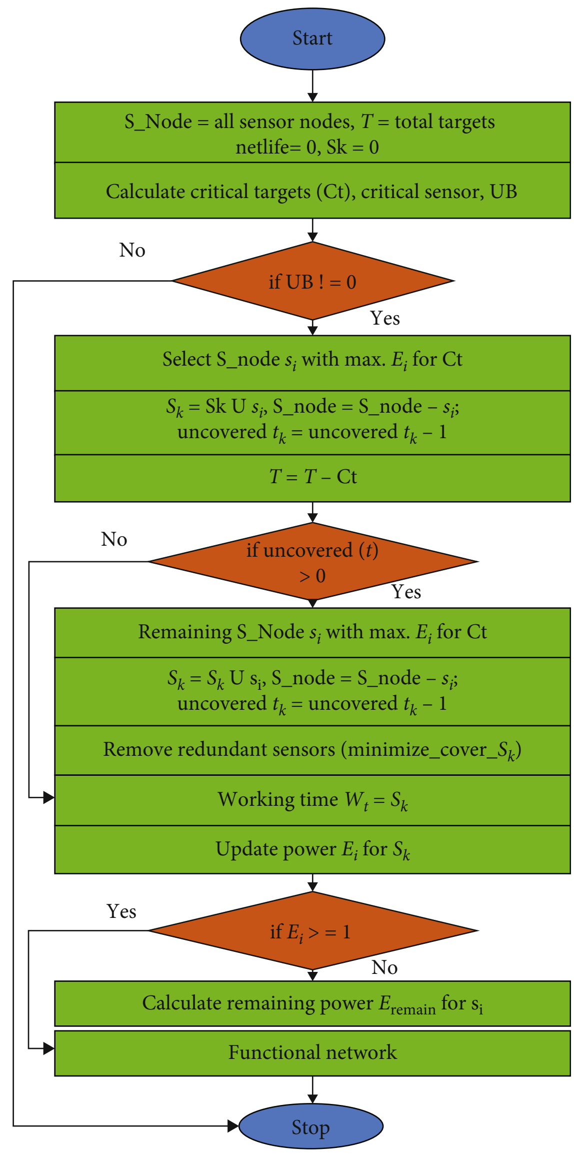

FIGURE 2: Generating cover sets through the proposed algorithm.

A cover set (S_k) is the subset of total sensor nodes, and there are one or more cover sets that can be generated for maximum coverage.

3.3. Critical Target and Sensor. The target having minimum number of sensor nodes operating in a particular coverage area is known as critical target (C_t) and the sensors are called critical sensors (C_s) in that area.

3.4. Maximum Lifetime of Cover Set. The lifetime assigned to each cover set that acts for a specific time with maximum working time for minimum power of sensor nodes participating in the cover set is calculated as

$$\text{Max}_{\text{Lifetime}}(S_k) = \text{Min}_{S_i \in S_k} E_i, \quad (4)$$

where S_k is the network lifetime set for all nodes and S_i represents the number of sensor nodes.

```
Input: S_Node = Total Sensor nodes; T = Total number of Targets;
        NetLife =0; Uncovered (t) = T; Ei = Initial Battery Power of sensors; S_k = φ;
Output: Generate k- Cover Sets.
        Calculate Critical Target c_t
        Calculate Critical Sensor C_s
        Calculate upper bound UB
    While UB !==0
        While uncovered (c_t) >0
          Select Critical Sensor node s_i with highest battery Power E_i that covers maximum uncovered target
          S_k = S_k U s_i ;
          S_Node = S_Node - s_i;
          for all targets covered by s_i
            Uncovered (c_t) = Uncovered (c_t) – 1;
          end for
        end While
        T = T - c_t;
        While uncovered (c) >0
          Select Sensor node s_i with highest battery Power E_i that cover maximum uncovered target
          S_k = S_k U s_i;
          S_Node = S_Node - s_i;
          for all targets covered by s_i
            Uncovered (c) = Uncovered (c) – 1;
          end for
        end While
      //Remove redundant sensors generated in k-Cover
      Minimize_Cover_Sk ( )
        //Assign Working time of Generated K-Cover
          W_t = Min s_i ε S_k (E_i);
        //update remaining battery power of sensor nodes
          for s_i ε S_k
            E_i = E_i - W_t
            if E_i < =1
              Calculate required power using Equation ((7))
              Add Power to the sensor node
            end if
          end for
      end While
```

Algorithm 1: Generate cover set (S_k).

3.5. Network Lifetime ($N_{Lifetime}$). The lifetime of the network is the summation of all maximum lifetime of each cover set participating in the network. Let x be the total number of covers set; then, the network lifetime can be calculated as

$$N_{\text{Lifetime}} = \sum_{k=1}^{x} W_k, \tag{5}$$

where N is the number of nodes and W_k is the working time.

3.6. Upper Bound of Network (UB). The upper bound can be calculated as the total number of critical targets that are poorly covered in the sensing range. Using upper bound, the number of generated cover sets can be equal to or less than the limit.

3.7. Estimated Battery Power Required for Charging. Consider a network of sensors $S = \{s_1, s_2, s_3, \cdots, s_m\}$ with all sensor nodes having the same battery power E_i. When the sensor power vanishes, the sensor nodes need to be recharged. After that, the remaining power of the sensor nodes is E_{remain}, which is $0 \le E_{\text{remain}} \le E_i$ and calculated as follows:

$$\sum_{s_i \in S} C_i \le U, \tag{6}$$

$$\begin{aligned} C_i &\le E_i - E_{\text{remain}} \quad \forall s_i \in S, \\ C_i &\ge 0 \quad \forall s_i \in S, \end{aligned} \tag{7}$$

$$E_i = C_i + E_{\text{avail}} \quad \forall s_i \in S, \tag{8}$$

where U is the charging unit that preserves the energy for later use and C_i is the energy transferred from the charging point U to the sensor battery. The given batteries never exceed the total capacity given in Equation (7) and Equation (8).

```
Input: S_Node = Total Sensor nodes; Minimize_Cover_Sk = φ;
Output: Minimize_Cover_Sk
for i = length (Sk) down to 1 do
    if Sk − {si. Sk} meets k coverage requirement Then
        //Ignore si. Sk
        Sk = Sk − {si, Sk}
    else
        Minimize_Cover_Sk = Minimize_Cover_Sk U {si, Sk}
    end if
end for
```

Algorithm 2: Minimize_Cover_Sk.

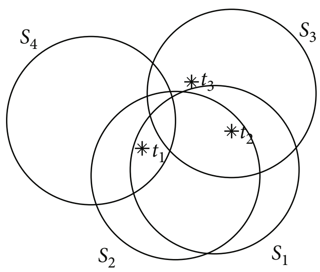

Figure 3: Initial coverage area with 4 sensor nodes and 3 targets.

Table 1: Target coverage matrix before mobility.

S/t	t_1	t_2	t_3
s_1	1	1	0
s_2	1	1	0
s_3	0	1	1
s_4	1	0	0

4. Methodology for the Proposed Efficient Heuristic

An efficient heuristic algorithm is proposed to maximize the wireless sensor network coverage area of targets so that the overall network lifetime is enhanced by generating the heuristic cover sets where each cover set guarantees the efficient coverage of targets. The management of cover sets needs to be done properly and efficiently so that the network lifetime is maximized with nonoverlapping cover reduction. The proposed algorithm consists of phases as shown in Figure 2 and is implemented through these phases to carry the heuristic functionality of target coverage with maximum network lifetime. The working of the proposed algorithm is discussed in the following subsections.

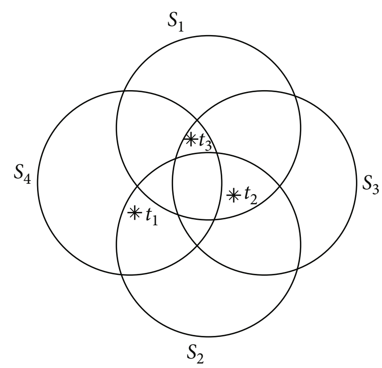

Figure 4: The network structure after the mobility of 4 sensor nodes and 3 fixed targets.

Table 2: Target coverage matrix after mobility.

s/t	t_1	t_2	t_3
s_1	0	1	1
s_2	1	1	0
s_3	0	1	1
s_4	1	0	1

Table 3: Different parameters with their values.

Parameters	Values
Area	100 m × 100 m
Sensor nodes	10–50
Targets	3–20
Battery power (E_i)	5 J
Sensor range	15, 20, 30 meters
Working time (W_t)	1 J, 2 J, 3 J, 4 J

4.1. Generate Cover Set (S_k). The proposed heuristic algorithm selects the sensor nodes for generating the cover sets S_k, which cover the maximum targets, and must contain at least one critical target C_t and a maximum battery power E_i. Therefore, the proposed heuristic first finds the critical targets and their corresponding sensors to utilize them in generating the cover sets as shown in Algorithm 1. After wisely covering the critical targets, the next process is to cover the simple targets with the highest remaining battery power E_i.

4.2. Minimize Cover (S_k). When cover sets generate, a simple function is used to solve the overlapping problem to remove the extra sensor nodes covering the target redundantly which causes the extra battery consumption. In Algorithm 2, if sensor node S_i is removed and the coverage requirement is

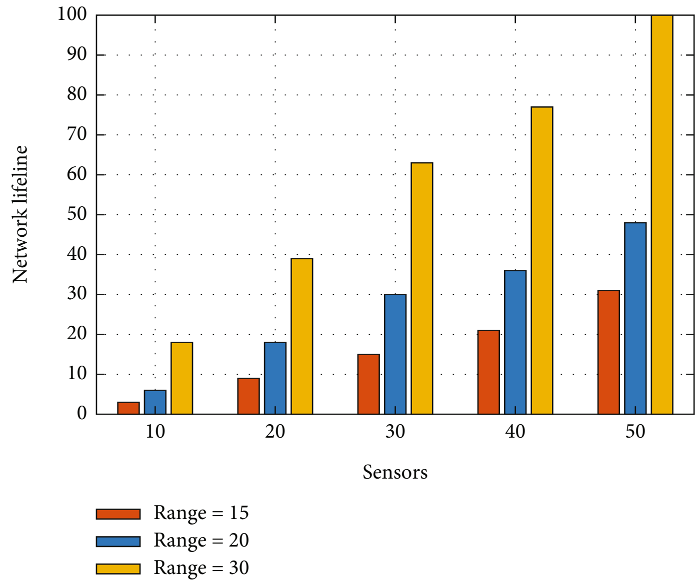

FIGURE 5: Network lifetime with different ranges.

satisfied accordingly, then remove S_i because this sensor node does redundant coverage. In this way, battery consumption will reduce due to the removal of extra sensor nodes.

4.3. Maximum Lifetime of Cover Set (W_t). In the next phase, the maximum lifetime of the cover set (S_k) is assigned using Equation (4), which is given in Mathematical Model to describe the maximum lifetime of the cover set. The maximum lifetime of cover set can be user-defined or generated at that time. In this way, an efficient improvement can achieve for the maximum lifetime.

4.4. Update Remaining Battery Power of Sensors. In this phase, the proposed heuristic algorithm updates the remaining battery power for generating the cover sets that avoid the duplication.

4.5. Charging Battery Power of Sensor Nodes. Finally, in the last phase, after updating the remaining battery power, it refiled the battery power through charging by the solar energy. This charging will work only if the battery power of the sensor nodes is less than 1 unit. In this way, the network continuously performs its working with maximum coverage and no sensor node will die.

5. Mathematical Analysis

Let us assume that there are 4 sensor nodes $S = \{s_1, s_2, s_3, s_4\}$ and 3 targets $T = \{t_1, t_2, t_3\}$ with initial battery power E_i for S_j. To determine the critical targets and their critical sensors, the coverage area is shown in Figure 3. According to critical target definition, t_3 is termed as the critical target, and the remaining targets t_1 and t_2 having the covering sensor nodes 3 are shown in Table 1. The sensor node s_3 will become the critical sensor and can make the cover set $S_{k1} = \{s_1, s_3\}$, and no other cover set will be generated because of the coverage area requirements.

TABLE 4: Network lifetime values with varying ranges.

Sensors	Range 15	Range 20	Range 30
10	2.9	5.9	17.9
20	8.9	17.9	38.9
30	14.9	29.9	63.9
40	20.9	35.9	76.9
50	30.9	47.9	99.9

For target coverage matrix F_{ij}, using Equation (3), the coverage area can be expressed in Table 1.

The maximum number of cover sets is required to achieve the maximum network lifetime because when the number of cover sets increases, the network lifetime also increases. After the mobility of sensor nodes, the coverage requirement is satisfied and makes more cover sets. In this case, the network structure with 4 sensors and 3 fixed targets is illustrated in Figure 4.

After the mobility of sensor nodes, a new target coverage matrix is achieved given in Table 2. Here, the critical target is t_1 because this is the only target covered by two sensor nodes and the other targets t_2 and t_3 cover 3 sensor nodes each. The proposed algorithm selects the nodes which contain the highest remaining battery power for making cover sets. After the execution, the generated cover sets are $S_{k1} = \{s_1, s_2\}$ and $S_{k2} = \{s_3, s_4\}$, and using the proposed Algorithm 1, the cover sets are generated until all the targets are covered. The cover sets can be generated as many times as needed until it will not exceed the upper bound limit of the coverage area of WSN.

After making the cover sets, the next phase is to remove the redundant sensor nodes. For this, every sensor node in

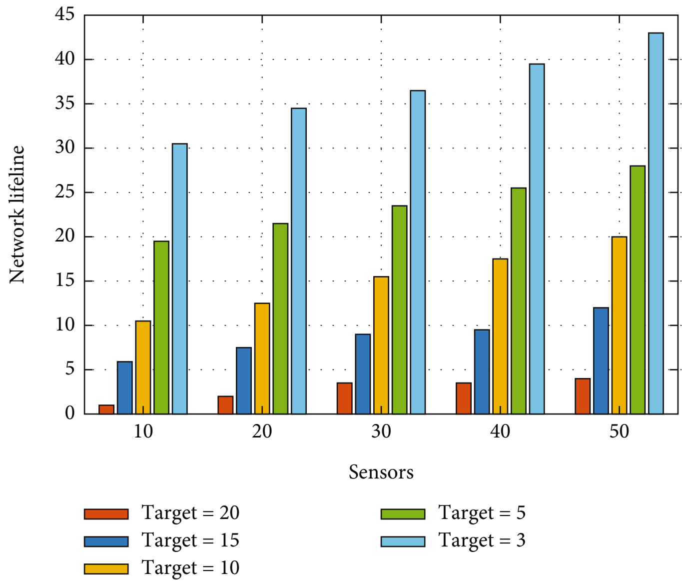

Figure 6: Network lifetime with varying targets.

the cover sets is to be checked. For the removal of any sensor node, the given cover set should satisfy the coverage requirements and then remove that sensor; otherwise, it will be there in the sensor cover. After this, assign the working lifetime of each cover set which has the minimum battery power of sensor nodes participating in the cover set using Equation (4). Then, update each sensor node's remaining power, and if the power of any sensor node s_i is going to be dead, it will recharge again. To charge a sensor node, first, it calculates the required battery, and then by using the charging unit, a specific amount of power is transferred to the sensor node s_i. The network lifetime before the mobility of sensor node is 2.99, but after the mobility of sensor nodes, it increases up to 3. The range of each sensor node is 15 m with the cover sets $S_{k1} = \{s_1, s_2\}$ and $S_{k2} = \{s_3, s_4\}$; it is assumed that 0.5 Joule (J) battery power is utilized during the mobility of sensor nodes. In this situation, the network lifetime will attain a value of 5.49.

6. Simulations and Result Analysis

The simulation is carried out in MATLAB/Simulink (R2019b) environment on a system of core i5 with 2.30 GHz processor and 8 GB RAM. The area under consideration is 100m × 100m having different sensor nodes with initial battery power of 5 J. The simulation parameters used in this work are given in Table 3. We have presumed that a confidence interval is 0.05 for the trust rating to allow the entities to make accurate decisions participating in WSN. If the confidence interval is sufficiently narrow, it proceeds with its decision-making process. However, if the confidence interval is too wide, then additional experiences are collected at the expense of additional resources. This confidence interval will assist nodes in making decisions for routing, sensing, and data aggregation.

Table 5: Network lifetime values with varying targets.

Sensors	Target 20	Target 15	Target 10	Target 5	Target 3
10	0.99	5.9	10.49	19.49	30.49
20	1.99	7.49	12.49	21.49	34.49
30	3.5	8.99	15.49	23.49	36.49
40	3.5	9.5	17.5	25.5	39.49
50	3.99	11.99	19.99	27.99	42.99

The proposed algorithm is compared with the MCSL algorithm on various parameters. The simulation results are analyzed and discussed in the following subsections.

6.1. Network Lifetime with Varying Ranges. In this experiment, 3 fixed targets are used which cover the different number of sensor nodes in the interval [10, 50] with the step of 10. If working time of each cover set is 3 units within varying ranges of sensor nodes such as 15 m, 20 m, and 30 m, then it is clearly shown in Figure 5 that the network lifetime increases for all targets. The maximum number of cover sets can be generated as the number of sensor nodes increases to achieve the maximum network lifetime as it is shown in Table 4 for different experimental values. The duty cycle of a node is based on the queue size and priority class of a packet to reduce the delay of high priority packets and support time-bounded delivery of priority packets. By checking the queue size and the priority class of packets in the message queue of each node, the node determines whether or not to adjust its duty cycle. In this approach, a node increases the length of its active period in the event of high traffic which provides less waiting time for the packets in the queue. The sender node informs the receiver the duration for which it has to stay awake at the beginning of data transmission; both the sending and the receiver's duty cycle is controlled based on the queue length and the priority of

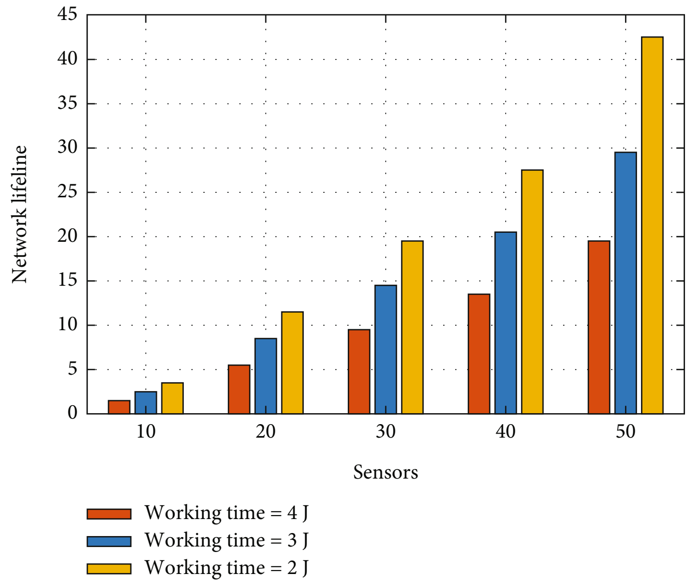

Figure 7: Network lifetime with varying W_t.

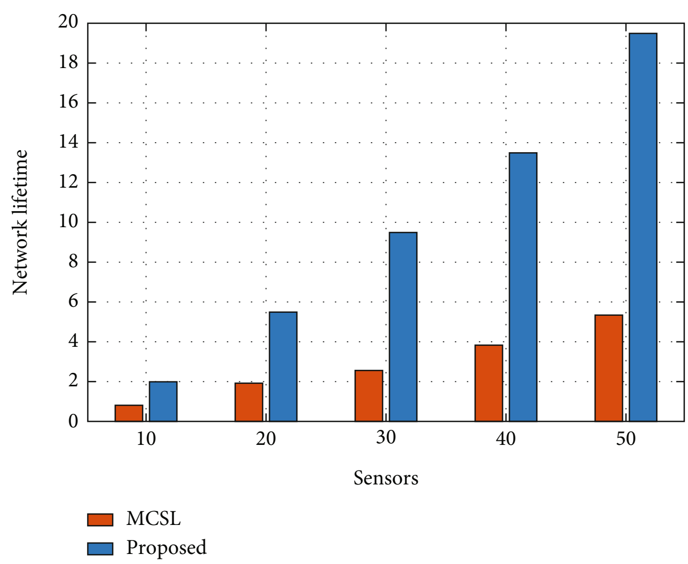

Figure 8: Comparison of network lifetime between MCSL and proposed algorithm.

the packets. This approach saves energy and lessens packet latency.

6.2. Network Lifetime with Varying Targets. In this experiment, several targets are incorporated for coverage with sensor nodes in the interval of [10, 50] with the step of 10. Here, the working time of each sensor cover is 1 unit. Figure 6 shows that the network attains different lifetimes at varying targets. When target increases, the network lifetime decreases. This is due to the increment of coverage area. So, if the number of sensor nodes increases and the given targets are fixed, then the network lifetime will be increased because of the maximum number of covers set alive for maximum time. Similarly, when the number of targets increases and sensor nodes are fixed in numbers, then, due to continuous coverage, all cover sets will be active and the lifetime will be decreased as it is depicted in Table 5.

Table 6: Network lifetime values of MCSL and proposed algorithm.

Sensors	Proposed	MCSL
10	1.99	0.81
20	5.49	1.92
30	9.49	2.56
40	13.49	3.83
50	19.49	5.34

6.3. Network Lifetime with Varying Working Time. In this experiment, we used 3 fixed targets for coverage and assume

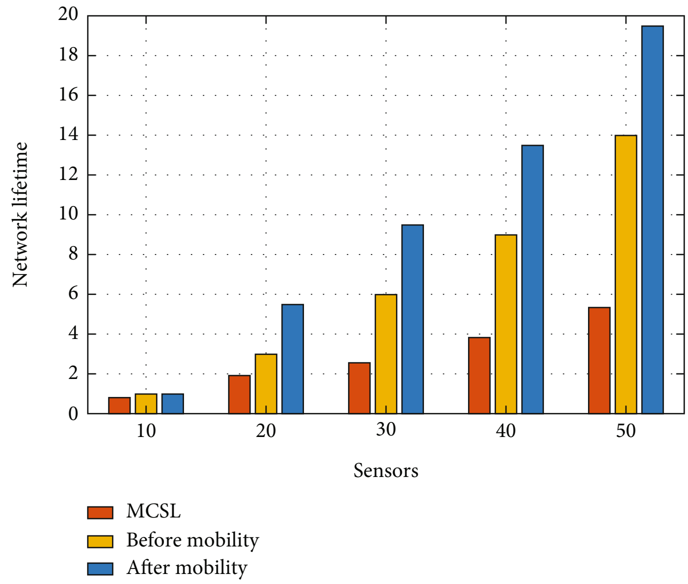

Figure 9: Comparison of proposed and MCSL algorithms with mobility.

that the maximum range of sensor nodes is 15 m. At working time = 2 J and no.of sensor nodes = 10, then network lifetime is about 4 units as shown in Figure 7. When number of sensor nodes either increases from 10 to 20 or from 20 to 30 at the same working time, the network lifetime increases from 4 units to 12 units and from 12 units to 20 units, respectively. Similarly, when number of sensor nodes increases from 40 to 50, the network lifetime increases from 28 units to 43 units. The similar results for working time =3 J and 4 J. It means that at any working time, when number of sensor nodes increases, then the network lifetime increases and vice versa. Now, again at any number of sensor nodes along with the fixed targets, if working time increases, the network lifetime decreases.

6.4. Network Lifetime Comparison of Proposed Algorithm with MCSL. In order to compare the enhanced network lifetime of the proposed algorithm with the MCSL algorithm, we have 3 fixed targets and assume that the working time of each cover set is 1 unit. From Figure 8, it shows that the proposed algorithm provides better results than the MCSL algorithm.

Using experimental results given in Table 6, it shows that the proposed and existing algorithm values have a major difference. The network lifetime increases when the number of sensor nodes increases and also network lifetime decreases with the increment in number of targets. This is due to the increment in the number of sensor nodes with the possibility of generating the maximum cover sets, and hence, the network lifetime will be increased. Similarly, as the number of targets increases, it causes a decrement in network lifetime because of the smaller number of cover set generation.

Figure 9 shows the comparison of our proposed algorithm with MCSL algorithm for network lifetime before and after the mobility of sensor nodes in the range of 15 m. After the mobility of sensor nodes, the network lifetime achieves the bigger value as compared to the MCSL algorithm. When the sensor nodes and targets increase, the more cover sets are generated so that the network lifetime will be increased with maximum network coverage as it is shown in Table 7.

Table 7: Network lifetime values of MCSL and proposed algorithm on mobility.

Sensors	MCSL	Before mob.	After mob.
10	0.81	0.99	0.99
20	1.92	2.99	5.49
30	2.56	5.99	9.49
40	3.83	8.99	13.49
50	5.34	13.99	19.49

6.5. Comparison of Target Coverage with MCSL. In this comparison, the different numbers of targets are used in the interval of [10-50] by the step of 10 with the given parameters. Initially, the sensor nodes are placed randomly. Due to the enhanced mobility of the sensor nodes, the target coverage using proposed algorithm is high as compared to the MCSL algorithm as shown in Figure 10. It means that after the mobility of sensor nodes, coverage can be enhanced. In this way, the network can be able to provide maximum lifetime.

6.6. Discussion. The proposed heuristic generates the cover sets by selecting the sensor nodes with highest remaining battery power. These cover sets remove the redundant sensor node in an area of interest that causes the overlapping issue and also assign the maximum lifetime which is the minimum amount of battery power of the sensor node participating in the cover set. The results indicate that the maximum coverage can be attained by using mobility of sensor

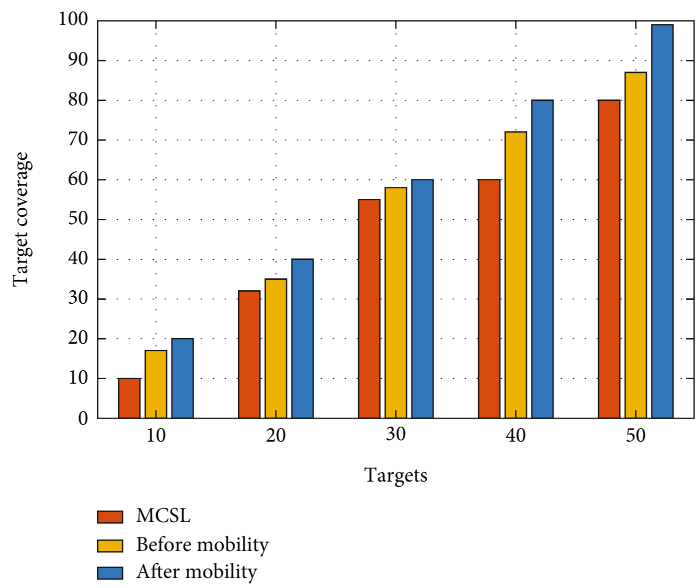

Figure 10: Target coverage and their comparison with MCSL.

nodes with maximum network lifetime as compared to the existing algorithms.

7. Conclusion and Future Work

An efficient heuristic algorithm has been proposed for covering the targets with chargeable sensor nodes. Our main objective was to enhance the network lifetime for prolonged period and to reduce the consumption of battery power with the help of removal of redundant sensor nodes. In order to achieve this, those critical targets that are poorly covered in the network have been determined and a subset of sensors containing at least one critical target has been made. These cover sets reduce the battery power consumption by activating a specific cover set while others are in sleeping mode avoiding the redundant coverage of the target. After making cover sets, the maximum lifetime of each cover set has been assigned. The working time of each cover can be user-defined or has minimum battery power of sensor nodes participating in the cover set. It can be observed that the network lifetime can be increased with the increment in the number of sensor nodes working for a fixed target, and due to this, the coverage performance can be improved. The proposed algorithm performed well as compared to MCSL algorithm in enhancing the network lifetime with respect to various parameters such as changing working time of cover sets, range of sensor nodes, varying targets, and sensor nodes. In the future, the machine learning techniques can be utilized for making a more efficient heuristic algorithm that can consume less energy with better target coverage and a longer network lifetime.

Data Availability

All data generated or analyzed during this study are included in this article.

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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