

Energy-Efficient Unequal Clustering Routing Algorithm for WSNs

Priyanka Handa, Tripatjot Singh Panag, Balwinder Singh Sohi



Abstract-Wireless sensor networks (WSNs) are used to monitor the environment where the networks are deployed. The Lifetime of WSNs can be increased by energy-efficient or energy balancing algorithms. Balanced energy consumption among all nodes is the main issue. In this paper, a new energy-efficient unequal clustering routing protocol (EEUCR) has been presented. In this protocol, the area of the network is divided into the number of rings of unequal size and each ring is further divided into a number of clusters. Rings nearer to the base station (BS) have a smaller area and the area of rings keeps on increasing as the distance from BS increases. This helps to balance the energy consumption among the sensor nodes. The nodes with heterogeneous energy are deployed in the network. Nodes nearer to the base station have higher energy as compared to farther nodes. Static clustering is used but cluster heads (CHs) are not fixed and are elected on the basis of the remaining energy of the sensor node. Simulation results are compared with existing protocols and show improvement in energy consumption, which, in turn, increases the network lifetime of WSN and also balance the energy consumption of sensor nodes.

Keywords: energy balancing, hotspot problem, network lifetime, unequal clustering, wireless sensor networks.

I. INTRODUCTION

Advances in WSNs have provided tiny and less-costly sensors having the ability to sense various types of physical and environmental conditions [1][3]. They can process the data and can transmit that data to distant places through wireless communication. The main issue with WSN is that its energy depletes very hastily and becomes lifeless [18]. The maximum energy is consumed by the communication subsystem. To minimize energy consumption during communication, routing protocols can play a vital role. Therefore, to enhance the lifetime of the sensor node, routing algorithms should be energy-efficient [4]. The major goal of routing protocols is to find an energy-efficient and reliable route to transmit data from the sensor nodes to the sink so that the lifetime of the network is maximized [2]. The sensor nodes may communicate their data to BS through single-hop communication or multi-hop communication. In single-hop communication data is transmitted by every CH to the BS, this will lead to faster energy depletion of farther CHs as compare to CHs those are closer to the BS.

This introduces the problem of the hotspot which results in network partitioning in an area that is farther from BS. But in multi-hop communication farther CHs send data to BS through hopping. This method is more energy-efficient than the single-hop communication but this introduces hotspot problems in the area nearer to the BS due to overburden of relay traffic. Sensor nodes in the hotspot area exhaust their energy to a large extent which results in network partitioning near to the BS. So, there is a requirement of energy balancing among the nodes. A lot of work has been done in the last few years in the field of WSNs. We reviewed some of the most relevant papers. Heinzelman et al. [4] introduced clustering for the first time. This is a single-hop clustering algorithm. Adaptive clustering is used and also every node has the same probability to be elected as cluster head irrespective of remaining energy. TDMA (time division multiple access) is used for intra-cluster communication. Han et al. [5] proposed a hybrid unequal multi-hop clustering based on density (HCD) which enhances the lifetime of the network. This protocol selects the cluster head (CH) by comparing the status of each node to its adjacent nodes. It will consider a number of parameters for CH selection such as the energy of nodes, the number of adjacent nodes, the distance to the BS, and the layer where the node is placed. This technique tries to minimize the energy consumption of the network and improve load balancing. It follows unequal and hybrid dynamic-static clustering to achieve the objectives. Ye et al. [8] reported an energy-efficient clustering scheme. Cluster heads are elected with more residual energy through local radio communication while achieving well cluster head distribution. It also balances the load among the cluster heads. Yao et al. [9] focused on energy balancing to avoid network partitioning. The protocol is based on a heterogeneous network. The network is divided into rings of unequal sizes and every ring is further divided into clusters. As the rings approach BS, their size reduces. Two types of nodes are used regular sensor nodes (RSN) and CH. This avoids extra burden to elect the CH and CHs are of high energy than RSNs. Muhammad et al. [10] approached an energy-efficient hybrid routing protocol for underwater WSNs. In this protocol, WSN is divided into four regions of different radii. An equal number of nodes are deployed in all regions. Sensor nodes with more energy are deployed in region 1 and 2 as compared to sensor nodes deployed in the region 3 and 4 to balance the energy consumption. Smaragdakis et al. [12] proposed a protocol that uses the concept of the heterogeneous node to improve the stability period of the network. In this protocol, two types of nodes are deployed: advanced nodes and normal nodes. The advanced nodes have higher energy as compared to the normal nodes.

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Aderohunmu et al.[13] introduced the concept of three types of nodes in the network: advanced nodes, intermediate nodes, and normal nodes. This is also an improvement of SEP. The advanced nodes have higher energy than Intermediate and normal nodes. Intermediate nodes have energy level between advanced and normal nodes. Normal nodes have less energy as compared to other nodes. This method also improves life span of the WSN. Faisal et al.[14] describes an algorithm, in which sensor field is divided into three regions. Nodes in region near to the BS will directly send data to the BS. Sensor nodes deployed in the faraway region are higher energy nodes. These nodes follow clustering mechanism and data will be sent to BS by CH. Malathi et al.[15] highlighted a hybrid of static and dynamic clustering. In this algorithm network is divided into number of layers and then static clusters are formed. The parameters used to select the CH are residual energy of the sensor nodes, distance of CH from the sink and the number of their neighbors. Zhao et al.[16] illustrated a mechanism to manage the number of CH in the area where nodes are densely deployed. This algorithm improves the formula to find threshold by considering the distance between node and BS, the no. of nearest nodes, residual energy, and the average distance between sensor nodes. Khan et al.[17] proposed a cluster-based energy-efficient routing protocol. A CH receives data from root nodes, aggregate and then communicates aggregated data to the BS. This protocol uses static clustering. This protocol works well in both large and small areas. A large field is divided into rectangular clusters and then these clusters are grouped to form zones. This way communication between CH and BS is very efficient. Khan et al.[18] implemented a multistage data transmission mechanism. In this protocol CH is selected in a very efficient manner and static clustering is used which improves energy efficiency than dynamic clustering. Panag et al.[19] proposed dual-head static clustering algorithm to balance energy consumption by the sensor nodes. In this protocol two nodes in a cluster are selected as the CHs on the basis of remaining energy and distance from the BS and other nodes within the cluster. One CH is responsible for aggregation of data and second CH is responsible for transmission of data to BS. Gu et al. [20] have implemented a protocol that focuses on the coverage of the area of the WSN. The proposed protocol is ECDC that joins together both residual energy and the coverage importance metrics of the nodes to select the CH. Pramanick et al.[21] proposed a Clustering-based Routing scheme(EASSR) for WSNs. They use the sleep and wake property of some of the sensor nodes, which helps to increase the life of network. In this algorithm, a node is selected as a CH if its residual energy is greater than average energy of the system and if remaining energy of a node reaches five percent of its initial energy then sensor nodes can directly send data to BS.

After reviewing the literature it is found that a lot of work has been done for an energy-efficient network. Although many protocols proposed in literature try to use the energy of the network efficiently. Many researchers work to improve energy consumption among the nodes using unequal clustering[5-10] or deploying heterogeneous nodes[11-17] in the sensor field. Still, there is a requirement of some improved methods that can solve the problem in a better way.

In this paper, EEUCR is proposed and it is a heterogeneous-aware unequal clustering routing protocol to solve the problem of the hotspot in WSNs and enhance the lifetime of the network. It is designed for a long-lived network and also enhances the time period before the exhaust of the first node of the network. It is assumed the network field is circular and BS with unlimited energy is placed in the middle of the field. The network is divided into five rings of unequal size around the BS and each ring is further divided into clusters as shown in fig 2. Also, the radii of rings and cluster size increases as their distance from the BS increases and vice-versa. This results in unequal clustering. The heterogeneous energy nodes are deployed in the network. The sensor nodes in rings 5, 4 and 3 are the same energy nodes. The energy of sensor nodes in rings 1 and 2 is two times extra than sensor nodes in rings 5, 4 and 3. The reason for increasing the energy of nodes in regions 1 and 2 is to balance the overburden of forwarding the relay traffic. This is beneficial for energy balancing among the network and tries to solve the hot spot problem and enhances network lifetime also shown by simulation results. Static clustering is used in this protocol. The remaining energy is considered as the parameter for the selection of CH. If the distance of CH to BS is less than d_0 then there will be single-hop communication but if the distance is greater than equal to d_0 then there will be multihop communication. The next-hop selection is done by considering two parameters: distance from current CH and remaining energy of the CHs in the lower ring.

The following sections discuss the remainder paper. Section II presents the network model. Section III shows the simulation results. In Section IV, conclusion and future scope is discussed

II. NETWORK MODEL

The EEUCR uses the concept of heterogeneity of nodes, unequal clustering, and multi-hop communication. The protocol is divided into three different phases: initialization phase, setup phase, data transmission phase. Fig.1 shows the radio energy dissipation model[4]. The transmit electronics circuit will sense the data and then convert the data into the electronic form.

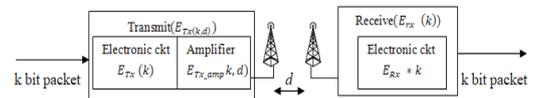


Fig.1. Radio energy dissipation model.

The signal is amplified by the transmit amplifier and then transmitted by the antenna. Receiving antenna will receive the data and then processed by the receive electronics circuit. The following equations show the energy consumption to transmit and receive the k-bit packet to the distance (d) [4][12].

$$E_{Tx(k,d)} = E_{Tx}(k) + E_{Tx,amp}(k,d) \quad (1)$$

$$E_{Tx}(k,d) = \begin{cases} E_{Tx} * k + \epsilon_{fs} * k * d^2, & d < d_0 \\ E_{Tx} * k + \epsilon_{mp} * k * d^4, & d \geq d_0 \end{cases} \quad (2)$$

$$E_{rx}(k) = E_{Rx} * k \quad (3)$$

$$\text{Where, } d_0 = \sqrt{\epsilon_{fs} / \epsilon_{mp}} \quad (4)$$

Equation 1 and 2, shows energy consumption for data transmission. where, $E_{Tx}(k)$ represent energy consumption for the transmission of k bits and $E_{Tx_amp}(k,d)$ is energy consumption for the amplification of k bits. The transmitter and receiver are apart by a distance(d). Equation 3, shows energy consumption for the reception of k bits. Energy consumption for the transmission increases with the increase of distance for the transmission. If $d < d_0$ it will be single-hop communication but if $d \geq d_0$ then this is multipath communication. The d_0 as shown in equation 4, is critical distance and ϵ_{fs} and ϵ_{mp} are the constant coefficients for free-space communication and multipath communication, respectively[4]. The value of d_0 depends upon system parameters such as the height of the antenna, the carrier signal wavelength, etc[9].

A.Initialization Phase

The initialization phase includes network architecture, node deployment, and clustering. This phase is necessary only one time in the origination before the communication rounds start. This phase includes the following steps.

Step:1 Network architecture

In this model unequal clustering is proposed, we have considered that a BS is deployed at the center in the area under observation. The sensor field is divided into m rings. Radii of rings are not equal, this will help to balance the energy consumption of the sensor nodes. Radii reduce as the rings approach towards BS as shown in Fig.2 and Fig.3. radius $r_0 < r_1, \dots < r_{m-1}$. The ring0 has radius r_0 , the ring1 has radius r_1 and so on. Nodes those falls in radius (BS, r_0) will belong to ring0, nodes those falls in radius (r_0,r_1) will belong to ring 1, it can also be stated that nodes in (r_{i-1},r_i) will belong to ring i here, ($0 \leq i \leq m - 1$). The radius of the innermost ring r_0 and the radius of the outermost ring r_m . q is 0.5 [9], as it gives better results at this value. Radii of other rings are calculated by the following equation[9]:

$$r_{m-1} = q(r_m - r_0) + r_0 \tag{5}$$

The following fig2 shows Network architecture. This fig represents rings with different radii which results in unequal clustering.

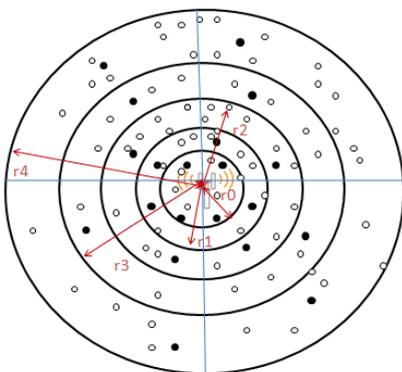


Fig.2. Network Architecture

Step:2 Node deployment

In this protocol, sensor nodes are deployed in a uniform random manner in WSN. BS is placed in the middle of the network field. Sensor nodes in the internal two rings r_0 & r_1 are higher energy nodes[10] and are called supernodes(N_s). The energy of nodes N_s is (E_s) which is two times higher than the initial energy. Nodes in outer three rings r_2, r_3 & r_4

are of initial energy(E_0) nodes and are called normal nodes(N_n). The total energy of the network is T_E as given in equation (7). The area of the network is divided into two zones A_s and A_n . where, A_s is an area where supernodes are deployed i.e area of ring r_0 & r_1 . A_n is an area where normal nodes are deployed i.e area of rings r_2, r_3 & r_4 . The number of nodes in zone A_s and A_n are proportional to their area and is given by the equation(6).

$$\frac{A_s}{A_n} \propto \frac{N_s}{N_n} \tag{6}$$

$$T_E = E_s + E_0 \tag{7}$$

Step:3 Clustering

This protocol uses static clustering. Static clustering reduces the energy consumption than the dynamic clustering because it reduces extra communication required before every round in dynamic clustering. The algorithm divides the monitored area into predefined numbered clusters. Each node is aware of its position and transfers information to the BS through the control packet. The BS divides the network into four clusters per ring. Clusters are 90° apart from each other. The size of clusters is not the same in the network, it varies as the radii of rings varies.

B.Setup Phase

In the Setup phase, the proposed protocol selects the CHs and find the best route.

Step:1 CH selection

The CH will be selected before the start of every communication round. The sensor node in the cluster having maximum residual energy will be selected as CH. A node in a cluster will compare its residual energy with other nodes in the cluster and after comparison node with higher residual energy will be selected as CH. This will maximize the life of the network because of the proper rotation of CH among a cluster.

Step:2 Route formation

When a CH has been selected among the cluster, it will receive data from nodes of the cluster and other CHs and finally send the data to the BS. Let, CH_{ij} is cluster head of jth cluster and ith ring then it will calculate its distance from BS. If the distance of CH_{ij} to the BS is less than the critical distance then BS will be next-hop. Otherwise, it will use multi-hop communication and CH in the ring (r_{i-1}) will be selected as next-hop. This is shown in equation[19]

$$\text{Next-hop} = \begin{cases} BS, & \text{if } d(CH_{ij}, BS) < d_0 \\ CH_{i-1}, & \text{if } d(CH_{ij}, BS) > d_0 \end{cases} \tag{8}$$

When the d is greater than d_0 then the next hop will be a CH in the lower-numbered ring and is selected by using the following steps.

When a CH_{ij} has to transfer data a list of negotiable-CHs(N_{Ch}) is prepared. An N_{Ch} is one that is closer to BS than the CH_{ij} or in the ring (r_{i-1}), and its distance must not more than d_0 from the CH_{ij} .

The fitness of the N_{Ch} is evaluated by the following equation:

$$F_{\text{Next-hop}}(N_{Ch}) = w_1(E_{res_N_{Ch}}) + w_2\left(\frac{1}{d_{N_{Ch}-CH_{ij}}}\right) \tag{9}$$

Where $E_{res_N_{Ch}}$ is the residual energy of N_{Ch} , $d_{N_{Ch}-CH_{ij}}$ is the distance of N_{Ch} from the CH_{ij} . w_1 & w_2 are weighting factors and have a value between 0 & 1. The N_{Ch} has the highest value of $F_{Next-hop}$ is selected as the next-hop. After finding the best fitness, CH_{ij} will transfer the data to next-hop.

C. Data transmission phase: Inter-cluster and intra-cluster communication

Actual data communication takes place during this phase. The data transfer phase is divided into two parts— intra-cluster communication and inter-cluster communication. Intra-cluster communication means within the same cluster, In this phase, data is gathered by the cluster node in the j th cluster of the ring (r_i) and forwarded to the respective CH_{ij} in their allocated time slot as per the TDMA schedule. TDMA is used here to avoid collision between the transmitted packets. During inter-cluster communication, CH_{ij} receives data from other CHs. The CH_{ij} aggregate the received data and then data is transmitted to the BS or to the next hop. The total energy consumed[12] in every cluster during each round is given in the following equation.

$$E_{cluster_{ij}} \approx E_{CH_{ij}} + lE_{non_CH} \quad (10)$$

The energy consumed by a sensor node which is not a CH, is given in the following formula:

$$E_{non_CH} = k(E_{Tx} + \epsilon_{fs}d_{to_CH}^2) \quad (11)$$

$d_{to_CH}^2$ is the distance of a sensor node to its CH within the cluster.

If, l =the number of non- cluster head nodes in the cluster and $i=m-1$, then $E_{CH_{ij}}$ is given as the following equation:

$$E_{CH_{ij}} = E_{Rx}(lk) + k(l + 1)E_{DA} + k(l + 1) (E_{Tx} + \epsilon_{fs}d^2) \quad (12)$$

But, if $0 \leq i \leq m - 1$ then $E_{CH_{ij}}$ is given as the following equation.

$$E_{CH_{ij}} = E_{Rx}(\lambda_{ij} + lk) + (\lambda_{ij} + k(l + 1))E_{DA} + (\lambda_{ij} + k(l + 1)) (E_{Tx} + \epsilon_{fs}d^2) \quad (13)$$

Here, E_{DA} is energy consumed for data aggregation. λ_{ij} is the bit arrival rate at CH_{ij} from other CH of ring $_{i+1}$.

$$\lambda_{ij} = nk(l + 1), \quad n=\text{number of hops} \quad (14)$$

III. SIMULATION RESULTS AND DISCUSSION

The following parameters are measured by the simulations.

Stability Period: This is the time gap between the start of the operation of the network and the death of the first sensor node.

Instability Period: This is the time gap between the death of the first sensor node and the death of the last sensor node.

Network lifetime: This is the time between the start of the network operation and the death of the last node.

MatlabR2015b is used for simulations and is run over a computer with Intel® Core™ i5 CPU @2.4GHz having 4GB RAM. The following Table-I shows the value of parameters used for simulation. The protocol is executed many times to evaluate its performance. The details of the parameter values used in these scenarios are listed in Table-I. Three scenarios are taken to check the performance of EEUCR in different conditions. The EEUCR is compared with different groups of protocols in different scenarios because the results of the same protocols are not available in all the scenarios. Also, the total energy of EEUCR is equal to the total energy of the protocols used for comparison.

Table –I: Parameters used for the simulation in three different scenarios.

PARAMETERS	VALUES		
	Scenario1	Scenario2	Scenario3
Network diameter	100m	200m	500m
Base station location	(50,50)	(100,100)	(250,250)
Number of nodes	100	100	200
r_m	50	100	250
r_0	5	10	25
E_0	0.5j	0.82j	0.41j
E_s	1j	1.64j	0.82j
Total energy	60j	100j	100j
Data packet size	4000bits	8000bits	4000bits
Number of rounds	10000	10000	10000
m	5	5	5
q	0.5	0.5	0.5
E_{DA}	5nj/bit	5nj/bit	5nj/bit
d_0	36.17m	36.17m	36.17m
Control packet size	400bit	400bit	400bit
E_{Tx_amp}	0.014pj/bit	0.014pj/bit	0.014pj/bit
E_{Tx}	50nJ/bits	50nJ/bits	50nJ/bits

E_{Rx}	50nJ/bits	50nJ/bits	50nJ/bits
E_{fs}	6.37×10^{-2} nj/bit/m ²	6.37×10^{-2} nj/bit/m ²	6.37×10^{-2} nj/bit/m ²
E_{mp}	4.87×10^{-5} nj/bit/m ⁴	4.87×10^{-5} nj/bit/m ⁴	4.87×10^{-5} nj/bit/m ⁴

Following Fig.3 shows the formation of variable radii of rings as per scenario1. Ring formation for other scenarios will also be same. The only difference will be in their dimensions. The radii of rings increases as the distance from BS increases. The area is divided into five rings. The BS is located in the innermost ring of the network.

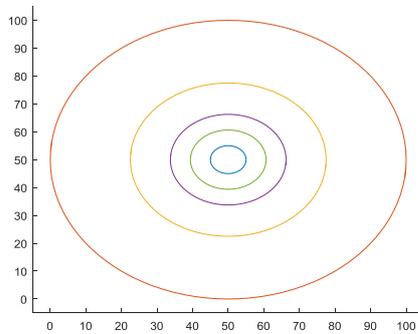


Fig.3. Variable radii of rings as per scenario1

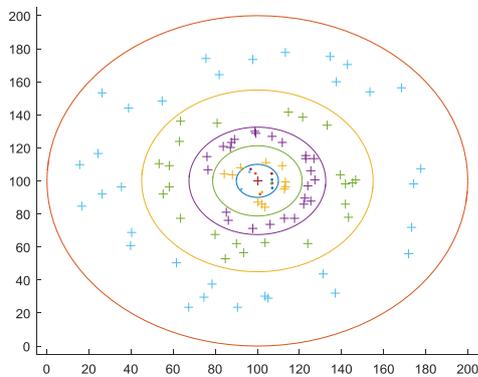


Fig.4(a).Scenario1

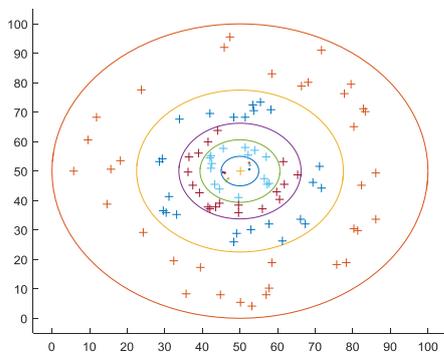


Fig.4(b).Scenario2

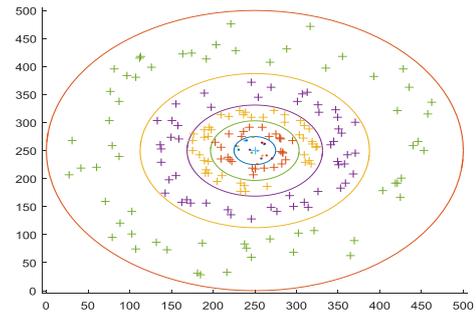


Fig.4(c).Scenario3
Fig.4. Uniform random node deployment

Fig.4. shows node deployment of all three scenarios in the area of rings. The Fig 4(a), 4(b) and 4(c) show node deployment of scenario1, scenario2, scenario3 respectively. The ratio of nodes deployed in the area A_s to nodes deployed in the area A_n is approximately one ratio four as given in the following equation.

$$\frac{N_s}{N_n} = \frac{1}{4} \quad (15)$$

A.Energy consumption of EEUCR

As per scenario1, The total energy of all the sensor nodes in the network is approximately 60j. The total energy of all the sensor nodes in the network as per scenario2 is 100j and the total energy of network as per scenario3 is also 100j. Fig.6 shows energy consumption wrt round, graph 5(a),(b) and (c) shows energy consumption by the network as per scenario1, 2 and 3, respectively. As shown in graph 5(a), high energy is consumed upto1900 rounds because almost all the nodes are alive. After 3000 rounds, 80% of nodes die which results in less energy consumption after 3000 rounds. The graph 5(b) shows high energy is consumed upto1600 rounds because a large number of nodes are alive. The graph 5(c) shows high energy is consumed upto1000 rounds. A sheer slope of the graph shows that better energy balancing is achieved. The Fig.5 (a) for scenario 1 shows a sheer slope of the curve than the 5(b) and 5(c). So scenario1 shows balanced energy consumption as compared to other scenarios.

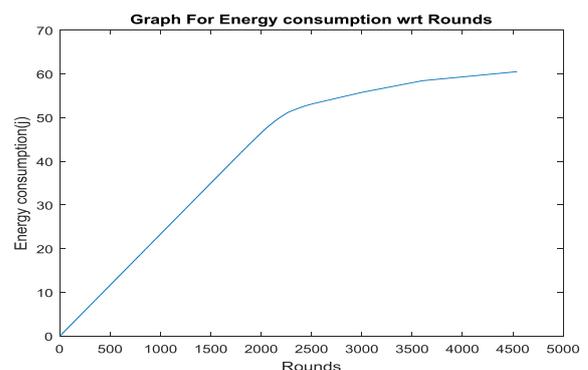


Fig.5(a).Scenario1

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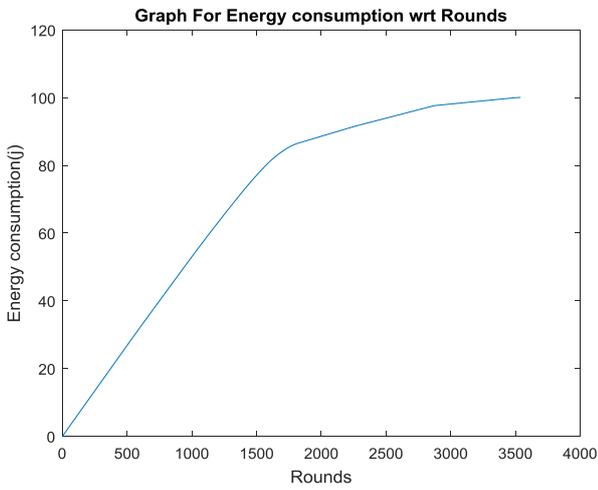


Fig.5(b).Scenario2

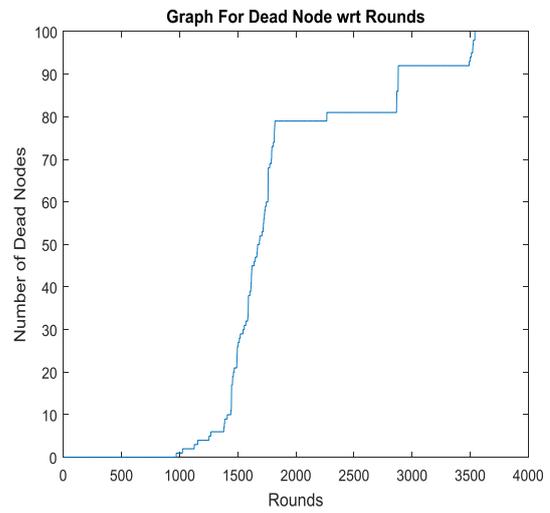


Fig.6(b). Scenario2

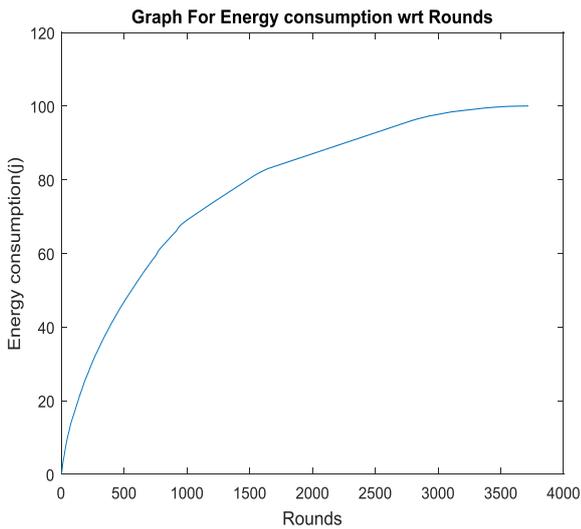


Fig.5(c).Scenario3

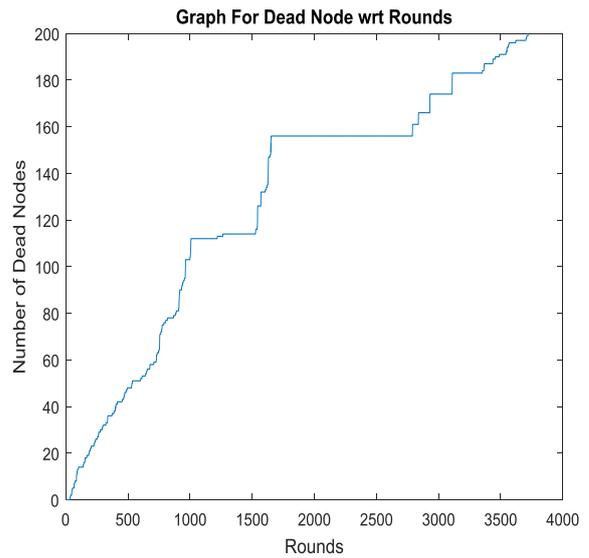


Fig.6(c).Scenario3

Fig.5. Energy consumption w.r.t rounds

Fig.6. Dead nodes w.r.t rounds

Following Fig.6 shows the number of dead nodes wrt rounds and graphs 6(a),6(b) and 6(c) shows dead node of the network as per scenario1, 2 and 3, respectively.

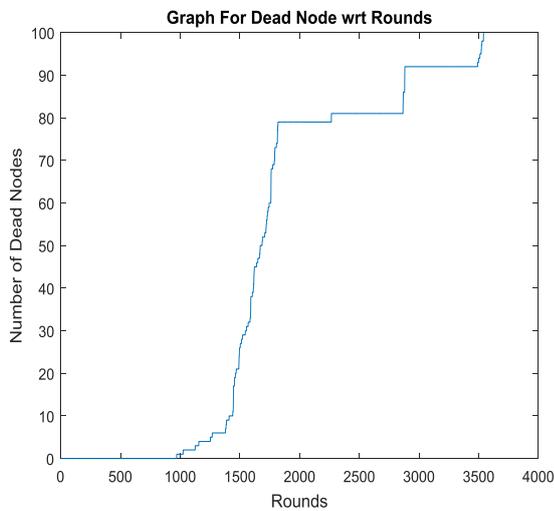


Fig.6 (a).Scenario1

As shown in graph 6(a), the stability period of the network is up to 1893 rounds. All the nodes die at 5024 rounds. The graph 6(b) shows the stability period of the network is up to 1061 rounds and all the nodes die at around 3541 rounds. The graph 6(c) shows the stability period of the network is up to 63 rounds and all the nodes die at 3780 rounds. Following Fig.7 shows the number of alive nodes wrt rounds and graphs 7(a), 7(b) and 7(c) shows the alive node of the network as per scenario1, 2 and 3, respectively. By comparing 7(a), 7(b) and 7(c), it is found that the instability period of the network is long in scenario3 and also the life of the network is small than scenario1. As shown in graph 7(a), the stability period and life of the network in scenario1 is long as compared to scenario 2 and 3. The graph 7(b) shows that the stability period of the network is large than scenario 3 but smaller than scenario1 and the life of the network is smaller than the other scenarios.

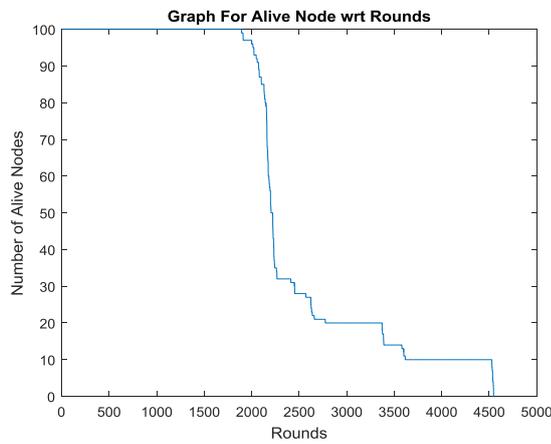


Fig.7(a).Scenario1

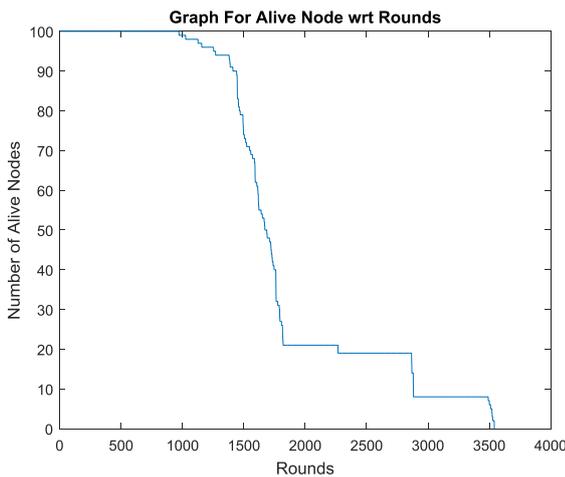


Fig.7 (b).Scenario2

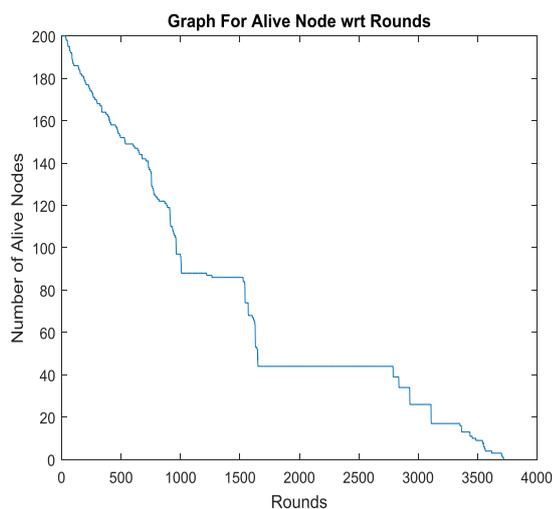


Fig.7 (c).Scenario3

Fig.7. Alive nodes w.r.t rounds

B.Comparison of the EEUCR with algorithms as per scenario1

This section shows an evaluation of the EEUCR with other routing algorithms like LEACH[4], EASSR[15], SEP[12], ITSEP[16]. Table-II shows the values of first node dead (FND) and last node dead (LND) of all the protocols. In ITSEP, FND after 1400 rounds but 40% of nodes are alive after 2500 rounds but in the EEUCR only 30% of nodes are alive. The EEUCR shows better results of the stability period as compared to ITSEP. In LEACH the FND after

1022 and LND after 3500 rounds. In SEP, FND after 1158 rounds which is better than LEACH but the whole network dies after 2500 rounds, the life of SEP is less than all protocols used for comparison. In EASSR, FND after 1350 rounds and LND after 4500 rounds. A sharp slope of EEUCR the graph indicates that better energy balancing is achieved until the first node dies. On reaching the FND round, the energy resources of many nodes start to deplete leading to the quick decline in the number of alive nodes. In EEUCR FND after 1893 rounds and network is alive up to 4544 rounds. Fig.8 graphically shows a comparison of the number of nodes dead with respect to rounds for the existing routing algorithms with EEUCR.

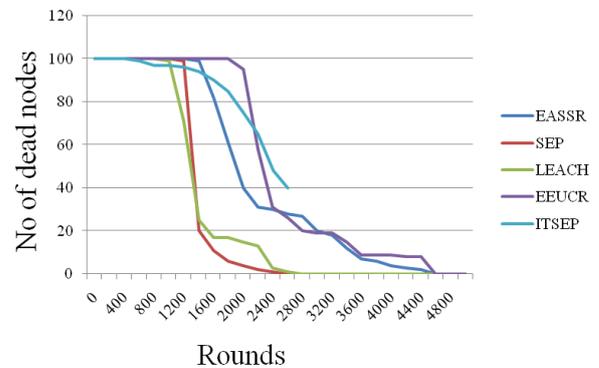


Fig.8. Comparison of EEUCR with existing protocols as per scenario1

C.Comparison of the EEUCR with algorithms as per scenario2

This section shows an evaluation of the EEUCR with other routing algorithms HUCL[15], ECDC[20], HCD[5] for scenario2. Results for comparison are taken from HCD[5] for all the protocols used for comparison in this scenario. Results of fig.9. and table-III show that the routing algorithm EEUCR increases stability period and network lifetime than the other three protocols. In HUCL the FND after 200 rounds and LND after 1000 rounds. In ECDC, FND after 300 rounds which is better than HUCL and the whole network dies after 1400 rounds. In HCD, FND after 400 rounds and LND after 1200 rounds. In EEUCR, FND after 1061 rounds and network is alive up to 3780 rounds.

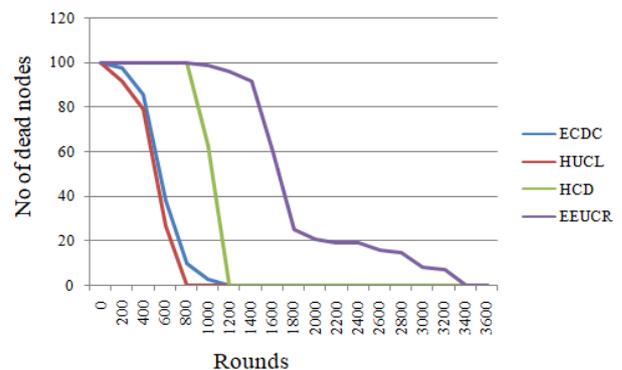


Fig.9. Comparison of EEUCR with existing protocols as per scenario2

D. Comparison of the EBUCR with algorithms as per scenario3

This section shows an evaluation of the EBUCR with other routing algorithms for large scenario3. AZR-LEACH[17] is static clustering routing algorithms and results for all the protocols used for comparison in this scenario are taken from this paper. The LEACH, SEP are dynamic clustering routing algorithms. Results show that the stability period of the EEUCR is slightly smaller than AZR-LEACH but greater than LEACH & SEP. The network lifetime and instability period of the EBUCR are greater than all the protocols as shown in Fig. 10 & Table-IV. In LEACH the FND after 39 rounds and LND after 1078 rounds. In SEP, FND after 62 rounds and the whole network dies after 1282 rounds. In AZR-LEACH, FND after 80 rounds and LND after 1400 rounds. In EEUCR, FND after 63 rounds and whole network dies after 3541 rounds. In this scenario EEUCR performs better than all protocols used for comparison in terms of lifetime of WSN. Table-IV shows that value of FND of EEUCR over the FND of LEACH is 1.61, which is second highest in the table. It is also shown

that value of LND of EEUCR over the LND of LEACH is 3.28, which is larger than all the algorithms used for the comparison.

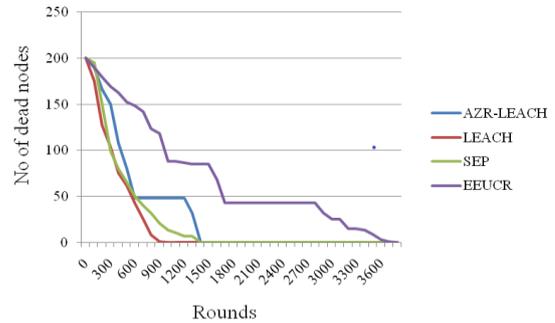


Fig.10. Comparison of EEUCR with existing protocols as per scenario3

Table-II: FND and LND values of LEACH, EASSR, SEP, ITSEP, and EEUCR for scenario1.

Protocol	FND	FND over the FND of LEACH	LND	LND over the LND of LEACH
	Round		Round	
LEACH	1022	1	3500	1
EASSR	1350	1.32	4500	1.28
SEP	1158	1.13	2500	0.71
ITSEP	1400	1.36	40% nodes alive after 2500 rounds	-----
EEUCR	1893	1.85	4544	1.29

Table –III: FND and LND values of HUCL, ECDC, HCD, and EEUCR for scenario2.

Protocol	FND	FND over the FND of LEACH	LND	LND over the LND of LEACH
	Round		Round	
HUCL	200	1	1000	1
ECDC	300	1.5	1400	1.4
HCD	400	2	1200	1.2
EEUCR	1061	5.30	3780	3.78

Table –IV: FND and LND values of LEACH, AZR-LEACH, SEP, and EEUCR for scenario3.

Protocol	FND	FND over the FND of LEACH	LND	LND over the LND of LEACH
	Round		Round	
LEACH	39	1	1078	1
SEP	62	1.58	1282	0.71
AZR-LEACH	80	2.05	1400	1.29
EEUCR	63	1.61	3541	3.28

IV. CONCLUSION AND FUTURE SCOPE

The proposed protocol is an unequal clustering based routing protocol to balance the energy consumption among nodes. The network area is divided into rings of unequal size so that nodes nearer to BS have less diameter and can save energy. Heterogeneous nodes are deployed in the sensor field. In the ring 1 and 2 supernodes are deployed and in all other rings, normal nodes are deployed. This hybrid network reduces the overhead to relay traffic of sensor nodes of rings 1 and 2. This helps to balance the energy consumption among the network which leads to energy efficiency and further increases the network lifetime. After simulation results of EEUCR are compared with existing protocols in three different scenarios. Almost in all scenarios proposed

protocol shows better performance than the existing protocols. The authors would be evaluating the performance of the EEUCR for the packet delivery ratio and end to end propagation delay in their future work.

REFERENCES

1. I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, "Wireless Sensor Networks: A Survey," Elsevier, Comput Netw. 2002, pp 393–422.
2. K. Akkaya and M. Younis, "A survey on routing protocols for wireless sensor networks," Ad Hoc Networks, 2005, pp325–349.
3. P. Handa and B.Sohi, "A Survey on Various Layers of Wireless Sensor Networks, Journal of Mobile Computing," Communications & Mobile Networks,"Vol 2, No 2, 2015, pp1-9.

4. W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy efficient communication protocols for wireless microsensor networks," in: Proceedings of the 33rd Hawaiian International Conference on Systems Science, 2000.
5. T. Han, S. M. Bozorgi, A. V. Orang, A. A. R. Hosseinabadi, A. K. Sangaiyah and M.Y. Chen, "A Hybrid Unequal Clustering Based on Density with Energy Conservation in Wireless Nodes," Sustainability 2019.
6. S. Soro and W. Heinzelman, "Prolonging the lifetime of wireless sensor networks via unequal clustering," in: Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium (IPDPS) 2005.
7. G. Chen, C. Li, M. Ye, J. Wu, "An unequal cluster based routing protocol in wireless sensor networks," wireless netw, Springer, 2009, pp193-207.
8. M. Ye, C. Li, G. CHEN, and J. WU, "EECS: An Energy Efficient Clustering Scheme in Wireless Sensor Networks," Ad Hoc & Sensor Wireless Networks, 2006.
9. M. Yao, C. Lin, Y. Tian, "Energy and Delay Minimization in Cluster-Based Wireless Sensor Networks," IEEE International Conference on Green Computing and Communications, Conference on Internet of Things, and Conference on Cyber, Physical and Social Computing, 2012.
10. Muhammad, N. Javaid, S. Hussain, T. Hafeez, H. Maqsood, S. Zarar, "EEHR: Energy Efficient Hybrid Routing Protocol for Underwater WSNs," 10th International Conference on Broadband and Wireless Computing, Communication and Applications, 2015.
11. A. Kashaf, N. Javaid, and Z.A. Khan, "TSEP: Threshold-Sensitive Stable Election Protocol for WSNs," In Proceedings of the International Conference on Frontiers of Information Technology, Islamabad, Pakistan, 2012, pp. 164–168,
12. G. Smaragdakis, I. Matta, and A. Bestavros. "Sep: A stable election protocol for clustered heterogeneous wireless sensor networks," In Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA), 2004.
13. F. A. Aderohunmu and J. D. Deng, "An enhanced stable election protocol (sep-e) for clustered heterogeneous wsn," ISDCA, 2006.
14. S. Faisal, N. Javaid, A. Javaid, M. A. Khan, S. H. Bouk, and Z. A. Khan. "Z-sep: Zonal-stable election protocol for wireless sensor networks," J. Basic Appl. Sci. Res, 2013, pp132–139.
15. Malathi L, Gnanamurthy R, Chandrasekaran K., "Energy efficient data collection through hybrid unequal clustering for wireless sensor networks," Comput Electr Eng, 2015, pp358–70.
16. L. Zhao, and Q.Tang. "An Improved Threshold-Sensitive Stable Election Routing Energy Protocol for Heterogeneous Wireless Sensor Networks," mdpi journal, 2019.
17. Z. A. Khan and S. Sampalli, "AZR-LEACH: an energy efficient routing protocol for wireless sensor networks," International Journal of Communications, Network and System Sciences, 2012, vol. 05, no. 11, pp. 785–795.
18. M. K. Khan, M.d Shiraz, K.Z.Ghafoor, S. Khan, A. S.Sadiq and G. Ahmed, "EE-MRP: Energy-Efficient Multistage Routing Protocol for Wireless Sensor Networks," Hindawi Wireless Communications and Mobile Computing, 2018.
19. T. S. Panaga, J.S. Dhillon, "Dual head static clustering algorithm for wireless sensor networks," Int. J. Electron. Commun. (AEÜ), 2018, Pp148–156.
20. X. Gu, Yu D. Yu J, Lv Y. Wang G, "ECDC: an energy and coverage-aware distributed clustering protocol for wireless sensor networks," Comput Electr Eng, 2014, pp384–98.
21. M. Pramanick, C.Chowdhury, P.Basak, M. A. Al-Mamun, S.Neogy. "An Energy-Efficient Routing Protocol for Wireless Sensor Networks. Applications and Innovations in Mobile Computing," 2015, pp124-131.



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