EE-LEACH: ENERGY ENHANCEMENT IN LEACH TO IMPROVE NETWORK LIFETIME OF HOMOGENEOUS WIRELESS SENSOR NETWORK

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Abstract

Purpose – In the recent scenario, there are various issues related to wireless sensor networks such as clustering, routing, packet loss, network strength. The core functionality of primary wireless sensor networks (WSNs) is sensor nodes that are arbitrarily scattered over a specific region. Sensor nodes sense the data and send it to the sink. Energy consumption is an important issue in wireless sensor networks. Clustering and cluster head selection are important methods used to extend the lifetime of WSNs. The main goal of this research article is to reduce energy consumption using a clustering process that involves CH determination, cluster formation, and data dissemination.

Methodology/approach/design – The simulation in this paper was finished utilizing MATLAB and the proposed technique is contrasted with LEACH and MOD-LEACH protocols.

Findings – The simulation results of this research show that the energy utilization and dead node ratio of WSNs are improved as compared to LEACH and MOD-LEACH algorithms.

Originality/value – In a wireless sensor network there are various constraints, energy being one of them. In order to solve this problem, we use CH selection algorithms to reduce energy utilization and, consequently increase network life span.

Keywords: Clustering. LEACH. Cluster Head. WSN. Energy Efficiency.

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INTRODUCTION

The area of WSN is growing very fast in the field of the medical sector, agricultural surveillance, battlefield, environmental monitoring, etc. Following recent developments in microelectronics, technology sensors and electronic circuitry (AKYILDIZ et al, 2002) (RAWAT et al, 2014) now have lower power consumption. A WSN collects information from the environment and working on some input parameters (energy, distance, communication quality) it maintains the information for a long time. WSNs have sensor nodes that sense, collect and compute data from the environment. These sensor nodes use a huge battery power supply, large memory and powerful processor. So, now it has become an issue for researchers how to use the energy of sensor nodes (MEHRA et al, 2019) efficiently. The WSN can be categorized into two parts homogeneous and heterogeneous. In homogeneous networks, all sensor nodes have the identical characteristics, unlike heterogeneous networks where each sensor node can have different characteristics. Each SN in the network contains three sub-systems: Sensor Subsystem: includes at least one sensor, which is used to sense natural parameters, e.g. temperature, wetness, pressure, earthquake etc. Handling Subsystem: It consists of a microcontroller that calculates neighborhood on detected information and controls activities and incoming memory to control information. Correspondence subsystem: This charge is for carrying the information up to BS.

There are two types of information gathering plans in WSNs; hierarchal and non-hierarchal protocols. In the hierarchal protocol, the sensor node only sends data to the cluster head (CH), thus conserving energy, whereas, in the non-hierarchal protocol, the sensor node sends information to the sink in single or multi-hops and thus conserves more energy (SINGH, 2017) (TANWAR et al, 2014). It is the responsibility of the cluster coordinator to not only collect the data but also to send data to BS. This aggregation of collected data can conserve a good amount of energy (MITTAL et al, 2011) (MEHRA et al, 2015). This literature mainly focuses on increasing the stability of LEACH (SAXENA et al, 2015) (MEHRA et al, 2018) protocol and improving its performance. The LEACH protocol aims to improve the lifetime of the network by creating a cluster and rotating CH role. The LEACH protocol has various limitations such as farness from BS, energy dissipation CH node by cluster head, residual energy, etc. (HEINZELMAN et al, 2000). It may be possible that due to the randomness of the protocol the energy of CH may be completely depleted at a location and point. This paper crosses all these boundaries and makes new networks aware of more energy. Basically, the most important goal of this paper

is to minimize energy dissipation and extend network lifetime of WSNs. The data routing through cluster head in WSN is depicted in Fig. 1.
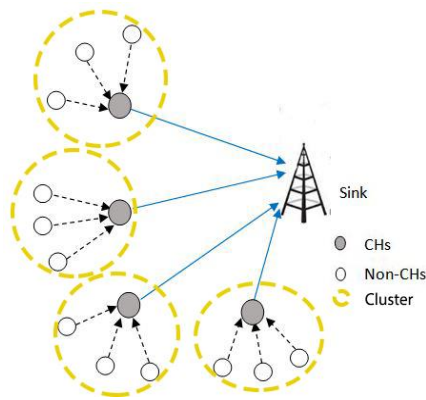
Figure 1 – Data routing via cluster head in WSN

Rest of the paper is organized as follows: discussion of related works, comparison of various LEACH successor protocols, providing the methodology& road-map for the proposed approach, simulation experiment and result analysis, concluding remarks.

RELATED WORKS

In this section, main features of an energy efficient clustering protocol are discussed. The LEACH (HEINZELMAN et al, 2000) algorithm is a distributional methodology that selects CH based on various input parameters. LEACH was developed in 2000 and is very important in calculating the cluster sizes in a WSN. It is a distributed protocol and requires universal knowledge of related fields. The protocol consists of rounds and operations and each round has two phases: the setup phase and the study phase. The setup phase is responsible for selecting CHs, creating clusters, and providing time division multiple access (TDMA) schedules to member nodes, while the stationary phase involves data gathering, fusion, and transmission of information to BS. The selection of CH among all nodes depends on the threshold value T(n) calculated according to equation (1). Each sensor node generates an arbitrary number and if it is less than T(n), then that node is chosen as CH. Here we use a formula to choose an optimal cluster head, where *p* is optimum percentage of CH and r is present round.

$$T\ (n) = \begin{cases} \dfrac{P}{1-P*\left[rmod\left(\frac{1}{p}\right)\right]} & ,n \in G \\\\ 0\,, & else \end{cases}$$

LEACH-C (HEINZELMAN et al, 2002) protocol was formulated in which BS, CH control the decision of selection and it worked upon the formation of clusters and distributed networks. In this, BS forms K-optimal clusters with evenly distributed sensor nodes and computes the average energy of the network and the residual energy of the sensor node. It is assumed that each GPS node has a GPS enabled for position. But LEACH-C uses a centralized approach, so it is not static. Handy et al. (2002) developed LEACH-DCHS by taking residual energy of nodes into consideration. LEACH-DCHS extended the network lifetime by 30% by multiplying remnant energy with threshold T(n). Voigt et al. (2016) proposed SLEACH in which sensor nodes transmit their stellar and remaining energy to BS in order to be selected as CH. Loscri et al (2005) proposed TL-LEACH with the two-level hierarchy of clusters. In which, upper layer performs partial computation and the lower layer performs complete computation before giving data to BS. Oliveira et al (2006) proposed SEC-LEACH for secure WSN. It is a lightweight approach. Chen and Shen (2007) proposed ME-LEACH with the static and homogeneous sensor node. It uses residual energy in the selection of CH and also residual average distance between nodes cannot be used for large WSN. Ali et al (2008) proposed ALEACH, in which the current situation and general probability are used for the selection of factions. Hong et al (2009) proposed a T-leach in which CH is fixed for a few rounds that it will continue the role of CH until its energy level falls below a calculated threshold. Wang et al (2009) proposed LEACH-H in which BS used a simulated annealing algorithm for CH selection. Tong and Tang (2010) proposed LEACH-B for equilibrium of clusters. Previously, CH was selected as LEACH, and then residual energy was used for CH selection. Abdul Salam et al (2010), proposed a W-leach in which the weight of each node is determined based on residual energy and node density. It somehow improves the lifetime of network. Farooq et al. (2010) proposed MR-LEACH in which the sensor node with the maximum energy level is selected as CH. The number of hops for transmission of data from BS is equal for all groups in this approach. Liv and Ravi Shankar (2011) proposed LEACH-GA; using evolutionary optimization to find the optimal CH percentage. This included a message of network overhead. Feda 'al-Maqbeh et al. (2012) proposed FL-LEACH in which it uses fuzzy logic to find the number of clusters in WSN. Chen et al (2013) proposed LEACH-G which uses a centralized and distributed approach for CH

selection and cluster formation. Mahmood et al. (2013) proposed MOD-LEACH which conserves energy by simple amplification. Sudhanshu et al. (2013) proposed an EHE-Leach in which all sensor nodes approaching BS communicate directly while remote sensor nodes use cluster-based communication. Gnanambigai et al. (2013) proposed Q-LEACH in which the targeted area is divided into four quadrant and clusters are formed in each quadrant. Salim et al (2014) proposed IB-LEACH whose goal was to minimize CH load and intra cluster communication. Though, it increased the wastage of energy. P-LEACH (CHO et al, 2014) increases the duration of stability but has a high cost, complexity and message overheads. Batra et al (2016) proposed LEACH-MAC which prohibits CH advertisement. A counting variable called CH is used which counts the number of advertisements received by the sensor node. If the value of a cluster head is less than Popt and SN considers it CH. Marappan and Paul use CL-LEACH (2016) for relay nodes to collect relay data into BS. The sensor node chooses CH using its residual energy and distance from BS. Terbi et al. (2016) proposed O-LEACH that takes care of orphaned nodes, which are not part of a cluster. A comparison between different leach successor protocols for better understand their feature and limitations are depicted in Table 1. In this order, a lot of clustering algorithms are shown through Figure No. 2, which shows which algorithms are used for clustering and which algorithms are used for cluster head selection.
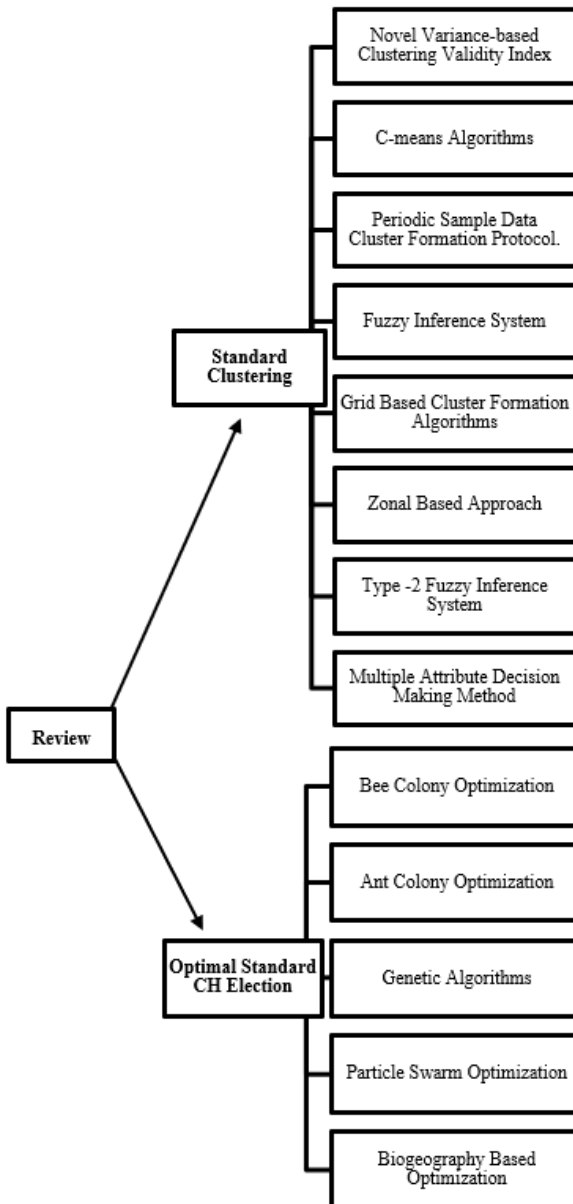
Figure 2 – Categorization Based on Clustering Algorithms

Comparison of Various LEACH Successors Protocols

In traditional LEACH protocol, researchers made numerous upgrades and proposed various types of modified algorithms. These algorithms are made enabling CH determination, energy responsiveness and optimization of CH choices. LEACH protocol has various successors. Table 1depicts the different comparisons parameters and their salient features made by the improved LEACH protocols.

Year	Routing Protocol	Mobility	Scalability	Self-Organization	Distributed	Hop Count
2002	LEACH	F. BS	Limited	✓	✓	S. Hop
2002	LEACH-C	F.BS	Good	✓	✗	S. Hop
2002	LEACH-F	F. BS	Limited	✗	✗	S. Hop
2003	LEACH-B	F. BS	Good	✓	✓	S. Hop
2005	TL-LEACH	F. BS	V. Good	✓	✓	S. Hop
2007	LEACH-E	F. BS	V. Good	✓	✓	S. Hop
2007	MH-LEACH	F. BS	Good	✓	✓	M. Hop
2008	LEACH -M	Mobile BS	V. Good	✓	✓	S. Hop
2009	I-LEACH	F. BS	V. Good	✓	✓	S. Hop
2010	LEACH-A	F. BS	V. Good	✓	✓	S. Hop
2012	CELL-LEACH	F. BS	V. Good	✓	✓	M. Hop
2013	V- LEACH	F.BS	V. Good	✓	✓	S. Hop
2015	W-LEACH	F. BS	V. Good	✓	✓	M. Hop
2016	ICA-LEACH	F.BS	Good	✓	✓	S. Hop
2017	NR-LEACH	F. BS	V. Good	✓	✓	M. Hop
2018	LEACH-GA	F. BS	V. Good	✓	✓	M. Hop

Table 1 – Analysis of LEACH Successor Protocols
(F.BS=Fixed BS/S.Hop=Single Hop/M.Hop= Multiple Hop)

PROPOSED PROTOCOL

EE-LEACH is proposed for a homogeneous network where entire nodes have the equal capacity in terms of sensing, processing, and energy levels. The LEACH protocol has some limitations. In LEACH, CH is not selected after a few rounds. Therefore, the remaining energy is not taken into account in this protocol. In LEACH, there is also a restriction that the sink is only positioned at the centre of the sensor network. Energy is propagated by the node selected as CH. Now the distance of BS from the cluster head is equally important because communication carries a large amount of energy. EE-LEACH attempts to

overcome these limitations and improve energy growth with load balancing. Here, the proposed algorithm presents the system model of the EE-LEACH protocol.

Network Assumptions

Some assumptions are considered when designing the EE-LEACH protocol.

- Sensor node deployment is random way.
- Every sensor node has initially equal energy level.
- BS and sensor nodes are deterministic in nature.
- Battery used in sensor node is not replaceable and non-rechargeable.
- Power supply is always available for base station.
- Receive signal strength index (RSSI) plays an important role in the distance estimation between two devices.
- Communication over network is symmetric in nature.
- If a battery level reaches at zero, then the node becomes dead.
- The area of interest (AOI) assumed to be 100 ×100 m2 with randomly scattered sensor network over AOI with BS located in the center as depicted in Figure 3 and at the right end side in Figure 4 respectively.
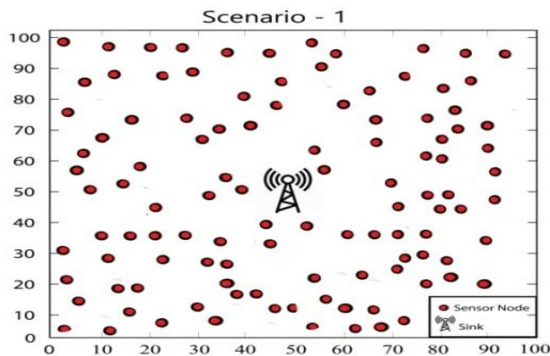

Figure 3 – Network Layout (Scenario-1)

Energy Radio Model

In this proposed work, the radio model used is adopted from the LEACH (HEINZELMAN, 2000). This model is very simple with open space and multipath fading relying and the separation between transmitter and receiver. The E_{mp}, E_{fs} and E_{elec} are the energy used for amplifier in multipath, open space and electronics energy respectively.
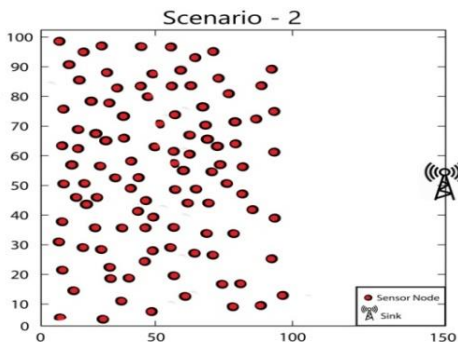

Figure 4 – Network Layout (Scenario-2)

To transmit z bits, packet energy consumed by transmitter and receiver are denoted by E_{Tx} and E_{Rx} respectively as shown in equations (2) and (3).

$$E_{Tx}(z, d) = \begin{cases} zE_{elec} + z\varepsilon_{fs}d^2 & ,d < do \\ zE_{elec} + z\varepsilon_{mp}d^4 & ,d \geq do \end{cases}$$

Where, $do = \sqrt{\dfrac{\varepsilon_{fs}}{\varepsilon_{mp}}}$, d is the partition space.

Then requirement of energy for receiving z-bit message as follows.

$$E_{Rx}(z) = E_{Rx\text{-}elec}(z) = z.E_{elec}$$

For the network we have assume that the volume of network S=a*b square meter with n number of SN which are deployed over the specified region S. In one round the total energy exhausted by a CH is calculated by equation no (4) as given below.

$$E_{CH} = (n/p)z \, (E_{elec} + \varepsilon_{fs}d_{BS} + E_{DA})$$

Where the distance to BS is represented by dBS and n/p is cluster member. Likewise, the sum of energy consumption by a cluster member (CM) is evaluated by Equation (5) in which d_{CH} is the Distance to its CH.

$$E_{CM} = (z E_{elec} + z \, \varepsilon_{fs} d_{CM})$$

$$\text{Where, } d_{CM} = \sqrt{\frac{M^2}{2\Pi P}}$$

Clustering Procedure

Proposed approach consists of three stages:

1. CH Determination;
2. Cluster Formation;
3. Data Dissemination.

CH Determination Stage

In this part, the proposed protocol tries to find the best candidate for CH role. When sensor nodes are deployed, a packet (Loca_BS) is transmit by base station which contains the co-ordinate of base station (BS) and time division multiple access (TDMA) programme technique .All sensor nodes are active and they collect all important information from the deployed area in their neighborhood and broadcast (INFO_PKT) within its radio range accordingly to schedule receive signal from BS. When all broadcasts are completed, sensor node calculates local information like distance from BS, energy level, average distance from each node and average power required to communicate with each node within radio range after the calculation of CH rank as per the Equation (6).

$$\text{Rank (R)} = \frac{SN(R).E * SN(R).N\_density}{SN(R).AD\_MN * SN(R).DBS * SN(R).AVG\_POW}$$

All nodes broadcast their candidature within radio range as per schedule. When all ranks are received and if the rank of a sensor node is highest, then it will proclaim its candidature and broadcast (HEAD_NODE) which has its density, energy level and average distance to nearby node or else it will wait to join best cluster. The CH selection phase algorithm for EE-LEACH is proposed below.

Algorithm: CH Selection Phase in EE-LEACH

Begin
1. Total nodes in network →TN
2. Number of Identity nodes →j
3. Current battery level → TN (j).Energy
4. Member → TN (j).Type
5. TN(j). Rank→0 // initially rank is set to 0
6. TN(j). AD_MN //Average distance to member nodes
7. TN(j). AVG_Pow // Average power required if chosen as CH
8. Count_of_CH → 0
9. Nodes within radio range→ TN(j).N_Density
10. Distance of sensor node to BS→ TN(j).D_BS
11. Every node computes its rank
12. Every node broadcasts its rank to pronounce its CH candidature
13. For (j=1 to p%)
14. {
15. If TN(j).Rank >Received_TN(k).Rank then
16. CH→ TN(j).Type
17. Count_of_CH ++
18. Add TN(j) to List_of_CH
19. Broadcast _(HEAD_NODE) packet
20. end If
21. }
22. End For
End

Cluster Formation Stage

When CH is decided, cluster formation comes into existence and cluster formation begins based on certain parameters, viz. the density around the cluster, distance from BS, residual energy. Normal nodes now have to decide to link cluster heads based on their chance calculations using equation 7.

$$\text{Chance(c)} = \frac{CHNode(c).E * CHNode(c).N\_Density}{Dist\_to\_CHNode(c) * CHNode(c).AD\_MN}$$

Where CHNode (c).E represents the energy of the CH, CHNode(c).N_Density identifies the density of a member node with respect to cluster head (CH). Dist_to_CHNode(c) identifies the distance of a member node to cluster head (CH). The last CHNode(c).AD_MN shows the average distance

from the CH to the member node (MN). After calculating the chance of every CH node, NON_CH node will choose a CH with highest chance with some parameters viz; density, energy, distance and send a request information of packet (JOIN_CH).The CH node will agree to the request and sends an acknowledgement (ACKN) for joining to requesting node with a TDMA schedule. In this way all the clusters are formed.

Data Disseminated Stage

After the completion of cluster formation task, the main goal of this stage is to collect information from the field, apart from CH; all the nodes communicate sensed data to their respective CH according to TDMA slot. To avoid the redundant information, CH collects the received information from the SN and communicated to sink according to the TDMA schedule. Along these lines round is finished by EE-LEACH.

SIMULATION AND EXECUTION ASSESSMENT

The proposed protocol is simulated in MATLAB. The total area of interest is assumed to be 100×100 m2 with deterministic node deployed around the area. The experiment is performed for normalization consequence. The optimal percentage (p%) of CH is kept 10%. In this paper, we have considered two scenarios of BS or sink. In the first scenario, BS is located at the centre, say (50, 50) and in the second scenario; the BS is positioned at the one side of the network, say (150, 50). EE-LEACH is compared with LEACH and MOD-LEACH. Simulation parameters considered are depicted in Table 2.

Parameters	Value
Total Nodes, N	200
Free Space Model	10pJ/bit/m^2
Multipath Model	0.0015pJ/bit/m^4
Initial Battery Level(E_o)	0.7J
Packet Size (*s*)	3000bits
Data Aggregation (E_{DA})	7nJ/bit/report
Electronic Circuitry (E_{elec})	52nJ/bit

Table 1 – Configuration of Simulation Parameters

The output of the proposed protocol is calculated on the following metrics.

- Stability Period: The period is said to be stable period if the node completes coverage area of interest (AOI) as all node are alive.
- Death Node per Round: It finds total nodes deactivate till current round.
- Half Node Death (HND): It is the round where only half of the deployed sensor nodes (SN) are alive.
- Throughput: It is calculated as the successfully transmitted packets to the base station (BS).

Death Node per Round

Figure 5 shows death nodes per round for both the scenarios considered. The premature death of sensor nodes makes the network unstable and unreliable. It exhibits the network life span after the network gets operational i.e. beginning of clustering processing. We can observe from Figure 5 that the EE-LEACH successfully distributes equal energy depletion of the network for both the scenario.
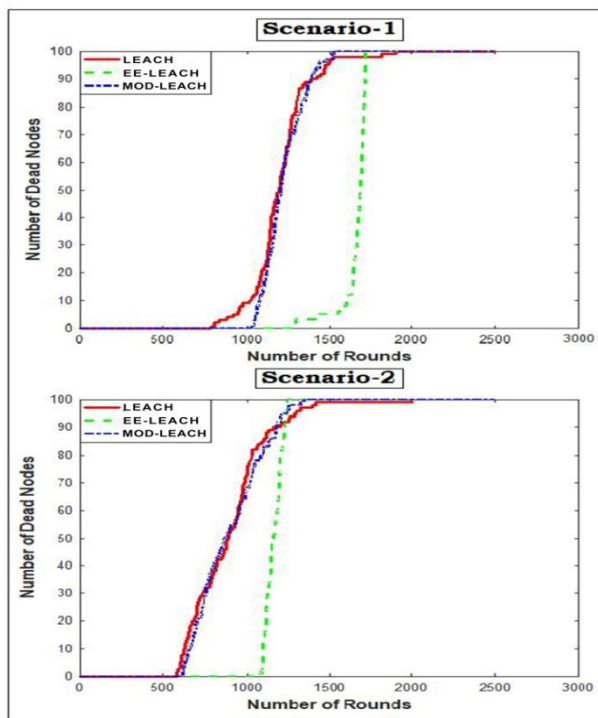

Figure 5 – Dead Node per Round

Average Energy per Round

In this metric, the energy of the network is dissipated mainly in sensing, processing, and communication for any type of network. If the network is consuming more energy per round and depleting its average energy, then its lifetime of the network gets affected and that protocol will have a poor stability region. Figure 6 depicted the average energy of EE-LEACH is always greater than and much more than LEACH and MOD-LEACH protocols in both the scenarios hence making the protocol more reliable. This performance improves to select the best candidate for cluster head (CH) by considering the parameter which affects energy more.
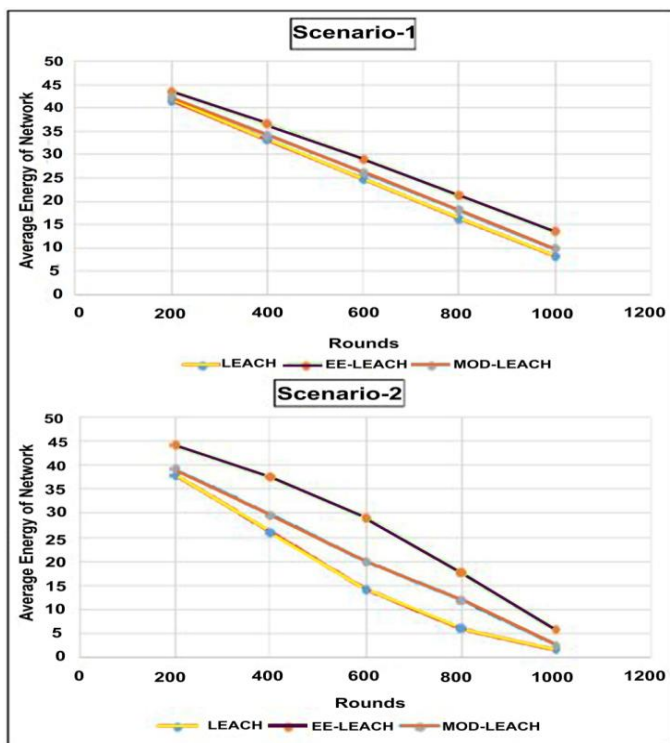

Figure 6 – Network Average Energy

Throughput

Figure 7 shows the total packets delivered to the sink per round. Figure depicted that the EE-LEACH delivered more packets as compared to LEACH and MOD-LEACH protocol in both the scenarios. If a greater number of packets are delivered to the sink, then more information is collected fulfilling the purpose of WSNs. The packet delivery is p which is proportional to the energy

utilization by the network. If energy is available for the network, then more packet delivery will be there to the base station.
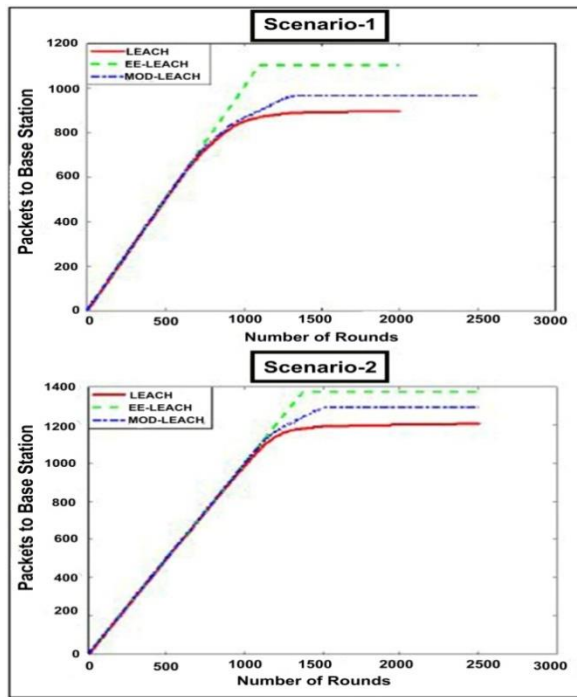

Figure 7 – Network Throughput

Network Strength and Half Node Death (HND)

The main goal of proposing EE-LEACH is the enhancement of network strength of LEACH. Figure 8 depicts the network strength as well as half node death plot for both the scenarios. In protocols (SMARAGDAKIS et al, 2004) longer stable regions are established. In Scenario 1, stable region for EE-LEACH is 1185 which is around 43.45% and 21.51% more than LEACH and MOD-LEACH protocols. In the same way, Scenario 2 network strength is attained till round number 1000 whereas in LEACH and MOD-LEACH, its only 490 and 560 rounds respectively which means that EE-LEACH overpower LEACH by 51.0% and MOD-LEACH by 44.0%. For Scenario 2, the number of rounds to which half of the nodes are available in the network for EE-LEACH is 1180 whereas it is 820 for existing LEACH and 800 for MOD-LEACH which is around 30.5% and 32.20% more respectively corresponding for scenario-2, again for scenario 1 EE-LEACH shows improved performance in half node

death (HND) by 36.25% and 31.87% as compared to LEACH and MOD-LEACH respectively.
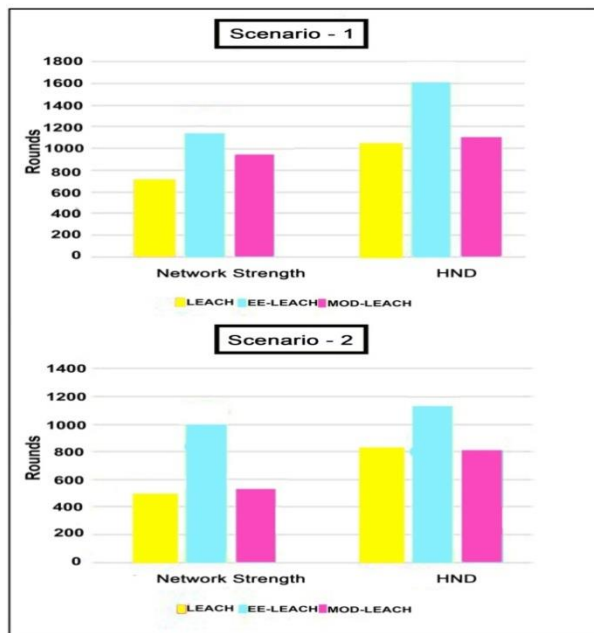

Figure 8 – Network Strength& Half Node Death

CONCLUSIONS AND FUTURE DIRECTIONS

In this paper EE-LEACH is anticipated, a round of activities divided into three phases, with the goal of defeating restrictions and enhancing the stability of the LEACH protocol in EE-LEACH. Cluster head (CH) determination phase, cluster formation phase, and information dispersion phase. While CH is chosen with respect to the average distance between left over energy and density around the node, the energy depletion of CH occurs during communication with BS. Hence the position of BS is taken into consideration. When creating a cluster, all non-CH nodes choose their CH by locating the location of each CH node based on the parameters. Testing has been done for two different scenarios by developing a BS condition to suit the protocol of any application in a wireless sensor network. Improved results throughput, average energy and network strength have been demonstrated. In future work, we will apply fuzzy logic system (FIS) for selection of CH to enhance the more energy and stability period of a network.

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