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Energy-Efficient and Coverage-Guaranteed Unequal-Sized Clustering for Wireless Sensor Networks

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ABSTRACT In the last years, due to the limited resources of consumer products, energy-saving is known as one of the design challenges of Wireless Sensor Networks (WSNs). Clustering is a practical technique to enhance the performance of the network including energy efficiency, network scalability, and network easier management. In cluster-based networks, the size of clusters has a key role in the network power consumption. Non-optimized clustering results in increasing the power consumption of the whole network. The small size clusters leads to appear coverage hole in the network, as well as this property is the opposite of being the scalability of the network. In addition, in non-optimized clusters, reducing the energy consumption of the nodes as the key objective of clustering, cannot be pursued, thus the clustering will result contrary. Consequently, the energy consumption reduction after clustering can be guaranteed by considering the power consumption of nodes before clustering in cluster size optimization. Hence, in this paper, an Energy-efficient and Coverage-guaranteed Unequal-sized Clustering (ECUC) scheme is proposed which considers both energy and coverage issues simultaneously in optimizing the cluster size. Based on the simulation results, the proposed scheme remarkably enhances the network lifetime by reducing the total dissipated energy while guarantying the coverage issue.

INDEX TERMS Wireless sensor networks, clustering; cluster size, coverage hole, energy efficiency.

I. INTRODUCTION

A Wireless Sensor Network (WSN) usually consists of many types of consumer devices. The main duty of these components is to sense data from the environment and transmit toward a Base Station (BS) [1], [2]. Transferring the data packets from nodes to BS is performed by different routing methods. Due to limited power supplies of nodes, these components should be taken advantages as much as possible [3], [30]. Clustering is the one of the most effective and promising schemes in order to enhance the energy efficiency [32], [33]. In the past few years, several energy efficient based clustering routing algorithms have been proposed to enhance the energy conservation in WSNs [25]–[31]. Most of the previous clustering schemes construct sub-optimal clusters without considering joint energy consumption reduction and coverage issues, which leads to high energy consumption and deficiency of coverage. Based on literature review, generating the small sized clusters increases the probability of constructing empty clusters in the network, which leads to coverage holes, as well as, this property diminishes the scalability of the clustering scheme. On the other side, large size clusters trigger excessive energy consumption in the network. Moreover, if this parameter is not adjusted properly, decreasing the energy consumption of nodes as a key objective of applying clustering, cannot be achieved; hence, the clustering process will act contrary in this regard. In order to guarantee the energy consumption reduction after clustering, the energy consumption of nodes before clustering should be considered; however, this principle is not addressed in previous works. Therefore, ECUC scheme is proposed in this paper, which aims to eliminate the aforementioned drawbacks of existing schemes. ECUC scheme defines a cluster size interval and then detects the

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optimal cluster size from this range. Improving a cluster size range helps to consider all objectives of ECUC in order to construct the optimal size clusters. The upper bound of the range of clusters number is obtained based on node density, which is required for coverage preservation. Furthermore, the lower bound is computed based upon dissipated energy of nodes before and after clustering to enhance the energy saving. The ECUC models the problems of lower bound calculation and optimal cluster size derivation, as Integer Linear Programming.

The remainder of this paper is organized as follows: Sections II gives the literature review of the research area. The system model is provided in section III. Energy-efficient and Coverage-guaranteed Unequal-sized Clustering (ECUC) scheme is introduced in section IV. Sections V, VI and VII give the analysis, performance evaluation and conclusion, respectively.

II. RELATED WORKS

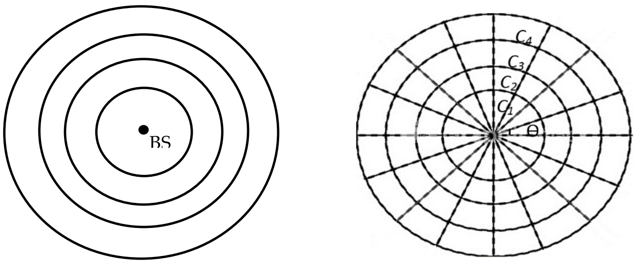
In the past years, an increasing number of studies has been devoted to optimize the size of clusters in WSNs. The idea of dynamic clustering is proposed by LEACH [4] and HEED [5] for the first time, which aims to improve the energy efficiency. However, performing dynamic clustering imposes extra overhead on the network. This drawback has been dissolved in Unequal Clustering Size (UCS) [6] model as the first unequal clustering scheme. The target of such schemes [7]–[10] is to address the hot spot problem, which happens in clusters around BS since these clusters require more energy to relay the data packets from outer clusters.

In UCS, the balanced energy consumption of CHs can be achieved through adjusting the number of nodes in different clusters with respect to the traffic load. Therefore, UCS improve the energy efficiency which results in a longer network lifetime. In addition, using two-hop inter-cluster communication leads to decrease transmission distance compared with LEACH. However, since, the network is divided into only two layers, UCS is not applicable for large size networks. Furthermore, intra-cluster energy consumption is not considered in UCS.

An Energy-Balanced Data Gathering (EBDG) protocol is proposed by [11] to enhance the balanced energy consumption of CHs. In EBDG, the network is divided into coronas and coronas into equal size sub-coronas and finally sub-coronas into zones so that EBDG aims to achieve load balance in each zone. The main objective of EBDG is to optimize the number of coronas, which is modeled as an optimization problem. Although, EBDG can balance the workload among different zones, however, this scheme is proper for small size networks since sensor nodes can directly communicate with the BS. In addition, it is observed that balanced energy consumption is achieved by assigning larger cluster size to the CHs belonging to outer layers, which has less communication load [12]; whereas this issue is not considered in EBDG. To enhance the network lifetime, a coverage-time optimization based scheme is presented [13], which aims to calculate the optimal cluster size in different layers. However, one of the requirements of such scheme is the number of clusters; however, it is infeasible [14]. Arranging Cluster sizes and Transmission ranges (ACT) strategy have been introduced by [14] aims to overcome the hot spot problem and maximize the lifetime of the network. In ACT, the topology of the network consists of multiple layers and the size of clusters belonging to each layer is determined according to the distance from BS. Thus, this property can solve the energy hole problem. However, the size of clusters belonging to outermost clusters is too large, which leads to increase the intra-cluster energy consumption of outer layers. In addition, since the location of the newly selected CH deviates from the ideal ones, this property makes the distribution of energy fluctuate.

Energy-Balancing unequal Clustering Approach for Gradient-based (EBCAG) scheme is introduced by [15]. EBCAG aims to optimize the cluster size in different layers of the network to avoid the unbalanced energy consumption of nodes belonging to different layers. The size of clusters is calculated by the gradient values of their CHs which are computed based on received data from the nodes with gradient values. This scheme balances the energy consumption of CHs, as well as, it overcomes the drawbacks of previous cluster size optimization based schemes. However, EBCAG constructs the small size clusters and it is opposite of being the scalability of the network. This weak point has been eliminated in DBS [16] through providing a mathematical framework to optimize the cluster size in different layers of the network. DBS divides the network into coronas. Afterward, different clustering rules are applied to each corona, which results in enhanced load balancing and energy conservation. A sub-optimal clustering algorithm named Optimal Clustering in Circular Networks (OCCN) is proposed by [17] to reduce the dissipated energy and prolong the network lifetime. To this end, the energy consumption is optimized by partitioning the network into equal size clusters in a distributed manner. However, equal sized clustering leads to imbalance energy consumption during inter-cluster communications, which results in early partitioning of the network.

Finally, it is observed that most of the existing schemes construct the sub-optimal clusters, which leads to coverage holes and compromised network lifetime. Generating the small clusters without considering the density of nodes, increase the probability of constructing empty clusters in the network, which results in coverage and connectivity problems. On the other side, constructing the large size clusters leads to increase the intra-cluster overheads. Moreover, reducing the energy consumption is one the critical goal of clustering technique; however, it cannot be pursued without comparing the energy consumption before and after clustering in optimizing the cluster size. Therefore, it is required to discover a cluster size optimization based scheme with considering both energy-efficiency and coverage-guarantee to improve network performance.



(a) Corona based WSN. (b) Clustered Corona based WSN.

FIGURE 1. Circularly symmetric network before and after clustering.

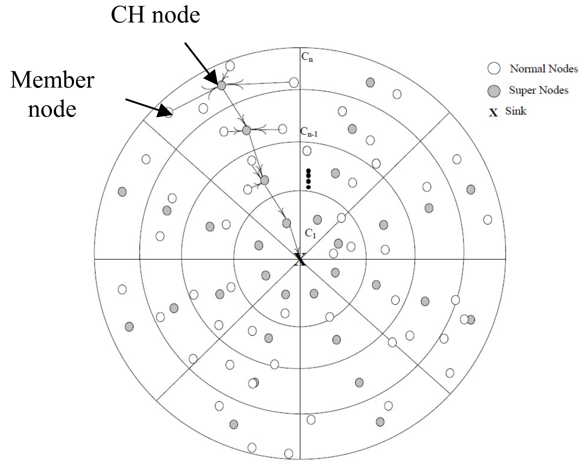


FIGURE 2. Data transmission mode in CCWSN.

III. SYSTEM MODEL

In this paper, it is considered that N location aware consumer products are uniformly distributed throughout the circular network area [18]. The transmission range of nodes is adjustable based on the distance between source and destination nodes. A static BS is utilized which is located at the center of the network. The BS is equipped with an unlimited power supply; however, sensor nodes are limited in energy supplies and computational power.

The proposed ECUC scheme is specially designed for circularly-symmetric WSNs called Corona Based WSNs (CBWSN) [19]–[21], since it is easy to abstract in a view of routing optimization and the energy consumption can be easily controlled in this type of network. ECUC divides the network into coronas with an equal thickness (Fig.1.a). Then it is divided into constant angle sectors (Fig.1.b) called Clustered Corona-based WSN (CCWSN) [28]. By employing the clustering on CBWSNs, energy efficiency, easier management and scalability can be achieved [22]. In the proposed scheme, the clusters are constructed in centralized manner and the BS acts as a powerful controller node which is responsible to optimize the size of clusters. Exploiting the centralized clustering leads to transfer the cluster formation duty from the nodes with limited energy to the BS with unlimited power supply at the beginning of the network operation.

In addition, it needs to be mentioned that in each round, the node with minimum distance to the centroid point of each cluster is selected as the CH. MNs generate l bit data packet per each time unit and transmit toward the respective CH, and then CHs send the aggregated data packets to the BS in a multi-hop fashion (Fig.2).

In CCWSN, the cluster size depends on the angle of sectors (⊖). Selecting the very large angle leads to increase the distance between MNs and CHs that results in increasing the energy consumption of MNs. Therefore, clustering acts contrary in terms of energy saving, if the energy consumption of Member Nodes (MN) exceeds their energy consumption before clustering. On the other side, if this angle is too small, some empty clusters are constructed, which leads to coverage limitation in the network. In addition, constructing the small size clusters diminishes the scalability of the clustering schemes. Consequently, since the angle of sectors depends on the number of sectors, an optimal number of sectors range in CCWSN is needed.

IV. ENERGY-EFFICIENT AND COVERAGE-GUARANTEED UNEQUAL-SIZED CLUSTERING

Reducing energy consumption is one of the main objectives of utilizing clustering; however, if the cluster size parameter is not optimized, clustering acts contrary in this regard. Therefore, in order to ensure the energy consumption reduction after clustering, the energy consumption of nodes before applying clustering is required to be considered; however, it is not discussed in most of the previous schemes. In addition, constructing the small sized clusters leads to coverage holes, as well as, this property is opposite of being the scalability of the network. To address such problems, Energy-efficient and Coverage-guaranteed Unequal-sized Clustering (ECUC) scheme is designed to generate optimal sized clusters, which decreases the energy consumption of nodes and results in improving the network performance.

In ECUC, after node deployment, BS propagates the request message throughout the network. Upon receiving the message, sensor nodes reply their position information. Then, BS calculates the upper bound number of sectors range, based on the density of sensor nodes thereby results in coverage preservation. Afterward, the lower bound is determined by comparing the energy consumption of nodes before (CBWSN) and after clustering (CCWSN). A new metric is proposed called Difference between the Energy Consumption Before and After Clustering (DECBAC), which is exploited to ensure that the energy consumption would reduce after applying clustering. To this end, the problem is modeled as an Integer Linear Programming with the objective of minimizing the DECBAC. Finally, in third phase, the optimal cluster size is extracted from the defined range using an Integer Linear Programming. The objective of third phase is to minimize the total energy consumption of the network. The detailed discussion on each phase is presented in following sub-sections. Moreover, the flowchart in Figure 3, explains the phases of ECUC scheme, where the highlighted blocks refer to the contributions in the proposed scheme.

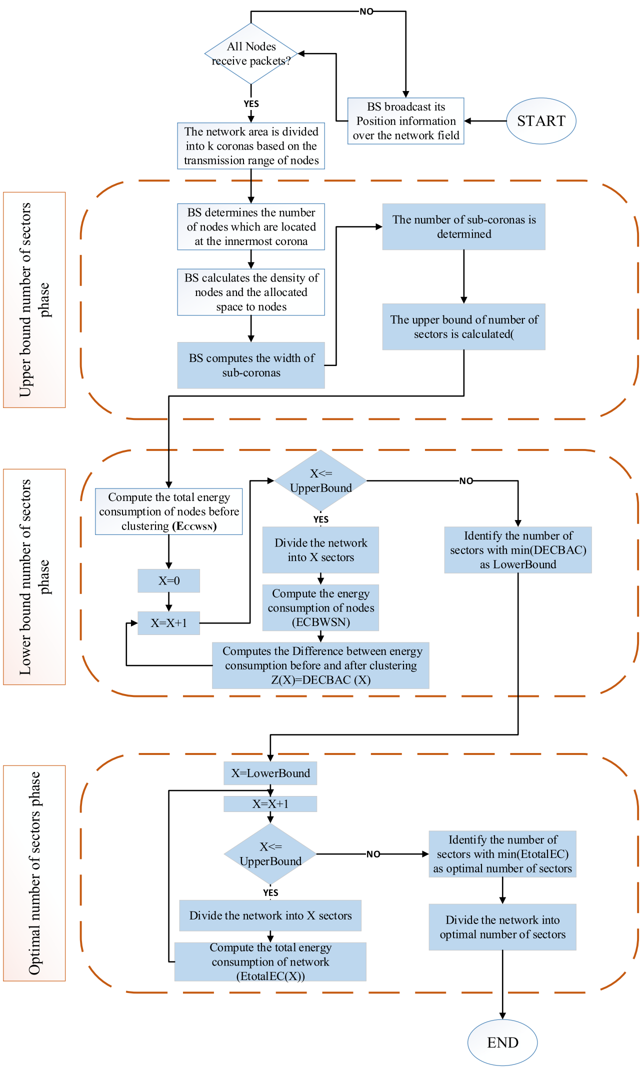


FIGURE 3. The flowchart of the ECUC scheme phases.

A. UPPER BOUND NUMBER OF SECTORS

Assuming that there is M nodes distributed throughout the network area, where is divided into K coronas. In uniform node distribution, the number of nodes located at the first corona can be calculated using Equation 1. Accordingly, the number of nodes located at the ith corona will be calculated using Equation 2 [23].

$$N_1 = \frac{M}{K^2} \tag{1}$$
$$N_i = (2i-1)N_1 \tag{2}$$

These equations have been presented to prove the following lemma. This lemma expresses that the CCWSN encounters coverage problem whenever very small value has been chosen as the angle of sectors.

Lemma 1: Empty clusters are constructed in CCWSN, if the angle of sectors is adjusted with small value without considering the density of nodes.

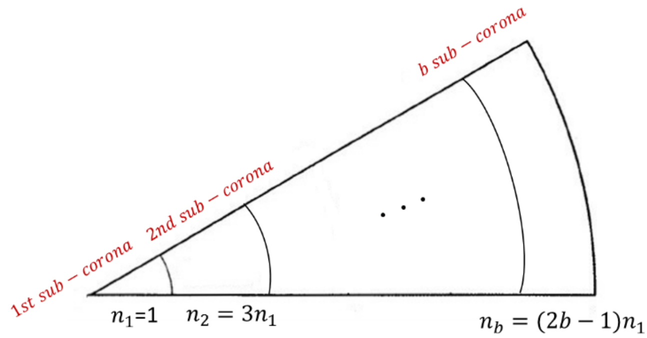


FIGURE 4. A sector of the innermost corona, which is divided into sub-coronas.

Proof: In a uniform node distribution based network, the number of nodes located in each corona depends on the number of nodes located in innermost corona (according to equation 2), then following relation can be considered:

$$N_i = 0 \quad IIF\ N_1 = 0,\ 2 \le i \le k \tag{3}$$

Moreover, CCWSN is the outcome of dividing the corona based WSN into equal sectors. Likewise, due to uniform node deployment, the number of nodes in the clusters formed at the ith corona is as following:

$$\frac{N_i}{NS} = (2i-1)\,\frac{N_1}{NS} \tag{4}$$

where NS accounts the number of sectors, i shows the corona number where cluster is formed. Consequently, in a CCWSN, based on equation 4, a cluster will be empty if the cluster belonging to innermost corona and same sectors is empty, then:

$$\frac{N_i}{NS} = 0 \quad IIF \frac{N_1}{NS} = 0$$
$$2 \le i \le k \tag{5}$$

Then, Lemma 1 is proved. □

To overcome the aforementioned limitation, the density of nodes is taken into consideration for calculating the upper bound of the cluster size interval. In ECUC, the space occupied by nodes has a circular shape and the nodes cover the area from interior zones of the network. The interior zones of the network would be accessed by dividing the interior corona into sub-coronas as shown in Figure 4.

In addition, to ensure the coverage preservation, at least one sensor node is deployed at the interior sub-corona in each sector. Consequently, the number of nodes located in the other sub-coronas are determined as follows:

$$n_i = (2i-1)\,n_1 \tag{6}$$

In order to construct a sector while only one sensor node located at the interior sub-corona, the area of the interior sub-corona of sector should be equalized with the allocated space to a sensor node. Due to uniform node distribution, the allocated space or the sensing range of the nodes will be determined by equation 7.

$$SR = \frac{S}{M} \tag{7}$$

where, S shows the area of the network and M denotes the total number of nodes located at the network area. In addition, if b is the number of sub-coronas, a is the number of sectors, and N_1 denotes the total number of nodes belonging to the innermost corona, the bellow relation can be considered:

$$a.\sum_{j=1}^{b}(2j-1) = N_1 \tag{8a}$$

After simplifying:

$$a.b^2 = N_1 \tag{8b}$$

The number of sub-coronas can be determined according to the thickness of sub-coronas. In ECUC, it is considered that the area of the interior sub-corona of a sector is equal with the allocated space to a sensor node. Since the allocated space and sensing range of each node is circular, the diameter of the sensing range shows the width of each sub-corona. Then, the thickness of a sub-corona can be calculated as follows:

$$SR = \pi.radius^2 \tag{9a}$$

Then,

$$radius = \sqrt{\frac{SR}{\pi}} \tag{9b}$$

$$x = radius \times 2 \tag{9c}$$

where x denotes the diameter of the allocated space to each sensor node. Then, the width of the coronas (r) to the width of sub-coronas is the number of sub-coronas as follows:

$$b = round\left(\frac{r}{x}\right) \tag{10}$$

By substituting (10) in (8), the number of sectors is determined as follows:

$$a = \frac{N_1}{b^2} \tag{11}$$

Now, the upper bound of the cluster size interval is acquired, thus coverage-guarantee can be considered.

B. LOWER BOUND NUMBER OF SECTORS

The aim behind utilizing clustering is to reduce the total dissipated energy of sensors. In CCWSN, the angle of sectors (⊖) affects the size of clusters. Choosing a large value as the angle of sectors leads to increase the distance between CHs and MNs. Consequently, the energy consumption of MNs exceeds their energy consumption before clustering. Then, clustering on CBWSN acts contrary and leads to rise in the energy consumption of MNs. Therefore, a lower bound should be defined for constructing the clusters so that the size of clusters does not exceed this value. Thus, a novel metric called Difference the Energy Consumption Before and After Clustering (DECBAC) is exploited to ensure that the energy consumption will decrease after clustering. Then, DECBAC is calculated as follows:

$$DECBAC = (E_{CCWSN} - E_{CBWSN})^2 \tag{12}$$

ECCWSN and ECBWSN denote the energy consumption before and after clustering. In this paper, the energy consumption for transmitting and receiving 1 bit data is calculated as following [24]:

$$E_{tx} = l\left(E_{elec} + \propto d^n\right) \tag{13}$$

$$E_{rx} = l\left(E_{elec}\right) \tag{14}$$

where $\propto$ and n show the energy consumed in the op-amp transmitting the data packets and the path loss exponent, respectively. d is the distance between the source node and the destination. In addition, E_{elec} accounts the electronic energy. Therefore, the total energy consumption of MNs in CCWSN and CBWSN is determined as follows:

$$E_{CCWSN} = \sum_{i=1}^{M} l\left(E_{elec} + \propto d_{toCH}^n\right) \tag{15}$$

$$E_{CBWSN} = M(E_{tx} + E_{rx}) \tag{16}$$

The objective of this phase is to minimize the DECBAC, which is the differences between the total energy of sensors in CBWSN (before clustering) and CCWSN (after clustering).

$$\begin{aligned}&Minimize\ DECBAC\\&\forall X \in N,\quad 1 \leq X \leq Maximum\ number\ of\ sectors\end{aligned} \tag{17}$$

Which X denotes the number of sectors and the constraint indicates that the number of sectors should be less than the maximum number of sectors derived from the first phase.

C. OPTIMAL NUMBER OF SECTORS

One solution to enhance energy efficiency is to reduce the energy consumption of the network, which leads to improving the network lifetime. Choosing an improper value as cluster size results in increasing the energy consumption of the network in both situation when the cluster size is smaller or larger than the optimal size. Therefore, developing a proper solution to calculate the optimal cluster size is vital. Consequently, this phase is presented to extract the optimal cluster size from the between the energy consumption of nodes determined cluster size interval, which aims to reduce the total energy expenditure of network.

$$\begin{aligned}&Minimize\ (E_{Total}EC)\\&\forall\, \mathrm{X} \in \mathrm{N},\quad Minimum \leq X \leq Maximum\end{aligned} \tag{18}$$

V. ANALYSIS AND VALIDATION OF ECUC

In EUC design, the important functionality is to determine the optimal size of clusters, which depends on the number of sectors. If cluster size is not optimized (not according to the density of nodes and energy consumption before clustering), it prevents the benefits of clustering. Unlike previous sub-optimal clustering algorithms, EUC mechanism constructs

TABLE 1. Simulation parameters.

Parameter	Value
Area of the network	R=50~200 m
E_{elec}	50e-9
Transmitter Amplifier	0.0013e-12
Path loss exponent	2
Number of nodes	100~300
Number of coronas	5
Packet length	2000 bite

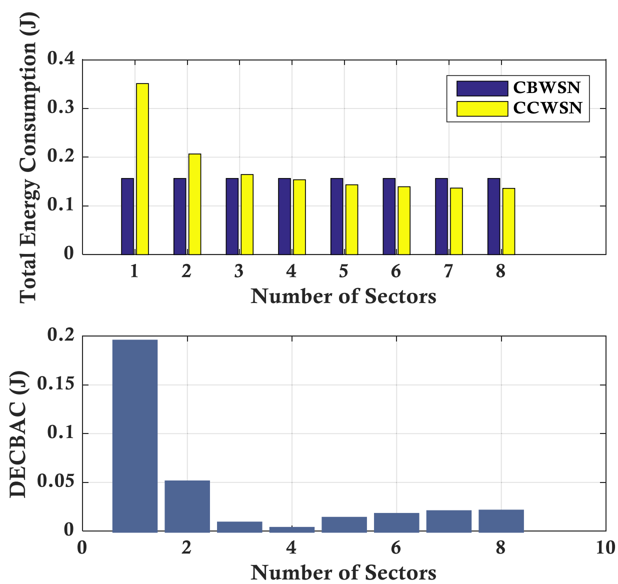


FIGURE 5. (a) Total energy consumption in CBWSN and CCWSN (b) Difference between energy consumption before and after clustering.

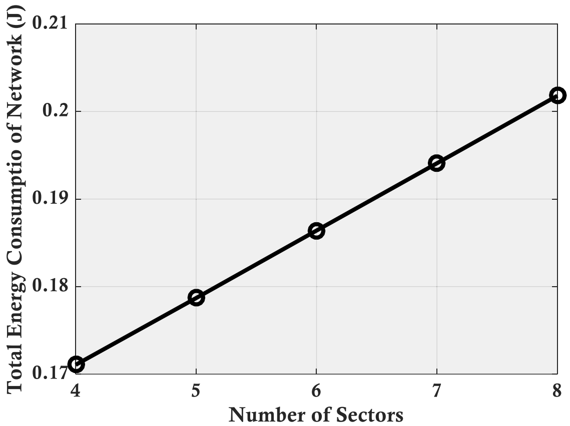


FIGURE 6. Total energy consumption of network v/s number of sectors.

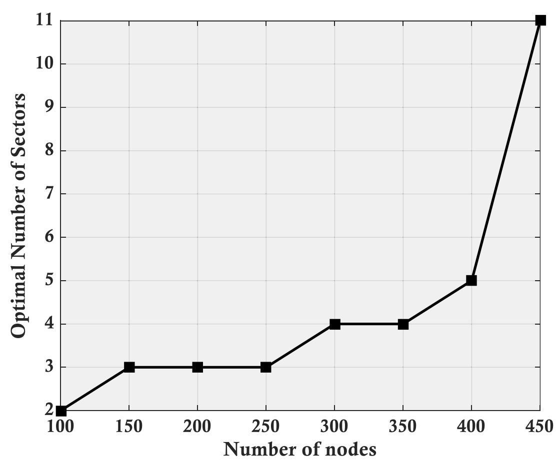


FIGURE 7. Optimal number of sectors with different number of nodes.

the clusters with considering both energy efficiency and coverage guarantee issues. In the proposed mechanism, since eight number of sectors is obtained as the upper bound number of sectors range, the number of sectors more than this value are ignored. The relevant parameters are shown in the Table 1.

Moreover, the aim of the second phase (lower bound number of sectors) is to determine the number of sectors so that the difference between the energy consumption of nodes before and after clustering is minimized as much as possible. Figure 5 (a) demonstrates the influence of the number of sectors on the energy consumption of MNs before and after clustering. In addition, Figure 5 (b) depicts the difference between the energy consumption of the network in CCWSN and CBWSN more accurately.

Furthermore, the third phase aims to drive the sectors number with minimum energy consumption from determined range (in our model, this interval is determined as [4], [8]). Therefore, Figure 6 depicts the total dissipated energy in one round. As can be observed, there is minimal energy consumption whenever the network is divided into 4 sectors (angle of sectors is 90°). In our model, a substantial amount of energy is consumed by CHs. Therefore, by increasing the number of sectors, the number of clusters is increased mutually, which leads to increasing the number of CHs and results in excessive communication cost. Thus, in CCWSN, rising the number of sectors leads to increasing the energy consumption of the network.

Figure 7 depicts the number of optimal sectors as the number of nodes increases. The Figure 6 demonstrates that the number of generated sectors is directly proportional to number of nodes and increases as total number of nodes increases from 100 to 450. In fact, the size of clusters decrease by incrementing the number of nodes. This is because, in EUC, the optimal number of clusters depends on the energy consumption of network. Obviously, increasing the number of nodes leads to increasing energy consumption. Consequently, constructing the small size clusters leads to decreasing the distance between MNs and CHs, which results in decreased energy consumption.

VI. PERFORMANCE EVALUATION OF ECUC

To evaluate the performance of ECUC scheme, numerical simulation experiments are carried out in OMNET++. The performance of the ECUC scheme is evaluated in

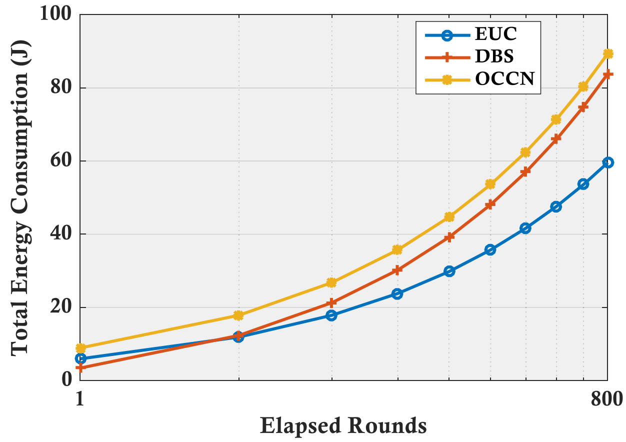


FIGURE 8. Total energy consumption of network.

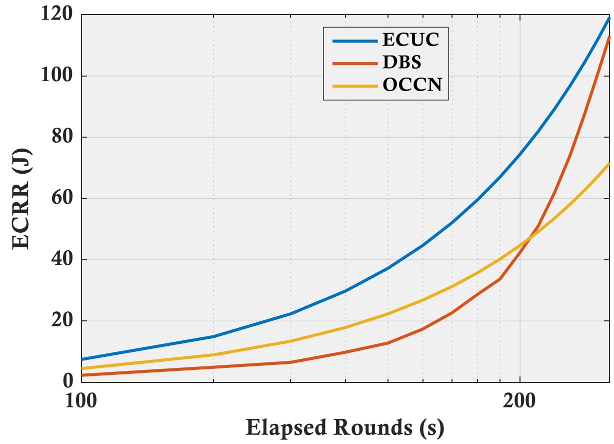


FIGURE 9. Energy consumption reduction ratio.

terms of the network lifetime, total energy consumption and energy consumption reduction ratio. Furthermore, DBS [16] and OCCN [17] are used to benchmark against the proposed ECUC. This is because these schemes are particularly designed to optimize the size of clusters in the sink centric circular networks and the main aim behind such algorithms is to reduce the energy consumption of nodes. Thus, the results of simulation experiments are discussed in the following performance evaluation sections.

A. TOTAL ENERGY CONSUMPTION OF THE NETWORK

This section discusses the impact of the ECUC scheme on the energy consumption of the network. The purpose of this measurement is to represent how ECUC reduces the energy consumption of the network, which results in improved network lifetime. Total energy consumption is defined as the difference between the total initial energy and the final energy level of the network that is left in all nodes. Figure 8 compares the total energy consumption versus simulation time in three different schemes. As can be observed in Figure 8, ECUC significantly reduces the overall energy consumption by 30% and 28% as compared to OCCN and DBS schemes. This is because, in DBS scheme, the number of clusters depends on the number of CHs. In fact, decreasing the number of CHs tends to construct large size clusters, which leads to increase the distance between MNs and their CHs and results in increasing the energy consumption of the network. In addition, it is observed that ECUC enhance the energy conservation in compared with OCCN. This is because, OCCN attempts to distribute the MNs into equal sized clusters, whereas it is perceived that equal cluster size results in an imbalance energy consumption during inter-cluster communications and can cause increasing the energy consumption of the network.

B. ENERGY CONSUMPTION REDUCTION RATIO (ECRR)

In this section, the simulation experiment has been carried out to evaluate the amount of energy consumption reduced after applying clustering, which is considered as Energy Consumption Reduction Ratio (ECRR) parameter. The purpose of measuring ECRR is to show the improvement of ECUC in terms of increasing the influence of clustering on reducing the energy. Figure 9 compares the ECRR parameter versus simulation time. As shown, ECUC significantly increases the ECRR by 30% and 28% as compared OCCN and DBS. Unlike existing schemes, those schemes which do not consider the energy consumption before clustering, ECUC remarkably increases ECRR parameter. As a matter of fact, considering the energy consumption of the network before clustering is one requirement to construct the optimal sized clusters. As mentioned before, employing clustering on a Corona Based WSN (CBWSN) aims to reduce the energy consumption of nodes. Thus, clustering mechanisms should be ensured to reduce the energy consumption after utilizing the clustering. For this purpose, ECUC takes in to consideration the energy of the network before clustering in the cluster formation.

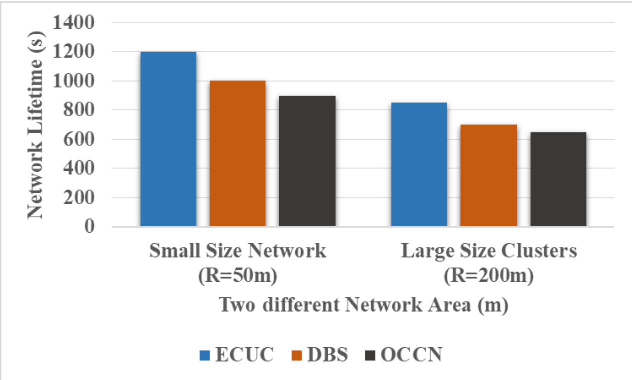


FIGURE 10. Network lifetime under two different network area.

C. NETWORK LIFETIME

In this section, the simulation experiment has been done to evaluate the network lifetime. The network lifetime is defined as the time when the first CH exhaust its battery. Figure 10 shows the plotted network lifetime in terms of seconds in

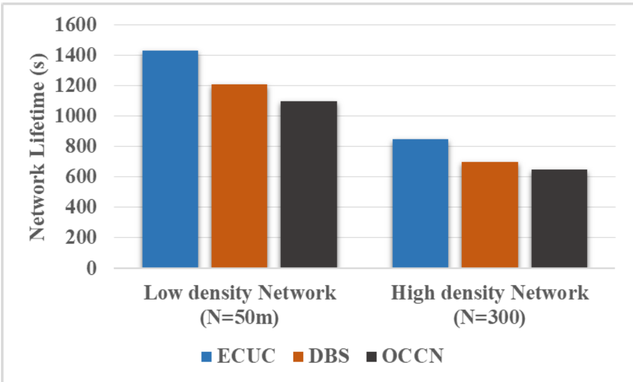


FIGURE 11. Network lifetime under different number of nodes.

three different schemes under two different scenarios. The simulation results show that ECUC scheme outperforms than other approaches as it has a longer network lifetime by 22% and 32% in large size network and 16% and 25% in small size network. In addition, in cluster-based schemes, a significant amount of energy is consumed by CHs. Clearly, increasing the number of clusters leads to increase in the energy consumption of the network. OCCN and DBS schemes divide the network into so many equal size clusters, which leads to increase energy consumption and results in decreased network lifetime. However, ECUC takes into consideration the energy consumption of MNs and CHs to construct the clusters, which leads to enhance network lifetime.

Furthermore, the network lifetime increases in all three schemes under small size networks. This is because decreasing the size of networks leads to decrease the distance between nodes and CHs and results in reducing the energy consumption of CHs and improving the network lifetime. Likewise, Figure 11 depicts the lifetime of network of three schemes in low and high density scenarios. As can be seen, the network lifetime increases in all three schemes under low density network scenario. It stems from decreasing the number of member nodes in low density network, which leads to decrease the energy consumption of CHs and enhancing the network performance and lifetime.

VII. CONCLUSION

In this paper, Energy-efficient and Coverage-guaranteed Unequal-sized Clustering (ECUC) scheme is presented that addresses the cluster formation problem while least overheads and coverage preservation. Most of the existing schemes construct sub-optimal clusters without considering both energy efficiency and coverage issues simultaneously. In addition, reducing the energy consumption is one objective of clustering; however, this goal cannot be reachable with constructing the clusters without considering the difference the energy consumption before and after clustering. Nevertheless, this rule has not been taken into account in most previous works. The ECUC overcomes these limitations by determining the optimal cluster size interval. At the later part of this paper, extensive simulation experiments are performed using OMNET++ to evaluate the performance of ECUC with relevant clustering schemes. The simulation results show that the verified ECUC scheme achieved better network performance as compared to related works.

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