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A NOVEL APPROACH FOR CLUSTERING IN WIRELESS SENSOR NETWORKS BASED ON EN-ERGY EFFICIENT TREE BASED CLUSTERING:EETC

Dr. Ankur Goyal[1], Dr Akash Saxena[2],Atul kumar Srivastava[3], Shivam Mudgal[4]

[1]Global Institute of Technology, Jaipur, India

[2]Compucom Institute of Information Technologyand Management,Jaipur

[3]Amity University,Tashkent

[4]Yagyavalkya Institute of Technology, Jaipur, India

Email: [1]ankur_gg5781@yahoo.co.in,[2] akash27jaipur"gmail.com, [3]aksrivastava@amity.edu, [4]shivammudgal562@gmail.com

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ABSTRACT

Wireless sensors network as an energy consumption technique has been widely discussed in several studies. However, factors such as cluster formation or Cluster Head (CH) assignment node approach have a dramatic effect on network performance as reducing energy efficiency involves restricted resources or network data traffic. For this purpose, we have developed a new energy-efficient tree-based clustering (EETC) model which is the combination of two algorithms, K-Median and Bellman ford algorithms. In the first unit, a hierarchical protocol for routing based on the K-median algorithm transforms a space partition data frame into node organizer clusters. The key purpose of this approach is to reduce sensor node communication by using clustering techniques. In this paper, K-Median is used to measure a decent median among sensor nodes to obtain an optimal result of a cluster. The related cluster heads may then be selected. The balancing of network demands among clusters will increase energy efficiency or effectively prolong network life. Simulation findings show the efficiency in terms of energy consumption or cellular network life of our proposed algorithm over other popular protocols.

Bellman-Ford algorithm is used later for establishing the communication among the CHs hence making a secure connection for nodes. The results are compared with the R-LEACH protocol in the MATLAB and parameters like nodes dead rounds, energy consumption has been calculated.

1. Introduction

As one of the key technologies for the 21st century[1], WSN is extensively measured. In recent years, the industry or academia all over the world has received tremendous attention. A WSN usually consists of multiple WSNs that are less strong, cost-effective, or multifunctional, using sensing, measurement as well as wireless communication[2, 3]. The WSN has become a significant tool for military applications, ID, monitoring of the perimeter of a wireless medium as well as attractive logistics support in an anonymous deployed region and work together to carry out a familiar job over a small distance. Any other applications: location detection, sensor-based personal health monitoring, or progress detection via WSNs. [1,4].

The number of algorithms for clustering was suggested to advance the lifespan of the WSN. The WSN is divided into groups in clustering algorithms, which are called clusters, as well as CH is selected from the one sensor knot from each cluster. All data aggregation actions within the cluster were done, preceded by CH (cluster head) to BS (base station), also a sinks node, to relay information from a specific cluster. Periodic CH selection within clusters is recommended for stability energy usage in each cluster. [5].

The uniform distributed CH will optimize energy usage between SNs or expand the life of the network. The system may not always be efficient by the non-uniform distribution of sensor nodes, methods used to regulate power use, or extend network lifetime. Clusters have consistent cluster areas and can even out resource uses throughout clusters or nodes by uniformly spaced CH cluster heads. However, due to the non-uniform node distribution of sensors, the imbalanced power utilization proceeds among CHs.

WSNs are a special type of computer network that has found wide applications due to its high capacity. Flexibility, self-organization, low-cost & rapid deployment are key features of ideal WSNs for many applications like data gathering, military environment, environment monitoring, intelligent control, traffic management, medical operations, etc. These networks are composed of many small sensor nodes with high capacity, low energy consumption, and a cheap price that can sense the parameters like humidity, temperature, pressure, etc. from the surrounding environment & send them to the sink node.

Sensor nodes are considerably lower or cost-effective. They are more mobile than ad hoc mobile networks which are less centralized. Since sensor nodes are still unattended, it is hard or impossible to reload them in often hostile environments[6]. Energy use is also a big problem in the design of sensor networks.

Efficient or inefficient work may be due to energy use in the sensor network. The transmitting/reception of data, inquiring demands, or decryption of data results in useful energy consumption. Wasteful energy consumption causes collisions or resulting retransmissions, idle channel listening, as well as the overhead of the packet header. Energy consumption reduces the durability of the network, defined as the period before the 1st node (or convinced no. of nodes[7] utilize their energy).

Clustering techniques have been proposed to minimize energy consumption [8]. These methods organize nodes in clusters in which certain nodes work or collect data from SNs. the head will then merge data and forward it in one packet to the data center, thus reducing the total expense of packet headers. Clustering has benefits:

- Decreasing useful energy consumption by improving the usage of bandwidth (i.e, decreasing channel collisions);
- Cognitive shortcuts waste by cutting down on electricity usage. we aim to get better cluster size balance or to achieve minimum energy topology for each cluster.

The paper is organized appropriately, in Section 2 we study literature & in Section 3 introduce EETC. In Section 4, we examine EETC 's accuracy and energy efficiency, complexity, and scalability. This paper shows the conclusion in Section 5.

2. Literature Survey

In the study of [10], authors proposed a hybrid hierarchy-based and long-range clustering of the Approximate Rank-Order WSNs (ARO-WSN). The frequently used ARO-WSN algorithms in image processing is in the order of O(n) in a large data set so that it can be extended to WSN. The results of this paper show that ARO-WSN beats the traditional LEACH, LEACH-C, or K-means algorithms for power usage or network life [10].

The presentors proposed the E-CRCP [11], a protocol that is based on a decrease in the system's energy consumption & use of geographic coverage. The first is to develop an energy model. The optimal No. of clusters is resolute by the 'low energy consumption' principle, & allocation of CHs is 'regional coverage maximization' principle. CH, by lowest residual energy& max energy consumption, is substituted in the next version of the selection of CH to extend the life of the network. [11].

The deep Reinforcement Learning (DRL) algorithm (E2S-DRL) is here proposed as energy-efficient scheduling. E2S-DRL leads to three stages, including the clustering process, the operation cycle process, as well as the routing phase, to extend network lives and to reduce network delay. E2S-DRL begins with the clustering phase of the data grouping, in which we reduce energy consumption. The effects of these measures include network life, energy use, throughput, or delay. The data are useful. It is seen from this evaluation that our E2S-DRL decreases energy usage, delays from 40%, and improves network and flow up to 35% over TDMA, DRA, LDC, and iABC systems. [12].

The goal of the work is to improve the current LEACH or LEACH-C by dynamically selecting clusters along with the residual energyof nodes.

Simulation results indicate that by contrast with the original LEACH or LEACH-C the algorithms are given more stability [13].

The analysis of the work presented in [14], involved the implementation in the network model, both clustered or distributed k-means clustering algorithms. K-means is a prototype-based algorithmthat alternate connecting 2 major steps or identifies cluster observations or cloud computing Centers until a stop criterion is met. There are simulation findings which show that distributed clustering is effective as hierarchical clustering [14].

A fuzzy-based clustering protocol was proposed in [15].The proposed protocol not only extends the life of the network but also manages the load between nodes. Previous protocols don't consider load balancing. Fuzzy logic is used for 4 inputs: residual energy, BS size, node degree, or centrality. A new protocol is compared to other applicable protocols to verify its performance. Findings obtained reveal that the protocol proposed here exceeds other state-of-the-art protocols [15].

A modern methodology known as the hybrid optimization algorithm was based on Lagrangian relaxation or entropy to minimize energy consumption [16].Iin this paper,a theory proposed to preserving complex multi-hop communication. The nodes can interact with high-QoS energy parameters dependent on energy, bandwidth, neighbor connectivity, or hop count. The simulations were given in NS2. The approach proposed estimates overall energy usage, average energy left, rate of reception of packets, drop rate, normalized overhead routing, latency, throughput, goodput, jitter, and service life of the network. The findings of the comparison indicate that optimum cluster formation is hybrid; the lifespan of the nodes has increased [16].

The paper [17] uses a method in which multiple clusters of nodes are generated using an improved K-means clustering algorithm called Optimized K-means. In intra-cluster communication is used with a single hop communication mode, while the inter-cluster communication uses a multi-hop communication mode. The efficiency of the NS-2 simulator is evaluated. The findings of these simulations illustrate the uniform distribution inside the space domain of CH by the proposed algorithm. That balances energy consumption effectively. Also, detailed simulations of various node densities were conducted to show the maximum potential of OK-means. [17].

In the study of [18], 'CH selection' was both optimized through a hybrid method which includes both a GA and PSO algorithm for each work. The powerful GA analysis helps to maximize CH selection & PSO helps to find a path to an optimum reduction in mobility. The proposed GAPSO-H (GA &PSO hybrid) approach was demonstrated in the study of a simulation or impact statistics to overcome conventional algorithms at various phases of efficiency metrics[18].

In WSN, it is very important to examine the formation of load-balanced sensor node clusters. Most existing node clustering systems suffer from problems with the distribution of energy as well as non-uniform lots and lots. These issues have a serious impact on the WSN 's network life. Authors of this paper proposed an improved selection process for Memeticclusters and a load-balanced cluster formation scheme. For certain problems to be solved. The efficiency of the proposed scheme has been contrasted with the two well-known cluster schemes for energy usage, residual energy, and network life. The comparison of data of the proposal validates its superior results in various files to existing node clustering methods [19].

Authors of the paper gave an algorithm to deal both with the cluster-head as well as the sink mobility problem with an energy-efficient cluster or sink (PSO-ECSM) algorithm. Thorough computer simulations were carried out to test the PSO-ECSM performance. CH selection is consistent with five variables, like residual energy, distance, node degree, average energy & energy consumption rate (ECR). The PSO-ECSM algorithm determines the optimal value of these variables. PSO-ECSM also addresses the issue of data traffic transmission through sink mobility in a multi-hop network. In the light of five efficiency indicators (stability time, network, durability, number of dead round nodes, throughput, or increasing network remaining) PSO ECSM outputs are being evaluated against state-of-the-art algorithms. To assess performance value, mathematical analyses are performed. Simulation results show PSO-ECSM improves stability time, half node death, network service lifestyles and ICRPSO throughput by 24.8%, 31.7%, 9.8% as well as 12.2% [20].

3. Research Methodology

3.1 Problem Formulation

Typically, WSNs contain thousands of resource-limited sensors to monitor their setting, gather data, and upload it for further processing to remote servers. Although WSN is considered extremely flexible ad hoc networks, given their deployment scale and their related efficiency issues, like resource management or reliability, Network management was an important challenge for these forms of networks. Because of scarce funds in WSN, direct sensor node communications to BS or BS multi-hop sensor node communication are not feasible, because the EC is high, resulting in early detectors expiry.

3.2 R-LEACH

Clusters or CHs are generated with a standard LEACH algorithm for the first round or CHs are selected with both the equation (4). every node in the network expends a certain amount of energy after the data transfer that is different for each node. power consumption depends upon the distance between nodes defined as 'd' (sending and receiving). The CH is then selected with a modified equation for the next round:

$$T(n) = \begin{cases} \frac{P}{1-P(rmod\frac{1}{P})} \; X \; \frac{E_{residual}}{E_{initial}} k_{opt} \\ 0; \qquad Otherwise \end{cases} \qquad (1)$$

The initial energy level allocated for $E_{residual}$ is the remaining of the node energy level and $E_{insitial}$. The optimal cluster number can be reached as shown [33].

$$k_{opt} = \sqrt{\frac{n}{2\pi}} \sqrt{\frac{E_{fs}}{E_{amp}d^4(2m-1)E_0-mE_{DA}}} M \qquad (2)$$

'M' indicates the network diameter or E0 represents the initial source of energy for every node.

Whenever CHs are selected for the current round, they send their CH announcement information to their respective clusters. The sensor nodes review the signal force of the message to determine which CHs it would like to enter. CH then broadcasts TDMA (Multiple Access Time Division) schedules for participants to relay data in various time slots to eliminate data collisions. The process then continues in the remaining rounds until all nodes in the network consume all their resources.

3.3 Proposed Approach

We are proposing a new energy efficient tree based clustering system (EETC), hybridizing two algorithms, the K median, and the Bellman ford algorithm to reduce energy consumption and extend network life. K-median clustering is used to obtain a universal clustering approach to reduce energy consumption or to increase the network lifespan. We use the base station in our proposed scheme to obtain all sensing data from cluster nodes. Further, we have also usedthe Bellman ford algorithm for establishing the connection between the nodes which will be chosen as CH which will directly communicate to the sink node hence reducing the load among the nodes.

Any reasonable assumptions were followed for the model system as follows:

Nodes with initial 0.5J, 1.0J & 0.25J energy static and homogeneous are available in rooms to monitor humidity, temperatures, acoustics & luminosity variables.

- BS/sink is fixed in the center of the network or installed
- Random deployment of Nodes or periodic transfer of data
- A CH communicating with BS in a single hop or multi-hop communication is supplied in each of the rooms.
- The BS receives CH data or distributes it to the cloud.

3.3.1 K-Median (KM)

KM is applied to isolate all sensor nodes into k clusters. Unlike KM, the K-median algorithm uses a real node instead of the theoretical mean point to represent a CH node. The partition approach is then based on minimizing distance among the popular node as well as a node. Equation 3 should exactly represent the absolute error criterion E.

$$E = \sum_{i=1}^{k} \sum_{x \epsilon c_i} dist(x, r_i) \quad (3)$$

where x in cluster C_i is the most common node and C_i in cluster I is the most common node. E is the sum of distance here between nodes as well as nodes. K-median's main idea is to minimize E, but it is an NP-hard issue. A positive greedy way to solve this problem should then be hired.

Let $I = \{I_1, I_2, \ldots, I_j, \ldots, I_{k-1}, I_k\}$ As a set of head nodes of the cluster. We get an I_{random} common node to replace I_j CH, as well as residual of the random node's energy should be higher than the total residual energyof all nodes. Equation 2 indicates the return method.

$$I^{(t+1)} = \begin{cases} I^* & , E^* - E^{(t)} < \\ I^{(t)} & , \quad otherwi \end{cases} \quad (4)$$

whereverI^*= {I_1, $I_{2,}$…, $I_{random,}$…, I_{k-1}, I_k}, The network should be temporarily distributed to k clusters. new absolute error criterion E * may be determined according to Eq. 4 and new clusters. If E^* is less than $E^{(t)}$ $I^{(t+1)}$ would have been replaced by I^* compared to the initial absolute error criterion $E^{(t)}$ of the clusters through t iteration. Nothing would be done otherwise and the next iteration occurs. Figure 1 displays the flow chart of our proposed procedure i.e., EETC (Energy Efficient Tree based Clustring) approcah.

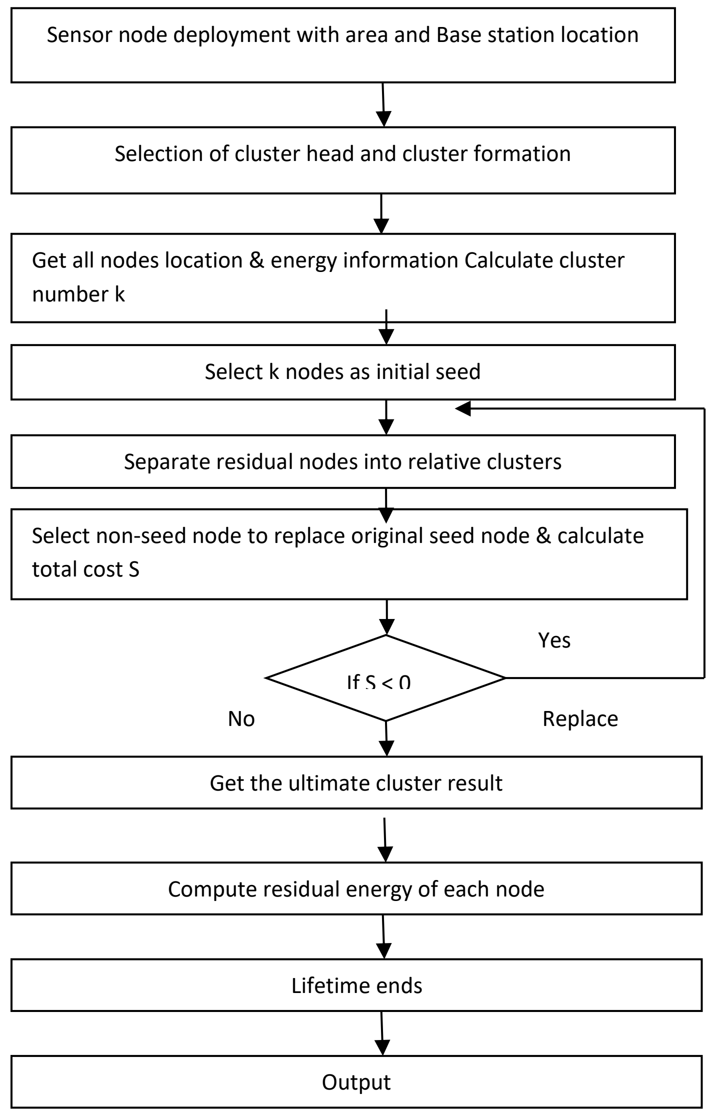

Fig 1.*Flow diagram of proposed System*

We will achieve the final clustering result by executing Equation 2 again and again.

3.3.2 Bellman ford algorithms Negative weight edges can at first seem needless, but may clarify other phenomena. Negative weight edges can establish negative weight loops i.e. a loop that reduces the cumulative distance by returning to the same location in figure 2.

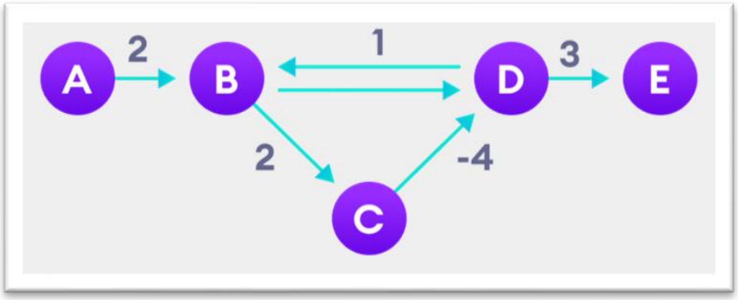

Fig. 2: *Negative weight cycle*

Such a loop can't be identified by other shortest path Algorithms because they will go through a negative weight process and minimize the path length.

By overestimating the direction from the beginning vertex to all other vertices, the Bellman-Ford algorithms function. This then relaxes these calculations iteratively by discovering different forms which are shorter than the already overestimated conduct. This will guarantee that outcome is optimized on all vertices repeatedly.

Step 1	function bellmanFord (G, S)
Step 2	for every vertex V in G
Step 3	distance[V] <- infinite
Step 4	previous[V] <- NULL
Step 5	distance[S] <- 0
Step 6	for every vertex V in G
Step 7	for every edge (U,V) in G
Step 8	tempDistance<- distance[U] + edge_weight(U, V)
Step 9	if tempDistance< distance[V]
Step 10	distance[V] <- tempDistance
Step 11	previous[V] <- U
Step 12	for every edge (U,V) in G
Step 13	If distance[U] + edge_weight(U, V) < distance[V}
Step 14	Error: Negative Cycle Exists return distance[], previous[]

4. Results And Discussion

Table 1 includes a description of network parameters assumed for MATLAB model simulation. The size of a packet is 4000-bit. As seen in Figure, 100 nodes are distributed randomly of BS in a network area Fig. 3.

Table 1: *Simulation parameters*

Parameters	Value
Network diameter	100 meters^2
Total no. of nodes (n)	100 nodes
Total network energy (E_0)	0.5 J
Energy dissipation: receiving (E_{amp})	0.0013 pJ/bit/m^4
Energy dissipation: free space model (E_{fs})	10 pJ/bit/m^2
Energy dissipation: power amplifier (E_{amp})	100 pJ/bit/m^2
Energy dissipation: aggregation (EDA)	5 nJ/bit

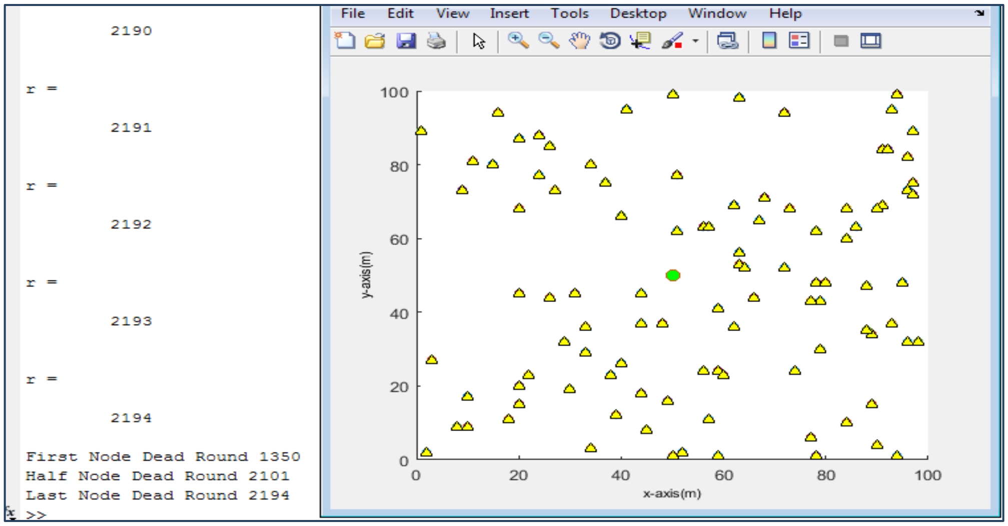

Fig 3. *Node Deployment with total dead node rounds by R-LEACH (0.5J)*

Fig. 3displays node deployment of R-LEACH protocol with initial energy (0.5 Joule) for network life. The simulation result shows that at 1350 round first R-LEACH node dies, while it is at 1662 rounds for proposed algorithm i.e. EETC. Likewise, R-LEACH's last node dies at 2194 rounds, while EETC is still alive as shown in fig 4. R-LEACH protocol assumes that for each round CHs dispense the same energy, which results in an inefficient selection of CHs or affects the durability of the network. Proposed protocol,EETC, chooses CHs to maximize network life by considering the remaining node energy and the optimum number of clusters.

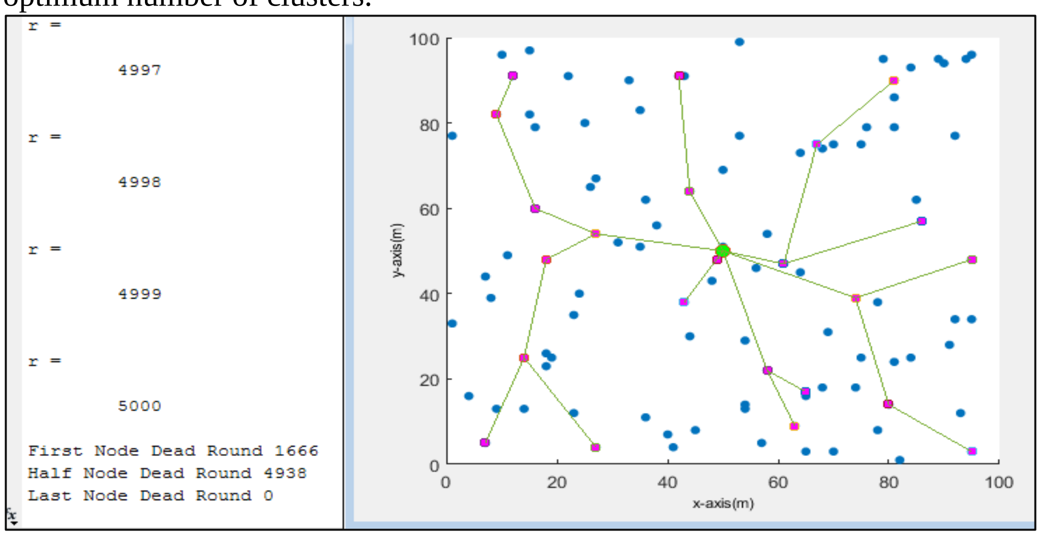

Fig 4. *Node Deployment with total dead node rounds by EETC(.5 J)*

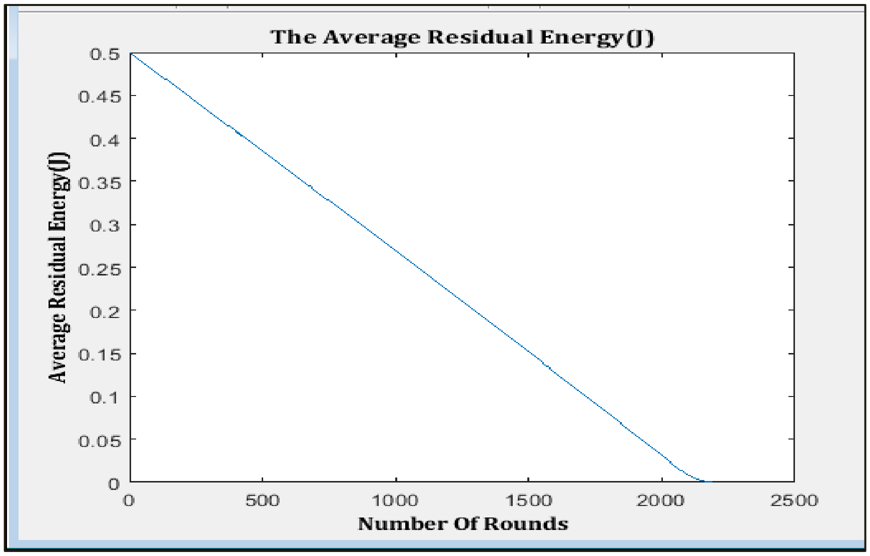

Fig 5.*R-LEACH average residual energy (.5J)*

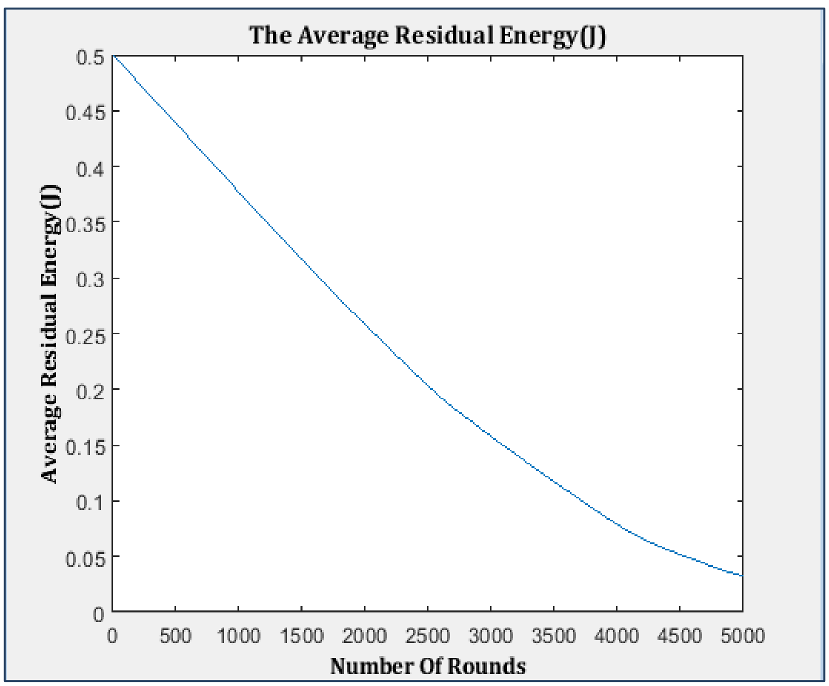

Fig 6.*EETC average residual energy (.5J)*

Network model and Network Lifetime are two main metrics for consistently delivering batter network output in an IoT system. Stability of the network is the time from initiation of the network, before FND (death of the first node), as well as time from FND & LND (death of the last node) in the network, decides the time that has elapsed. We evaluate parameters like network stability FND, network life LND, or network HND (Half node death) for our analysis of the behavior of the proposed EETC model. We consider packet size to be 2000 for a fair comparison in WSN. For network analysis, initial energy E_0 of 0.25, 0.5 & 1J is considered.

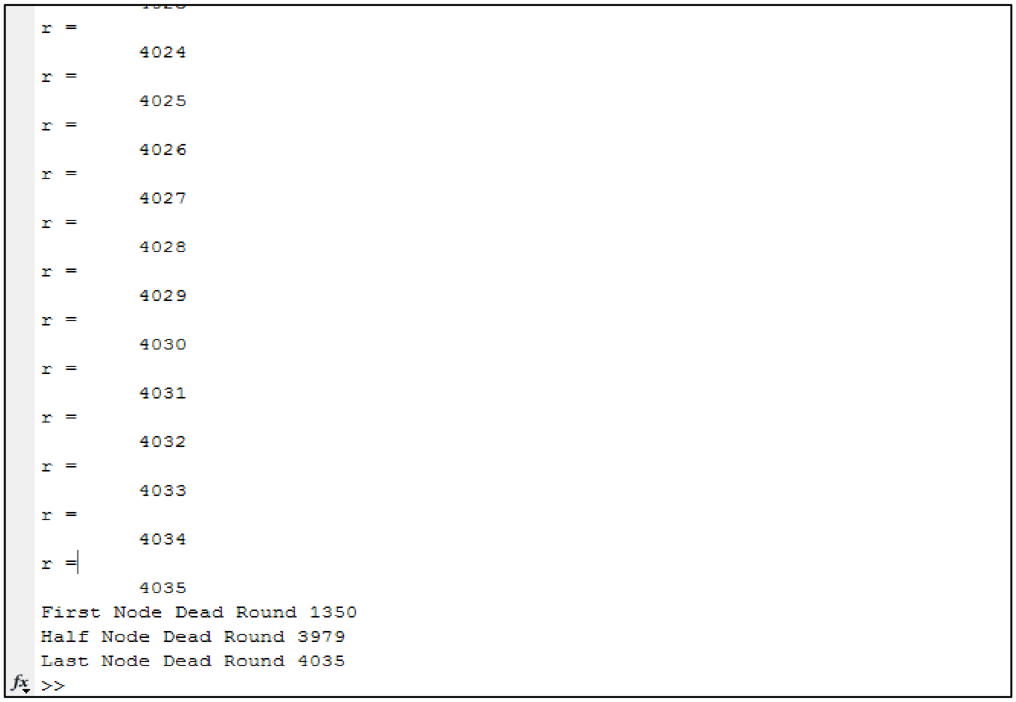

Fig 7. *Node Deployment with total dead node rounds by R-LEACH initial energy(1 Joule)*

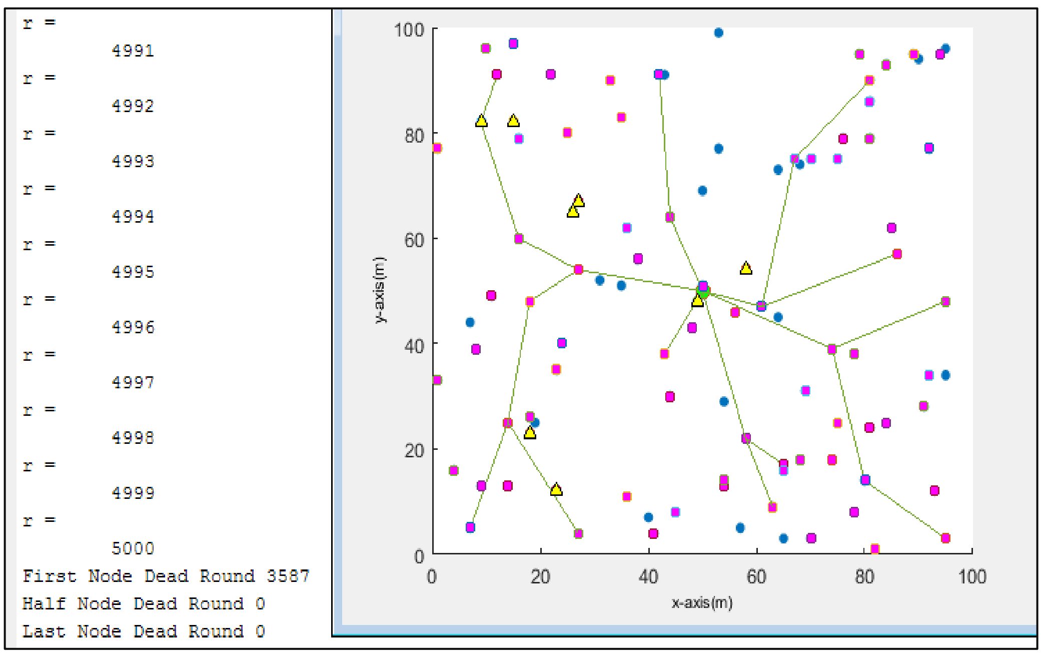

Fig 8.*Node Deployment with total dead node rounds by EETC initial energy (1 Joule)*

Figures 7 and 8 visualize the dead node rounds of R-LEACH and EETC. From the above figures, we noticed that FND, HND, and LND of R-LEACH is at 1350, 3979, 4035 round respectively while FND will find at 3587 round but HND and LND of EETC are not found as the nodes are not dead even at 5000 rounds hence we can say that the network lifetime of EETC is more efficient than that of the R-LEACH.

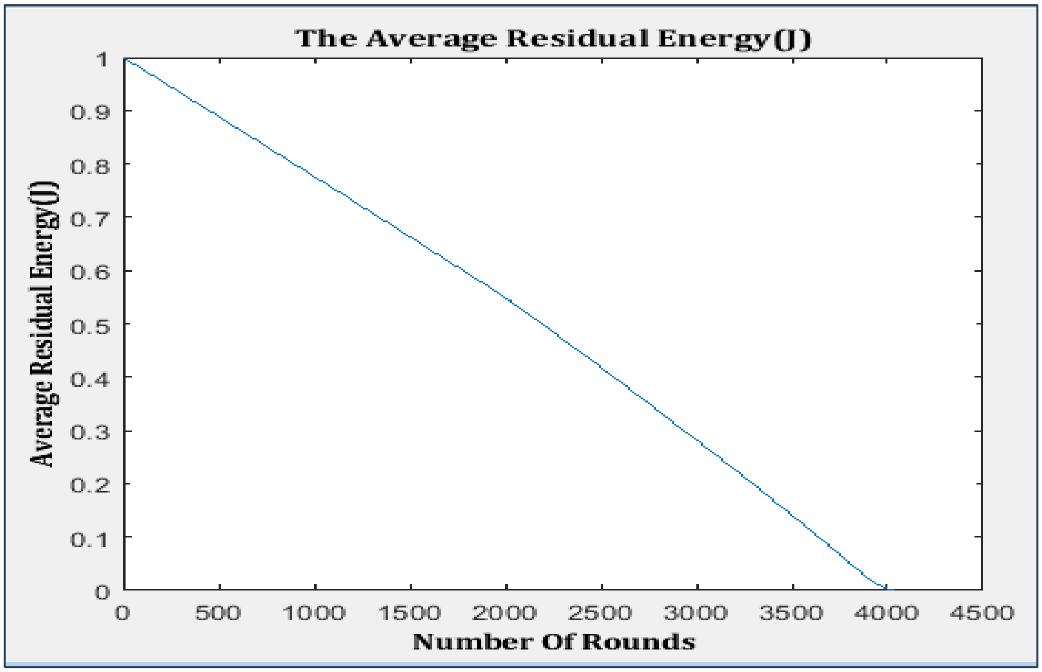

Fig 9.*R-LEACH average residual energy (1 J)*

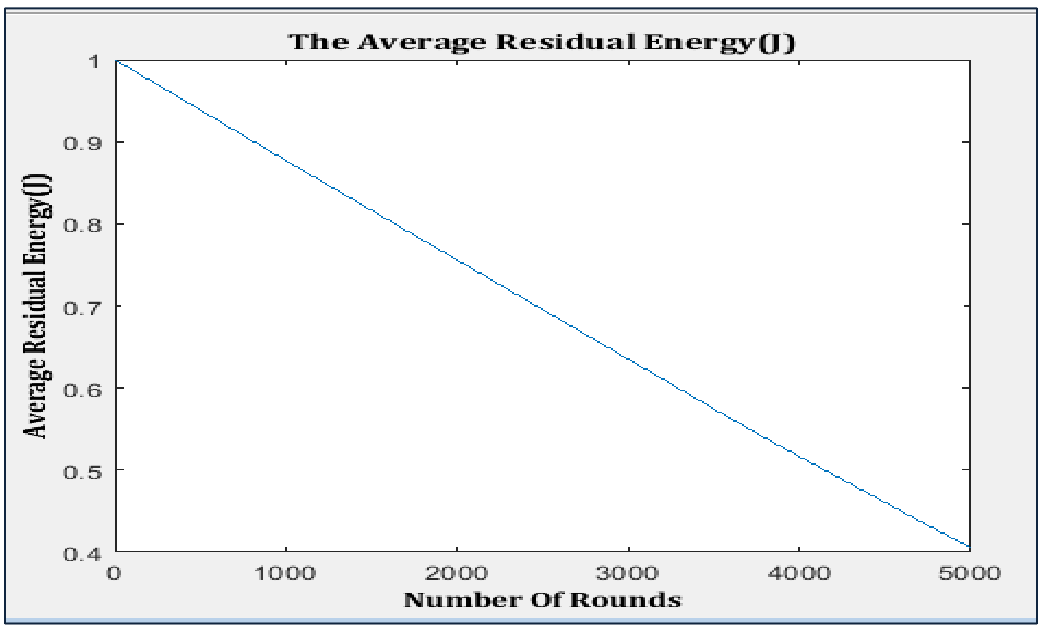

Fig 10.*EETC average residual energy (1J)*

The average residual energy of R-LEACH and EETC has a lot of variation as shown in figures 9 and 10 because the residual energy in R-LEACH is obtained at round 4000 with initial energy 1J but in EETC the energy has remained even at 5000 rounds. Hence we are capable to run our model till 5000 round having remaining energy of 0.99J.

EETC model aims at increasing the life of the network by covering further rounds of HND or FND for all energy levels, so it selects stable nodes for CH.

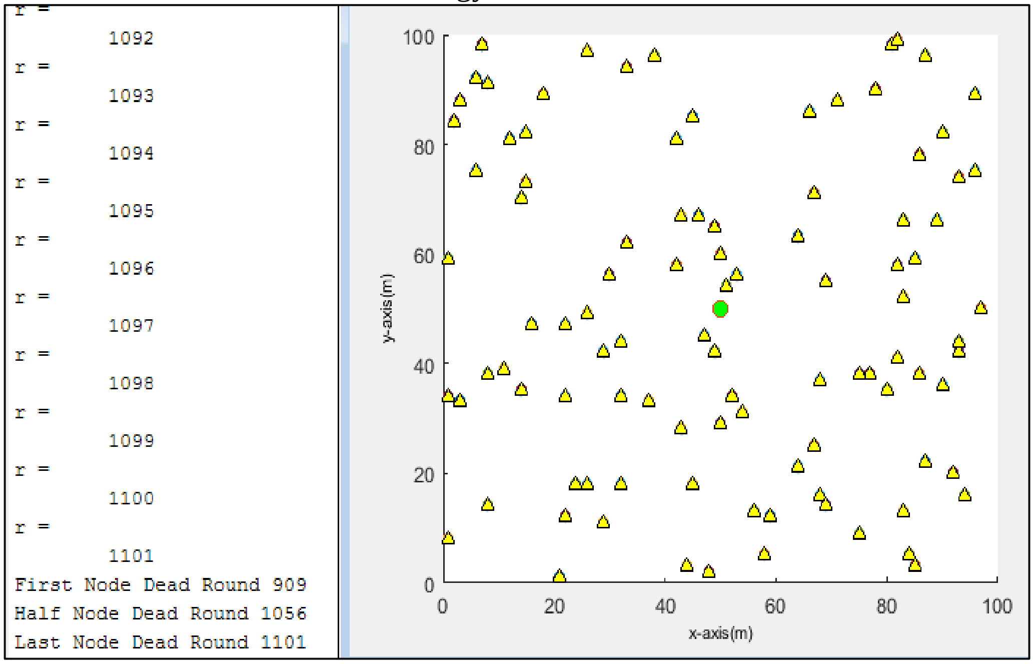

Fig 11. *Node Deployment with total dead node rounds by R-LEACH (.25 J)*

Figures 11 and 12 display the resultant at 0.25J as initial energy. The figures clearly show values of all the dead rounds found in R-LEACH, which are further improved by EETC where the life of dead rounds is increased hence the EETC model is capable to enhance the network lifespan of the nodes working in an area.

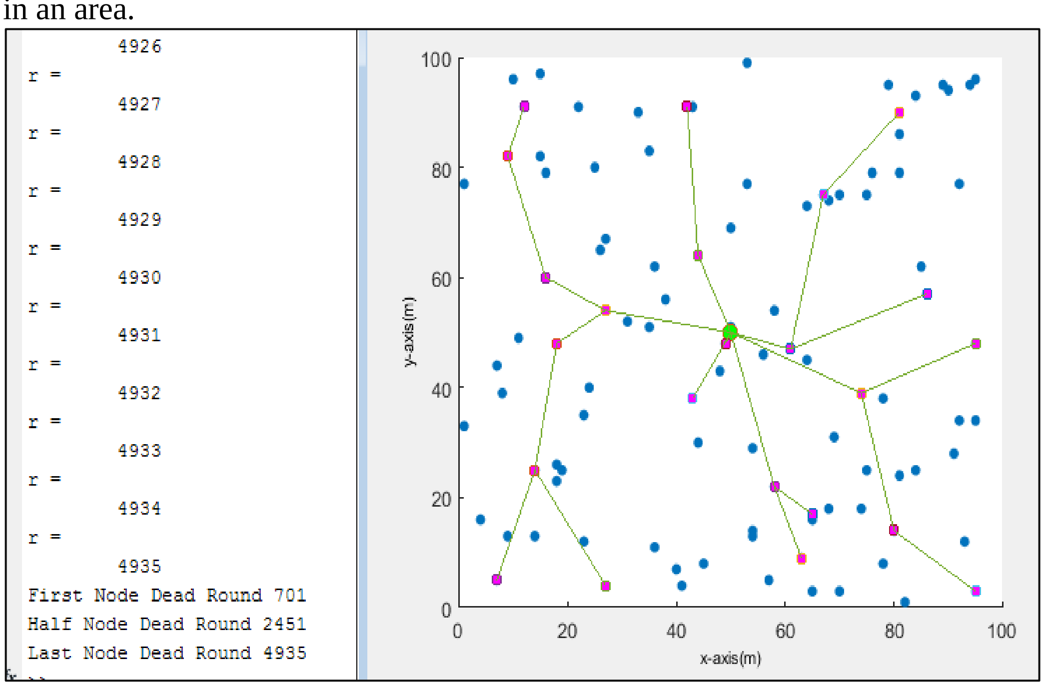

Fig 12.*Node Deployment with total dead node rounds by EETC initial Energy (0.25 joule)*

Figures 13 and 14 display the energy remained at 0,25J, where R-LEACH is having remaining energy only at 1200 rounds while it is working till 5000 rounds for EETC.

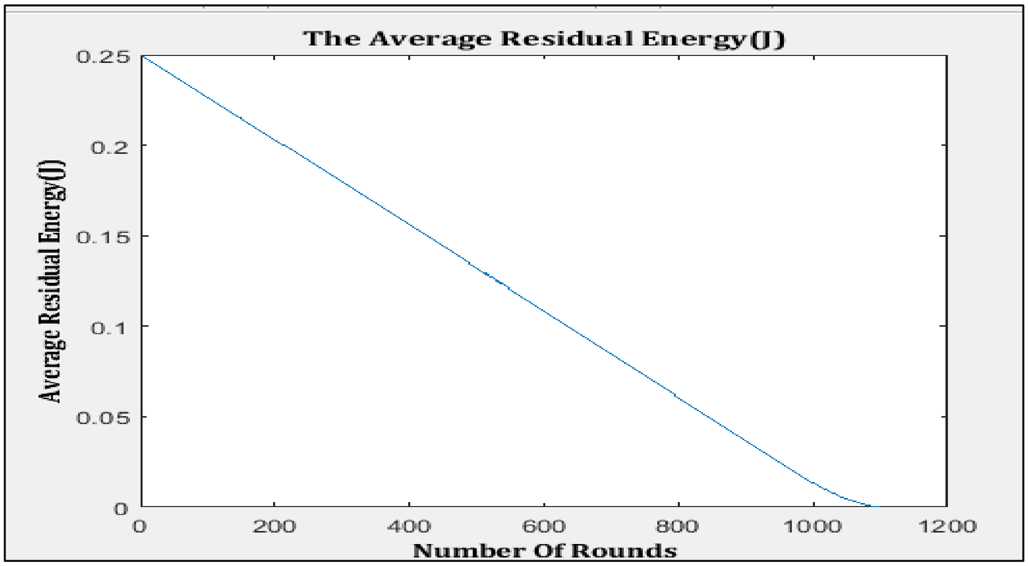

Fig 13.*R-LEACH average residual energy (.25J)*

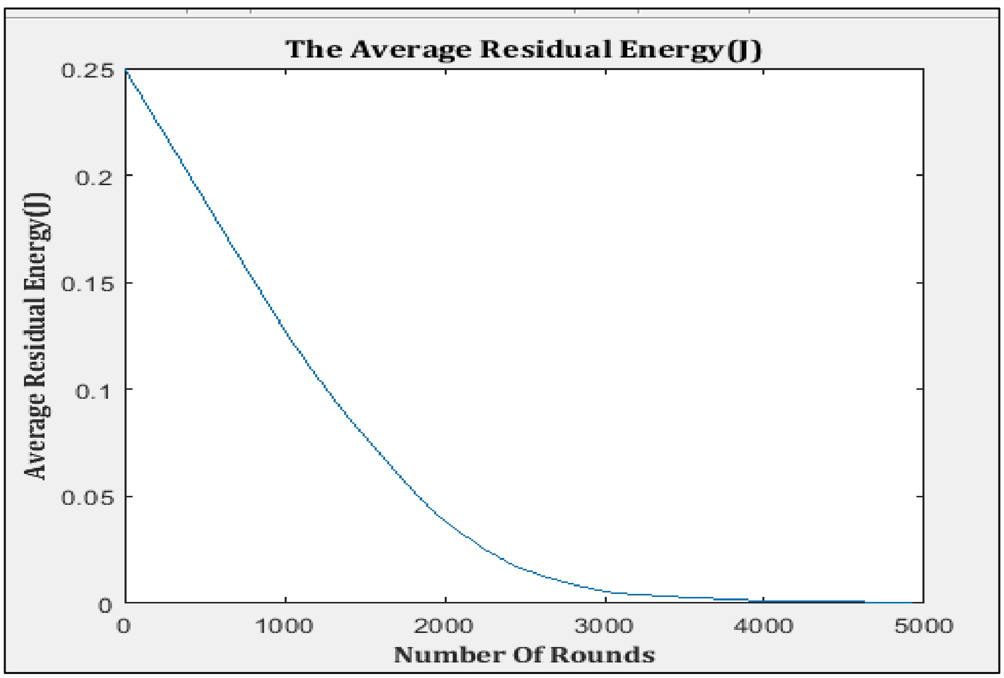

Fig 14.*EETC average residual energy (.25 J)*

Figure 15,shown below, displays the comparison graph of all dead node rounds for all the initial energy levels. The figure clearly shows the improvements obtained by the EETC model hence improving the lifespan of the network and reducing the energy consumption as shown in figure 16. But we can also notice that results of last node dead rounds are not mentioned in figure 15 because we can see in previous figure 8 in which nodes are deployed with initial energy 1 joule, the nodes have not died even at 5000 rounds hence not giving the value of last node and giving the value 0. This indicates that the nodes with energy 1J are alive even after 5000 round or more than 5000 rounds..

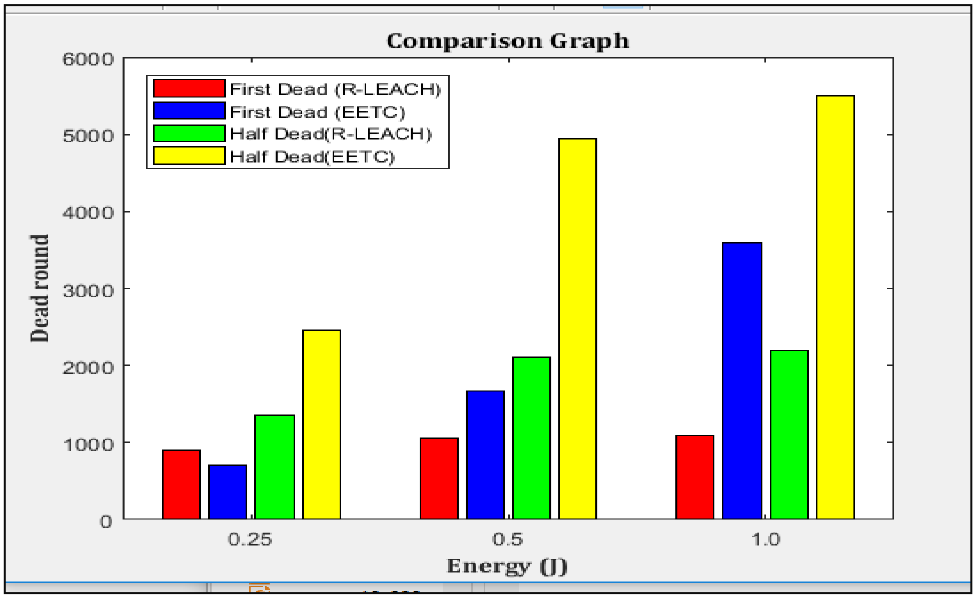

Fig 15.*Comparison graph for dead node rounds of R-LEACH and EETC*

Figure 16 displays the remaining energy at all the initial energy levels obtained by the EETC model after completing the 5000 rounds.

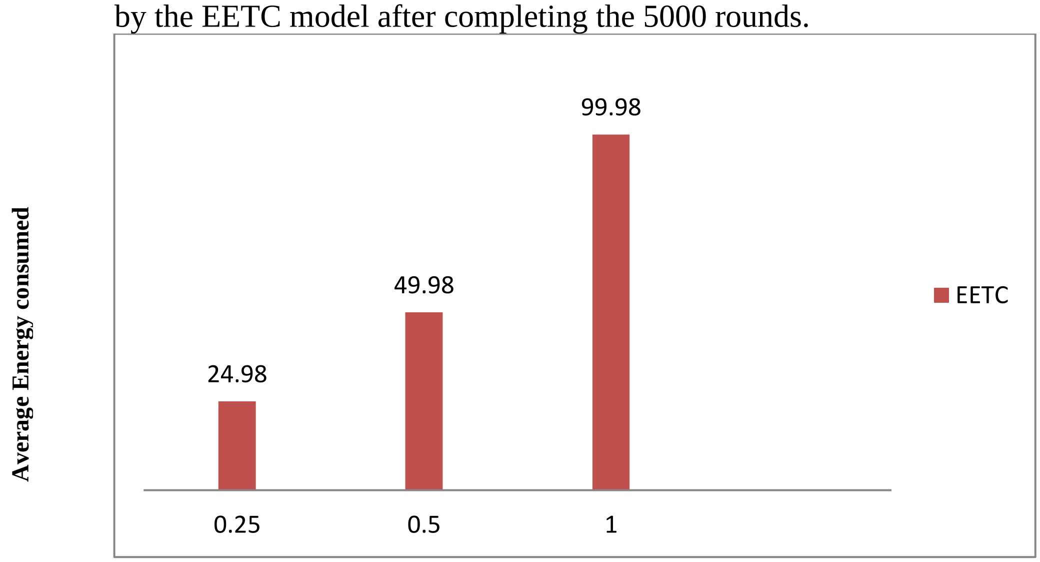

Fig. 16 *Residual Energy obtained by EETC*

5. Conclusion

As the energy and lifespan of each routing protocol are two major constraints for WSN, there has been much study into achieving the aim. It is a difficult process to select an effective routing technique, which evenly distributes the load in the network. The R-LEACH protocol allows for an adaptive model but has some drawbacks. This study proposes modified CH selection to enhance network life by controlling the energy discharge in the network.It is the combination of two algorithms, K-Median and Bellman ford algorithms in our proposed algorithm. In situations like environmental monitoring with IoT, the improved routing mechanism can be effectively used as a protocol that offers better results for a heterogeneous system based on R-LEACH. The results of the simulation show improved network performance for measures like residual energy, BS packets, throughput, or lifespan.It shows that proposed protocol, EETC, is giving better results for 0.25J,0.5J and for 1J in terms of residual Energy and result also reflect that the lifespan of Proposed algorithm (EETC) is much better than the previous protocol (R-LEACH) in terms of the First dead node,Half dead node and Last dead node.In R-LEACH protocol Last dead node was found in 2194 rounds,4035 rounds and 1101 rounds for .5J,1J and .25 J respectively while in EETC protocol Last dead node was not found even after more than 5000 rounds.

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References

Ankur Goyal and Dr. Vivek Kumar Sharma," Modifying the MANET Routing algorithm by GBR CNR-Efficient Neighbor Selection Algorithm", International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-8 Issue-10, August 2019, pp: 912-917.

S.K. Singh, M.P. Singh, and D.K. Singh, "A survey of Energy-Efficient Hierarchical Cluster-based Routing in Wireless Sensor Networks", International Journal of Advanced Networking and Application (IJANA), Sept-Oct. 2010, vol. 02, issue 02, pp. 570 - 580.

Ankur Goyal and Dr. Vivek Kumar Sharma," Design and Implementation of Modified local link repair Multicast Routing Protocol for MANETs", International journal of Scientific & Technology Research, ISSN 2277-8616, volume 9, issue 02, feb., 2020, pp: 2316-2321.

Rajkumar, Dr. H G Chandrakanth, Dr. D G Anand, and Dr. T John Peter." Research Challenges and Characteristic Features in Wireless Sensor Networks", in Int. J. Advanced Networking and Applications, Volume: 09 Issue: 01 Pages: 3321-3328 (2017) ISSN: 0975-0290

P. Kumarawadu, D. J. Dechene, M. Luccini, and A. Sauer, "Algorithms for Node Clustering in Wireless Sensor Networks: a Survey," Information and Automation For Sustainability, ICIAFS, 4th International Conference on, pp. 295–300, Dec. 2008

Blough, D.M., Santi, P.: Investigating Upper Bounds on Network Lifetime Extension for Cell-Based Energy Conservation Techniques in Stationary Ad Hoc Networks. In: Proceedings of the ACM/IEEE

International Conference on Mobile Computing and Networking, MOBICOM (2002)

Li, X.-Y., Wan, P.-J.: Constructing Minimum Energy Mobile Wireless Networks. In: Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM), Rome, Italy (July 2001)

Heinzelman, W.R., Chandrakasan, A., Balakrishnan, H.: Energy-Efficient Communication Protocol for Wireless Microsensor Networkings. In: Proceedings of IEEE HICSS (January 2000)

Rajkumar and H. G. Chandrakanth "EDCH: A Novel Clustering Algorithm for Wireless Sensor Networks EJERS, European Journal of Engineering Research and Science Vol. 4, No. 3, March 2019

Seyed Akbar Mostafavi, Vesal Hakami "A new rank-order clustering algorithm for prolonging the lifetime of wireless sensor networks" arXiv:1810.04831v3 [cs.DC] 4 Oct 2019

Mengjia Zeng,1,2 Xu Huang,1,3 Bo Zheng,1 and Xiangxiang Fan "A Heterogeneous Energy Wireless Sensor Network Clustering Protocol" Volume 2019 |Article ID 7367281

Ramadhani Sinde, Feroza Begum, KaroliNjau and Shubi Kaijage "Refining Network Lifetime of Wireless Sensor Network Using Energy-Efficient Clustering and DRL-Based Sleep Scheduling" Sensors 2020, 20, 1540.

Salim E.L.Khediri NejahNasriAnne Wei AbdennaceurKachouri"A New Approach for Clustering in Wireless Sensors Networks Based on LEACH" Procedia Computer ScienceVolume 32, 2014, Pages 1180-1185.

P.Sasikumar, SibaramKhara "K-Means Clustering in Wireless Sensor Networks" 2012 Fourth International Conference on Computational Intelligence and Communication Networks

Deepika Agrawal, Sudhakar Pandey "Load balanced fuzzy-based unequal clustering for wireless sensor networks assisted Internet of Things" published by John Wiley & Sons, Ltd, 21 January 2020.

Priya, A. V., Srivastava, A. K., &Arun, V. (2020) "Hybrid Optimal Energy Management for Clustering in Wireless Sensor Network", Computers & Electrical Engineering, 86, 106708.

El Khediri, S., Fakhet, W., Moulahi, T., Khan, R., Thaljaoui, A., &Kachouri, A. (2020)."Improved node localization using K-means clustering for Wireless Sensor Networks", Computer Science Review, 37, 100284. DOI:10.1016/j.cosrev.2020.100284.

Sahoo, B. M., Pandey, H. M., &Amgoth, T. (2020). GAPSO-H: "A Hybrid Approach Towards Optimizing the Cluster-Based Routing in Wireless Sensor Network", Swarm and Evolutionary Computation, 100772. DOI:10.1016/j.swevo.2020.100772.

Chawra, V. K., & Gupta, G. P. (2020)," Load Balanced Node Clustering scheme using Improved Memetic Algorithm based Meta-heuristic Technique for Wireless Sensor Network", Procedia Computer Science, 167, 468–476. DOI:10.1016/j.procs.2020.03.256.

Sahoo, B. M., Amgoth, T., &Pandey, H. M. (2020),"Particle Swarm Optimization Based Energy Efficient Clustering and Sink Mobility in Heterogeneous Wireless Sensor Network", Ad Hoc Networks, 102237.