CONSENSUS BASED DATA AGGREGATION FOR ENERGY CONSERVATION IN WIRELESS SENSOR NETWORK

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ABSTRACT

Our planet is abundant with raw data and to monitor the available data properly, processing of the enormous raw data is very vital. One of the key things in development of mankind and the nature is to acquire as much data as possible and to react appropriately in accordance with the studied data. It's nothing but diagnosis of the physical world by studying the data acquired from them in order to take proper measures that can help in treating them better. Large volume of data incurs high energy consumption for its transmission and thus results in decrease of overall network lifetime.

Wireless Sensor Network (WSN) is a collection of multiple sensor nodes that all together forms a network for transmitting data acquired by each sensor node to sink known as Base Station (BS). In hierarchical routing acquired data are sent via relay agents like Cluster Heads (CH). The Cluster Heads must be customised with computations and formulations, which will help in aggregating the gathered data, in order to reduce energy consumption while transmitting the data further in the network while maintaining the data integrity to withhold the significance of every single value in a data set.

The proposed work devised a data aggregation technique to reduce the size of data frame in Wireless Sensor Network which will have the following benefits:

- *Reduce the amount of data traffic between sensor nodes.*
- *Reduce overall energy consumption of the network.*
- *Communicating more data each round between Sensor Heads and finally to Base Station.*
- *Increase in network lifetime.*

The work performs data aggregation at bit level which produces better aggregated data as significance of all the bits are included in the data.
The consensus based data aggregation algorithm is further used to modify Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol for conserving energy and improving the network performance. Various parameters that are taken into consideration for evaluating Proposed Work protocol:

- *Operating Nodes per round*
- *Operating Nodes per Transmission*
- *Energy Consumed per Transmission*
- *Average Energy Consumed by a Node per Transmission*
- *Network Life-Time*

KEYWORDS

Wireless Sensor Network (WSN), Data Aggregation, Cluster Heads (CH), Base Station (BS), Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol

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1. INTRODUCTION

Wireless Sensor Network (WSN) is a network of multiple sensors within a physical phenomenon that communicates the collected data wirelessly. These sensors will transmit various data within the network which will be then aggregated to transform these data into reduced form, holding data integrity [8]. This aggregation of data will happen in between the sensor heads and finally to base station during data transmission and final aggregated data will be directly sent to the base station for further actions.

A sensor is a device that translates physical parameters like energy into signals that is electrical energy which are not able to be processed directly. This signal is passed through signal conditioning stage so as to make the signal able to be used further. Analogue-to-digital converter (ADC) is used to convert the signal to digital signal for further visualization, processing and storing. [16]

Wireless sensors have in-built sensing, processing, communicating and storing capabilities. These sensors form a network to analyze physical environments. The sensor nodes communicate with each other as well as to the base station either in single-hop or in multi-hop. In single-hop, each sensor node communicates directly to the base station whereas in multi-hop some sensor nodes also serve as relay agent which collaboratively propagates sensor data towards the base station. [16]

For communicating the data to the base station, LEACH protocol [17] is used. In this protocol, the sensor nodes are grouped into clusters [14] and each cluster is assigned with a cluster head, which will aggregate the data and then will transmit it either via relay agents or directly to the base station. The cluster head is selected based upon the threshold energy found by equation 2 [19] [7].

The sensor nodes are provided with limited power supply and as they are wirelessly deployed so it is very important to conserve the energy as much as possible so as to increase the network lifetime [8]. Thus, the Proposed Work protocol will help in conserving the energy of the network by reducing the data packet size during aggregation to single value which will represent the whole cluster using consensus based data aggregation at cluster head. [3]

Network Lifetime provides the sustainability of the network based upon the network energy calculated by equation 3 [7]. It can be viewed as:

1. First Dead Node: Round number in which the energy of any node in WSN gets exhausted first.

2. Half Dead Node: Round number in which the energy of half of the nodes in WSN gets exhausted.

3. Final Dead Node: Round number in which the energy of all the nodes in WSN gets exhausted.

2. LITERATURE SURVEY

Survey on Data Capturing/Processing/Transmission in WSN [9]:

The survey reveals the importance of data capturing and transmitting it after processing so as to gather important and crucial information from the data and to forward the info ahead.

TH-LEACH: Threshold Value and Heterogeneous Nodes-Based Energy-Efficient LEACH Protocol [2]:

Energy is required for a sensor node to transmit data. So to improve the lifetime of a cluster which indirectly improves the lifetime of the network, the energy of each sensor node and sensor head must be conserved as performance of wireless sensor network depends upon lifetime of the network that is directly proportional to the energy available to the network.

Energy Conservation in Wireless Sensor Networks by Exploiting Inter-Node Data Similarity Metrics [6]:

Sensor head transmits data to base station in either single hop or multiple hops. Thus sensor head takes data from sensor nodes and then transmits it after aggregation for better network performance. While accumulating data from different sensor nodes within a same cluster there is a chance of getting duplicate data. Energy can be conserved before data aggregation at sensor head by reducing duplicate data within the same cluster.

Urban Sprawl Analysis of Tripoli Metropolitan City (Libya) Using Remote Sensing Data and Multivariate Logistic Regression Model [13]:

Urban sprawl was analysed using logistic regression model in Metropolitan city (Libya). The expansion of people is quite similar to raw data that sprawls in nature. Logistic regression model validation was conducted using the relative operating characteristic (ROC) method. The validation result was having 0.86 accuracy rate. The results indicated that the logistic regression model is effective in explaining urban expansion and thus it was used in finding threshold for humidity data sensed by the wireless sensors deployed in soil.

3. PROBLEM DEFINITION

Data nowadays are enormous and to monitor the available data properly, processing of the huge data is very vital. These data takes a lot of time to get transmitted and thus delays the respond time towards the incoming data. Large volume of data incurs high energy consumption that results in decrease of network lifetime. Also during the transmission of the data via cluster heads, data integrity is very hard to achieve as the significance of every single value in a data set is tough to maintain. This leads to in-accuracy in data transmission.

4. PROPOSED SOLUTION STRATEGY

Data needs to be transmitted on time and there should be no or less data traffic within the network so that data can be responded accordingly to take corresponding action. Thus data aggregation is required within the network for conserving the energy of the network which in order increases the network lifetime and to improve the performance of the network. So aggregation part of LEACH protocol is modified so as to reduce data packet size by using consensus based data aggregation technique at cluster head, which will then reduce the energy

consumption for transmitting the data further in the network and thus will result in decrease of overall energy consumption of the network and will increase network lifetime.

5. METHODOLOGY

In this modified LEACH protocol, the consensus based data aggregation technique used at cluster heads is given as follows:

Step 0: Start
Step 1: Read Dataset.
Step 2: for i in range 1 to (length of dataset):
            Convert each decimal data to binary
Step 3.1: Apply machine learning upon the dataset by forming training and testing dataset.
Step 3.2: threshold=60% (Based upon Logistic Regression over humidity data set)
Step 4: for i in range (length of data):
            Check (value at position[i] for all the bits in data is greater than threshold)
            If(true):
                    Store 1 at ith binary position in final binary result
            Else:
                    Store 0 at ith binary position in final binary result
Step 5: Convert final binary to decimal
Step 6: Take final decimal as representative for entire dataset/cluster.
Step 7: Forward final decimal value from one cluster head to another or to base station.
Step 8: End.

The proposed algorithm installed at each relay nodes aggregates and transfer data ahead. In the given consensus based data aggregation, the data will be collected by the sensors deployed in the physical environment. Here the sensed data is humidity data [21] that describes the topological condition. Now cluster formation will take place via LEACH protocol [20]. The data collected in a cluster will be forwarded to cluster head. At cluster head all the data will be converted to binary. Now logistic regression will help to find the threshold, using equation 1, for aggregation of all the data at sensor head [1].

In Logistic Regression all the data will be trained first. Then all the data will be plotted based upon sigmoid function, which plots the data between 0 to 1 giving the probability of the dataset. Then midway the S-curve, that is obtained by applying sigmoid function, will be divided and the probability of data lying on curve after midway will be considered as 1 and rest will be 0. Thus, this will give the threshold.

$$y = \frac{1}{1 + e^{-x}} \qquad\qquad equation\ 1$$

where, y gives the value on S-curve and x are the points for which values are to be taken.

Based upon the threshold, all the data will be aggregated to single value. At every binary position for all the data simultaneously, if the percentage of 1 present at that binary position is more than that of the threshold then put 1 at the same binary position in the final aggregated value. In this way continue till all the binary positions are traversed.

Finally, a single value will be obtained at the sensor head which will represent the overall cluster holding the integrity and significance of each data in the cluster [8]. Likewise, the cluster heads, sensor nodes will transfer data finally to base station and at base station a single value will be obtained with the help of consensus based data aggregation that will be representing the entire network.

In LEACH protocol there are 2 phases [20]. First one is Set-Up phase, where the protocol decides the node which is applicable for the next cluster head in the corresponding area. Protocol also clusters the nodes of the corresponding area to the cluster head.

Process: Protocol selects the node for the cluster head on the basis of Threshold energy. Threshold energy calculated on basis of following formula :

$$t(n)= (p/ (1-p*(mod (r, 1/p))))$$ ……equation 2

Where,

t – Threshold Energy
p –No. of nodes desired per cluster
n- No. of nodes
r – Round No.

Every wireless sensor node has their own energy for sending and receiving the data. The node having energy smaller than this Threshold energy will be applicable to be a cluster head at once. In this way, every node will be cluster head, one at a time and the node which is previously allowed for the cluster head will not be allowed for the cluster head in future until every node gets a chance to be cluster head once.

Second phase is **Steady-State Phase**, Transfer and Reception of data takes place and energy dissipates continuously with transfer of data. [4] The Energy Dissipation mainly depends on the distance between the adjacent nodes where transfer is taking place [1]. It is calculated by the following formula [7];-

$$Ex= Elect*k + Amp * k * SN (i).Dist^2$$ ……equation 3

where,

Elect: Energy consumed to open and close the packet at the node.
Ex: Energy consumed units in Joules/bit
K: Total Energy units in bits
Amp: amount of energy spent by the amplifier to transmit the bits
Dist: distance between the adjacent nodes

6. IMPLEMENTATION DETAILS

Humidity data was used during simulation which helped in understanding the topological condition of a particular area. Out of the entire dataset available, 100 random humidity data are used for simulation and performing the comparison between actual and modified LEACH protocol. For analysing and responding in accordance to the sensed humidity value, the humidity data is aggregated by modifying LEACH protocol using consensus based data aggregation so as

to conserve energy of the sensors used for sensing humidity. The proposed work was evaluated against LEACH protocol.

7. DATA AVAILABILITY STATEMENT

The humidity data used to support the findings of this study have been deposited in the KAGGLE repository.

(Dataset Link: https://www.kaggle.com/yungbyun/sensor-data).
Accessed on-(23/09/2019, 9:27:59 am).

Sample dataset

Out of the overall humidity data, 20 humidity data are taken as a sample.

Table 1: Sample Dataset

1)33.06045426	2)33.09548316	3)33.08046737	4)33.10548665
5)33.10548169	6)33.10047989	7)33.12549354	8)33.13049525
9)33.14549582	10)33.14549582	11)33.12048705	12)33.15549928
13)33.14549582	14)33.15549928	15)33.15550367	16)33.1805119
17)33.18550949	18)33.20051836	19)33.20051836	20)33.20551995

8. EXPERIMENTAL RESULTS

The proposed algorithm was carried out considering following simulation parameters.

Simulation parameters

Number of nodes : 100
Area : (70 x 70) m2
Simulation time (s) : {50,100,150,200,250,300}
Data packet size (B) : 2000
Deployment : Randomly uniformly distributed
Mobility : Static
Radio module : CC2420.txt
Eelect : 50 nJ/bit
Eamp : 0.00134 pJ/bit/m4
Eaggr : 5 nJ/bit/signal

Results after applying the consensus based data aggregation algorithm over LEACH Protocol:

8.1. Operating Nodes per Rounds

Operating nodes serves the purpose of acquiring sensor data and transmitting the data through the sensor network. The result in Table 2 shows the rounds up to which the nodes remain operating by being able to acquire and transmit sensor data.

Table 2: Operating Nodes per Round

Round	Operating Nodes (Modified LEACH)	Operating Nodes (LEACH)
1000	100	100
2000	100	9
3000	76	0
4000	54	0
5000	39	0
6000	22	0
7000	13	0
8000	6	0
9000	1	0

Below graph shows the comparison among actual and Proposed Work protocol regarding the nodes being able to operate with respect to number of rounds.

Round: Round is time slot for transfer of data from one node to base station (via number of cluster heads and finally to base station).
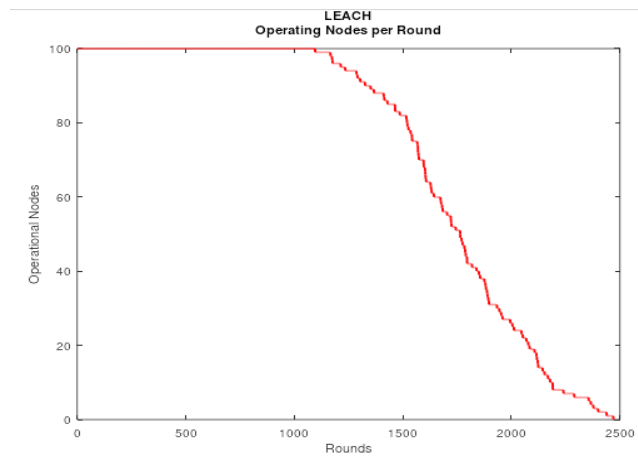
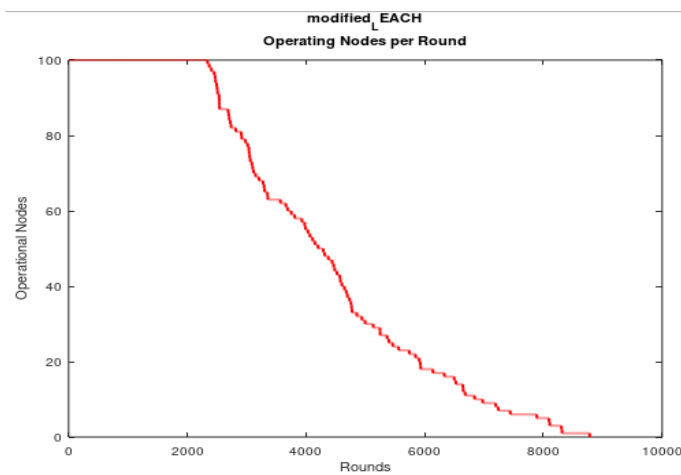Figure 1: Operating Nodes per round (LEACH)

Figure 2: Operating Nodes per round (Proposed Work)

Operating Nodes per round (LEACH) :- In Figure 1, shows the number of operating nodes per round that means in one round how many operating nodes are working. It also gives the information about how many nodes are becoming dead in each round. The other information is that after how many rounds, all the operating nodes will become dead (Life Time of the protocol on the basis of number of rounds). Operating Nodes per round (Proposed Work):- In Figure 2 shows the result after applying consensus based data aggregation at sensor head in LEACH protocol.

Advantage:

It was observed that in Figure 1, the energy of all the operating nodes is getting exhausted by 2500 rounds whereas In Figure 2, all operating nodes are surviving till 8000+ rounds making the proposed technique more efficient than that of LEACH. Network Life time Gain Percentage per round= 68.75%

8.2. Operating Nodes per Transmission

The result in Table 3 shows the number of nodes that remains operating by being able to acquire and transmit sensor data per transmission.

Table 3: Operating Nodes per Transmission

Transmission	Operating Nodes (Modified LEACH)	Operating Nodes (LEACH)
1000	100	100
2000	100	0
3000	75	0
4000	53	0
5000	34	0
6000	17	0

Figure 3 and 4 shows the comparison among actual and Proposed Work protocol regarding the nodes being able to operate per transmission.

Transmission: Transmission is the time slot for transfer of data from one node to base station or one node to cluster head or cluster head to cluster head or cluster head to base station.
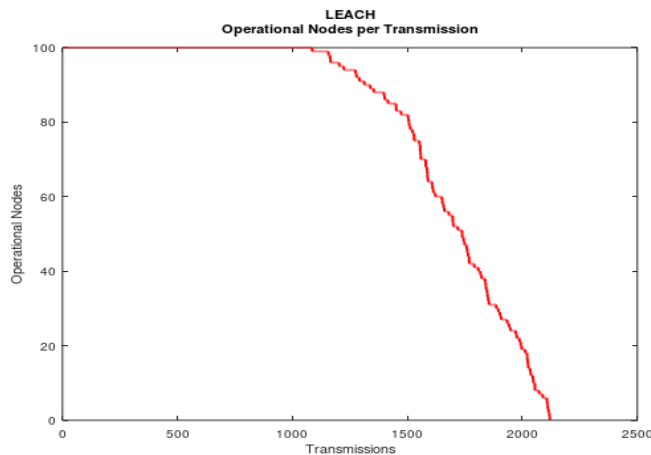

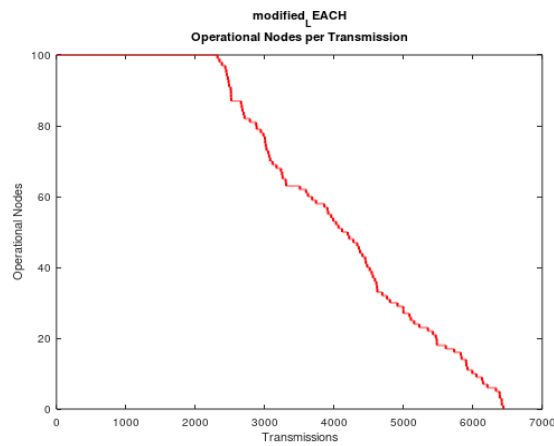Figure 3: Operating Nodes per Transmission (LEACH)

Figure 4: Operating Nodes per Transmission (Proposed Work)

Operating Nodes per Transmission (LEACH): - Figure 3 gives the information about the number of operating nodes per transmission that means in a transmission how many operating nodes are working. It also gives the information about how many nodes are becoming dead in which transmission. The other information is that after how many transmissions, all the operating nodes will become dead (Life Time of the protocol on the basis of number of transmissions).

Operating Nodes per Transmission (Proposed Work): - In Figure 4,it gives the same information as Figure 4 gives but this gives the information about the modified leach (i.e. consensus based leach).

Advantage:

It was observed that in Figure 3 (LEACH protocol), all the operating nodes were dead before 2500 transmissions whereas in Figure 4 (Proposed Work), all operating nodes are becoming dead after 6000 transmissions. Network Life time Gain Percentage per transmission= 58.33%

8.3. Energy consumed per transmission

Energy consumed denotes the energy associated to a node, after consuming certain amount of energy from available energy of the node, for acquiring, aggregating and transmitting the sensor data. The following result shows the energy consumed by the network per transmission.

Table 4: Energy consumed per transmission

Transmission	Energy(J) (Modified LEACH)	Energy(J) (LEACH)
1	0.041413	0.116246
201	0.0984561	0.111358
401	0.0513913	0.114959
601	0.0129045	0.135568
801	0.0298366	0.138249
1001	0.039545	0.126957
1201	0.0422535	0
1401	0.0852474	0
1601	0.0447934	0
1801	0.0155833	0
2001	0.0286065	0
2201	0.0627182	0

Figure 5 and 6 shows the comparison between LEACH and Proposed Work protocol regarding the network consuming energy per transmission.
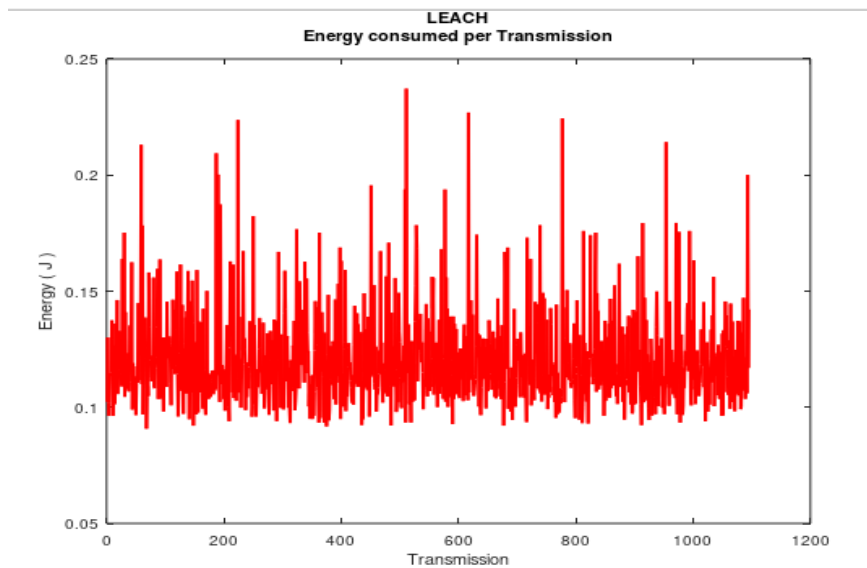

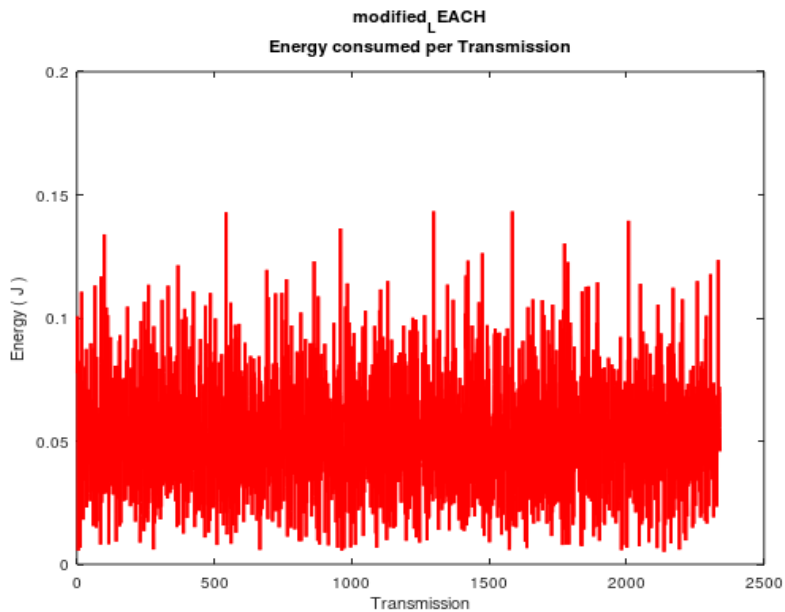Figure 5: Energy Consumed per Transmission (LEACH)

Figure 6: Energy Consumed per Transmission (Proposed Work)

Every node has their own energy to do their works. For transferring and reception of data, some energy will be consumed.

Energy Consumed per Transmission (LEACH):- Figure 5 shows the energy consumption of the nodes at every transmission in LEACH protocol.

Energy Consumed per Transmission (Proposed Work):- Figure 6 shows the energy consumption of the nodes at every transmission in modified LEACH protocol.

Energy consumption basically depends on the distance between the adjacent nodes. It was calculated by equation 3:

$$Ex= Elect*k + Amp * k * SN (i).Dist2 \qquad .... equation\ 3$$

Advantages:

It was observed that in Figure 5 (LEACH protocol), energy consumption of the node starting in the range from 0.1 to 0.15 whereas in Figure 6 (Modified LEACH protocol), energy consumption of the node starting in between the range from 0.01 to 0.05.

In the Figure 5 (LEACH protocol), energy consumption of the node was ending in between the range from 0.13 to 0.22 whereas in Figure 6 (Modified LEACH protocol) energy consumption of the node was ending before 0.15.

The aggregation of the waves in Figure 6 is more than the aggregation of the waves in Figure 5. This implies that at some instant of time, more transmissions can take place with less amount of energy.

8.4. Average Energy consumed by a node per transmission

The following result shows the overall average energy consumed by the network per transmission.

Table 5: Average Energy consumed by a Node per Transmission

Transmission	Energy(J) (Modified LEACH)	Energy(J) (LEACH)
1	0.041413	0.116246
201	0.0984561	0.111358
401	0.0513913	0.114959
601	0.0129045	0.135568
801	0.0298366	0.138249
1001	0.039545	0.126957
1201	0.0422535	0
1401	0.0852474	0
1601	0.0447934	0
1801	0.0155833	0
2001	0.0286065	0
2201	0.0627182	0

Figure 7 shows the comparison among actual and Proposed Work protocol regarding the average energy consumed by the entire network per transmission.
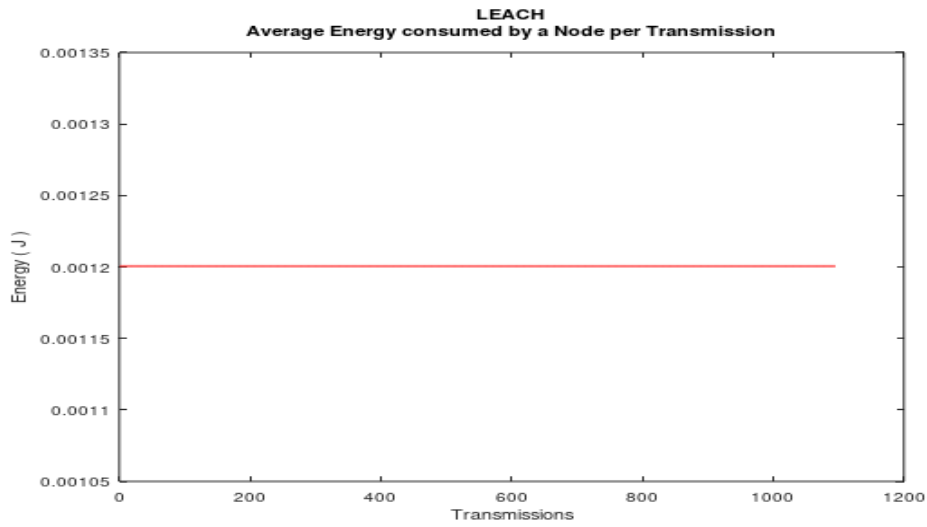
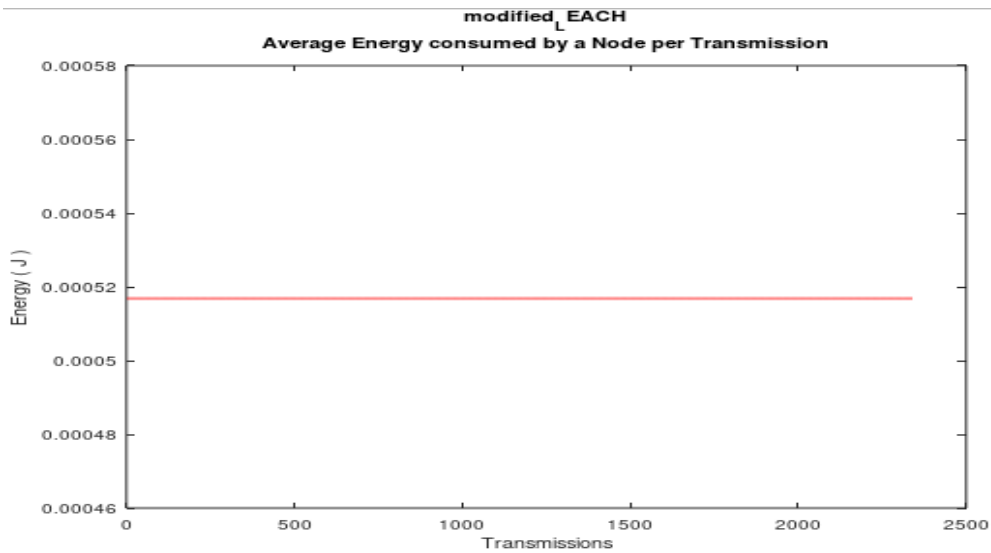Figure 7: Average Energy Consumed by a Node per Transmission (LEACH)

Figure 8: Average Energy Consumed by a Node per Transmission (Proposed Work)

Figure 7 (LEACH protocol) shows the average of the energy consumed by the nodes. Figure 8 (Modified LEACH protocol) shows the average of the energy consumed by the nodes.

Advantage:-

In Figure 7, Average energy consumed=0.0012.
In Figure 8, Average energy consumed=0.00052.

This gives a significant amount of conservation in energy consumption while using Proposed Work protocol using consensus based data aggregation.

Increase in average Energy consumption Percentage =56.667%

8.5. Network Life-Time

The lifetime of a network is determined by the quantity of nodes that remain operational over period of time. First node dead is considered as the round at which the first node of the network uses all its available energy and gets exhausted and thus fails to operate further. Similarly, Half node dead is considered as the round at which half of the nodes of the entire network uses all their available energy and gets exhausted and thus fails to operate further. All nodes dead is considered as the round at which every node in the entire network uses all their available energy and thus the network becomes dead as not a single node in the network is capable to operate further.

Table 6 and 7 shows the comparison among actual and Proposed Work protocol regarding the lifetime of the entire network upon parameters like first node dead, half nodes dead and all nodes dead.

Table 6: Network Life-Time (LEACH)

LEACH protocol	Round
First Node Dead	1140
Half Nodes Dead	2183
All Nodes Dead	2594

Table 7: Network Life-Time (Proposed Work)

Proposed Work protocol	Round
First Node Dead	1410
Half Nodes Dead	4177
All Nodes Dead	8518

As shown in Table 6, First Node is becoming dead at round number 1140 and half of the nodes are becoming dead at round number 2183 and all nodes are becoming dead at round number 2594.

As shown in Table 7, First Node becoming dead at round number 1410 and half of the nodes are becoming dead at round number 4177 and all nodes are becoming dead at round number 8518. Thus Proposed Work protocol gives an advantage over total network lifetime by decreasing the energy consumption of the entire network.

Network lifetime percentage increased=69.94%

8.6. Data aggregation at each round

Data aggregation is done by consensus based data aggregation algorithm applied during modifying the LEACH protocol.

Table 8 shows the cluster and cluster head formation at each round along with the values of each node inside the cluster and the final aggregated value found after data aggregation at each round.

Table 8: Aggregated data at base station per round

Round	Cluster Head/s	Nodes	Values	Aggregated Value	Final aggregated Value at base station
1	2	3, 8, 9, 10, 14, 16	33.08046737, 33.13049525, 33.14549582, 33.14549582, 33.15549928, 33.1805119	33.125	33.125
	20	1, 4, 5, 6, 7, 11, 12, 13, 15, 17, 18, 19	33.06045426, 33.10548665, 33.10548169, 33.10047989, 33.12549354, 33.12048705, 33.15549928, 33.14549582, 33.15550367, 33.18550949, 33.20051836, 33.20051836	33.125	
2	9	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	33.06045426, 33.09548316, 33.08046737, 33.10548665, 33.10548169, 33.10047989, 33.12549354, 33.13049525, 33.14549582, 33.12048705, 33.15549928, 33.14549582, 33.15549928, 33.15550367, 33.1805119, 33.18550949, 33.20051836, 33.20051836, 33.20551995	33.125	33.125

The snapshot of the output obtained while aggregating data at each sensor head in Table 8 shows the formation of clusters and cluster heads and how the nodes are grouped into clusters and the details of data aggregation per round.

9. CONCLUSION

It was observed that in comparison to the LEACH the proposed technique has,

a) Operating nodes will live longer in modified LEACH protocol as they will be functional for more rounds in comparison with LEACH protocol.

b) Operating nodes will perform better in modified LEACH protocol as they will be able to do more transmissions in comparison with LEACH protocol.

c) Energy consumption per round is less in case of modified LEACH protocol.

d) Average energy consumption is less for modified LEACH protocol in comparison to LEACH protocol.

e) Proposed Work protocol is better performing as,

- Network Life time Gain Percentage per round= 68.75%
- Network Life time Gain Percentage per transmission= 58.33%
- Average energy consumed in LEACH protocol = 0.0012J
- Average energy consumed in modified LEACH protocol =0.00052J
- Increase in average Energy consumption Percentage=56.667%
- Network Lifetime percentage=69.94%

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