Threshold Driven Energy-Efficient and Scalable Dual Cluster Head Protocol

Navajyoti Nath, Biswanath Dey

Abstract: *In WSN cluster-based routing approach is a major step in the direction of energy efficiency. However, research shows that energy dissipation in a cluster-based approach predominantly occurs in two cases; first during data transmission to the base station and second during data fusion/aggregation. Eventually, this leads to sizable energy dissipation, the early death of CHs and results in lower network lifetime. Moreover, in most of the recent proposed works, it is never assured that an individual node selected as a Cluster-Head would perform all the assigned tasks without dying in the process. Thus to address these problems, a new approach is proposed in this paper, where two cluster-heads (CHs) in every cluster are selected; first cluster-head being used for data aggregation (Primary-CH) and second for data transmission (Secondary-CH), which assists in reducing the burden of a single Cluster Head. Along with the dual Cluster-Heads, another key feature adopted in this paper is the Energy Threshold values for PCH and SCH. These Energy Thresholds for different CHs calculates the minimum energy required by a node to perform all the tasks assigned to it when elected as CH. So, while electing Primary Cluster-Head (PCH) and Secondary Cluster-Head (SCH) along with other criterions energy threshold values for PCH (E_{PO}) and energy threshold values for SCH (E_{SO}) are also used. Any node with remaining energy less than that of energy thresholds would never be considered for Cluster-Heads. Therefore, by employing the above-mentioned criterions, this article proposes a new protocol that uses dual heads and assists in enhancing the network life of a network as compared to LEACH protocol.*

Keywords: *LEACH, Clustering Protocols, Dual Cluster Head, Routing Protocols, Energy Efficient, Energy-Threshold, WSN.*

I. INTRODUCTION

W IRELESS Sensor Network is a collection of sensor nodes which are randomly deployed in harsh conditions or difficult terrains to monitor and gather information of surrounding environment like temperature, humidity, forest fire, automobile movement, etc. As the nodes deployed are limited on battery power and due to the area of deployment, replacing or replenishing of power source becomes very difficult. To overcome this issue, numerous studies were brought out to look out for solutions to increase the network lifetime [1][2][3][4][5]. One of the prominent solution among others was proposed by Heinzelman et al in 2002 [6], the LEACH protocol. In LEACH protocol, the sensor nodes forward the sensed information to their respective cluster-heads (CHs) where the data aggregation/fusion is carried out and the output data signal is further sent by the CHs to the base-station (BS) or sink for further processing. The CHs sends the data to the base station using either a single-hop communication or a multi-hop communication approach on the basis of distance to the sink [7]. Multi-hop communication is preferred over single-hop communication for longer distance as, the single-hop communication would require more energy, which will lead to faster death of nodes; however the energy usage of CHs increases exponentially. Thus rotation of role of CHs among other nodes is used and the nodes are restricted to be elected again till a certain interval (rounds) is over, to reduce the burden of the Cluster Heads. But still having the rotation of roles of cluster heads would not ascertain the efficiency or increase in the network lifetime. Therefore two energy thresholds are devised in this paper to further minimize the energy usage of CHs. This paper focuses on two aspects: 1) Recent achievements in the field of clustering protocols in WSN which are developed using either LEACH, HEED or PEGASIS protocols and; 2) Proposal of a new cluster based routing protocol using Dual Cluster Head.

Two CHs that are employed here are for two different tasks; one for data reception and data aggregation (Primary Cluster Head), and another cluster head for data transmission (Secondary Cluster Head). The emphasis of this work is to increase the network lifetime of a given network. The fundamental objective behind the selection of two CHs is to reduce the burden of a single CH. In our approach, two roles (aggregation and transmission) of CHs are separated and are designated to two different CHs. Thus decreasing the energy dissipation of CHs and eventually increasing the lifetime of CHs. This paper is separated into following different sections: Section II provides with the review the literature of related protocols and algorithms that are based on dual cluster head. Section III-V discusses the recent works that are based on LEACH, HEED [8] or PEGASIS [9] protocols. Section VI proposes the new algorithm using dual cluster head. Thereafter, Section VII discusses the results. And finally, Section VIII provides with the conclusion of the paper.

II. RELATED WORKS

This section reviews various routing techniques and dual cluster head based clustering on homogeneous as well as heterogeneous networks that are proposed in recent times.

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In LEACH protocol [6], the sensor nodes in the network if not elected earlier claims to be the cluster heads and based on that claim, the remaining nodes organize themselves to form clusters. The process of selection of CHs, cluster formation and data transmission are done in four separate parts: advertisement phase, cluster-setup phase, schedule-creation phase and data-transmission phase. In the first phase, the nodes randomly chooses a number in range of [0,1] and if the number is less the threshold function value then the node gets elected as a new cluster head for that round. As the cluster heads are now decided, the non CH nodes now decides to which cluster head it should select for the present round depending on the signal strength obtained. In cluster formation phase, after selecting the CHs nodes now inform the cluster head by an ACK control message to form a cluster. In schedule creation phase, the cluster head, depending on the nodes in the cluster, forms a TDMA schedule directing the nodes when to send the data to the cluster head. In the final phase i.e. data transmission phase, the nodes in the cluster send the sense data in their allotted transmission time to the CH and after receiving the data from all the non-CH nodes, the cluster head performs data aggregation to compress the data into single data signal. This composite data is then forwarded to the base station for further processing.

Hongjun Wang et al. in [10] proposed an algorithm to improve LEACH using double cluster heads and a mechanism for data fusion. In this algorithm, the clusters are formed on the basis of k-Medoids clustering algorithm, and after the completion of cluster formation the first and the second cluster heads in the cluster are elected. As the algorithm follows k-medoids, where the value of 'k' is selected based on the ratio of number of cluster heads required to total number of nodes in the network. Election of cluster heads is same as in the LEACH [6], but the probability is based on the ratio of number of cluster head expected in a cluster to the number of nodes in the given cluster.

Jie Huang in [11], a double cluster head based algorithm is proposed to reduce the effects of premature death of cluster head due to heavy energy consumption. In this algorithm, two cluster heads are used, namely Master-CH, which is selected based on the LEACH protocol and Vice-CH, which is selected among non-CH nodes in the cluster, depending on the node distance to the master node. In [11], the non-CH nodes send the data to any of the two cluster-heads based on the distance. If the node is nearer to the master-CH it transmits the data to the master-CH and if is nearer to the vice-CH it relays it to the vice-CH. On receipt of the data both the master head as well as vice cluster head performs data integration but only master-CH sends the information to the base station whereas the vice cluster head sends the integrated information to the master cluster head from where the data is further forwarded to the base station.

In [12], the number of clusters is predefined and based on this criterion the network is partitioned into equal sized clusters which are static throughout. Based on the cluster information and the information imparted by the sensor nodes about their location, the sink assigns each node into a cluster. After the nodes are assigned to their clusters, two nodes in each cluster are selected as cluster heads, one being an Aggregating CH (ACH), used for data aggregation and the other being a Transmitting CH (TCH), used for relaying the data to the sink. The ACH is selected among other nodes in the cluster, based on a fitment factor which includes three weighted criterion residual energy, distance of nodes from sink, and distance of other nodes. The node with most residual energy and being in the center is given the highest score and is finally selected as the ACH. On the other side, the TCH among other non-cluster-head nodes is also selected based on the same fitment factor used by the ACH, but the weightage is mainly focused on the distance between the node to the sink and the residual energy. Thus a node with highest residual energy and with least distance from the sink is given priority and hence is selected as a TCH. After the selection of cluster heads are completed, the sensor node send their data to the ACH where data aggregation is performed and then the aggregated data is forwarded to the TCH and the TCH further sends the data to the sink. This reduces the energy consumption during inter-cluster and intra-cluster communication and results in overall increase in network lifetime.

In Dual Head Clustering Scheme (DCHS) [13], the authors have used two heads namely: aggregator head (AH) and cluster head (CH). In DCHS, the nodes are deployed randomly and are location aware and moreover the network rotation does not happen after every round instead the rotation takes place only after fixed rounds as decided by the user. After the deployment the BS broadcasts a signal which enables every node to calculate the distance to the base station. Then the nodes based on a formulation find out cluster size and radius, and then propagates the information to the network. Every nodes compare the information received with its own values and then based on energy level chooses a CH. Finally the CH, among the member nodes elects one aggregator head with high residual energy and location closest to the cluster head. The role of AH is to collect data from the nodes within cluster and after aggregation, transmit it to the CH, and the responsibility of CH is to further forward the data to the BS.

Dual Cluster Head Routing Protocol (DCHRP) [14], is implemented on heterogeneous network [15], which is implemented using dual cluster head and has three levels of heterogeneity. DCHRP is fundamentally based on Enhanced Threshold Sensitive Stable Election Protocol (ETSSEP) [16]. There are three categories of nodes advance nodes, intermediate node and normal nodes. Advance nodes have energy "α times" and intermediate nodes have "β times more than the normal nodes. In this, initially the CH is elected among the advance nodes and sub-CH is elected among the intermediate and normal nodes. Afterwards any node in the network gets to participate in the election process, but for sub-CH election intermediate and normal nodes can only participate. The election procedure for both the cluster heads is based on the maximum probability, residual energy and distance to the sink.

III. PROPOSED ALGORITHMS BASED ON LEACH

a) LEACH-with Supporting Cluster Heads (LEACH-SCH)

In [17], an algorithm proposed by A. Solanki et al, which considers two types of CHs. Cluster heads of the first type are known as normal CHs and the second type of cluster heads are referred as supporting CHs (SCH).

In this algorithm, every nodes generate two random numbers in range [0, 1] one for the normal CH and other for the SCH. The normal CHs are elected depending on LEACH [1] protocol and the SCHs are elected among the normal CHs. An existing normal CH is elected as SCH, if the second random value generated by the existing normal CHs is less than the threshold value of SCH which is decided a priori. On selection, CHs broadcasts the information to the rest of the non-CHs nodes. Based on these broadcast rest of the nodes sends join request to the CHs and then they forms clusters and finally TDMA schedules are provided to the nodes in the clusters. Once the clusters are formed and TDMA schedules are known to the nodes, the non-CHs nodes send their data to the normal CHs. The normal CHs on receiving the data from its cluster member nodes, aggregate the data and forwards it to the nearby SCH, and lastly the job of SCH is to transmit the data received from CHs to the base station.

b) 3.2: Universal - Low Energy Adaptive Cluster Hierarchy (U-LEACH)

The U-LEACH [18] algorithm is fundamentally a combination of LEACH [3] and PEGASIS [5] protocols. In this algorithm, first the clusters are formed on the basis of the coordinates of the nodes and then CHs are selected based on the residual and initial energy of the node, that is, a node in the cluster with highest initial energy is selected as the CH. Immediately after the clustering is done, the chain formation is started beginning from the farthest node in the cluster to the CH. The data transmission in this algorithm is done through the chain and finally to the CH, where the data diffusion (aggregation) is conducted. A Master CH is selected among the CHs in every round for collecting the information from the different CHs and then after data fusion the data is transmitted to the base station.

c) Energy influenced Probability based LEACH Protocol (EiP-LEACH)

A.M. Bongale et al in [19] proposed an EiP-LEACH algorithm which is based on LEACH [1]. In this algorithm, the cluster head election is different from the original LEACH protocol. In the original protocol a node is elected as cluster head based on the equation (1), but in this algorithm the authors have proposed another selection criteria that is based on the residual energy and as well as the initial average energy of all the nodes in the network.
Where n_j is the node participating in the election of process of CH, E_{nj} is the current residual energy of the node, $E_{initavg}$ is the average initial energy. Rest of the operations are just like that are in the LEACH [6] protocol, that is, the clusters are formed by nods sending out join request to the CH and in return TDMA schedules are forwarded to the nodes in the cluster.

$$T(n_j) = \begin{cases} \dfrac{p}{1 - p * \mathrm{mod}(round, \frac{1}{p})} * \dfrac{E_{n_j}}{E_{init_{avg}}}, & if \quad n_j \in G \\ 0: , & otherwise \end{cases} \qquad (1)$$

Data transmission process is initialised at the node-level in the cluster, by relaying nodes data to the CH and then further to the BS.

d) CH-LEACH

In [20] W. Abushiba et al proposed an energy efficient and adaptive clustering for wireless sensor network using LEACH. Unlike LEACH, this algorithm first forms *k* number of clusters (value of k is a priori) using *Centralised k-Means algorithm*. After the clusters are formed, the node which is closest to the centroid (center of the cluster) in each clusters with residual energy above a certain threshold value are selected to perform as cluster heads (CH). Once the CH is selected, other nodes in the cluster relay their data to the CH and eventually after data aggregation the data is converted into a signal and is finally relayed to the base station. The CH shall remain as CH until it slips down below the threshold value assigned for energy, then the above process is repeated again to find for a closest node with sufficient energy.

IV. PROPOSED ALGORITHMS BASED ON HEED

a) A New kind of multi-hop routing protocol based on HEED (NHEED)

H. Wang et al in [21] proposed an algorithm which is principally based on HEED [8] protocol. Here in this protocol authors have proposed a way to deal with the isolated nodes (uncovered nodes). Isolated nodes are those which don't receive updates from any of the CHs and then elect themselves as CH, which sometimes increases the power dissipation if the isolated nodes are far from the base station. To overcome this issue, isolated nodes increase the transmit power to look for a nearby CH. After a CH has been located, distance between the isolated node-CH (D_{iso_CH}) and distance between isolated node-base station (D_{iso_BS}) is compared. If (D_{iso_CH}) is less than (D_{iso_BS}) then the isolated node joins that CH, otherwise it remains to act as isolated node and transmits directly to the base station. One more enhancement is proposed in this algorithm, is that; it evolves from single-hop to multi-hop. If a CH is far away from the base station then it would require larger sum of energy to transmit the data to the base station, therefore it selects a CHs that is closer to the base station and transmits the data to that CH. Thereby reducing the energy requirement of the CH. The process of choosing the next hop for a CH is based on a broadcast message which includes the cluster radius. Due to the information of cluster radius all the CH can know their neighbouring cluster as well as the next hop (i.e. CH of neighboring cluster).

b) Energy based Rotated HEED (ER-HEED)

In [22] Z. Ullah et al proposed ER-HEED which is an improvement in the HEED [8] protocol. The election of cluster head and cluster formation is similar to that of original HEED protocol. The additional aspect that has made improvements in the HEED protocol is by including the *cluster head rotation* rather than cluster head re-election. In HEED once the round is over a new set of CHs are re-elected, whereas in proposed ER-HEED after a round is over the current CH elects a new CH among its cluster member with highest residual energy. This drastically reduces the energy overhead which is imparted every time the re-election happens. In ER-HEED, only when death of nodes occurs in the system, the process of re-election and re-clustering is conducted. The decision of new CH is made on the basis of the data (including all the information relating to the status of the node) send by the member nodes to the present CH.

V. PROPOSED ALGORITHMS BASED ON PEGASIS

a) Distributed PEGASIS (DPEGASIS)

In most of the chain-based algorithms, the chain is either formed by the base station or it is formed when every node has the structural information of the network. But in [23], J. Kulshrestha and M. K. Mishra have proposed a distributed algorithm where the chain is formed automatically among the nodes without any information regarding the network. In this proposed algorithm, the network is initially divided into zones (areas) based on the nodes distance to the base station. Now based on the demarcated zones, a PEGASIS chain formation starts with the node that is in the farthest zone as well as at a certain distance from the network outer region (boundary).

$$E_{rx}(m) = m * E_{elec} \quad (3)$$

The PEGASIS chain is formed zone-wise, that is, the chain is first formed for the nodes in the farthest zone and then continues to move closer to the base station zone by zone.

b) PEGASIS-LEACH (P-LEACH)

A. Razaque et al in [24], proposed an algorithm that eliminates the shortcomings of both the LEACH [6] and the PEGASIS [9] protocol. The reason we have kept this under the PEGASIS, is because of the characteristics adopted by algorithm to be a chain based approach. In this approach, all the nodes in the network are required to send their energy and location information to the base station. Once all the data is received by the base station, it forms different clusters based on the location information of the nodes and also selects a CH for every cluster. The selection of CH depends upon the maximum residual energy, that is, the node with the highest residual energy within the cluster is selected as CH. For data transmission, a chain is formed using the PEGASIS protocol that includes only the CHs of all clusters. The data send by the nodes to their CH are aggregated and is transmitted to the next CH in the chain. After the formation of the chain is completed, the CH in the chain with minimum distance from the Base Station and with highest residual energy is selected as *leader*. The role of the leader in the chain is to collect all the data from the neighboring CHs and transmit the aggregated data to the base station. A CH in this scenario remains a cluster head until its residual energy is below the expected energy level (threshold), then the node with the present highest residual energy (more than expected energy level) within the cluster is selected as the new CH.

c) Modified PEGASIS

In [25], a modified PEGASIS is proposed where the modification lies in the chain formation as well as in the selection of leader node in the chain. This algorithm proposes a different way in the chain formation, that is, during the formation of the chain the nodes once visited may again be visited if the node is the nearest neighbor node among other nodes. This way a tree type chain is formed as there are nodes which are visited more than once. A node in a chain is only visited again if, for a node the nearest neighbor is that node. For the leader node selection also this algorithm proposes a dissimilar approach, here the leader is selected on the basis of a function which includes residual energy level, distance from the sink, and node degree. For a node to become a leader, it must have highest residual energy, with minimal distance from the sink and minimum node degree. A node with higher node degree has the least chance to be selected as leader, as it is already overloaded, and a node with longer distance from the sink is also likely to have less probability to be a leader, as it would require more energy to transit the data to the sink. Once the chain is formed and the leader is selected the data transmission is as per the parent protocol (PEGASIS [9]).

VI. PROPOSED ALGORITHM

The fundamental objective of this study is to propose a new clustering approach using dual cluster head to enhance the lifetime of the network. By increase in network lifetime we mean, prolonged lifetime/delayed death of nodes and to do so the following are the assumptions that we have considered for our model:

A. Network Model

- Nodes are homogeneous having uniform energy and energy constrained.
- Base station is fixed and is far from the sensor nodes.
- Nodes are stationary.
- All nodes are in communication range with the base station.

B. Energy Dissipation Model

The communication energy model used in our proposal is the first-order radio model [9] and is used by many models including [6][8][9][10][11][12][13]. Here two channel models are use one being the free space channel and the multipath space model. The choice is based on the distance of the transmitter to the receiver, if the lesser distance (less than threshold distance, D_0) free space is adopted and, if distance of transmitter to the receiver is more (more than threshold distance, D_0) multipath space model is selected. Thus the expression for the energy consumption when a m-bit message is transmitted over a distance d is as follows:

where $E_{tx\text{-}elec}(m)$ is the electrical energy required by the transmitter circuit which includes coding, modulation, filtering, and spreading of the signal, to transmit a m-bit message, whereas $E_{tx\text{-}amp}(m,d)$ is the energy consumed by the amplifier transmitter for transmitting a m-bit message to a receiver over a distance of d. E_{elec} is the energy consumed by the transmitting circuit to transmit a bit message and the ε_{fs} and ε_{mp} are the constant coefficients for free space and multipath respectively [7]. The values of ε_{fs} and ε_{mp} are as per the values used in [6].

In addition to the energy consumption on transmission, the expression for the energy consumption on receiving a m-bit message is as follows:

Further the expression for threshold value of distance used in our model is as proposed in [6], and is as given as:

$$\begin{aligned} E_{tx}(m,d) &= E_{tx\text{-}elec}(m) + E_{tx\text{-}amp}(m,d) \\ &= m(E_{elec} + \varepsilon_{fs} d^2), d <= D_0 \\ &= m(E_{elec} + \varepsilon_{mp} d^4),\ d > D_0 \qquad (2) \end{aligned}$$

Moreover, as discussed earlier, that for the Cluster Heads, huge amount of energy is dissipated in both the data transmission and data aggregation. Accordingly it becomes utmost important that we include energy consumption in data aggregation along with the consumption in data transmission. In this paper, therefore we take E_{DA} which represents energy consumption in data aggregation.

C. Threshold Driven Dual Cluster Head Clustering Protocol

The proposed algorithm is based the LEACH protocol which is considered as the benchmark of clustering protocols, however uses dual cluster head. The proposed algorithm is primarily divided into two stages: Initialisation Phase and Transmission Phase. These two stages are further divided into different sub-stages. The initialisation phase consists of three sub-phases; first sub-phase is where the primary cluster head election is carried out, in second sub-phase, based on the primary cluster head election information cluster formation is performed, and lastly in the third sub-phase the secondary cluster head is elected with in the newly constituted clusters. In the transmission phase, the actual data transmission is taken out. This stage starts with the data transmission from member nodes to the cluster heads, where data is processed and later after aggregation is transmitted to the secondary cluster head for further relaying to the base station. The detailed approach is discussed in the following sections.

$$D_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad (4)$$

D. Initialisation Phase:

- **Primary Cluster Head Election**

The objective of this stage is to find the primary cluster heads. This stage follows similar process that is adopted in [2]. But in LEACH protocol, while electing the cluster heads the residual energy is not considered. Thus, there could arise a situation at some point of time, where a node might get elected as cluster head which could not be able to perform the complete duties assigned and might die in between the stages due to less amount of residual energy. Therefore, considering this possibility with the cluster head death, the approach discussed in this report has computed a way out, where a threshold energy value is calculated, which is the estimation of the energy dissipation by a cluster head to perform the assigned duties, that data collection, data aggregation and then data transmission to the secondary cluster heads. This approach also considers the same for the secondary cluster heads and is discussed in the later section.

To begin with the threshold energy level, one needs to find out where the energy dissipation of a node occurs once elected as a cluster head. This could be found by looking at the primary responsibilities of a cluster head (primary). In this approach, the responsibility of a cluster head (primary) is to collect the sensed information from the cluster nodes and after performing data-aggregation, finally transmits it to the secondary-cluster-head. So, it could be pointed out that the energy dissipation of a primary cluster head takes place in three aspects: data reception, data aggregation, and data transmission. Thus to calculate the optimal threshold energy value E_{PO}, equation (2) and (3) to be considered. In (2), where the calculation for the amount of energy dissipation is shown while transmitting a signal, and in the (3), the formulation for

$$E_{S0} = m*(E_{elec} + (E_{elec} + \varepsilon_{fs} * D_0^2)) \qquad (6)$$

the energy consumption is shown when reception of a data signal is performed. Moreover, from [1][3][4][8][10] we could also find the formulation amount of energy dissipation while performing data aggregation.

Finally, with the combination of the aforementioned we could find the amount of energy dissipation that occurs for a node when elected as a primary cluster head.

where N is the total numbers of network node, p is the percentage of clusters decided a priori, E_{elec} is the consumption of energy in reception of a *single-bit* message as well as in transmission of *single-bit* message, E_{DA} is the amount of energy that is consumed during data aggregation

$$E_{PO} = m*[(E_{elec}*((N*p)-1)) + (E_{DA}*(N*p)) + (E_{elec} + \varepsilon_{fs}*D^2)] \qquad (5)$$

and is considered to be a constant, ε_{fs} is the constant coefficient for free space transmission and D_0 is the threshold distance.

To illustrate the election process of primary cluster head a flowchart (figure 1) for the same is provided for better understanding of the process.

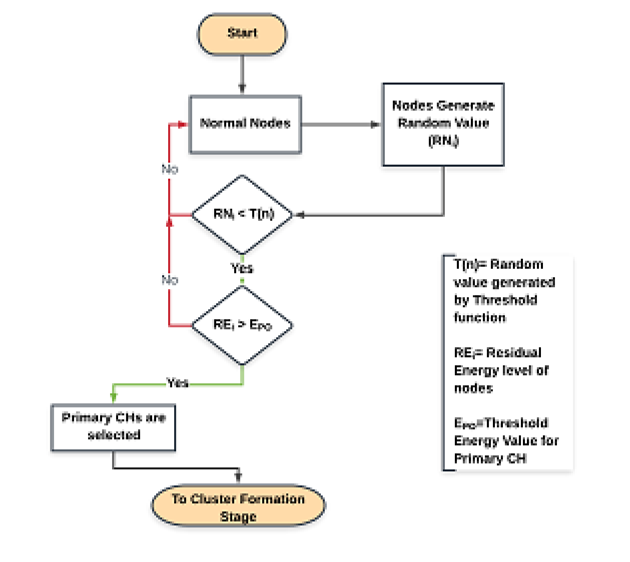


Figure 1: Flowchart of Primary Cluster-Head

Once the process of election of primary cluster head is over, the primary cluster heads broadcast this information with their unique ids to the network. On listening to the broadcast, the remaining nodes choose to respond primary cluster heads with the highest signal strength. That is, the nodes selects a primary cluster head among other primary cluster heads when the received signal strength (RSSI) [26-28] is higher than others, which implies that the communication cost with that cluster head would require less energy as the distance to this primary cluster head is less.

Once all the non cluster nodes select their primary cluster heads, they respond with a message indicating their unique ids, residual energy, and distance to the base station. Thereby, finalising cluster formations in the network.

- **Secondary Cluster Head Election:**

In this stage, the main intent is to select a node among other member nodes in the cluster which can act as secondary-cluster-head. The responsibility of this cluster head is to receive and relay the aggregated information received from primary-CH to the base station. The criterion for the selection of secondary-CH is principally depends on the remaining energy which is more than the energy threshold value for secondary cluster head (E_{SO}) and the minimum proximity to the base station among other nodes in the cluster. Here the nodes can only participate in the selection process until the threshold value of energy for secondary CH of that cluster, E_{S0} is attained. That means that, even if a node has the shortest distance from the base station but the energy level is below the threshold value, the said node will not be considered for the role of secondary cluster head.

As it is already discussed that, the responsibilities of secondary cluster head is, one, to collect the aggregated data transmitted by the primary cluster head and secondly to transmit the data to the base station. Thus the calculation for the threshold energy level for secondary cluster head E_{S0} would depend on two factors: energy dissipation while receiving and energy dissipation while transmitting data to a certain distance.

To illustrate the election process of secondary cluster head a flowchart (figure 2) for the same is provided for better understanding of the process.

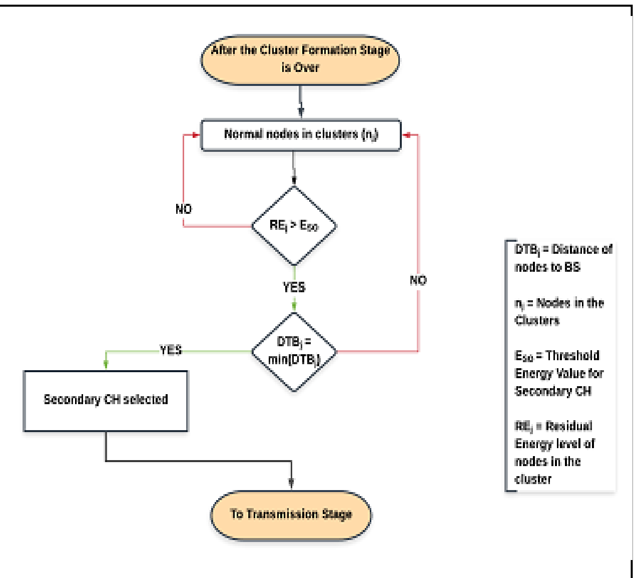


Figure 2: Flowchart of Secondary Cluster-Head election

Immediately after the secondary-CH is elected, the primary-CH transmits a TDMA schedule.

E. Transmission Phase:

After the selection of both the cluster heads, the primary cluster head broadcasts a TDMA schedule to all the non cluster heads in the cluster to inform about when the nodes can send data to the primary cluster head and when to be idle. The primary and secondary cluster heads will always be in the listening mode.

Once the schedule is notified, all the nodes in the cluster as per the schedule passes the data to the primary cluster head, where the data collection and aggregation is performed and the multiple data signals are transformed into a single data signal and as the transmission is within the cluster the energy consumption is way lesser than the original protocol [2]. Further, the data signal is transmitted to the secondary cluster head for relaying it to the base station. As the distance of secondary cluster head is lesser as compared, which enables it to transmit the data with comparatively lesser energy.

Therefore by using the dual cluster head approach in our proposed algorithm, energy consumption in LEACH protocol is reduced. As the role of one cluster head is divided into two and a optimal node is used for data transmission which lowers the energy dissipation in the network, thereby enhancing the lifetime of the network.

VII. RESULT AND DISCUSSION

In this section, the objective is to showcase the performance comparison of LEACH protocol and our proposed model in context of lifetime of the given network. The simulation of the algorithm is performed on MATLAB and the parameters and the network scenario is given in Table 1.

Parameters for Scenario	
Parameters	**Parameter values**
Network Area	100 m X 100 m
Base station position	(100m, 200m)
E_{elec}	50nJ/bit
EDA	5nJ/bit
E_{PO} @ p=5%	100 nodes = 7.03×10^{4} J
	500 nodes = 2.9×10^{3} J
	1000 nodes = 5.7×10^{3} J
E_{PO} @ p=10%	100 nodes = 1.3×10^{-3} J
	500 nodes = 5.7×10^{-3} J
	1000 nodes = 1.12×10^{-2} J
E_{SO}	3.538×10^{-4} J
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
D_O	87.7m
Size of data frames	2000 bit

A. Network Scenario

In this article, four network scenarios are used. In first two scenarios, the initial energy is $E_O = 0.5J$ both the scenarios and the percentage of CHs is $p = 10\%$ and $p = 5\%$ respectively and for the last two scenarios, the initial energy is $E_O = 1J$ whereas the percentage of CHs $p = 10\%$ and $p = 5\%$ respectively in Table 2.

	Scenario 1	Scenario 2	Scenario 3	Scenari o 4
Initial Energy	E_O =0.5J	E_O =0.5J	E_O =1J	E_O =1J

Percentage of nodes to be CH	*p*=10%	*p*=5%	*p*=10%	*p*=5%

B. Wireless Sensor Networks

In this section, three networks are implemented. First network consists of 100 nodes, second network contains 500 nodes and the last network has 1000 nodes. For all the three networks the sink position is same i.e. at (100m, 200m).

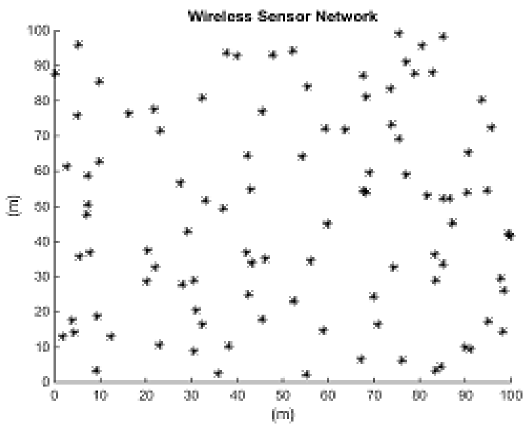


Figure 3: Scenario 1 containing 100 nos. of nodes

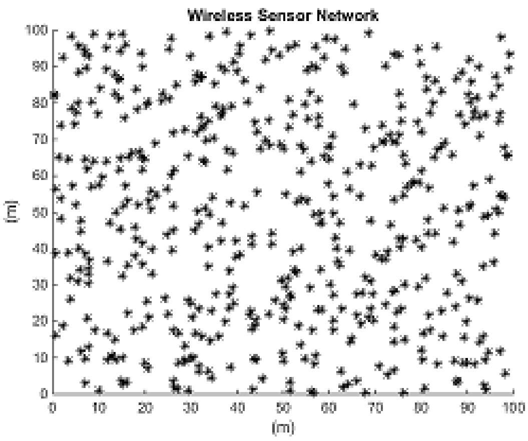


Figure 4: Scenario 2 containing 500 nos. of nodes

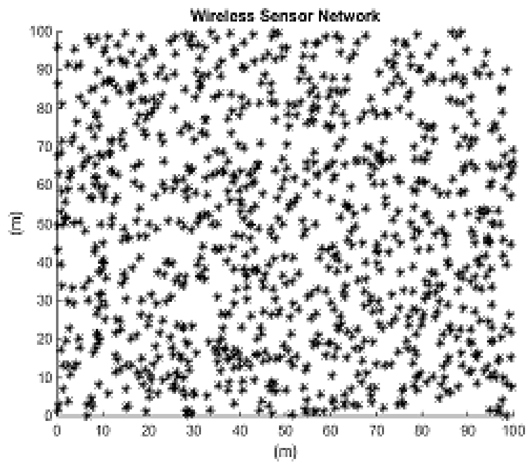


Figure 5: Scenario 3 respectively containing 1000 nos. of nodes

C. Network Lifetime

To evaluate the behavior of the proposed model and thereafter to differentiate with the performance of LEACH protocol, the simulation is being carried out in MATLAB. The performance comparison is based on the lifetime of the entire network. Below are the simulations results that were performed on LEACH and TDCH on four different scenarios using three different networks.

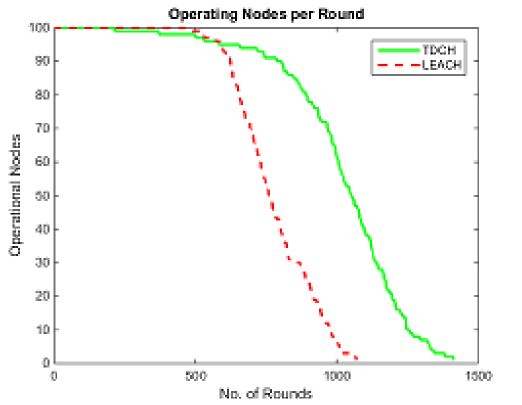
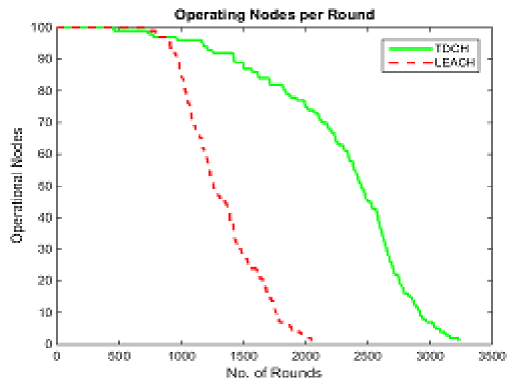


Figure 6: Compares the network lifetime of LEACH and TDCH for 100 nodes at E_O=0.5 J/node, *p*=10% and *p*=5% respectively



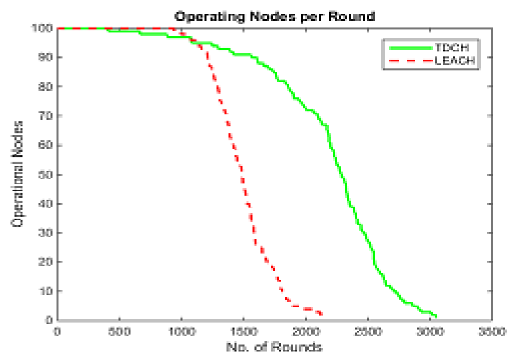
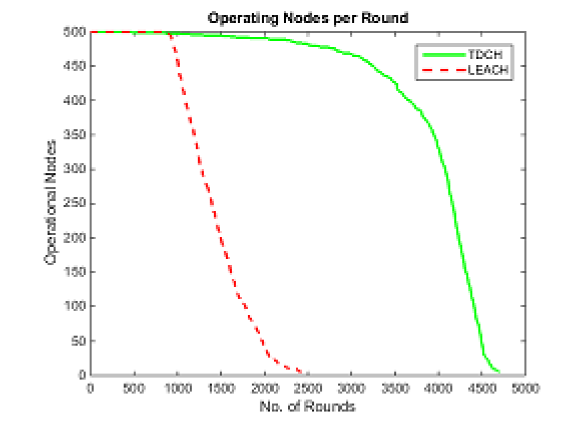
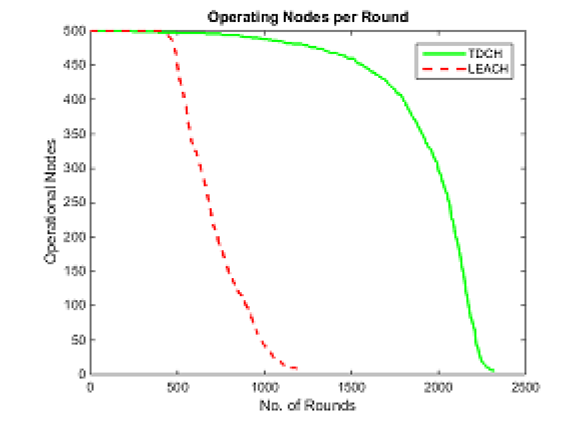
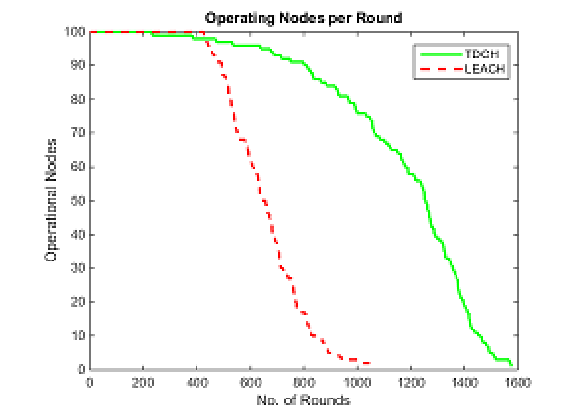


Figure 7: Compares the network lifetime of LEACH and TDCH for 100 nodes at E_O=1 J/node, *p*=10% and *p*=5% respectively







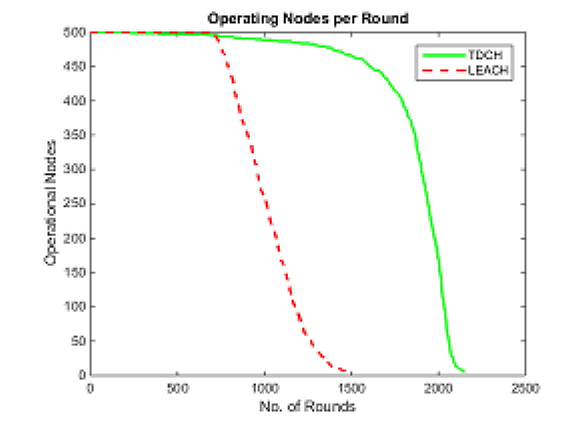
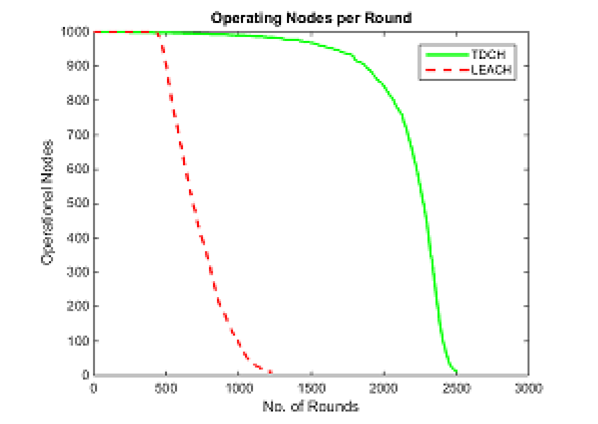


Figure 8: Compares the network lifetime of LEACH and TDCH for 500 nodes at E_O=0.5 J/node, *p*=10% and *p*=5% respectively



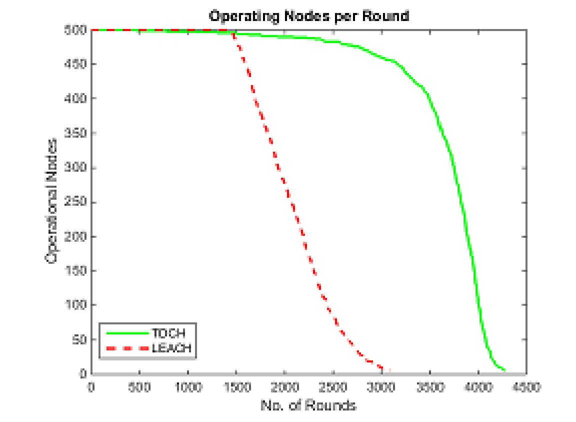


Figure 9: Compares the network lifetime of LEACH and TDCH for 500 nodes at E_O=1 J/node, *p*=10% and *p*=5% respectively

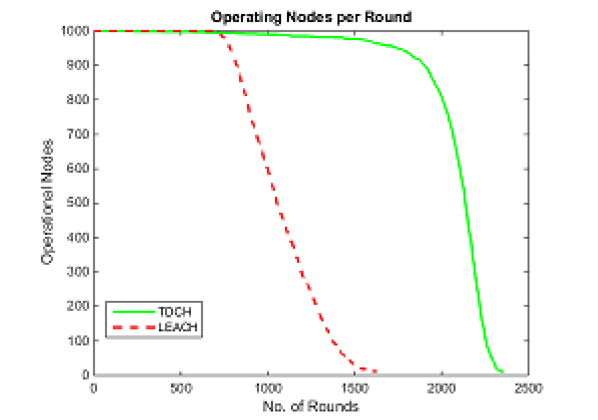


Figure 10: Compares the network lifetime of LEACH and TDCH for 1000 nodes at E_O=0.5 J/node, *p*=10% and *p*=5% respectively

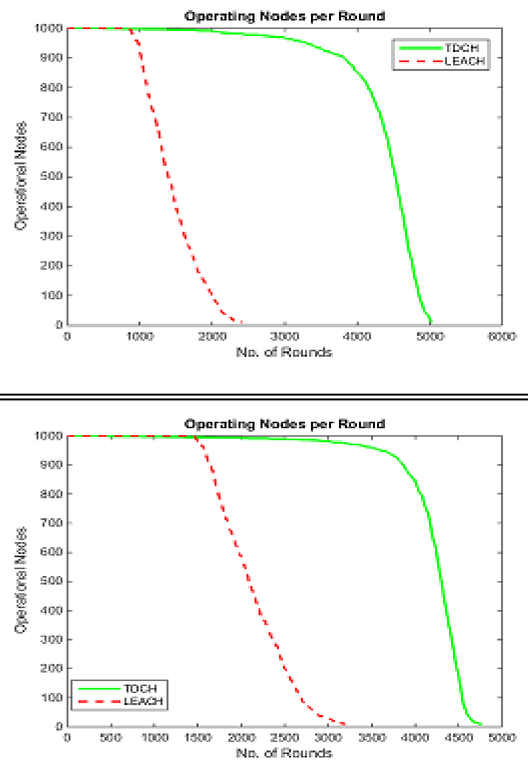


Figure 11: Compares the network lifetime of LEACH and TDCH for 1000 nodes at E_O=1 J/node, p=10% and p=5% respectively

D. Analysis

From the above simulation, it is now beyond doubt that the proposed protocol, that is, threshold driven dual cluster head clustering protocol has outperformed LEACH protocol. As exhibited in the table, the performance of TDCH protocol on 100 nodes among all the scenarios performs better for the half node death (HND) and network death (ND) as compared to LEACH protocol, but in case of first node death, the LEACH is performing little better. That is, for less number of (100) nodes in TDCH protocol, first node dies earlier than that of LEACH protocol but the network performs better for the other two aspects of death of nodes, i.e. network death and half node death . However, for 500 nodes and 1000 nodes, the proposed protocol transcends the LEACH protocol with a huge margin. The details of the comparison between TDCH and LEACH for all the node death are shown in figure (12-14) below.

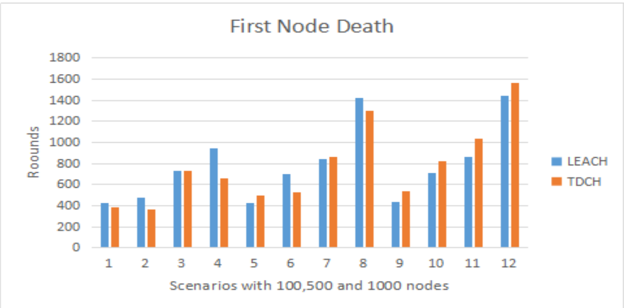


Figure 12: Comparison of FND for LEACH and TDCH on four Scenarios for the three networks (100, 200 and 1000 nodes)

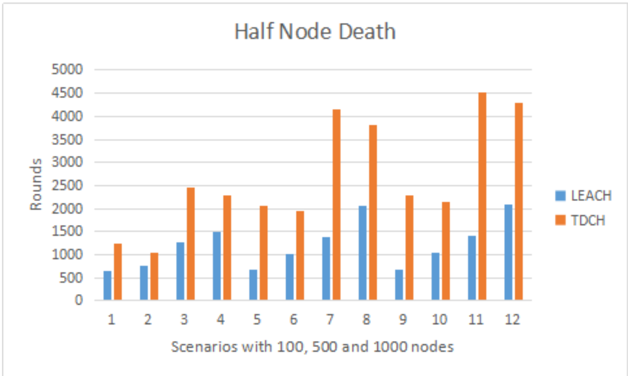


Figure 13: Comparison of HND for LEACH and TDCH on four Scenarios for the three networks (100, 200 and 1000 nodes)

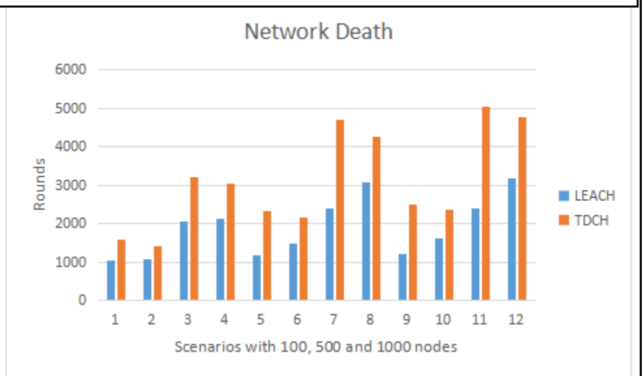


Figure 14: Comparison of ND for LEACH and TDCH on four Scenarios for the three networks (100, 200 and 1000 nodes)

VIII. CONCLUSION

From the above experiments performed on different network scenarios, with LEACH protocol and TDCH protocol. It is observed that the TDCH clustering protocol is outperforming the LEACH protocol with a considerable margin. The performance of TDCH clustering protocol w.r.t deaths of nodes, that is, network death and half node deaths, when compared to performance of LEACH protocol is far beyond. Whereas in the case of the first node deaths, it is observed that the TDCH protocol with fewer nodes performs at-par with the LEACH protocol but with an increase in node population the performance grows exponentially. Thus, the finding shows that the TDCH protocol outperforms the LEACH protocol. With the help of the analysis on the results, it is suggested that the primary reason behind the exemplary performance of TDCH protocol is that unlike LEACH protocol none of the nodes in the network with less remaining energy (below energy thresholds) is ever considered for the election process of cluster-heads and even the burden of a single cluster-head is shared among two cluster-heads.

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