Enhanced LEACH for Distributed Clustering in Heterogeneous Wireless Networks

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Abstract:
Wireless networks have recently come into importance because they hold the potential to revolutionize many segments. Since wireless nodes have battery constraints that limits lifetime of wireless network, Energy management plays a vital role in improving network life time in wireless sensor and ad hoc networks. In Wireless Sensor network, performance of Routing and energy consumption of wireless nodes are determined by distributed clustering algorithm which is used to distribute the energy and load balancing among nodes by promoting an appropriate node as coordinator. In wireless Ad hoc networks, there is no fixed topology and communications between nodes occur through sink node. An efficient energy rich node is to be elected as sink node dynamically in order to coordinate routing. So, this research focuses to compare the present distributed clustering algorithm (LEACH) with EEDCBRP for wireless Ad Hoc and Sensor network. During this study, LEACH algorithm which is used to select cluster head, shows some drawbacks that need improvements to overcome it as to improve the performance. This proposal uses energy level and distance of node to select cluster head. In the wireless network, Base station maintains the table to hold the information about energy and location of the wireless nodes. After receiving the information about all sensor nodes, base station performs the clustering process. Mobile nodes are grouped into the layer based clusters by checking energy and distance. The improvement is done in cluster head selection procedure. Finally the performance of proposed algorithm is compared with Low Energy adaptive clustering hierarchy. Network Simulator (NS2) is used to simulate and evaluate the performance. The results of simulation show that Enhanced Distributed Clustering Routing protocol effectively balances energy consumption of wireless node.

Keywords: Sensor Networks, Ad Hoc Networks, LEACH, Clustering

1. Introduction

In the WSN, energy efficiency is major challenges because wireless network support device are movable therefore they consume more battery power in sensor nodes. When changing in topology or moving from one base station to another base station, can cause more battery life. In wireless network ad Hoc and sensor each node dynamically forms a temporary network without any existing infrastructure or central administration.

LEACH is one of the distributed clustering protocols used to minimize energy consumption in wireless network. There are two phases in leach such as set up and steady phase. In set up phase cluster are grouped and elect randomly the cluster head for the clusters. In steady phase data or the information transferred from cluster head to base station. There is some drawback of leach are select CH randomly among the cluster nodes and CH consumes more energy. So, there is high possibility for each node to be elected as cluster head at each round. As a result, each node which is a candidate for the election consumes much energy. Cluster Head election process is carried out frequently, Selection process itself consume more energy in the system.

LEACH algorithm which is used to select cluster head, shows some drawbacks that need improvements to overcome it as to improve the performance. This proposal uses energy level and distance of node to select cluster head. In the wireless network, Base station maintains the table to hold the information about energy and location of the sensor. After receiving the information about all sensor nodes, base station performs the clustering process. Sensor devices are grouped into the layer based clusters by checking energy and distance. The improvement is done in cluster head selection procedure and the performance of proposed algorithm is compared with Low Energy adaptive clustering hierarchy

Distributed clustering algorithm is used to balance energy dissipation among nodes and extend the network lifetime. According to Mamta (2014) perspectives, there are two types of wireless sensor networks such as structured and unstructured networks. Structured networks have fixed topology and unstructured network have not fixed topology therefore, wireless sensor networks are unstructured network because often change their topology. Clustering is the way of grouping similar cluster node and arranging cluster head for them, so through cluster head information was flowed for all nodes in the cluster. There are different types of distributed clustering protocols such as Event-to-Sink Directed Clustering, Load balanced clustering scheme, K-means algorithm, Low-Energy Adaptive Clustering (LEACH), Hybrid Energy-Efficient Distributed clustering (HEED), Energy Efficient Hierarchical Clustering (EEHC), Weight-Based Clustering Protocols (WCP) and etc. the researcher will

concentrated on leach and improve the existing leach protocols to increase efficiency of energy in the wireless environment.

Low-Energy Adaptive Clustering Hierarchy (LEACH) is distributed clustering algorithm and there are two phases to select cluster head. Set up phase and steady phases. In set up phase, the clusters nodes are formed and randomly select cluster head from the cluster node. In the steady phases the cluster head chosen and broadcasts itself for the neighbor nodes.

Energy efficient homogenous clustering algorithm is used for wireless sensor network to increase life span of the network. (Shio kumar Singh et al., 2010). In this clustering algorithm, energy efficiency is distributed and network performance is improved by selecting cluster head on the basis of residual energy and nearest hop distance of the node. The cluster members are uniformly distributed and the life of the network is further extended. The author (Kumar et al., 2014) proposed that sensor nodes are grouped in to hierarchal by clusters. In the clustered sensor networks the sensor node does not directly communicates with base station but there is designated cluster head with aggregate data packets and send them via multi hop communication to the base station. The one of the effective approaches used to save energy in wireless sensor network are clustering techniques.

The authors suggested that (Sanjeev Jain et al, 2011) to increase energy efficiency in Wireless Sensor Networks (WSNs) the paths for data transfer are selected in such a way that the total energy consumed along the path is minimized. There are challenges in wireless sensor networks, because In WSN sensor nodes have limited processing power, communication bandwidth, and storage space. This gives rise to new and unique challenges in data management and information processing.

The best way to save energy in the WSN are clustering technique(Deepak Kumar Yadav et al., 2013) defined as grouping or organizing sensor nodes in to different clusters and in each cluster, there is group coordinator called cluster head (CH). The responsibility of CH is collect all information from sensor nodes, and then sends to base station.

There are two types of clustering procedures in wireless networks such as distributed and centralized clustering. In the distributed clustering each sensor node can route their own algorithm and takes the decision of becoming CH. And in the centralized clustering, a central authority groups the nodes to form clusters and cluster heads. There are different cluster properties in cluster nodes

- Cluster count. Is number of clusters formed in a round
- Cluster size: is the maximum path length among the cluster nodes from CH.
- Cluster density: defined as the number of cluster member in the cluster and cluster area.

Message count is the number of message transmission requiring for CH selection. More number of message transmission lead to large amount of energy consumption for CH selection procedure.

There are two phases in Leach protocols such as a set-up phase and a steady-state phase. In the set-up phase, the clusters are constructed, and in the steady-state phase, the data is acquired and transferred. Once the steady-state phase is finished, the next iteration begins. a big challenges in wireless sensor network (Amandeep Kaur et al.., 2015) are routing because sensors have limited battery power. To solve those problems there are many routing technique which increase lifetime of battery.

Various routing protocols are available to increase the lifetime of network. Hierarchical routing protocols are more energy efficient routing protocols. In this network is divided into various clusters. In every cluster, single node is considered as a cluster head (CH) and non-cluster head nodes are treated as cluster members (CM).In every cluster, cluster head gathers the data from the cluster members and aggregate this data and broadcast this data to Base station through single-hop or multi-hop. CHs utilize more energy than the CM. So clustering protocols distributes the load of the CHs amongst the sensor nodes and their role is revolved among all nodes for energy-consumption equalization.

Distributed clustering algorithm is used to balance energy dissipation among nodes and extend the network lifetime. According to mamta (2014) perspectives, there are two types of wireless sensor networks such as structured and unstructured networks. Structured networks have fixed topology and unstructured network have not fixed topology therefore, wireless sensor networks are unstructured network because often change their topology. Clustering is the way of grouping similar cluster node and arranging cluster head for them, so through cluster head information was flowed for all nodes in the cluster. There are different types of distributed clustering protocols such as Event-to-Sink Directed Clustering, Load balanced clustering scheme, K-means algorithm, Low-Energy Adaptive Clustering (LEACH), Hybrid Energy-Efficient Distributed clustering (HEED), Energy Efficient

Hierarchical Clustering (EEHC), Weight-Based Clustering Protocols (WCP) and etc. the researcher will concentrated on leach and improve the existing leach protocols to increase efficiency of energy in the wireless environment.

2.1. Proposed System

Low-energy adaptive clustering hierarchy is a TDMA-based MAC protocol which is integrated with clustering and a simple routing protocol in Wireless Networks. The goal of LEACH is to lower the energy consumption required to create and maintain clusters in order to improve the life time of a wireless sensor network.

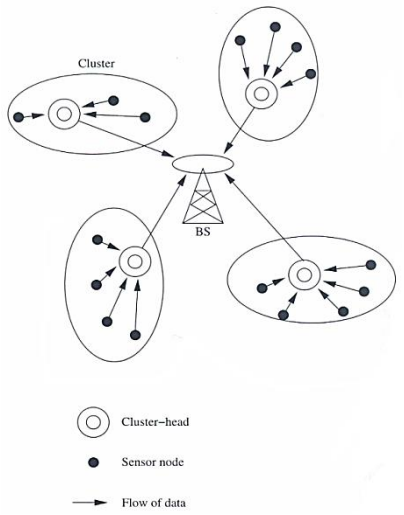

Figure 2.1 Distributed Clustering

LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). Each node uses stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the baseStation or the nearest cluster head, but that using this radio at full power all the time would waste energy. Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired percentage of cluster heads. Thereafter, each node has a 1/P probability of becoming a cluster head again. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data.

2.2 Setup Phase

During the setup phase each node generates a random number between 0 and 1. If the random number is smaller than the threshold value then that node becomes CH. The threshold value is calculated based on the following equation [1] that is given below: - Here p is the desired percentage of cluster heads and r is the current round, G is the group of nodes that has not been the CHs in the last rounds. The sensor node that is selected as a CH in previous round is not selected in the next rounds until all other nodes in the network becomes cluster heads.

The threshold T (n) is calculated as

$$T(n) = \frac{P}{1-P\left[r \; x \; mod \left\lfloor \frac{1}{P} \right\rfloor\right]} \quad if \; n \in G \text{ otherwise}$$

P: the percentage of nodes which are cluster-heads

r: the current round

G: the set of nodes that has not been cluster-heads in the past 1/P rounds

After selection, the cluster-heads advertise their selection to all nodes. All nodes choose their nearest cluster-head by signal strength (RSSI). The cluster-heads then assign a TDMA schedule for their cluster members.

2.3 Steady Phase

In the steady phase, nodes send their data to the cluster head using a TDMA (Time Division Multiple Access) schedule. TDMA schedule allots time slots to every node. The CH aggregates the data and send it to the base station sensor nodes are grouped to form clusters and each cluster is having a Cluster Head. The cluster head

collects data from the nodes of its cluster and then it send the aggregated data to the base station. The nodes in the cluster do not directly communicate with the base station [1].

2.4 Proposed Algorithm

The Base station executes the BS_Timer to broadcast the BS Hello message as network wide broadcast message. Sensor devices receive the BS_Hello message and stores the id & location of the base station. These sensor devices initiates sensorHello message which contains the energy, distance and location information about the device to the base station.

Base station maintains the table to hold the information about energy and location of the sensor. After receiving the information about all sensor nodes, base station performs the clustering process. Sensor devices are grouped into the layer based clusters by checking energy and distance. For each clusters, expansion parameter is validated by checking the connectivity between the nodes for the verification of the clusters stability.

Once clusters formed, the cluster information is broadcasted by the base station to the sensor devices. The member nodes are joined with the corresponding cluster head based on the energy, distance and characteristics of wireless mobile node. Cluster head maintains the member list while receiving the join message from the member nodes. Cluster head allocates communication channel for each nodes in the cluster using TDMA. Then node transfers data to base station through cluster head, when it gets its turn. In this research, for choosing the cluster head, distance, residual energy add the characteristic of a wireless mobile node into the evaluation formula, such that the nodes chosen as cluster heads may have a better behavior in heterogeneous wireless networks than those without the additional factor. The degree of a node is computed based on its distance from others. A node x is considered to be a neighbor of another node y if x lies within the transmission range of y. Transmission range is the average distance of the all the nodes from the base-station. The parameter defined in the proposed algorithm is defined in Table 2.1

Table 2.1. Various Parameters used in the algorithm

Parameters	**Description**
P	Probability of node to be a cluster head
node_distance (i)	Distance of ith node from base station
S(i).xd , S(i).yd	Location of the ith node
sink.x , sink.y	Location of the base station S(i).
E	Energy of ith node
ETX	Transmit energy
EDA	Data aggregation energy
Efs , Eamp	Transmit amplifier energy
rmax	Maximum number of rounds
Eavg	Average energy of the node
Cnode	node characteristics
n	number of nodes

2.5. EECBRP Procedure

Step 1: BS broadcast “BS_Hello” message

Step 2: wireless mobile node with in the coverage area receive it and store BS id and location.

Step 3: node sends its location, energy, distance, nature of node details to BS through

“nodeHello” message.

Step 4: BS records all node details in database

Step 5: BS does clustering operation based on information in database

Step 6: mobile devices are grouped in to the layer based cluster

Step 7: for each cluster expansion parameter is validated by checking connectivity between nodes for verification of the cluster stability.

Step 8: cluster information is broadcasted to all mobile nodes.

Step 9: one node is promoted as cluster head based on energy + distance

Step 10: information about cluster head is initiated to all the nodes in the cluster.

Step 11: step 9 &10 is repeated, so that other nodes get chance to become as CH

Step 11a: CH creates TDMA schedule for each node

Step11b: enter in to steady phase to transmit data

Step12: energy efficiency & performance is measured

2.6 Cluster Head Selection Formation Algorithm

Step-1: Create mobile wireless Network Model with Sensor and Ad Hoc nodes

Step-2: Assign initial energy to sensor nodes.

Step-3: Sort the nodes based on the distance from Base station using Bubble Sort in increasing order.

To calculate node-distance from Base-Station the given formula is used:-

node_distance (i) = √ ((S(i).xd-(sink.x))^2+(S(i).yd-(sink.y))^2)

Step-4: For round=1 assign cluster heads based on minimum distance from the base-station. No of Cluster Heads for round-1= (p*n). Decrease the energy of the nodes chosen as cluster head by the formula as mentioned below by checking the conditions:-

If (node_distance (i) > do)

S(i).E = S(i).E- ((ETX+EDA)*(4000) + Emp * 4000 * (node_distance(i) *

node_distance(i) * node_distance(i) * node_distance(i)));

else

S(i).E = S(i).E - ((ETX+EDA)*(4000) + Efs*4000*(node_distance (i)*

node_distance(i)));

Step-5: For the next round r =1:1: rmax

If (S(i).E >=Eavg) then

i = nominee_clusterhead //nominated for cluster-head selection

Calculate node-degree of the chosen nominee for cluster heads

If (node_degree>=avg_degree)

If the neighbourhood of the nominee cluster head is not a cluster head then

i=cluster head //cluster-head selected

Step-6: Dead node: if (S(i).E = 0) then Dead=i //ith node dies

n=n-dead //n: decrease no of alive nodes

Step-7: Go to step-5

Step-8: End

2.7 Energy Calculation

The following is the formula used to calculate total cluster distance. [19]

Total Cluster Distance = $\sum_{i=1}^{i=n} distance\ (i, CH)$

Where, N is number of nodes, CH denotes Cluster-Head and the distance of ith node to Cluster Head - Distance (i, CH)

For finding m bit data over a distance d, total energy consumed by a node

E_{Tx} (m,d) = $E_{Tx\text{-}dc}$ (m) +$E_{Tx\text{-}am}$ (m,d)

Hence, the Total Transmission Energy for transmitting m bit over a distance d is calculated by using the following formula.

$ETx(m,d) = mxE_{dc} + (mx\ E_{fs} x\ d^2)\ d<do$

$Mx\ E_{ch} + (mxE_{am} x\ d^4)\ d>do$

And also receiving m bit of data,

$ERx(m) = mx\ E(elect)$

3. Experimental Setup

Simulation environment is created with different sets of wireless and ad hoc nodes (50, 75,100,125 & 150) using NS2. The total simulation area for all scenario if fixed with (500m X 500m) and number of rounds to be carried out in each scenario to choose the cluster head is 100. It is set the minimum probability for becoming a cluster head (minimum probability) to 0.1 and initially energy given to each node is 500J.

A few reasonable assumptions of the network model are made based on [13] and they are:

- There exists only one base station and it is fixed at a far distance from the sensor nodes.
- The sensor nodes are homogeneous and energy constrained with uniform energy.
- Sensor nodes are immobile and all nodes are able to reach BS.

The RAM size for each node must be sufficient enough to store the distance of the node from BS.

- The base station is situated at the center of the area space.
- Clusters and nodes are static.
- Normal nodes transmit directly to their respective cluster heads within a particular cluster. The desired parameters are shown in Table.

Table 3.1Various Parameters used in the Simulation Environment

Parameters	Description
Simulation Size	500m X 500m
No of Nodes	150
Sink Node	at (100,100)
Electric Energy (Elect)	70nJoul
Transmit Amplify Energy (Eamp)	120nJoul
Data Aggregation Energy EDA	5nJoul
Initial Energy	500Joul
No of Rounds	100
Maximum Simulation Time	3600s
No of Clusters	10
Node Distribution	Random

The following figure shows the experimental setup with 100 node and a base station with 10 clusters. Each node has been set initial and transmission energy. The modified clustering algorithm is set with the above said parameters.

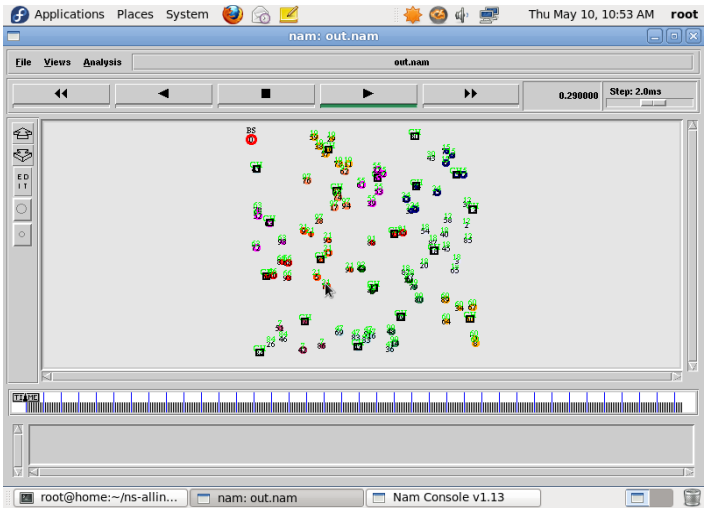

Figure 3.1 Simulation with 100 Nodes

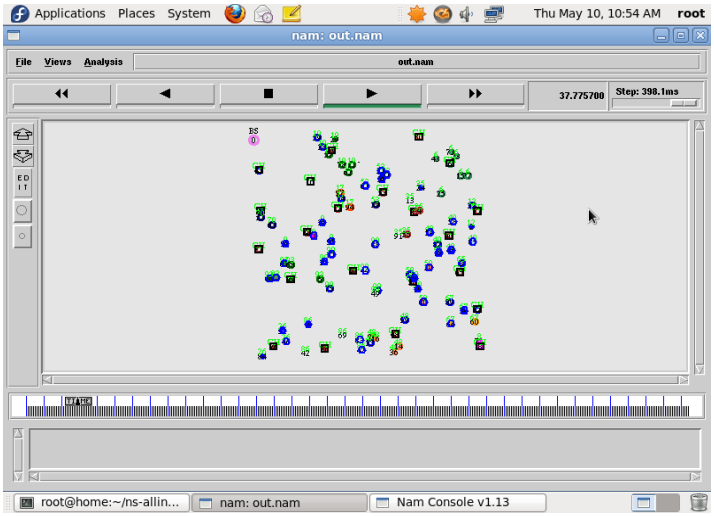

Figure 3.2 Simulation with 150 Nodes

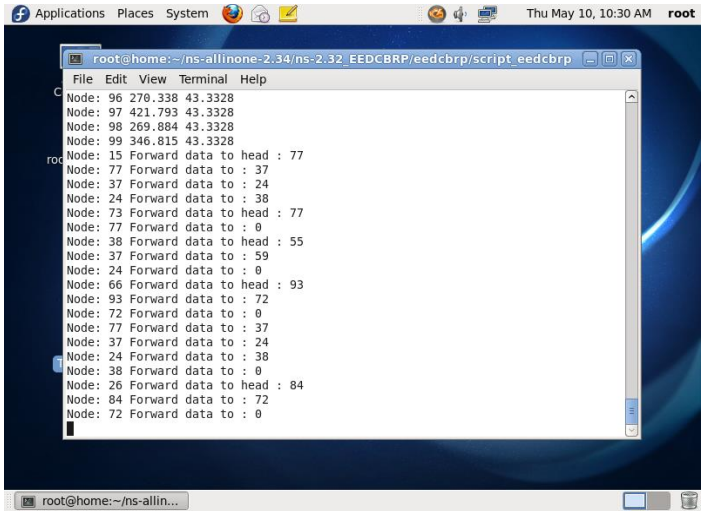

Figure 3.3 Cluster Head Selection Process

In the simulation environment, initially, the Base station executes the BS_Timer to broadcast the BS Hello message as network wide broadcast message. Sensor devices receive the BS_Hello message and stores the id & location of the base station. These sensor devices initiates sensorHello message which contains the energy, distance and location information about the device to the base station. Base station maintains the table to hold the information about energy and location of the sensor.

After receiving the information about all sensor nodes, base station performs the clustering process. Sensor devices are grouped into the layer based clusters by checking energy and distance. For each clusters, expansion parameter is validated by checking the connectivity between the nodes for the verification of the clusters stability. Once clusters formed, the cluster information is broadcasted by the base station to the sensor devices. The member nodes are joined with the corresponding cluster head based on the energy, distance and characteristics of wireless mobile node. Cluster head maintains the member list while receiving the join message from the member nodes. Cluster head allocates communication channel for each nodes in the cluster using TDMA. Then node transfers data to base station through cluster head, when it gets its turn.In this research, for choosing the cluster head, distance, residual energy add the characteristic of a wireless mobile node into the evaluation formula, such that the nodes chosen as cluster heads may have a better behavior in heterogeneous wireless networks than those without the additional factor.

4. Results and Discussion

4.1. Packet Delivery Ratio (PDR)

Packet delivery ratio is packets successfully received from the total sent packets or total received packet from total sent packet. PDR measured in number of bits per second.

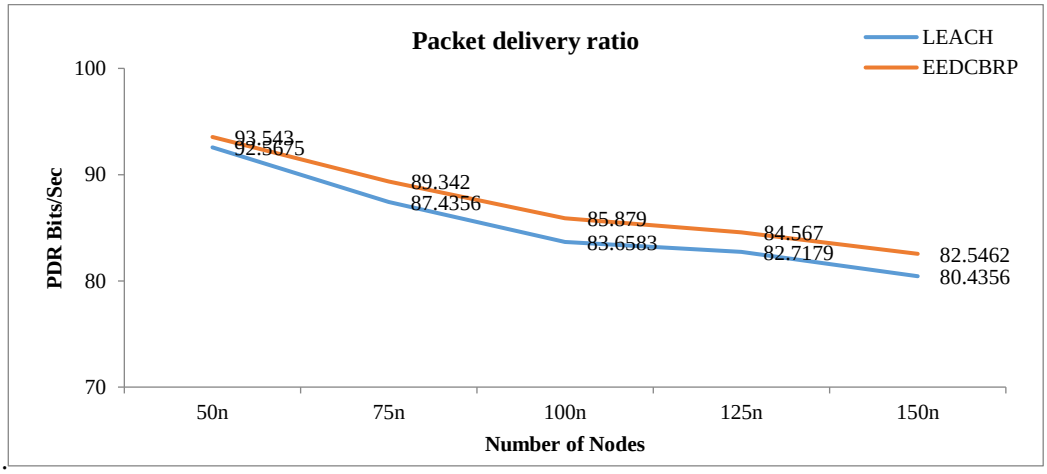

Figure 4.1PDR

The Packet Delivery Ratio is calculated using EEDCBRP and LEACH with 50, 75, 100, 125 and 150 nodes. The result shows that there is an improvement between 2% to 2.5% in every scenario.

4.2. Packet Delay

Delay refers to the time taken for a packet to be transmitted across a network from source to destination or the time taken to reach from source to destination. i.e End-to-end delay or one-way delay.

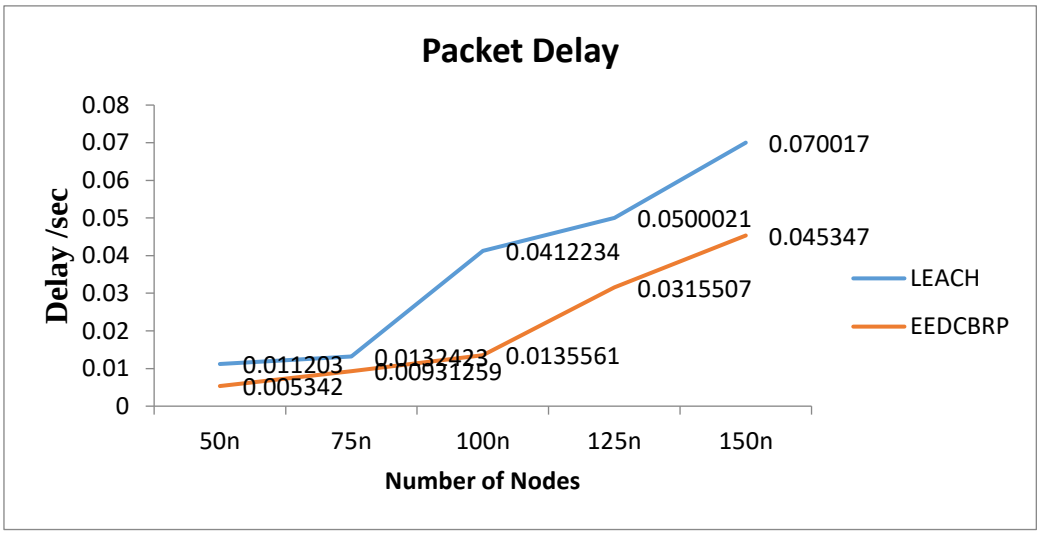

Figure 4.2.Delay

The delay in packet delivery Ratio is evaluated for EEDCBRP and LEACH with 50, 75, 100, 125 and 150 mobile and sensor nodes. The result shows that the enhanced energy distributed clustering based routing protocol yields minimum of 0.01s less delay time when compare to LEACH.

4.3. Packet Dropped Ratio

A Packet drop refers to number of lost Packet occurs when packets sent from source to each the destination. The total number of packets dropped in each node at the time of simulation is calculated for EEDCBRP and LEACH with 50, 75, 100, 125 and 150 mobile and sensor nodes.

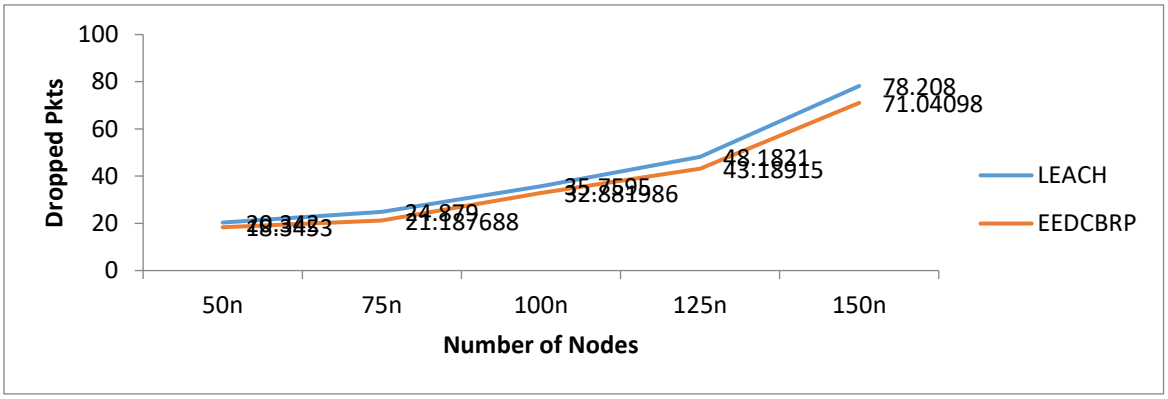

Figure 4.3.Packet Drop

The result shows that the enhanced energy distributed clustering based routing protocol minimizes the packet drop with minimum 2% to 3% when compare to LEACH.

4.4. Average Energy Consumption

Average energy consumption refers the total amount of energy used in the node to do specific tasks. The average amount of energy required for performing cluster head selection process by every node is calculated for every scenario for EEDCBRP and compared with LEACH.

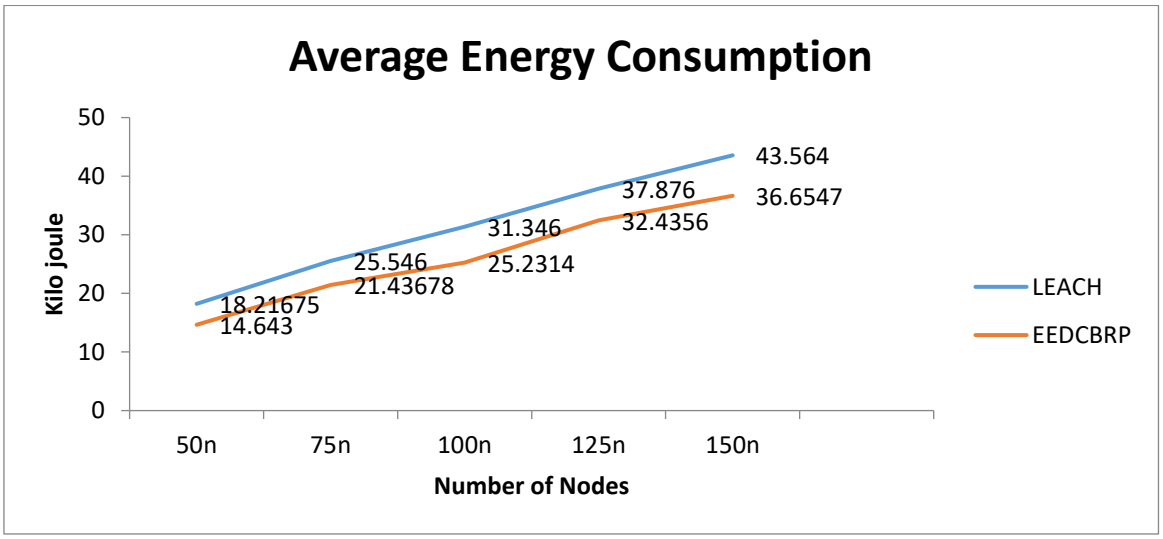

Figure 4.4 Average Energy Consumption

The result shows that the enhanced energy distributed clustering based routing protocol saves minimum of minimum 4% to 5% of energy when compare to LEACH.

4.5. Average Residual Energy

An Average Residual Energy can be considered as the remaining energy for each nodes. The average amount of remaining energy at each node is calculated while performing cluster head selection process with different rounds for every scenario of EEDCBRP and compared with LEACH

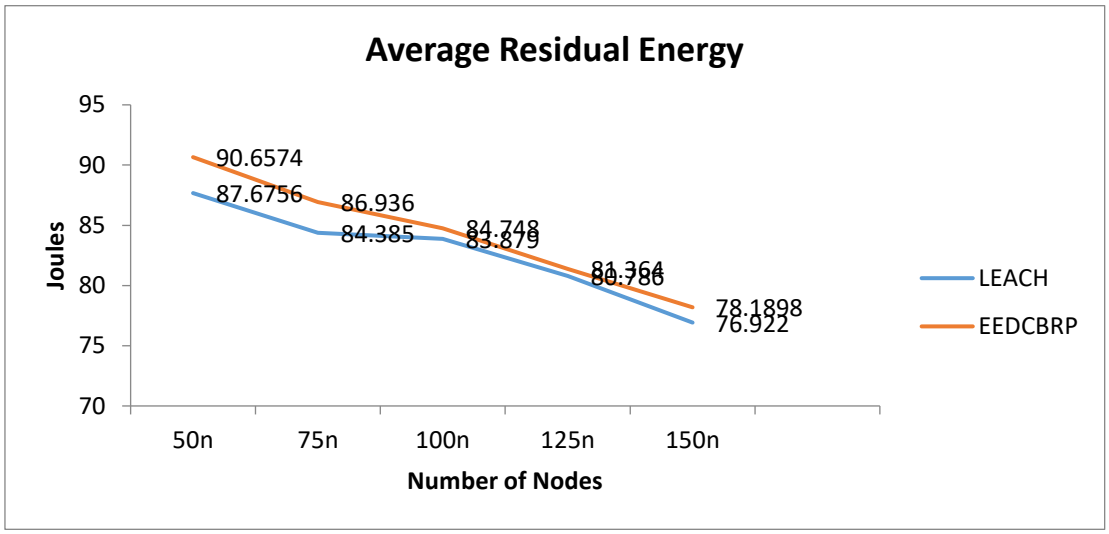

Figure 4.5 Average Residual Energy

The result shows that the EEDCBRP consumes less energy. Average amount of remaining energy in each node is 3% to 4% higher when compare to LEACH.

4.6 Jitter

Jitter is defined as a difference in packet transmission delay of received packet. Jitter sometimes will occur by improper queuing, network contention and configuration errors.

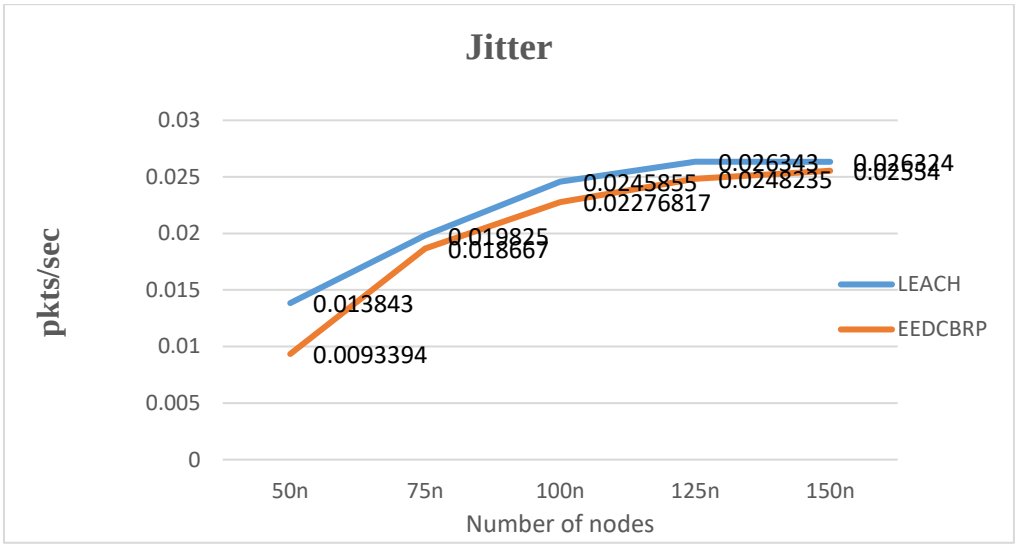

Figure 4.4. Jitter

The Jitter value for is calculated for every scenario for EEDCBRP and compared with LEACH. The result shows that the enhanced energy distributed clustering based routing protocol has minimum jitter value when compare to LEACH.

4.7 Throughput

Throughput can be defined as the amount of data or traffic that can flow through a network at a given time. Throughput of the each scenario is evaluated while performing cluster head selection process with different rounds and compared with LEACH

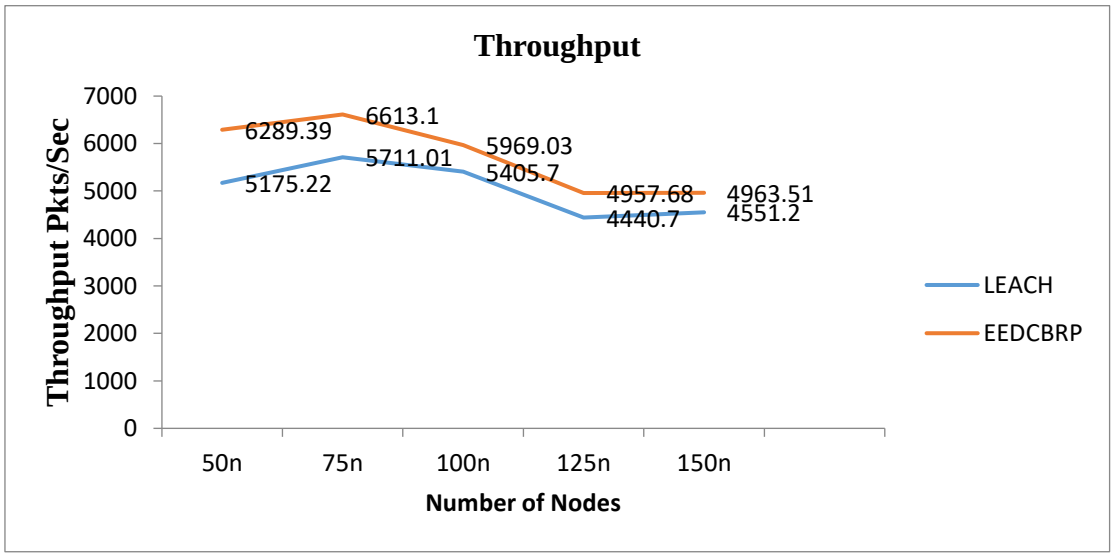

Figure 4.5: Throughput

The result shows that the EEDCBRP yields better throughput than LEACH. It improves minimum 5 to 7% of increase in throughput.

4.8. Control Overhead

The Control Overhead of the network scenarios are evaluated for EEDCBRP for 50, 75, 100, 125 and 150 and compared with LEACH.

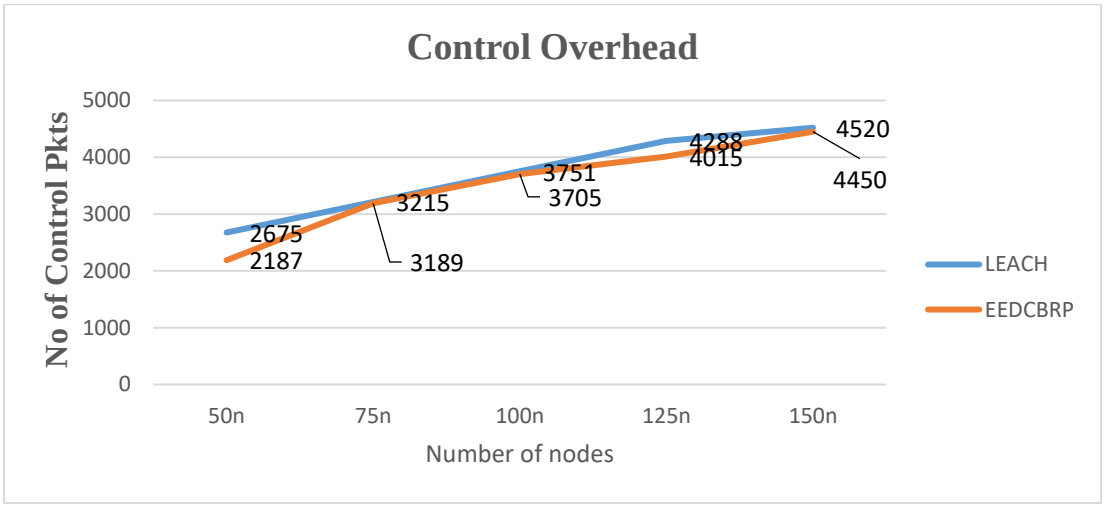

Figure 4.6.Control Overhead

The result shows that the EEDCBRP does not increases any control overhead in any of the scenario. Intern it yields less overhead when compare to LEACH.

4.9. Total Energy Consumption

Total energy consumption is defined as total amount of energy level for each nodes. The Total energy consumed by each node of all scenarios are recorded. The total energy consumption of the each scenario with EEDCBRP compared with LEACH.

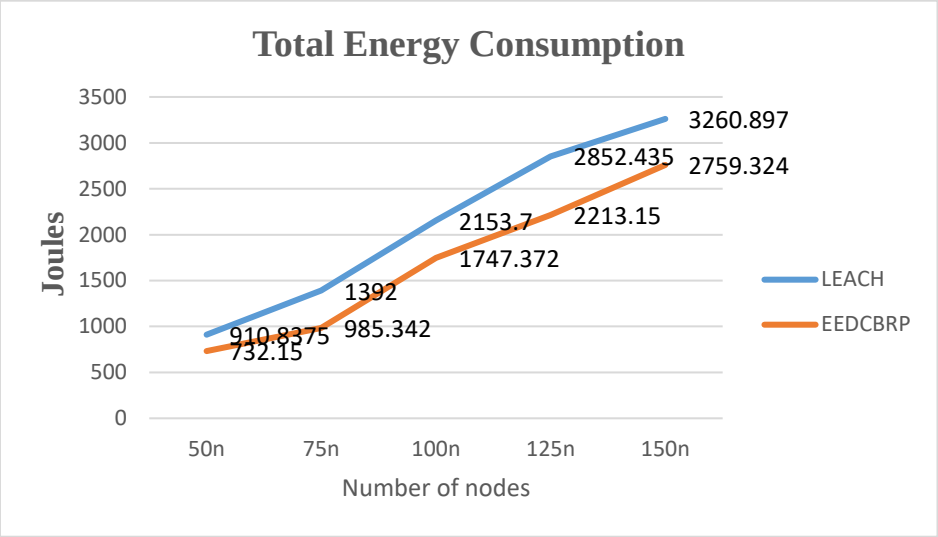

Figure 4.7. Total Energy Consumption

The result shows that the EEDCBRP consumes less energy with minimum of 5% to 7% when compare to LEACH.

5. Conclusions

The proposed EECBRP, for wireless heterogeneous networks tried to improve energy efficiency of network without performance degradation by modifying the Cluster Head selection process. This process considers node distance from the base station, present energy level and nature of the node for selecting cluster head. The proposed system is simulated using NS2 with different sets of nodes that includes both ad hoc and sensor nodes.

The result shows that the Packet Delivery Ratio of EEDCBRP is 2 to 2.5% higher than LEACH when it is tested with different sets (50, 75, 100, 125 and 150) of heterogeneous nodes. The delay in packet delivery with EEDCBRP is minimum 0.01s lesser than LEACH. The Enhanced protocol minimizes the amount of packets dropped during communication between 2% to 3%.

The average amount of energy required for selecting cluster head by the EEDCBRP is reduced between 4% to 5%. The average amount of remaining energy at each node is 3% to 4% higher than LEACH and the total energy conception by each scenario is 5% to 7% comparatively less. So, it shows that the consumption of energy for enhanced protocol is lesser than leach. Proposed system yields 5% to 7% better Throughput and The low Jitter with each different sets of node is achieved than LEACH. The control over head is not exceeding than LEACH that shows the efficiency of proposed system.

So, with the above results, it is concluded that the efficiency and energy conception of proposed system is better than Leach.

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