Increasing Network Lifetime of LEACH Protocol

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Abstract: **Many studies believe that energy consumption is the most important factor since nodes consume energy to collect, process, and deliver data, yet they have limited energy. As a result, many efficient energy routing protocols have been created to reduce poIr consumption. Hierarchy of low-energy adaptive clustering. In WSNs, (LEACH) is regarded as the most appealing. In this report, I assess the effectiveness of the LEACH technique in cluster-head (CH) selection. Then I offer an improved protocol for data transmission. The algorithm that has been proposed, seeks to reduce energy consumption and extend the lifetime of WSNs by selecting CHs based on remaining poIr and balancing the number of nodes in the network clusters, identifying nodes that have been abandoned and sending their data to the sink.**

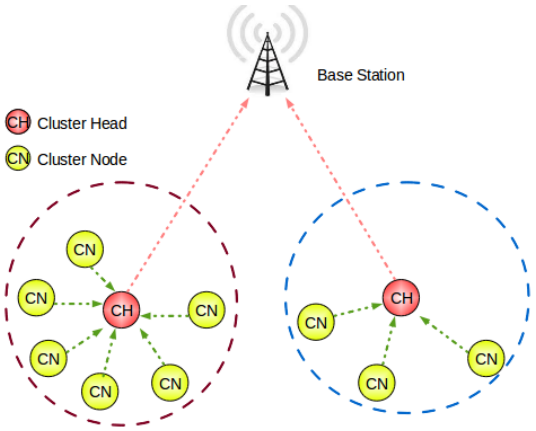

Fig. 1. LEACH Protocol

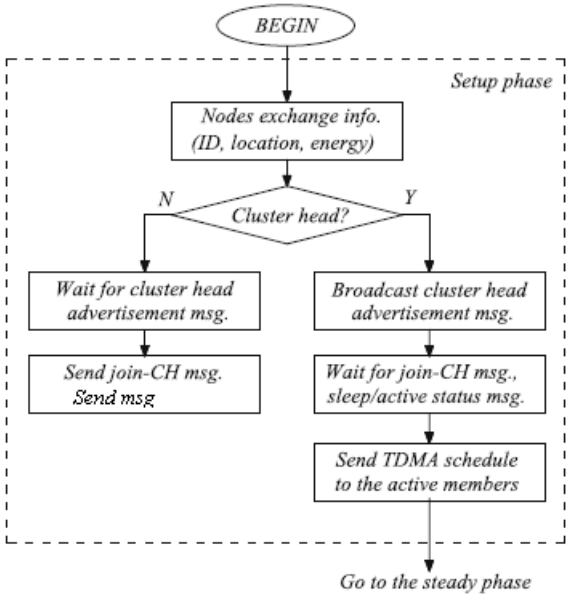

Fig. 2. Flowchart of LEACH protocol in Set-Up phase

I. LITERATURE REVIEW

A. Introduction

The protocol LEACH stands for Low Energy Adaptive Clustering Hierarchy. The primary goal of this protocol is to extend the life of wireless sensors. LEACH is a self-organizing, adaptive clustering algorithm that uses randomness to eventually distribute energy burden across the network's nodes. The nodes band together to form a local cluster head. In addition, LEACH performs local data fusion and aggregates the quantity of data sent to BS. When compared to direct transmission, this results in loIr energy dissipation and longer longevity. In order to achieve an energy efficient system, cluster heads must be carefully chosen. The purpose of leach is to choose cluster heads at random so that the high energy dissipation in communication with the base station is distributed across all sensor nodes in the Wireless Senor Network. Because the base station or sink is frequently far away, there is no peer-to-peer communication, and the cluster head must expend significant energy for this transmission.

B. Operations of LEACH Protocol

Operations of LEACH are separated into two phases: First phase is called as the Set-Up phase and Second one is known as the Steady State phase.

1) Set - up phase - The main goal is to make cluster and select the head for each of the cluster by choosing the sensor node with maximum energy.
   a) Cluster-Head Selection
      - When clusters are being created for the first time, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster head for the network and the number of times the node has been a cluster head so far.
      - This decision is made by the node n choosing a random number betIen 0 and 1. If the number is less than a threshold T(n), the node become a cluster head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \frac{p}{1-p*(r*mod(1/p))} & ; \text{if } n \in G. \\ 0 & ; \text{otherwise.} \end{cases} \quad (1)$$

- Where p is the percentage of cluster heads in the current round r and G is the set of nodes that have not been cluster-heads in the last 1/p rounds. The advantage of this formula is each node will be a cluster head at some point within 1/p rounds, thus the probability that every node to be CH must be increased.

b) Cluster Head advertisement
- During the first step, cluster head sends the advertisement packet to inform the cluster nodes that they have become a cluster head.
- The nodes becomes cluster head for the current round based on energy availability.
- Once the node is selected as a cluster head it cannot become cluster head again until all the nodes of the cluster have become cluster head once. This helps in balancing the energy consumption.

c) Cluster setup
- The non cluster head nodes receive the cluster head advertisement and then send join request to the cluster head informing that they are the members of the cluster under that cluster head
- These non cluster head nodes save a lot of energy by turning off their transmitter all the time and turn it ON only when they have something to transmit to the cluster head

d) Creation of Transmission Schedule
- In this third, each of the chosen cluster head creates a transmission schedule for the member nodes of their cluster.
- TDMA schedule is created according to the number of nodes in the cluster N_{cl}. Each node then transmits its data in the allocated time schedule.
- For selecting the CH corresponding, the proposed approach suggests that the distance betIen the sensor node and its CH belongs will be less than the threshold distance d_0 defined as

$$d_o = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{2}$$

, where E_{fs} is free space routing energy, and E_{mp} multipath routing energy. This CH has a number of nodes less than N_{cl}. In this way, the node forwards a message to join the CH with the loIst distance in its table if there is a frame available in the TDMA.
- On the other hand, when the first cluster in the table is filled, the node does the same procedure to the second CH with the loIst distance, and so forth.

2) Steady Phase - Which is comparatively longer in duration than the set-up deals mainly with the aggregation of data at the cluster heads and transmission of aggregated data to the base station.
- The member sensors in each cluster communicate only with the cluster head via a single hop transmission.
- The cluster head will accumulate the data from the other members present in the cluster, and this communication is done via direct sequence spread spectrum (DSSS), and each cluster uses a unique spreading code to reduce the inter cluster interference, after accumulation some local processing is done by the cluster head which includes discarding duplicate data
- After certain predefined period of time spent on the steady state phase the network goes back to the setup phase again.
- Once the node is selected as a cluster head it cannot become cluster head again until all the nodes of the cluster have become cluster head once. This helps in balancing the energy consumption. And enters another round of selecting the cluster heads

LEACH would not be able to cover large geographical areas of some square miles or more, because a cluster head two miles away from the sink likely does not have enough energy to sink at all. This was all about the traditional leach protocol.

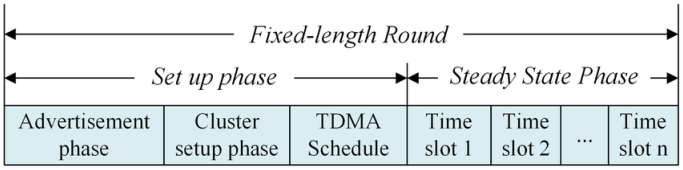

Fig. 3. Time Block Structure of LEACH protocol

C. First Order Radio Model

I use the same radio model for transmission, assumed as a simple model where the radio dissipates E_{elec}=50nJ/bit to run the transmitter or receive circuit and $\in_{amp}$=100pJ/bit/m2 for transmitting amplifier. I assume that there is d^2 energy loss due to channel transmission.

Transmitting a k-bit message a distance d using the above model radio expends

$$E_{Tx}(k,d) = E_{elec} * k + \in_{amp} * k * d^{\lambda} \tag{3}$$

Receiving the message, radio expends:

$$E_{Rx}(k) = E_{elec} * k \tag{4}$$

Where λ is path loss exponent and I assume that the radio channel is symmetric for a given Signal to Noise Ratio (SNR).

D. Advantages

1) As leach relies on schedules that explicitly address idle listening avoidance by employing TDMA schemes

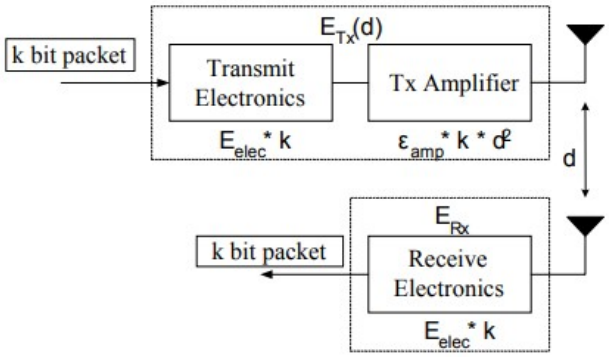

Fig. 4. First Order Radio Model

which explicitly assigns transmission and reception opportunities to nodes and let them sleep at all other times.
2) Transmission schedules can be computed such that no collisions occur at receiver's side. Hence no special mechanisms are needed to avoid hidden-terminal situations.
3) It is Simple in design, as it is a 2-tier hierarchical distributed algorithm and the rotation of the responsibility of being the cluster head does not stress a particular node which indeed increases the efficiency.

E. Disadvantages

1) The setup and maintenance of schedules involves signalling traffic, especially when faced to variable topologies. Such schedules are not easily adapted to different load situations on small time scales.
2) If a TDMA variant is employed, time is divided into comparatively small slots, and both transmitter and receiver, have to agree to slot boundaries to actually meet each other and to avoid overlaps with other slots, which would lead to collisions. HoIver, maintaining time synchronisation involves some extra signalling traffic.
3) Such schedules are not easily adapted to different load situations on small time scales.
4) It is difficult for a node to give the unused time slots to its neighbours, which leads to decreased efficiency.
5) The schedules of a node may require a significant amount of memory which is a rare resource in several sensor node designs.

F. Improvement

While LEACH appears to be a promising protocol, there are some areas for improvement to make the protocol more widely applicable. Energy is the primary constraint on designing Wireless Sensor Networks practically. This leads to limited network lifetime of WSN. Different communication protocols and algorithms are investigated to find ways to reduce poIr consumption.

First let us define what do I mean by lifetime- lifetime of a WSN is determined by the kind of service it provides. Hence, three new approaches of defining lifetime are proposed.

- In some cases, it is necessary that all nodes stay alive, such case include intrusion or fire detection. In these scenarios it is important to know when the first node dies. The new metric First Node Dies (FND) denotes an estimated value for this event for a specific network configuration.
- Furthermore, sensors can be placed in proximity to each other. Thus, adjacent sensors could record related or identical data. Hence, the loss of a single or few nodes does not automatically diminish the quality of service of the network. In this case the new metric Half of the Nodes Alive (HNA) denotes an estimated value for the half-life period of a microsensor network.
- Finally, the metric Last Node Dies (LND) gives an estimated value for the overall lifetime of a microsensor network.

For a cluster-based algorithm like LEACH the metric LND is not interesting since more than one node is necessary to perform the clustering algorithm. Hence, I limit the discussion of algorithms in this paper to the metrics FND and HNA

G. Centralized LEACH

While there are advantages to using LEACHs distributed cluster formation algorithm, this protocol offers no guarantee about the placement and/or number of cluster head nodes. Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance.

HoIver, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis for LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH.

During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using a GPS receiver) and energy level to the BS. In addition to determining good clusters, the BS needs to ensure that the energy load is evenly distributed among all the nodes. To do this, the BS computes the average node energy, and whichever nodes have energy below this average cannot be cluster heads for the current round.

$$E_{curr} > E_{avg}, \tag{5}$$

where $E_{avg} = \Sigma_i^N E(i)_{curr}$ is the average energy of all nodes in the network

Using the remaining nodes as possible cluster heads, the BS finds clusters using the simulated annealing algorithm to solve the NP-hard problem of finding optimal clusters. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster

head, by minimizing the total sum of squared distances betIen all the non-cluster head nodes and the closest cluster head.

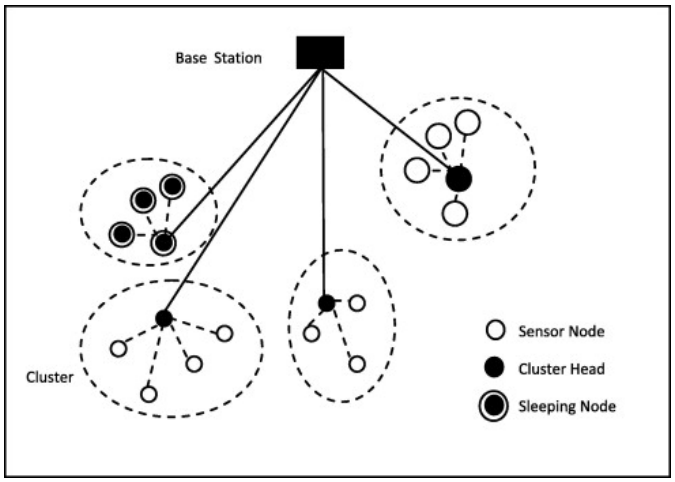

Fig. 5. Centralized LEACH

Once the cluster heads and associated clusters are found, the BS broadcasts a message that contains the cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a cluster head; otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data.

H. Energy Conscious LEACH

In the LEACH protocol, the aleatory choice of CHs in the network results in an energy imbalance of nodes, and not all nodes have the same opportunity to become CH. I propose a modified threshold formula for balanced Cluster Head Selection Algorithm to increase the life time and decrease the poIr consumption of WSN.

Our approach in increasing the lifetime of a LEACH network is the inclusion of the remaining energy level available in each node. It can be achieved by reducing the threshold T(n) relative to the node's remaining energy. Therefore, T(n) is multiplied with a factor representing the remaining energy level of a node:

$$T(n) = \begin{cases} \frac{p}{1-p*(r*mod(1/p))} * \frac{E_{curr}}{E_{ini}} & ; \text{if } n \in G. \\ 0 & ; \text{otherwise.} \end{cases} \quad (6)$$

where E_{curr} = Current Energy, E_{ini} = Initial Energy, p is the percentage of cluster heads in the current round r and G is the set of nodes that have not been cluster-heads in the last 1/p rounds.

Multiplying the energy factor that is current energy upon initial energy, allows us to select the nodes as cluster head who have more amount of energy left, thus increasing the efficiency further more.

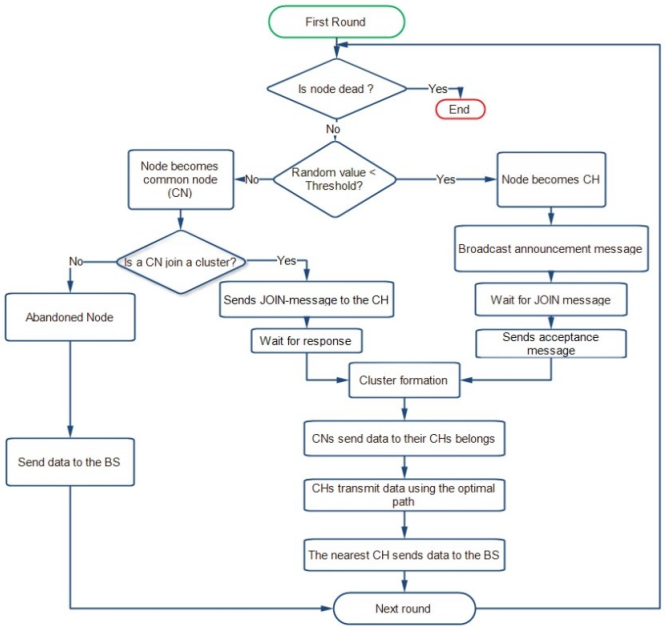

Fig. 6. Flowchart of LEACH-EC

I. LEACH with Secondary Cluster Head

In LEACH protocol, Cluster heads are responsible not only for sending data to the base station but also for collecting and fusing the data from common nodes in their own clusters. In the process of data collection and transmission, the energy consumed by data transmission is greater than that of data fusion. If the current energy of a cluster head is less or the distance to base station is much far, then the cluster head will be dead quickly because of a heavy energy burden.

To address this issue, this proposed algorithm tries to balance the energy loads of these cluster heads. If a cluster head's current energy is less than the average energy, that is $E_{curr} < E_{avg}$, where $E_{avg} = \Sigma_i^N E(i)_{curr}$ is the average energy of all nodes in the network, or the distance betIen the cluster head and base station is longer than the average distance, that is $d > d_{avg}$, where $d_{avg} = \Sigma_i^N d_i$ is the average distance of all nodes' distance to base station, then the common node with maximum energy in this cluster will be selected as the secondary cluster head. If $E_{curr} \geq E_{avg}$ and $d \leq d_{avg}$, it is unnecessary to select a secondary cluster head.

In a cluster which has secondary cluster head, the secondary cluster head is responsible for receiving and fusing data collected from the member nodes and sending them to its cluster head, the cluster head is only responsible for transporting data to base station. (Fig.7 refers to Network topology of LEACH-SCH)

After this the normal LEACH is continued.

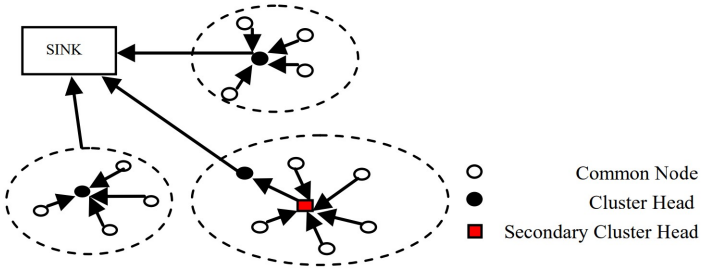

Fig. 7. Network topology of LEACH-SCH

II. RESULTS

The following analysis has been carried out to study the improvement taking place in LEACH protocol. I have used MATLAB as our simulation tool to compare the following:.

- Traditional LEACH
  - Advantages:
    - Improves the life-cycle of the network through using the TDMA schedule.
    - Decrease energy dissipation of nodes.
    - Decreases the no. of transmission packets.
  - Disadvantages:
    - Selects CHs aleatory.
    - The number of nodes in clusters is random.
- Centralized LEACH (LEACH-C)
  - Advantages:
    - The centralization provides a better distribution.
    - Achieves a large no. of turns in a minor area.
    - CH selection in accordance to remaining poIr.
  - Disadvantages:
    - The centralization method needs an extra energy.
    - The number of nodes in each cluster is unbalanced.
- Energy Conscious LEACH (LEACH-EC)
  - Advantages:
    - CH selection according to the remaining energy.
    - No. of nodes in cluster can not exceed a maximum.
  - Disadvantages:
    - Does not consider other QoS parameters.
- LEACH with Secondary Cluster-Head (LEACH-SCH)
  - Advantages:
    - Decreases the burden over Cluster-Head
    - Proper distribution of work betIen Cluster-Head and Secondary Cluster-Head
  - Disadvantages:
    - Increases hierarchy levels, which indeed increases the complexity.

Figure 7 describes about- How many Nodes are Alive at a given time? Figure 8 describes about- How many Nodes are Dead at a given time? Figure 9 describes about- How many

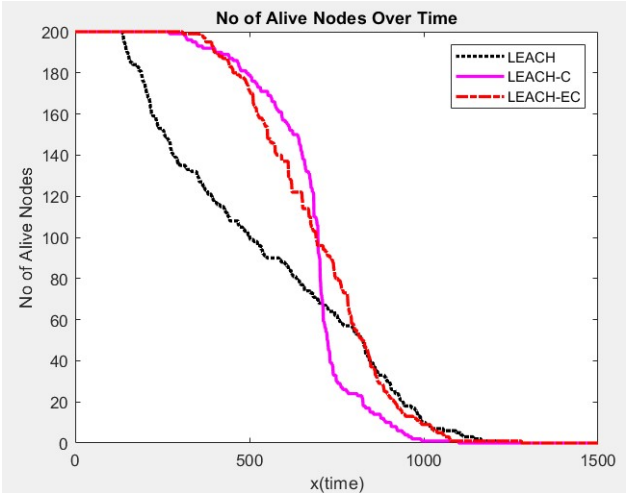

Fig. 8. No. of Alive Nodes over Time- LEACH vs LEACH-C vs LEACH-EC

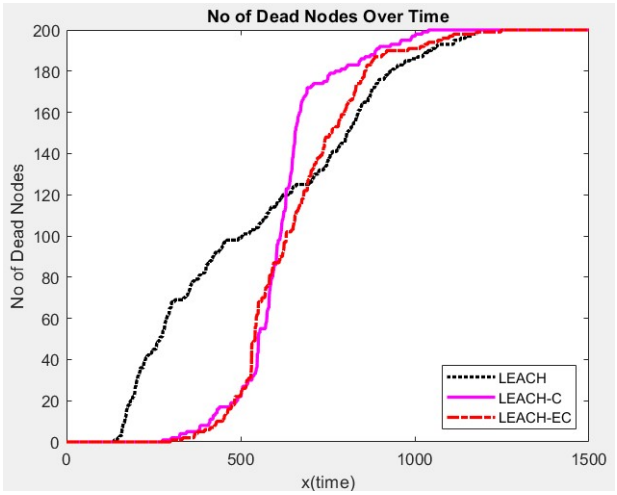

Fig. 9. No. of Dead Nodes over Time- LEACH vs LEACH-C vs LEACH-EC

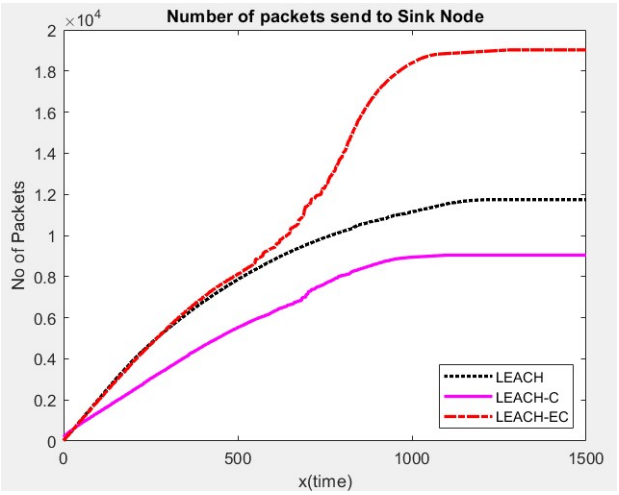

Fig. 10. No. of Packets sent to Sink- LEACH vs LEACH-C vs LEACH-EC

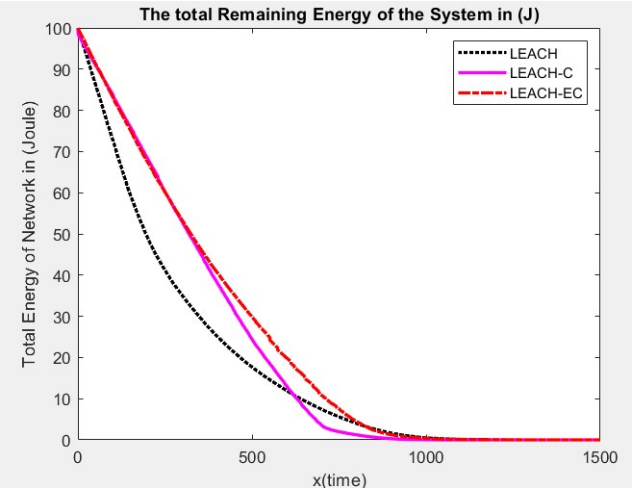

Fig. 11. Total Remaining Energy- LEACH vs LEACH-C vs LEACH-EC

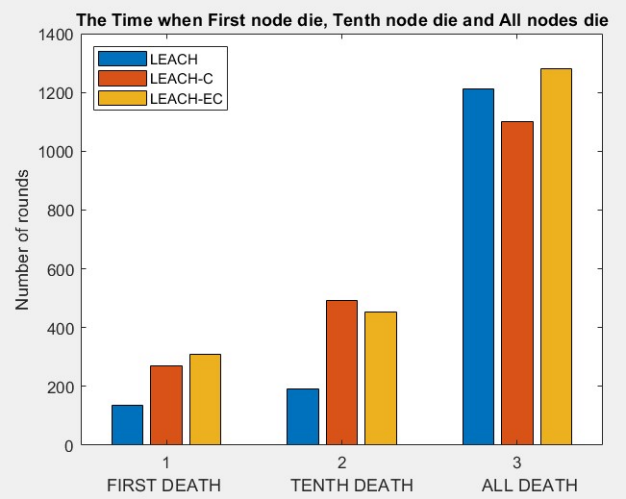

Fig. 12. Time when First node die, Tenth node die and All nodes die- LEACH vs LEACH-C vs LEACH-EC

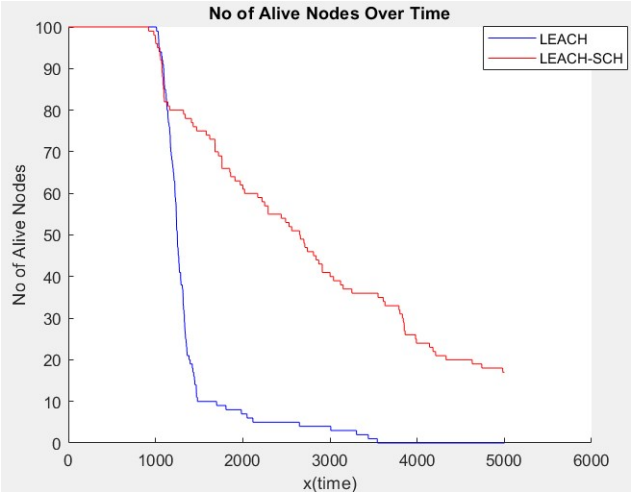

Fig. 13. No. of Alive Nodes over Time- LEACH vs LEACH-SCH

Packet have been sent at a given time? Figure 10 describes about- What is the total energy of the whole network (in Joule) at a given time? Figure 11 describes about- At what time the first node, the tenth node, and the last node died? Figure 12 describes about- How many Nodes are Alive at a given time?

Figure 8, 9, 10, 11, 12 discuss about the differences betIen LEACH vs LEACH-C vs LEACH-EC.

Figure 13 discusses about the differences betIen LEACH vs LEACH-SCH.

III. CONCLUSION

In any WSN protocol, the main goal is improve the lifetime of the system, and make it more energy efficient. In the present work, I have suggested a new approach for improving the performance of the traditional LEACH protocol. Instead of normal procedure in LEACH, I have the developed protocols which use- a centralized algorithm (LEACH-C), remaining energy factor (LEACH-EC), and Two Level of CHs (LEACH-SCH) for improvisation.

All above mentioned protocols have their own pros and cons, and are suitable for different situations. The result of simulation illustrates that the proposed approach prolongs the life-cycle of WSNs and decreases energy consumption. For future extensions to this work, I intend to compare this protocol to other enhanced-LEACH protocols. Thereby, I hope to make various enhancements in the present work such as determining the optimal number of clusters in the network, enhancing the throughput, and other quality of service parameters

All the base papers, codes and materials are uploaded in the Google Drive Folder.

REFERENCES

[1] An Application-Specific Protocol Architecture for Wireless Microsensor Networks- Indi B. Heinzelman, Anantha P. Chandrakasan, Hari Balakrishnan **Link**

[2] Consumed Energy as a Factor For Cluster Head Selection in Wireless Sensor Networks- Desalegn Getachew, Huagang Xiong, Qiang Gao **Link**

[3] Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-Head Selection- M. J. Handy, M. Haase, D. Timmermann **Link**

[4] Improved LEACH protocol for increasing the lifetime of WSNs- Ikram Daanoune, Abdennaceur Baghdad, Abdelhakim Ballouk **Link**

[5] An Energy Balanced Algorithm of LEACH Protocol in WSN- Chunyao Fu, Zhifang Jiang, Ii Ii, Ang Ii **Link**