Chapter 3

Low Energy Adaptive Clustering Hierarchy

3.1 Introduction:

WSN is a densely deployed group of a large number of self organising wireless sensor nodes with partial energy resource, and usually a base station to collect and process the data from sensor nodes. One of the significant aspects of WSNs is the designing of energy efficient routing protocols. Clustering-based routing protocols are more constructive in the context of energy efficiency where numerous sensor nodes in the communication range of one another form a cluster. Each cluster has a cluster head (CH), which coordinates all the nodes of a cluster. A number of base stations (BS) also known as sink in a WSN are those that communicate with other networks. A CH aggregates data that are received from all member nodes of a cluster and sends to the BS. Besides CH, there exist gateway nodes in a cluster which are used for inter-cluster communications. Hence, clustering protocols produce limited useful information from large amount of raw sensed data and transmitting this precise valuable information to the BS of the network consume less energy [100, 101]. Maximum clustering protocols of WSN in the literature are designed for static sensor nodes. Thus, these protocols do not work for WSN applications that require mobile sensor nodes, such as habitat monitoring, wild life monitoring, target tracking and battlefield surveillance. Moreover, these protocols do not support localization of sensor nodes but only assume that each node know their location, which make these protocols inefficient. For instance, low energy adaptive clustering hierarchy (LEACH) protocol [102] is a standard static clustering protocol of WSN.

In this chapter our main objective is to measure the performance of the existing static clustering protocol LEACH in terms of network energy consumptions, Latency Values, Packet Delivery and Residual Energy values respectively.

Network energy consumption is defined as the total energy consumed by all the sensors nodes for routing data over a certain period of time. Network energy consumptions also reflect the lifetime of the network, that is, the remaining network energy since network energy consumptions is inversely proportional to the network lifetime. The time that is required to transmit data from any source sensor node to the BS is based on the traversed Euclidean distances so we measure the end-to-end delay. We have also measured another important parameter, packet delivery ratio which is defined as the total number of packets received at the BS to the total number of packets transmitted by the senders and also measure Residual Energy values.

3.2 WSN Routing Protocols:

It is required to implement routing protocols defining set of rules specifying how message packets transfer from source to destination in a network, efficiently and with less amount of energy consumed so as to optimize energy consumption in the network. Figure 3.1 shows the classification of routing protocols in WSNs [103, 53].

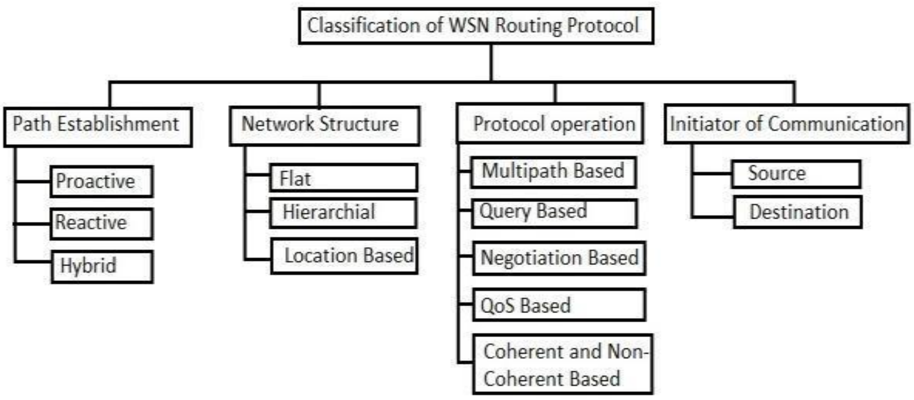

Figure 3.1: Classification of WSN Routing Protocols [103]

Path Establishment

Pro-Active (or Table Driven) Routing

Protocols figure all the routes using classical routing strategies such as distance-vector before they are really needed and then store these routes in a routing table in each node. When a route changes, the change has to be propagated throughout the network periodically. WSN could consist of thousands of nodes and needs a higher rate of routing table updates, the routing table that each node would have to keep could be vast and therefore proactive protocols are not suited to WSNs.

Reactive (or on-demand) Routing Protocols

In this type of routing determine routes to destination only when they are needed by broadcasting route query or request messages into the network.

Hybrid protocols use a mixture of these two ideas.

Network Structure

Flat-based Routing Protocols: Each node plays the same role in performing a sensing task and all sensor nodes are peers.

Hierarchical-based Routing Protocols: In this type of routing, sensor nodes are organized into clusters and the nodes with higher energy are served as cluster head (CH) and it used to gather data from cluster members (CM) having lower energy. Here the sensed data is sent to CHs by CMs where data aggregation and data fusion is done to decrease the number of transmitted messages to the sink. In this process create the clusters and CH rotation increases the network lifetime cycle, network scalability, and network reliability.

Location-based Routing Protocols: This type of routing sensor nodes is able to communicate on the base of location of each node with other node and the location or distance can be measured by two ways- the distance between two neighboring nodes can be estimated by incoming signal strength from the source or using GPS (Global Positioning System).

Protocol Operation:

Multipath-based Routing: Here it uses multiple paths instead of single path in order to increase fault-tolerance of the network on expense of increasing energy consumption and overhead of sending periodic messages to the alternative paths in order to keep them alive.

Query-based Routing: Here the destination node propagates a query to the network to send data. The query of having data matching node sends data to the desired node and these queries are in natural language.

Negotiation-based Routing: This type of routing protocol takes communication decisions based on availability of resources in the network suppressing duplicate information and prevent redundant data from being sent to the next sensor node.

QoS-based Routing: This routing protocol balances the network between energy consumption and data quality in order to satisfy certain QoS metrics such as delay, and bandwidth.

Coherent-based Routing*:* In this type of routing protocol, the local processing of data is based on minimum processing (coherent) and the full processing (non-coherent).

3.3 Low Energy Adaptive Clustering Hierarchy (Leach): Overview:

Low-Energy Adaptive Clustering Hierarchy (LEACH), proposed by Heinzelman et al. [104] is a classic hierarchical clustering routing protocol, which adopts distributed clustering algorithm. In LEACH the cluster-head rotation mechanism, data aggregation, and data fusion technologies effectively improves the lifetime of a network. Nodes are selected as cluster head circularly and randomly in order to optimize energy in the network. The normal nodes called cluster members connect the corresponding cluster head nodes on the basis of principle of proximity and normal nodes sense data and it send directly to the cluster head nodes. The cluster head nodes receive the sensed data, it aggregate the data to remove redundancy and fusion processes are carried out and data is send to the sink (or Base Station). So LEACH increases network lifetime by decreasing network energy consumption and reducing number of communication messages by data aggregation and fusion. The process of formation of clusters in LEACH is shown in Figure 3.2.

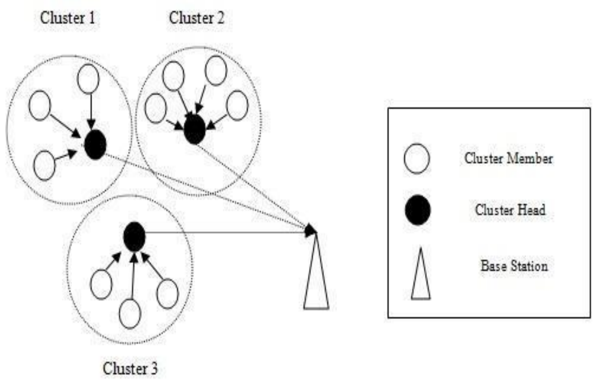

Figure 3.2: Formation of Clusters in LEACH

In order to achieve the design goal the key tasks performed by LEACH are as follows [105]:

- Randomized rotation of the cluster heads and the corresponding clusters.

- Global communication reduction by the local compression.
- Localized co-ordination and control for cluster setup and operation.
- Low energy media access control.
- Application specific data processing.

3.4 Running Process of LEACH:

Low energy adaptive clustering Protocol (LEACH) [101] works well for homogeneous networks, where every node has the same initial energy. This protocol works in rounds and each round is divided into cluster formation and steady phases. The LEACH operation is classified into different rounds, and each of these rounds has mainly two phases: the Set-up Phase and the Steady-state for data transmission [106].

The Set-up Phase: In this phase at first, the LEACH protocol randomly selects cluster heads (CHs) by randomly generating a number (n) between 0 and 1, for each node. If this randomly generated number is less than the threshold value given by threshold function T (n), the node would be selected as cluster head node.

$$T(n) = (p/(1-p(mod(1/p)))) \text{ if } n \in G \quad (3.1)$$

Where P is the cluster-head probability and G is the set of nodes that never be chosen as cluster-head nodes before 1/p round.

After the selection of cluster head nodes, each cluster-head node will send information via CDMA code to other nodes and normal nodes will join the corresponding cluster-head nodes. Then the cluster head nodes use TDMA to provide data transmission time for every node connected to them.

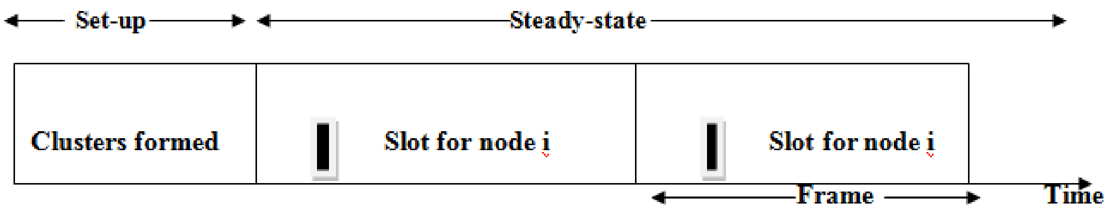

Figure 3.3: Cluster based mechanism of LEACH in WSN

The cluster head node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster [70] , completing the setup phase which is then followed by a steady-state operation as can be seen in Figure 3.3.

In the cluster formation phase, a cluster is formed and p.n sensor nodes are selected as cluster heads (CH) for the proper utilization of energy, where n is the number of sensor nodes and p is the desired percentage of CH. Otherwise, if only one node is selected as CH it will fail because of the shortage of energy. If a random number (between 0 and 1) chosen by a node A is less than a threshold value, A is selected as a CH in the current round.

The Steady-state: This stage is for data transmission where normal nodes sense data and send this sensed data to their respective cluster-head nodes. The processing of received data (data aggregation and data fusion) is done by cluster head nodes and then the processed data will be sent to the base station.

The steady state is divided into many frames where CH assigns time slots to each non-CH node using TDMA scheme. At the end of each round, the CH collects and aggregates data and sends to the BS. In LEACH, a new cluster formation is initiated in every round, which is not energy efficient. Moreover, occasionally all CHs exist in a close area (since CH rotates in a cluster) and require more energy for non-CH nodes to communicate CHs.

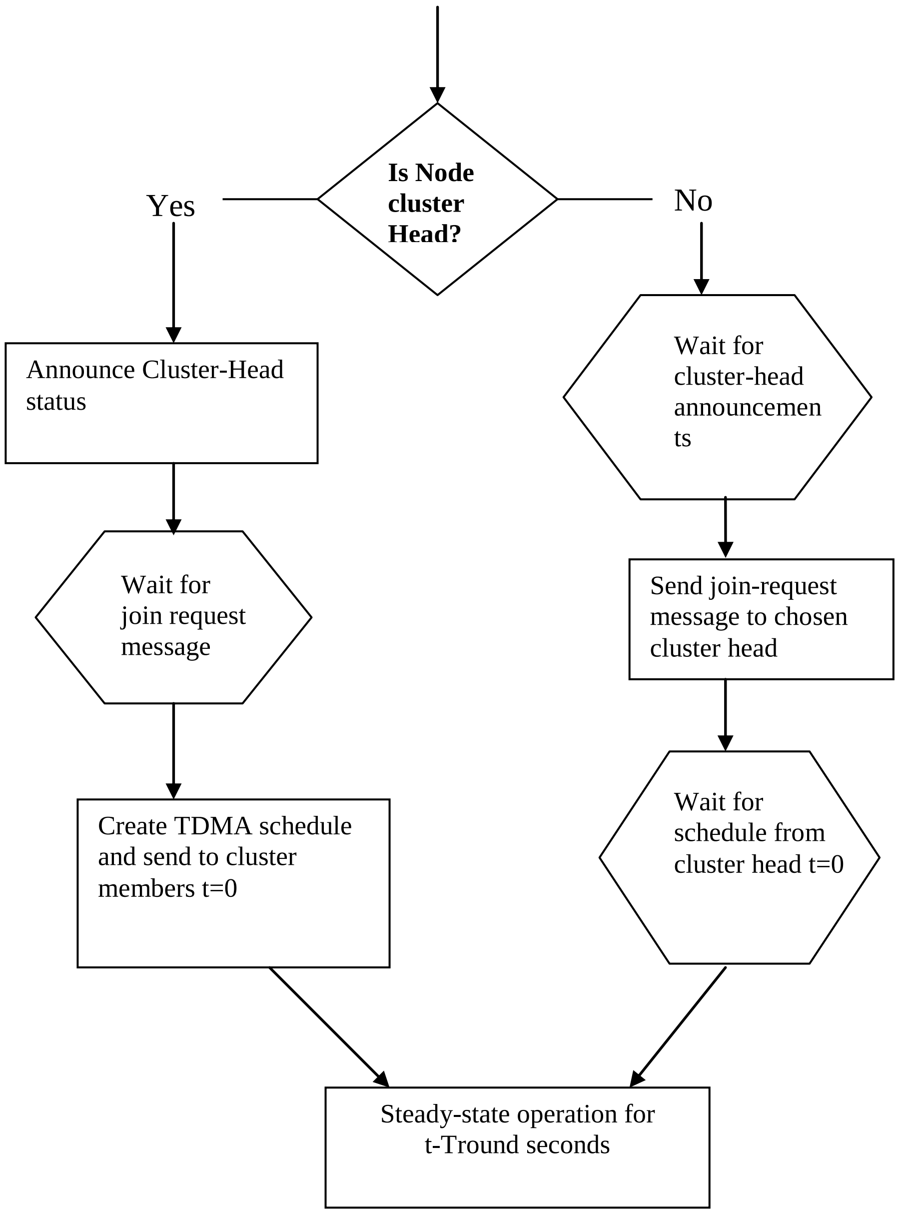

Figure 3.4: Flow chart of the Set-up phase of the LEACH protocol

3.5 Deficiencies in Classical LEACH Protocol [107]:

Unreasonable cluster head selection: LEACH protocol doesn't take residual energy of each node into consideration for the selection of cluster head node. In LEACH there is provision that each node has equal probability of becoming cluster head. If low-energy node is being selected as cluster head node, then the network fails soon due to high energy consumption causes adverse to energy balancing among the network. This results data loss and lower in survival time of the network.

Unreasonable distribution of cluster heads:

Due to the random selection algorithm of cluster head nodes there arises problem of imbalance in energy load. Distance factor is not considered in cluster formation due to which sometimes very big clusters and very class clusters exist at the same time in the network. More the distance between cluster head node and base station, more the energy consumption of that node.

More responsibility on Cluster Head node:

Cluster head nodes perform data aggregation and send processed data to the base station in single-hop due to which cluster head nodes deplete their energy too fast as compared to normal nodes. Also if a cluster head node fails, the whole nodes linked to it will deplete their energy too. Although, LEACH is the simplest hierarchical protocol and can lead to saving energy in WSN, some problems exist. Firstly, the residual energy of the node is not considered in CH selection. Hence, the nodes with lower initial energy can be selected as CHs which results in premature death, coverage and energy hole problems. Furthermore, as the clusters are reformed in each phase, a significant amount of energy is wasted in order to construct the clusters. Moreover, CHs can be dense or sparse in different areas, as LEACH performs the CH-selection phase in terms of probabilities. Since, CHs send the aggregated data to the BS directly; the CHs far away from the BS will die earlier. Finally, due to the single hop transmission in the inter-cluster and intra-cluster communications, LEACH is not appropriate for large size networks. Thus, it is not a scalable routing protocol.

3.6 Simulation and Results:

To simulate the LEACH protocol, NS2 2.35 simulator is used. The models were used for energy dissipation is as described below. In the wireless channel, the electromagnetic wave propagation can be modeled as falling off as a power law function of the distance between the transmitter and receiver. The free space model which considered direct line of sight and two ray ground propagation model which considered ground reflected signal also, were considered depending upon the distance between transmitter and receiver. If the distance is greater than crossover, two ray ground propagation model is used. The aim of this simulation is to evaluate the characteristics of hierarchical routing scheme for sensor network Low Energy Adaptive Clustering hierarchy (LEACH) based on the performance matrices like Energy Values, Latency Values, Packet Delivery Ratio and Residual Energy Values. This simulation of Clustering is done in NS2. The Number of nodes considered here is 40.

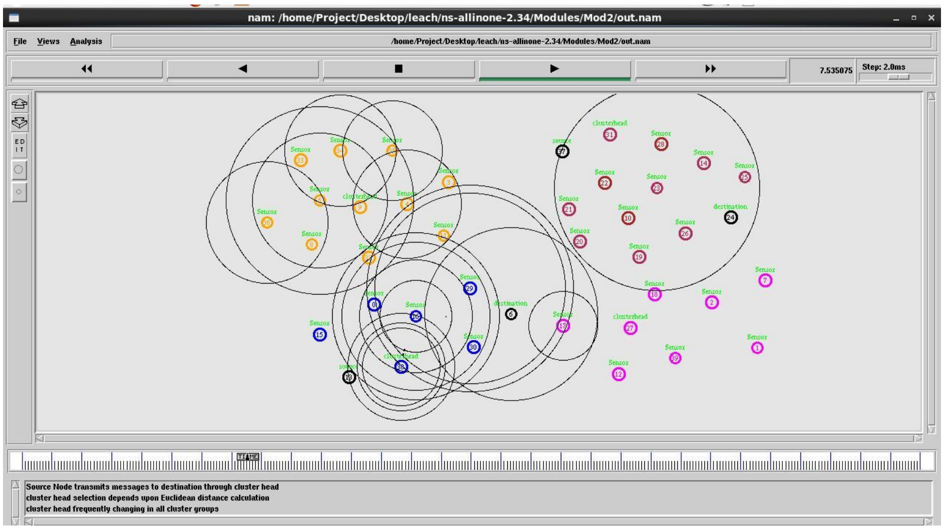

Figure 3.5: Layout of LEACH Simulation

3.7 Results and Performance Analysis:

The simulation Parameters and results of the simulation are shown in the Table 3.1, which shows the Energy Values, Latency Values, Packet Delivery and Residual Energy values of the different simulation Time in the sensor network. Figure 3.6, 3.7, 3.8 and 3.9 shows the simulation graphs for percentage of Simulation Time verses Energy Values, Latency Values, Packet Delivery and Residual Energy values respectively.

Simulation Parameters:

```
#===================================
#     Simulation parameters setup
#===================================
set NS /home/Project/Desktop/leach/ns-allinone-2.34/ns-2.34/
set val(chan)   Channel/WirelessChannel    ;# channel type
set val(prop)   Propagation/TwoRayGround   ;# radio-propagation model
set val(netif)  Phy/WirelessPhy            ;# network interface type
set val(mac)    Mac/802_11                 ;# MAC type
set val(ifq)    Queue/DropTail/PriQueue    ;# interface queue type
set val(ll)     LL                         ;# link layer type
set val(ant)    Antenna/OmniAntenna        ;# antenna model
set val(ifqlen) 50                         ;# max packet in ifq
set val(nn)     40                         ;# number of mobilenodes
```

```
set val(rp)      LEACH                      ;# routing protocol
set val(x)       1407                       ;# X dimension of topography
set val(y)       732                        ;# Y dimension of topography
set val(stop)    30.0                       ;# time of simulation end
set val(em)      EnergyModel                ;# energy model
set val(Energy) 1000                        ;#Joules
set speed        0.5                        ;#
set packet_size 811                         ;#
set interval .05                            ;#
source $NS.ns1
#====================================
```

Table 3.1: Simulation Results

Time(Sec)	Energy Values	Latency Values	PDR Values	Residual Energy Values
10.000	814.754	121.494	0.8645	38185.2
15.000	831.400	79.9305	0.9188	38168.6
20.000	848.049	63.546	0.9421	38152.0
25.000	864.712	54.7296	0.9549	38135.3
30.000	881.358	49.2427	0.9631	38118.6

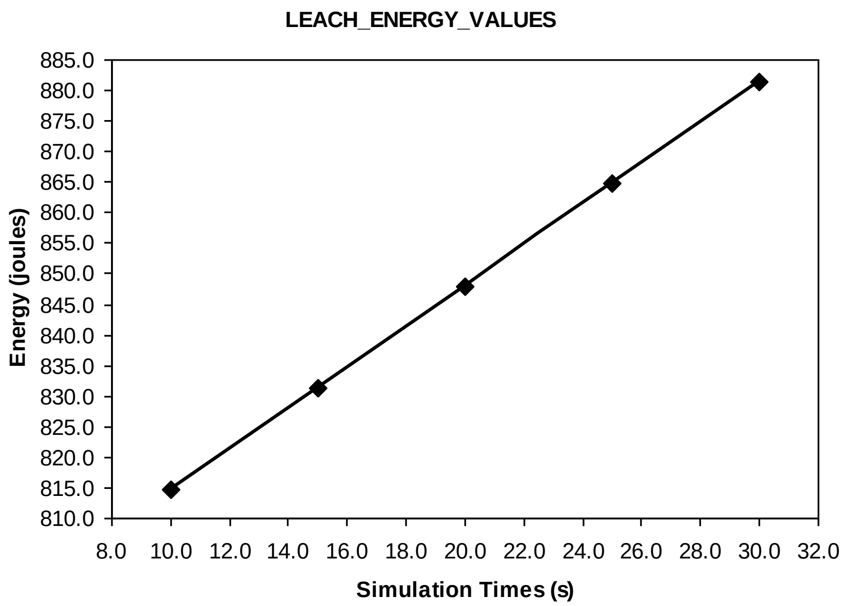

Figure 3.6: Simulation Time Vs Energy Values

The Energy Consumption Value at 10 sec Simulation Time is observed to be 814.754 for Low Energy Adaptive Clustering hierarchy Algorithm, at 15 sec, 20 sec, 25 sec, 30 sec are 831.400, 848.049, 864.712, 881.358 respectively. So it can be clearly seen that the variation of Energy Values with simulation time is increasing.

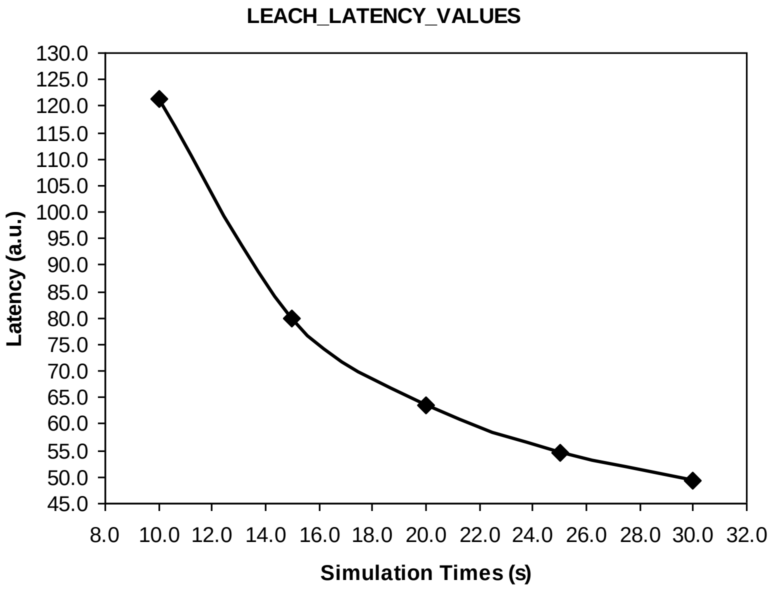

Figure 3.7: Simulation Time Vs Latency Values

Form the Figure3.7 it is shown that the Latency Value at 10 sec Simulation Time is 121.494 Then at 15 sec, 20 sec, 25 sec and 30 sec are observed to be 79.9305, 63.546, 54.7296, and 49.2427 respectively. So from the above results we can say that the variation of Latency Values with Simulation Time is not continuous in nature.

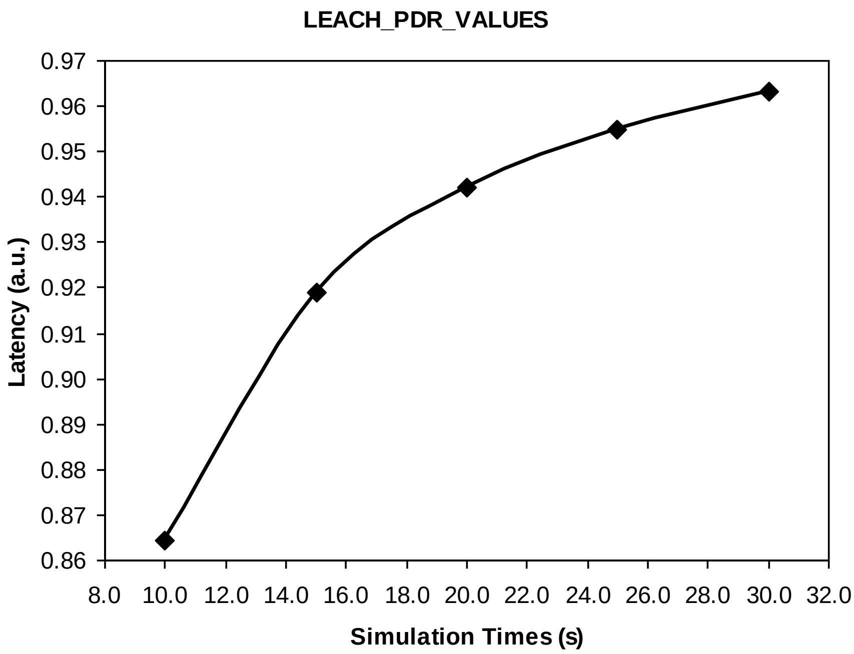

Figure 3.8:Simulation Time Vs PDR Values

Figure 3.8 shows the variation of Packet Delivery Ratio (PDR) values with simulation time from 10 sec to 30 sec at an interval of 5 sec. The PDR values are observed to be 0.8645, 0.9188, 0.9421, 0.9549 and 0.9631 respectively.

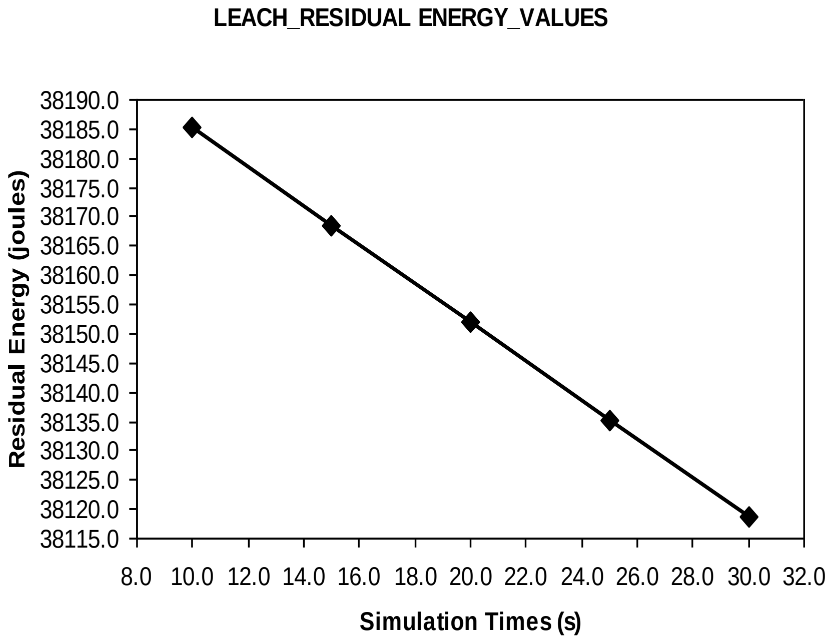

Figure 3.9: Simulation Time Vs Residual Energy Values

The Residual Energy Values at 10 sec Simulation Time is observed to be 38185.2 for Low energy adaptive clustering Protocol, at 15 sec, 20 sec, 25 sec, 30 sec are 38168.6, 38152.0, 38135.3, 38118.6 respectively.

3.8 Leach Assumption/Limitations:

Although LEACH is able to increase the network lifetime, there are still a number of issues about the assumptions used in this protocol. LEACH [22] assumes a homogeneous distribution of sensor nodes in the given area. This scenario is not very realistic.

LEACH assumes that all nodes can transmit with enough power to reach the BS if needed and that each node has computational power to support different MAC protocols. Therefore, it is not applicable to networks deployed in large regions.

It also assumes that nodes always have data to send and nodes located close to each other have correlated data. It is not obvious how the number of predetermined Cluster Heads [CH (p)] is going to be uniformly distributed throughout the network. Therefore, there is a possibility that the elected CHs will be concentrated in one part of the network. Hence, some nodes will not have any CHs in their vicinity.

3.9 Conclusion:

The present simulation represents the variation of different performance parameters for the LEACH Protocol. Efficiently use of energy in the network has been the main issue in WSNs for prolonging lifetime of the network. LEACH has found one of the most energy efficient protocols used in WSN. It is concluded from above discussion that for prolonging network lifetime of WSN, there is need to explore more robust, reliable and efficient protocols in future.