

Enhancing Packet Delivery Ratio and a lifetime of Wireless Sensor Networks using Energy-Efficient Unequal Clustering Routing Algorithm

Priyanka Handa, Tripatjot Singh Panag, Balwinder Singh Sohi

Abstract-Sensors are regarded as significant components of electronic devices. The sensor nodes deployed with limited resources, such as the power of battery inserted in the sensor nodes. So the lifetime of wireless sensor networks (WSNs) can be increased by using the energy of the sensor nodes in an efficient way. A major part of energy is consumed during the communication of data. Also, the growing demand for usage of wireless sensors applications in different aspects makes the quality-of-service (QoS) to be one of the paramount issues in wireless sensors applications. QoS guarantee in WSNs is difficult and more challenging due to the fact that the sensors have limited resources and the various applications running over these networks have different constraints in their nature and requirements. The packet delivery ratio (PDR) is a major factor of QoS. To achieve high QoS the packet delivery ratio should be maximum. The energy-efficient unequal clustering routing protocol (EEUCR) is evaluated and results show that it enhances the packet delivery ratio (PDR) and a lifetime of WSNs. In this protocol, the area of the network is divided into a 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 smaller area and area of rings keeps on increasing as the distance from BS increases for balanced energy consumption. 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 remaining energy. This helps to increase lifetime of EEUCR. PDR of EEUCR is improved because multiple rings help to find better route which further aids to ensure safe reception of packets at the destination. Simulation results are compared with existing protocols and show that this algorithm gives better results.

Keywords: network lifetime, packet delivery ratio, quality-of-service, unequal clustering, wireless sensor networks.

I. INTRODUCTION

The WSNs are defined as a very large number of nodes that are connected to each other so that nodes can sense and collect the environmental data, communicate with each other and can process that data. The sensors are usually deployed into the scattered area, known as sensor field. The data gathered by sensors from an environment is forwarded to the BS through multi-hops or single-hop. The BS, also known as the sink, generally communicates with the users through a satellite or an internet connection [1].

Revised Manuscript Received on October 05, 2019.

Priyanka handa*, Electronics and communication engg., research scholar at IKGPTU, Jalandhar, Punjab, INDIA..Email: priyankahanda19@gmail.com

Tripatjot singh panag, Electronics and communication engg., BBSBEC, Fatehgarh Sahib, Punjab, INDIA.. Email: tripatjot.singh@bbsbec.ac.in

Balwinder Singh Sohi, Electronics and communication engg., CGC, Gharuan, Mohali, Punjab, INDIA. Email: bssohi@yahoo.com

Long-lived networks are the prime objective of the researchers. Routing protocols should find the energy-efficient path to deliver the data to the BS. Also delivered data must be of high quality. The high QoS is necessary to guarantee the expected results provided by the network. QoS can achieve the following tasks.

- Offer high-level services even when data is of different types like video, audio, and images or VOIP.
- Uses network resources very carefully and can differentiate data as per the importance and priorities of that data.
- The limited resources of the network such as bandwidth, energy are managed efficiently.

WSNs are used for a wide range of applications and each application has its own QoS requirements such as delay sensitivity, network lifetime, fault tolerance, throughput and PDR, etc. Routing techniques play a major role to improve the QoS of the network. These protocols are called QoS Based routing protocols. QoS is an umbrella term for a group of technologies that permit network-sensitive applications to demand and receive expected services levels in terms of QoS requirements. The network's capability to offer superior services is measured as QoS of the network. However, in WSNs every class of application also has some common requirements. So the network must fulfill the QoS needs while transmitting the sensed data from the sensor field to the BS. The basic QoS issues in WSNs are described below in detail [1-4].

- Limited resources and capabilities: The WSNs have limited resources such as memory, bandwidth, power, and processing capabilities. So QoS can be improved by taking care of both QoS level and energy level consumption.
- Node deployment: The sensor node deployment is an important and critical task in WSNs. The proper deployment can improve the QoS of WSN.
- Dynamic network topology: The topology of WSNs may be dynamic or static. When WSNs are mobile then topology of the network is dynamic. The QoS in mobile networks is a common issue and can be solved by improving the communication between the nodes.
- Scalability: WSNs should be scalable. The QoS should not be affected by changing the number of sensor nodes in WSNs.
- Multi-source Multi-sink: If WSNs are using multi-source multi-sink then it should be capable to maintain the diversified level of QoS supports.
- Various traffic types: The data generated by sensor nodes may be different types such as image, video, audio, etc. So, if the WSNs are able to process the data in an equally efficient manner then QoS of the network will be high-quality.

- Less reliable medium: The WSNs can transfer their data by radio. The Radio channels are noisy and cross-signal interference is more.
- Redundant Data: Sensor nodes are densely deployed so they can generate redundant data. If the same data is transmitted many times then the energy of the network will be wasted and also it can arise more issues such as congestion.

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. Handa et al.[1] described different types of WSNs. They presented a survey of layers of WSNs and also discuss open research issues of different layers. The applications and challenges of WSNs are explained. Asif et al.[2] focused on the QoS satisfaction in WSNs, basics of QoS support in WSNs, and more importantly challenge, requirements of QoS at each layer. They also review the QoS protocols and categorize the QoS aware protocols and elaborate on their pros and cons. Heinzelman et al.[5] introduced adaptive clustering first time. This is a single-hop communication algorithm. In this protocol 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. Handa et al.[6] introduced EEUCR. This is a ring-based routing algorithm. The nodes deployed in the sensor field are heterogeneous energy nodes. The area of the sensor field is divided into five rings. Radii of rings decrease as they approach BS. Nodes deployed in ring0 and ring1 are supernodes having energy two times greater than the nodes deployed in rings 2, 3 and 4. Fissaoui et al.[7] is an energy-efficient and fault-tolerant distributed algorithm for data aggregation in wireless sensor networks (EFTA) to plan the itinerary for a mobile agent and another alternative itinerary in case of node(s) failure. This algorithm adopts a clustering method to group sensor nodes in clusters then plans the itinerary among those clusters efficiently. It consists of three phases: (1) sensor nodes grouping in clusters. (2) Itinerary planning among cluster heads. (3) Mobile agent migration. Nawar et al.[8] designed an enhancement LEACH protocol. This protocol considers energy and distance to choose best cluster head. This protocol after enhancement, similar to the original LEACH divides the nodes into clusters, each containing a cluster head whose task is considerably more energy-intensive than the rest of the nodes. Baz et al.[9] proposed Node Ranked-LEACH (NR-LEACH) that enhances the performance of the LEACH protocol. This enhancement is based on distributing the energy load among the sensor nodes by using a node rank algorithm(NRA) used to elect the CH. The operation of this protocol is divided into rounds. The process of CHs election in the proposed algorithm is depending on node rank calculation. CH election is based on evaluation of each node by calculating its weight. Panag et al.[10] 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 the transmission of data to BS. Zhu et al.[11] described Hausdorff clustering and minimum energy routing for wireless sensor networks use a three-part distributed approach. First, the nodes are organized into static clusters using the Hausdorff clustering algorithm based on location,

communication efficiency, and network connectivity. This is followed by the selection of cluster heads. The cluster head role is scheduled among the cluster members using a greedy algorithm that selects the cluster heads based on the residual energy and the proximity of the nodes. Finally, these cluster heads form a backbone network to transmit the periodically gathered data to the sink using the minimum energy routing based on Bellman-Ford's algorithm. Ferng et al[12] proposed ERPSCDS uses randomly distributed virtual points to divide the network into static clusters. Each node identifies its nearest virtual point to form a cluster. A node is selected to be the cluster head on the basis of its residual energy and its distance from the virtual point. Data from a CH to the sink is transmitted either directly or via multi-hop communication depending on the distance between the CH and the sink.

In this paper, EEUCR[6] is evaluated. The EEUCR uses the concept of unequal clustering, heterogeneous energy nodes, and multi-hop communication. The PDR of WSNs is improved and also the lifetime of the network increased in terms of first node dead(FND) as shown by simulation results.

This paper is organized as follows. Section II explains the network architecture of EEUCR. Section III shows the simulation results. Section IV concludes the paper and discuss future scope.

II. NETWORK ARCHITECTURE

The EEUCR[6] is a ring-based unequal clustering routing algorithm. The network region is divided into five rings. Radii of rings are non-uniform and decrease as distance of rings to BS decreases. The following Fig.1 shows the network architecture of EEUCR. It shows five rings of unequal sizes.

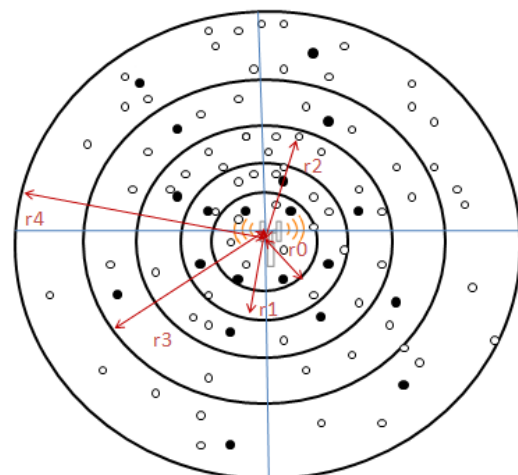


Fig.1. Network Architecture

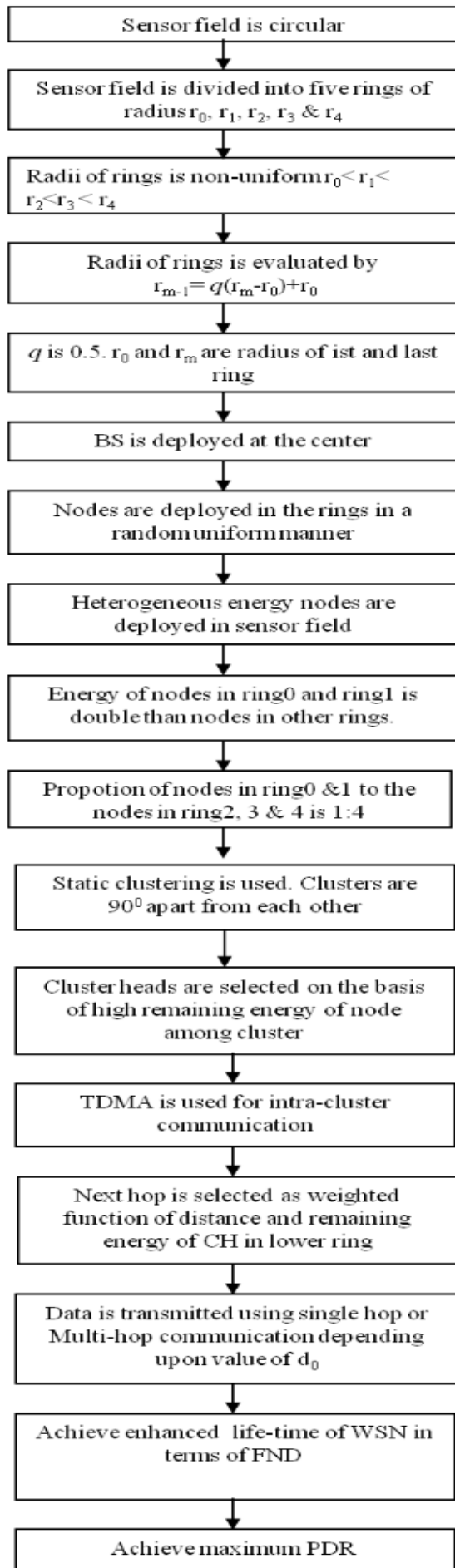


Fig.2. Flowchart of EEUCR

Fig.2 represents the flow chart of the process of EEUCR. Heterogeneous energy nodes are deployed in the network. 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 respective area. Value of q is such chosen that ratio of number of nodes in A_s to number of nodes in A_n is 1:4. The communication energy consumption model used is given by equations 1 to 4 [5]. To transmit k -bit messages over a distance d , the energy expended by the radio is given by following equations:

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

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

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

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

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 there will be multi-hop communication.

III. SIMULATION RESULTS AND DISCUSSION

The following parameters are measured by the simulations.

- Packet delivery ratio (PDR): The fraction of packets sent by the application that is received by the receivers. PDR is computed using the following equation.

$$PDR = \frac{\text{Total number of successful delivered packets}(P_d)}{\text{Total number of transmitted packets}(P_t)} \quad (5)$$

$$PDR(\%) = \frac{N_{BS_DP}}{\sum_{x \in N_S} N_{xSP}} * 100 \quad (6)$$

where N_{BS_DP} is the number of packets received by destination node BS and N_{xSP} is the number of packets sent by sender node x . N_s is the set of sender nodes.

- The lifetime of the network: Lifetime is the major criterion for evaluating the performance of sensor networks. The lifetime of WSNs is the time between the start of the first communication round and the round when first node dies. The first node dead (FND) will result in area partitioning, so the information from that area cannot be gathered.

MatlabR2015b is used for execution of EEUCR. A number of experiments have been conducted to evaluate the performance of the proposed protocol. The algorithm has been tested for its ability to increase the PDR of a WSN and to enhance the lifetime of the network. The following Table-I depicts the value of parameters used for simulation to get the values of PDR. Two

different scenarios are used to check the values of PDR. A set of different protocols is used for comparison because the results of the same protocols are not available for two scenarios. The Table-I shows values of the energy of E_s and E_0 for deployment of 300 nodes and 100 nodes for scenario1 and 2 respectively. The total energy of the network will be dependent on the total number of nodes deployed and accordingly, the energy of E_s and E_0 will vary.

Table –I: Parameters used for the simulation in two different scenarios for comparison of PDR

Parameter	Values	
	Scenario1	Scenario2
d_0	36.17m	36.17m
Network diameter	500m	600m
Base station location	250,250	300,300
r_m	250	300
The total energy of the network	18720j x No. of nodes(E_0 and E_s will vary as the number of nodes varies)	0.5j x No. of nodes(E_0 and E_s will vary as the number of nodes varies)
Data packet size	8000bytes	1024bytes
E_0	15600j for 300 nodes	0.42j for 100 nodes
E_s	31200j for 300 nodes	0.84j for 100 nodes
E_{DA}	5nj/bit	5nj/bit
Control packet size	400bit	400bit
E_{Tx_amp}	0.014pj/bit	0.014pj/bit
E_{Tx}	50nJ/bits	50nJ/bits
E_{Rx}	50nJ/bits	50nJ/bits
E_{fs}	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
Number of nodes	300-800	10-250

A. PDR of EEUCR for scenario1and scenario2

This section shows graphs PDR of EEUCR for scenario1 and scenario Fig.3 shows PDR with 800 nodes deployment for scenario1, it represents that average PDR of EEUCR is 99.2%. Fig.4 shows PDR for scenario2 with 250 nodes. The average PDR, in this case, is 97.5%.

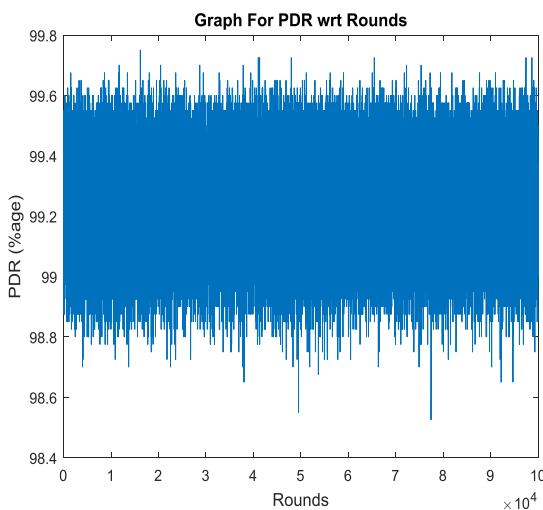


Fig.3. PDR of EEUCR with 800 nodes as per scenario1

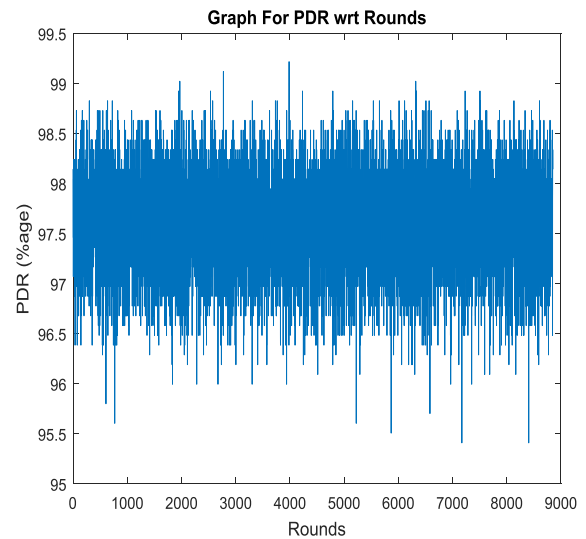


Fig 4. PDR of EEUCR with 250 nodes as per scenario2

B. Comparison of PDR of EEUCR with existing protocols for scenario1

In this section, a comparison of the performance of the EEUCR with existing protocols for scenario1 is described. Results of PDR of EEUCR are compared with EFTA[7] and alternative EFTA[7]. Results are shown in Fig.5 and Table-II. The EEUCR performs better than EFTA and alternative-EFTA. In alternative-EFTA for 300 nodes PDR is around 80% and for 400 nodes PDR is around 87%. PDR for 500, 600, 700 and 800 nodes is 85%, 90%, 87% and 90% respectively. In EFTA for 300 nodes PDR is around 84% and for 400 nodes PDR is around 87%. PDR for 500, 600, 700 and 800 nodes is 88%, 91%, 92% and 93% respectively. The PDR of EEUCR for 300 nodes is 97.5% and for 400 nodes PDR is around 98.3%. PDR for 500, 600, 700 and 800 nodes is 98.8%, 99%, 99.1%, and 99.2% respectively. Results for scenario1 show that EEUCR performs better than EFTA and alternative-EFTA.

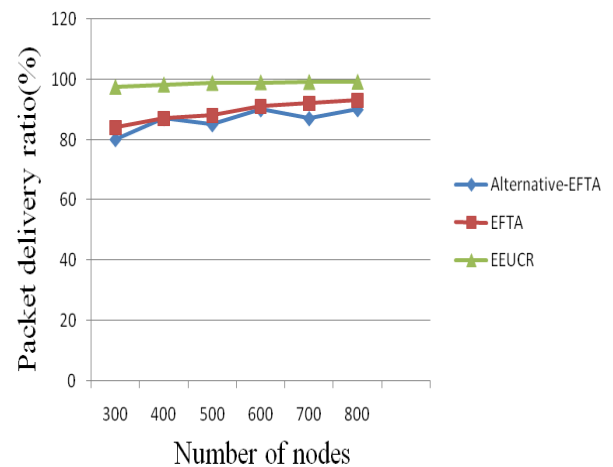


Fig.5. Comparison of PDR of EEUCR with EFTA and alternative-EFTA as per scenario1

TableII. Approximate values of PDR of Alternative EFTA, EFTA, EEUCR as per scenario1.

Number of nodes	Alternative-EFTA	EFTA	EEUCR
300	80	84	97.5
400	87	87	98.3
500	85	88	98.8
600	90	91	99
700	87	92	99.1
800	90	93	99.2

C. Comparison of PDR of EEUCR with existing protocols for scenario2

This section represents a comparison of the performance of the EEUCR with existing protocols for scenario2. Results of PDR are compared with LEACH[5], LEACH-E[8], NR-LEACH[9] and are shown in Fig.6 and Table-III. The values of existing protocols are taken from NR-LEACH[9]. The comparison shows that EEUCR performs better than other protocols when deployed nodes are greater than 25. The performance of EEUCR is poor than other protocols when deployed nodes are less than 25.

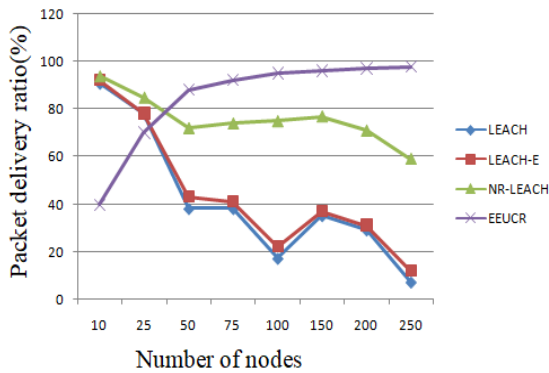


Fig.6.

Comparison of PDR of EEUCR with LEACH, LEACH-E, NR-LEACH as per scenario2

Table-III. Approximate values of PDR of LEACH, LEACH-E, NR-LEACH, EEUCR as per scenario2

Number of nodes	LEACH	LEACH-E	NR-LEACH	EEUCR
10	90.9	92	94	40
25	78	78	85	70
50	38	43	72	88
75	38	41	74	92
100	17	22	75	95
150	35	37	77	96
200	29	31	71	97
250	7	12	59	97.6

Table-IV: Parameters used for the simulation in two different scenarios for comparison of lifetime

Parameter	Values	
	Scenario1	Scenario2
d_0	36.17m	36.17m
Network diameter	100m	350m
Base station location	50, 50	175,175
r_m	250	300

The total energy of the network	$2j \times \text{No. of nodes}(E_0 \text{ and } E_s \text{ will vary as the number of nodes varies})$	$5j \times \text{No. of nodes}(E_0 \text{ and } E_s \text{ will vary as the number of nodes varies})$
Data packet size	125bytes	525bytes
r_0	25	30
E_0	1.67j for 300 nodes	0.42j for 100 nodes
E_s	3.34j for 300 nodes	0.84j for 100 nodes
q	0.5	0.5
E_{DA}	5nj/bit	5nj/bit
Control packet size	25byte	25byte
E_{Tx_amp}	0.014pj/bit	0.014pj/bit
E_{Tx}	50nJ/bits	50nJ/bits
E_{Rx}	50nJ/bits	50nJ/bits
E_{fs}	$6.37 \times 10^{-2} \text{ nj/bit/m}^2$	$6.37 \times 10^{-2} \text{ nj/bit/m}^2$
E_{mp}	$4.87 \times 10^{-5} \text{ nj/bit/m}^4$	$4.87 \times 10^{-5} \text{ nj/bit/m}^4$
Number of nodes	300-700	300-700

D. Lifetime of EEUCR

The network lifetime is defined as number of communication rounds before FND. After the death of first node, some areas will be partitioned because the information from that area can not be detected. So the lifetime of WSN is the time before the death of first node. Following Table-IV enlist the parameters used for simulation for two different scenarios. Results of protocols used for comparison with EEUCR are taken from DHSCA[10]. To take the values of FND of EEUCR is simulated 300-700 nodes deployment for scenario1 and scenario2.

E. Comparison of the lifetime of EEUCR with existing protocols for scenario1

In this section, EEUCR is compared with DHSCA[10], ERP-SCDS[11], Hausdorff[12] as per scenario1. The results of the comparison are shown in Fig.7 and Table-V. Results depict that EEUCR performs better than all other protocols. After simulation of EEUCR it is found that first node dies around 24000 rounds for 300-700 nodes deployment. The DHSCA's first node dies around 15000 communication rounds in every case of node deployment. Results of ERP-SCDS and Hausdorff show that the first node dies after 2800 and 2000 communication rounds respectively.

TableV. Approximate values of the lifetime(FND) of EEUCR, DHSCA, ERP-SCDS, Hausdorff as per scenario1.

number of nodes	EEUCR	DHSCA	ERP-SCDS	Hausdorff
300	25000	15665	2823	2042
350	24550	14995	2824	2163
400	24256	15689	2825	2093
450	24263	15022	2824	2042
500	23360	15033	2823	2042
550	24225	15045	2824	2042
600	23784	15347	2823	2042
650	24250	15165	2823	2042
700	24278	15469	2823	2042

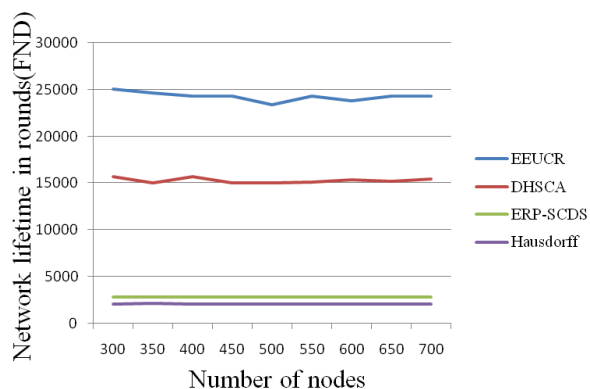


Fig.7. Comparison of lifetime of EEUCR with existing protocols as per scenario1

F. Comparison of lifetime of EEUCR with existing protocols for scenario2

In this scenario, EEUCR is compared with the same set of protocols as was compared in scenario1. Results are shown in Fig.8 and Table-VI. In this scenario,

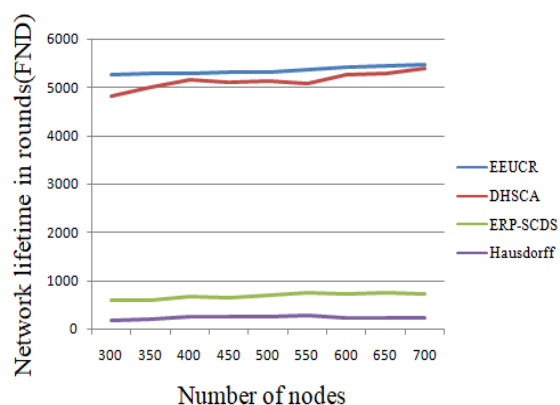


Fig.8. Comparison of the lifetime of EEUCR with existing protocols as per scenario2

EEUCR performs better than all other protocols. The values of EEUCR show that the first node dies between 5260 to 5460 communication rounds for 300 to 700 nodes deployed. For DHSCA first node dies between 4820 to 5393 communication rounds. The values of FND for ERP-SCD and Hausdorff are between 576 to 707 and 168 to 235 communication rounds respectively.

TableVI. Approximate values of the lifetime(FND) of EEUCR, DHSCA, ERP-SCDS, Hausdorff as per scenario2

number of nodes	EEUCR	DHSCA	ERP-SCDS	Hausdorff
300	5260	4820	576	168
350	5273	4993	577	206
400	5289	5165	648	242
450	5300	5100	630	250
500	5312	5130	690	253
550	5350	5081	728	280
600	5415	5250	700	220
650	5436	5280	737	230
700	5460	5393	707	235

IV CONCLUSION AND FUTURE SCOPE

EEUCR is an unequal clustering based routing protocol to balance the energy consumption among nodes. The sensor field is divided into rings of unequal size, this helps to save energy of nodes nearer to BS. 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 routing algorithm reduces the overhead of relay traffic to balance energy consumption and further increases the lifetime of the network. Results for PDR of the proposed protocol are compared with existing protocols in two different scenarios. For scenario1 PDR of EEUCR is compared with EFTA and alternative EFTA. The PDR of EEUCR is better than all other protocols. The PDR of EEUCR is compared with LEACH, LEACH-E, NR-LEACH in scenario2. The performance of EEUCR during scenario2 is better than other protocols except the number of nodes deployed is less than 25. Also, results of lifetime of EEUCR are compared with DHSCA, ERP-SCD, and Hausdorff in two scenarios. The lifetime of EEUCR in both scenarios show better performance than the existing protocols. The authors are working to extend this work to reduce propagation delay of WSNs.

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AUTHORS PROFILE



Priyanka Handa received her B.E. in Electronics and Communication Engineering from MDU, Rohtak in 2006 and M.E. in Electronics and Communication Engineering from Panjab University, Chandigarh in 2010. She is pursuing her Ph.D. from I. K. Gujral Punjab technical university, Jalandhar. At present, she is working as an Assistant Professor in the Department of Electronics and Communication Engineering at Ch. Devi Lal State Institute of Engg. And Technology, panniwala mota, Haryana, India. She is having 10 years of teaching and research experience. Her areas of research is Wireless Sensor Networks and Optimization techniques. She is a life member of Indian Society for Technical Education (ISTE).



Tripatjot Singh Panag obtained his Bachelor's degree in Electronics and Communication Engineering from Guru Nanak Dev Engineering College (GDNEC), Ludhiana, Punjab, in May 2001 and Master's degree in Electronics and Communication Engineering from Baba Banda Singh Bahadur Engineering College (BBSBEC), Fatehgarh Sahib, Punjab, in April 2008. He completed his Ph.D. from Sant Longowal Institute of Engineering and Technology, Longowal, Punjab in November 2017. At present he is working as an Assistant Professor in the Department of Electronics and Communication Engineering at Baba Banda Singh Bahadur Engineering College (BBSBEC), Fatehgarh Sahib, Punjab, India. He is having 16 years of teaching and research experience. His areas of interest are Wireless Communication, Data Communication Networks, Digital System Design, Wireless Sensor Networks, and Optimization techniques. He is a life member of Indian Society for Technical Education (ISTE).



Balwinder Singh Sohi received his B.Sc. Engineering, Masters of Engineering and Ph.D. in Electronics from Panjab University, Chandigarh, India in 1971, 1981 and 1992 respectively. He is the former Director of University Institute of Engineering and Technology, Panjab University. He is recipient of 'The Sir Thomas Ward Memorial Prize' of Institute of Engineers, Kolkata, in 2004 and 2005. He is a senior member of IEEE, fellow of Institution of Engineers, Life Member of ISTE. Presently he is working as director at Chandigarh Group of Colleges, Gharuan, Punjab. He has more than hundred research publications in various reputed journals and conferences. His areas of research are microprocessors and their applications, biomedical instrumentation, wireless networking, computer networking, microwave and RF engineering.