# Optimization of Energy Efficient Hierarchical Routing Protocol in Sensor Network

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# Optimization of Energy Efficient Hierarchical Routing Protocol in Sensor Network

## Major Project

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**May 2011**

# Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Computer Science & Engineering at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

**- Rajesh P. Patel**

# Certificate

This is to certify that the Major Project entitled " **Optimization of Energy Efficient Hierarchical Routing Protocol in Sensor Network** " submitted by **Rajesh P. Patel(08MCES60)**, towards the partial fulfillment of the requirements for the degree of Master of Technology in Computer Science and Engineering of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this Major Project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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# Abstract

Wireless sensor networks (WSNs) have gained increasing attention from both the research community and actual users. In the wireless sensor networks (WSNs), the sensor nodes (called motes) are usually scattered in a sensor field - an area in which the sensor nodes are deployed. These motes are small in size and have limited processing power, memory and battery life. The motes in these networks are coordinated to produce high-quality information and each of these scattered motes has the capabilities to collect and route data back to the base stations, which are fixed or mobile.

As sensor nodes are generally battery-powered devices, the critical aspects to face concern how to reduce the energy consumption of nodes, so that the network lifetime can be extended to reasonable times. I concentrated on optimization of Hierarchical Energy Efficient Routing Protocols. Since unstable and unevenly distributed cluster heads can increase power of the network system in some existing protocol. I have proposed new technique for cluster head selection and cluster formation so it selects the consistent cluster heads in each round, also form the balance clusters in the existing hierarchical routing protocol(LEACH) to reduce the energy consumption of sensor nodes in sensing, processing and communication activities, overall it increases the lifetime of network.

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There are times in such projects when the clock beats you time and again you run out of energy and you just want to finish it once and forever. At that time my family members has encouraged me with their warm wishes and constat support.

**- Rajesh P. Patel**
**08MCES60**

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# Chapter 1

# Introduction

## 1.1 Sensor Network

### 1.1.1 Definition

A wireless sensor network is an active research area. A Wireless Sensor Networks (WSN) is a set of hundreds or thousands of micro sensor nodes that have capabilities of sensing, establishing wireless communication between each other and doing computational and processing operations.

Each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer). The figure 1.1 shows the components of sensor node and communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s).

The typical configuration of such a sensor node in a WSN includes single or multiple sensing elements, a data processor, communicating components and a power source of limited energy capacity. The sensing elements of such a sensor node perform measurements related to the conditions existing at its surrounding environment. These measurements are transformed into corresponding electric signals and are processed by the processing unit. A sensor node makes use of its communication components in order to transmit the data, over a wireless channel, to a designated sink point, referred to as a base station. The base station collects all the data transmitted to it in order to act as a supervisory control processor or an access point for a human interface or even as a gateway to other networks.

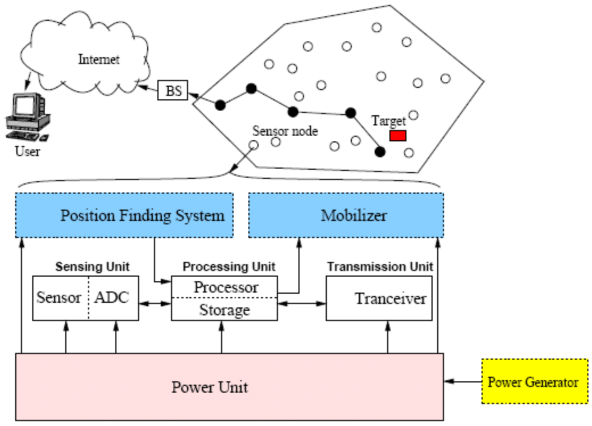


Figure 1.1: The components of a sensor node and communication architecture[1]

### 1.1.2 Applications

Sensor networks have a wide variety of applications and systems with vastly varying requirements and characteristics. The sensor networks can be used in,

- Military environment

- Disaster management
- Habitat monitoring
- Medical and health care
- Industrial fields, home
- networks, detecting chemical, Biological, radiological, nuclear, and explosive material etc.

Deployment of a sensor network in these applications can be in random fashion (e.g.,dropped from an airplane) or can be planted manually (e.g., fire alarm sensors in a facility). For example, in a disaster management application, a large number of sensors can be dropped from a helicopter. Networking these sensors can assist rescue operations by locating survivors, identifying risky areas, and making the rescue team more aware of the overall situation in the disaster area.

## 1.2 Routing In Sensor Network

### 1.2.1 Routing

Routing (or routeing) [2] is the process of selecting paths in a network along which to send network traffic. The goal of sensor network routing protocol is to disseminate data from sensor nodes to the sink node in energy-awareness manner, hence, maximize the lifetime of the sensor networks.

### 1.2.2 Routing protocol Classification

There are different routing protocols already reported for WSN applications but mostly they are for static networks. All major protocols may be categorized into following four categories:

Data Centric Protocols, Hierarchical Protocols, Location Based Protocols and Network Flow and QoS Aware Protocols. Few representative works of these categories are given below.

| **No.** | **Category** | **Representative Protocols** |
|---|---|---|
| 1 | Data Centric Protocols | Flooding and Gossiping,SPIN, Directed Diffusion, Rumor Routing, Gradient Based Routing, Energy-Aware Routing, CADR, COUGAR ACQUIRE. |
| 2 | Hierarchical Protocols | LEACH, PEGASIS, HPEGASIS, TEEN and APTEEN |
| 3 | Location Based Protocols | MECN, SMECN, GAF, GEAR |
| 4 | Network Flow and QoS Aware Protocol | Maximum Lifetime Energy Routing, Maximum Lifetime, Data Gathering, Minimum Cost Forwarding, SAR and SPEED |

Table I: Classification of Energy-efficient Routing Protocol

In data-centric routing,[1] the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. SPIN is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy. Later, Directed Diffusion has been developed and has become a breakthrough in data-centric routing.

The idea aims at diffusing data through sensor nodes by using a naming scheme for the data. The main reason behind using such a scheme is to get rid of unnecessary operations of network layer routing in order to save energy. Direct Diffusion suggests the use of attribute-value pairs for the data and queries the sensors in an on demand basis by using those pairs.

Directed Diffusion differs from SPIN in terms of the on demand data querying mechanism it has. In Directed Diffusion the sink queries the sensor nodes if a specific data is available by flooding some tasks.

In Network Flow Protocol route setup is modeled and solved as a network flow problem and QoS Aware Protocols consider end-to-end delay requirements during the setting up of the routes.

### 1.2.3 Routing challenges

Routing in sensor network is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks.

- Classical IP-based protocols cannot be applied to sensor networks.
- All applications of sensor networks require the flow of sensed data from multiple regions (sources) to a particular sink.
- Generated data traffic has significant redundancy, such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization.

### 1.2.4 Design Issues

Depending on the application, different architectures and design goals/constraints have been considered for sensor networks.

**Network Dynamics:** There are three main components in a sensor network. These are the sensor nodes, sink and monitored events. Aside from the very few setups that utilize mobile sensors,most of the network architectures assume that sensor nodes are stationary. On the other hand, supporting the mobility of sinks or cluster-heads (gateways) is sometimes deemed necessary. Routing messages from or to moving nodes is more challenging since route stability becomes an important optimization factor, in addition to energy, bandwidth etc. The sensed event can be either dynamic or static depending on the application [13]. For instance, in a target detection/tracking application, the event (phenomenon) is dynamic whereas forest monitoring for early fire prevention is an example of static events.

**Node Deployment:** The deployment is either deterministic or self-organizing. In deterministic situations, the sensors are manually placed and data is routed through pre-determined paths. However in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. In that infrastructure, the position of the sink or the cluster-head is also crucial in terms of energy efficiency and performance.

**Energy Considerations:** During the creation of an infrastructure, the process of setting up the routes is greatly influenced by energy considerations. Since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacles, multi hop routing will consume less energy than direct communication. However, multi-hop routing introduces significant overhead for topology management and medium access control.

**Data Delivery Models:** Depending on the application of the sensor network, the data delivery model to the sink can be continuous, event-driven, query-driven and hybrid. In the continuous delivery model, each sensor sends data periodically. In event-driven and query driven models, the transmission of data is triggered when an event occurs or a query is generated by the sink.

**Node Capabilities:** In a sensor network, different functionalities can be associated with the sensor nodes. In earlier works, all sensor nodes are assumed to be homogenous, having equal capacity in terms of computation, communication and power. However, depending on the application a node can be dedicated to a particular special function such as relaying, sensing and aggregation since engaging the three functionalities at the same time on a node might quickly drain the energy of that node.

**Data Aggregation/Fusion:** Since sensor nodes might generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions would be reduced. Data aggregation is the combination of data from different sources by using functions such as suppression (eliminating duplicates), min, max and average.

### 1.2.5 Key Issues in Routing protocol

Different from traditional networks, a typical sensor network has a great number of nodes, which are scattered over a region of interest. All the sensor nodes sense and gather information in a coordinated manner, and then pass the sensed information to the BS over the path determined by the routing protocol. The sensor nodes have much smaller memories, constrained energy supply, limited computer ability and more redundant information.

In order to design a good protocol for wireless sensor networks, it is important to improve the following parameters:

- System lifetime: These networks should function as long as possible.

- Timely: It is important to receive the data from a sensor in a timely manner.
- Quality: Protocols should be designed to be the optimum manner of aggregate data.
- Autonomy: Routing should be determined by a distributed algorithm.

Because sensor nodes have irreplaceable batteries, it is essential that the network be energy efficient in order to maximize the life span of the network. Besides this, autonomy is an important issue, for, sometimes, global information is hard or even impossible to achieve.

## 1.3 Hierarchical Routing Protocol

### 1.3.1 Introduction

There are the following important Hierarchical routing protocols.

- LEACH
- PEGASIS
- TEEN
- APTEEN

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensors proximity to the cluster head. LEACH is one of the first hierarchical routing approaches for sensors networks.

### 1.3.2 LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol for sensor networks is proposed by W. R. Heinzelman et.al [3] which minimizes energy dissipation in sensor networks, it is based on a simple clustering mechanism by which energy can be conserved since cluster heads are selected for data transmission instead of other nodes. The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

**Set-up phase:** During this phase, each node decides whether or not to become a cluster head (CH) for the current round. This decision is based on choosing a random number between 0 and 1. if number is less then a threshold *T(n)*, the node become a cluster head for the current round. The threshold value is set as:

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

where, P = desired percentage of cluster head, r = current round and G is the set of nodes which did not become cluster head in last $\frac{1}{P}$ rounds.

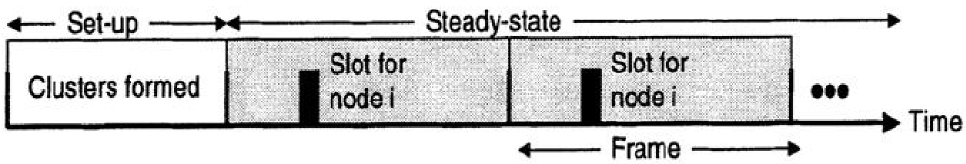


Figure 1.2: Time-line operation of LEACH

Once the cluster head is chosen, it will use the CSMA MAC protocol to advertise its status. Remaining nodes will take the decision about their cluster head for current round based on the received signal strength of the advertisement message.

Before steady-state phase starts, certain parameters are considered, such as the network topology and the relative costs of computation versus the communication. A Time Division Multiple Access(TDMA) schedule is applied to all the members of the cluster group to send messages to the CH, and then to the cluster head towards the base station. As soon as a cluster head is selected for a region, steady-state phase starts. Figure 1.3 shows the flowchart of the this phase.

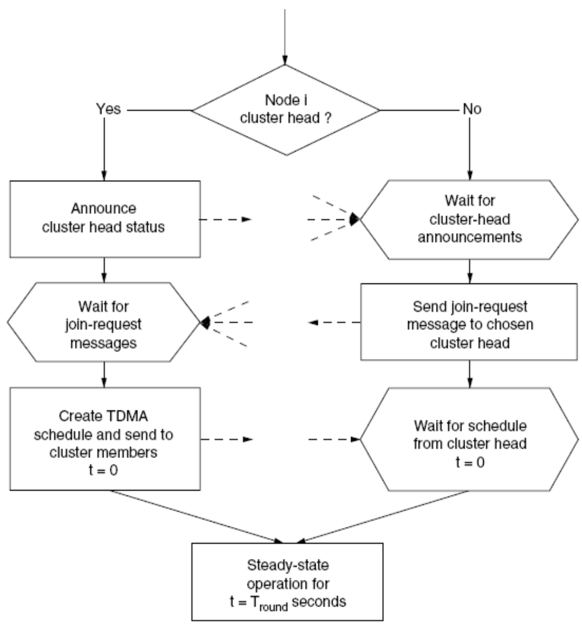


Figure 1.3: Flow chart of the set-up phase of the LEACH protocol

**Steady-state phase:** Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement). The radio of each non-cluster-head node can be turned off until the nodes allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster head node performs signal processing functions to generate the composite single signal. For example, if the data are audio or seismic signals, the cluster-head node can beamform the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission. F Code Division Multiple Access(CDMA) is utilized between clusters to eliminate the interference from neighboring clusters.

LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4-8 compared to the minimum transmission energy routing protocol. The nodes die randomly and dynamic clustering increases lifetime of the system. LEACH is completely distributed and requires no global knowledge of network.

### 1.3.3 PEGASIS

**PEGASIS: Power-Efficient Gathering in Sensor Information Systems** [3] is an improvement of the LEACH protocol. Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). Gathered data moves from node to node, aggregated and eventually sent to the base station. The chain construction is performed in a greedy way. Node c0 passes its data to node c1. Node c1 aggregates node c0s data with its own and then transmits to the leader. After node c2 passes the token to node c4, node c4 transmits its data to node c3. Node c3 aggregates node c4s data with its own and then transmits to the leader. Node c2 waits to receive data from both neighbors and then aggregates its data with its neighbors data. Finally, node c2 transmits one message to the base station.

The difference from LEACH is to use multi-hop routing by forming chains and selecting only one node to transmit to the base station instead of using multiple nodes. PEGASIS has been shown to outperform LEACH by about 100 to 300 percentage for different network sizes and topologies. Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation in LEACH and through decreasing the number of transmissions and reception by using data aggregation. However, PEGASIS introduces excessive delay for distant node on the chain. In addition the single leader can become a bottleneck.

### 1.3.4 TEEN AND APTEEN

**TEEN Threshold sensitive Energy Efficient sensor Network protocol** is a hierarchical protocol designed to be responsive to sudden changes in the sensed attributes such as temperature. Responsiveness is important for time-critical applications, in which the network operated in a reactive mode. TEEN pursues a hierarchical approach along with the use of a data-centric mechanism. The sensor network architecture is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until base station (sink) is reached.

After the clusters are formed, the cluster head broadcasts two thresholds to the nodes. These are hard and soft thresholds for sensed attributes. Hard threshold is the minimum possible value of an attribute to trigger a sensor node to switch on its transmitter and transmit to the cluster head. Thus, the hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest, thus reducing the number of transmissions significantly. Once a node senses a value at or beyond the hard threshold, it transmits data only when the value of that attribute changes by an amount equal to or greater than the soft threshold. As a consequence, soft threshold will further reduce the number of transmissions if there is little or no change in the value of sensed attribute.

**APTEEN: The Adaptive Threshold sensitive Energy Efficient sensor Network protocol** is an extension to TEEN and aims at both capturing periodic data collections and reacting to time-critical events. The architecture is same as in TEEN. When the base station forms the clusters, the cluster heads broadcast the attributes, the threshold values, and the transmission schedule to all nodes. Cluster heads also perform data aggregation in order to save energy.

APTEEN supports three different query types: historical, to analyze past data values; one-time, to take a snapshot view of the network; and persistent to monitor an event for a period of time.

Simulation of TEEN and APTEEN has shown [1] them to outperform LEACH. The experiments have demonstrated that APTEENs performance is between LEACH and TEEN in terms of energy dissipation and network lifetime. TEEN gives the best performance since it decreases the number of transmissions. The main drawbacks of the two approaches are the overhead and complexity of forming clusters in multiple levels, implementing threshold-based functions and dealing with attribute-based naming of queries.

# Chapter 2

# Literature Survey

## 2.1 Motivation

- Sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management.
- Research on wireless sensor networks has recently received much attention as they offer an advantage of monitoring various kinds of environment by sensing physical phenomenon. Among various issues to design routing protocol or to optimize routing protocol in sensor network, energy consumption of sensor node is one of the most important criteria for routing protocol in wireless sensor networks(WSNs) as sensor network performance rely on routing protocol.

## 2.2 Literature Description

- Routing techniques [4] are classified into three categories based on the underlying network structure: flat,hierarchical, and location-based routing. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, based depending on the protocol operation.

- **Average Communication Energy:** This is the total Communication Energy consumption, including transmission, retransmission, receiving, overhearing of both reports and control messages by the sensor nodes over the total number of reports received at the Base Station.

  **Average Energy:** This is the ratio of the total energy consumption including communication energy and idle energy consumption by the sensor nodes, over the total number of distinct reports received at the Base Station.

  **Control Message Overhead:** This is defined as the ratio between the total number of control messages received and transmitted by the nodes and the total number of distinct reports received at the Base Station.

- According to model [5], the energy consumed during transmission $E_{Tx}$ is given by:

  $$E_{Tx} = E_{lect} * k + Eamp * k * d^2 \tag{2.1}$$

  and the energy consumed during reception (ERx) is given by:

  $$E_{Rx} = E_{lect} * k \tag{2.2}$$

  where $E_{Elec}$ is the energy consumed by the transceiver electronics, k is the size of the message in bits, Eamp is the energy consumed by the transmitter amplifier and d is the transmission distance in meters.

Each cluster head dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the BS. Since the BS is far from the nodes, presumably the energy dissipation follows the multi path model (d 4 power loss). Therefore, the energy dissipated in the cluster head node during a single frame is:

$$E_{CH} = E_{lect} * K(\frac{N}{L-1}) + k * E_{DA} * \frac{N}{L} + K * E_{dec} + K\epsilon_{mp} * D^4_{tobs} \tag{2.3}$$

where k is the number of bits in each data message, $D_{toBS}$ is the distance from the cluster head node to the BS, $E_{DA}$ is data aggregation.

Thus, the energy used in each non-cluster head node is:

$$E_{noCH} = E_{lect} * k + k * \epsilon_{fs} * d^2_{toCH} \tag{2.4}$$

Where $d_{toCH}$ is the distance from the node to the cluster head and is free space (short) distance amplification factor for transmitter. The area occupied by each cluster is approximately $M^2/L$.
If the density of nodes is uniform throughout the cluster area, then

$$p = \frac{1}{\frac{M.^2}{L}} \tag{2.5}$$

the total energy for the frame is:

$$E_{total} = LE_{cluster} = k(E_{lect}*N+E_{DA}*N+L\epsilon_{mp}*d^4_{toBS}+E_{lect}*N+\epsilon_{fs}*\frac{1}{2*\Pi}*\frac{M^2}{L}*N) \tag{2.6}$$

- The cluster contains;[6] CH (responsible only for sending data that is received from the cluster members to the BS), vice-CH (the node that will become a CH of the cluster in case of CH dies), cluster nodes (gathering data from environment and send it to the CH).

In the original leach, the CH is always on receiving data from cluster members, aggregate these data and then send it to the BS that might be located far away from it. The CH will die earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing. When the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station.

V-LEACH protocol, besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies. This will extend the overall network life time.

- There main enabling techniques for energy conservation [7] namely, duty cycling, data-driven approaches, and mobility. Duty cycling is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the (low-power) sleep mode whenever communication is not required.Data reduction schemes address the case of unneeded samples, while energy-efficient data acquisition schemes are mainly aimed at reducing the energy spent by the sensing subsystem. Duty cycling can be achieved through two different and complementary approaches. From one side it is possible to exploit node redundancy, which is typical in sensor networks, and adaptively select only a minimum subset of nodes to remain active for maintaining connectivity. Nodes that are not currently needed for ensuring connectivity can go to sleep and save energy.

- A Density and Distance based Cluster Head Selection Algorithm [8] divides cluster area into several perpendicular diameters, and then selects cluster head by the density of member nodes and the distance from cluster head.considering node density and the distance from cluster head in sensor networks can be more energy efficient than considering only the distance between nodes in energy usage of Wireless Sensor Networks. During the phrase of cluster initialization, the sensed zone is divided into several virtual hexagons which it can avoid the overlapping nodes of circular cluster.

**[STEP-1] Local Grouping** divides cluster area into two perpendicular diameters to get four quadrants.

**[STEP-2]Compare the node density** that is the number of cluster members in each quadrant and select candidate quadrants.

**[STEP-3]Compare the node distance** that is from the nearest cluster head in candidate quadrants and select following cluster head.

- Mr. Mohebi Ali. proposed hierarchical routing protocol based on clustering to minimize the no.of hops required for data reporting as well as achieving energy efficiency. Data Expressways constructed initially by chains of cluster heads to find the routes in such a way that the less end to end delay is achieved while decreasing energy consumption. Simulation results provided shows that EELLER is not only energy efficient but also a reliable algorithm.

- In the proposed[9] scheme the nodes consider the complex distance of nodes to cluster head (CH) and CH to base station (BS), and join the cluster which the complex distance is minimum. This strategy balances the network energy efficiently. The communication of inter-cluster adopts multi-hop mode, which the next hop routing is chosen based on the network communication cost and the residual energy of CH, to make the network load more balanced.

  The proposed protocol[10] adds feature to LEACH to support for mobile nodes and also reduces the consumption of the network resource in each round. The proposed algorithm put some features that LEACH does not support such as: Mobility of cluster head and member node during one round Currently remaining battery power and the number of nodes per cluster are also considered.

- An Energy-Efficient Protocol with Static Clustering [19] EEPSC, partitions the network into static clusters, eliminates the overhead of dynamic clustering and utilizes temporary-cluster-heads to distribute the energy load among high power sensor nodes; thus extends network lifetime. EEPSC is a self-organizing, static clustering method that forms clusters only once during the network action. The operation of EEPSC is broken up into rounds, where each round consists set-up phase, responsible node selection phase and steady-state phase.According to the static clustering scheme which is used in EEPSC, cluster formation is performed only once at the beginning of network operation. For this aim, base station broadcasts k-1 different messages with different transmission powers, which k is the desired number of clusters.

- Geographic Routing for Prolonging Network Lifetime [11] which balances link-quality, distance and energy. Proposed scheme is more energy-efficient than previous routing protocols, and has longer lifetime. Numerical expressions such as Packet Reception Rate (PRR), distance, and Energy-level are used. The proposed scheme uses three factors, PRR, distance and Energy-level in 1-hop distance within a radius of 120 degree. Energy-level is a normalized value of a nodes residual energy. Selection of candidate nodes is identical with PRR Distance scheme. However, it use weight factors to balance between nodes Energy-level and PRR Distance.

- Some of the cluster-heads elected [12] during the set-up phase in LEACH were selected again as the level2 cluster heads which communicated with the base station. So unnecessary energy dissipation is reduced as the number of nodes communicating with the base station directly decreased. When the level1 cluster-heads choosing finished, the level2 cluster-heads which communicate with base station will be selected among these level l cluster-heads based on the left power of them. Each level1 cluster-head broadcasts its left power via CSMA (carrier-sense multiple access) protocol, and compares its own remaining power with other level1 cluster-heads to decide whether to be a level 2 cluster-head.

### 2.2.1 Proposed LEACH optimizations

- **E-LEACH:** It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. Same as LEACH protocol, E-LEACH [13] is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.

- **TL-LEACH:** The CH [12]collects and aggregates data from sensors in its own cluster and passes the information to the BS directly. CH might be located far away from the BS, so it uses most of its energy for transmitting and because it is always on it will die faster than other nodes.A new version of LEACH called Two-level Leach was proposed. In this protocol; CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station.

- **LEACH-C:** LEACH [6] offers no guarantee about the placement and/or number of cluster heads. In an enhancement over the LEACH protocol was proposed. The protocol, called LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using GPS) residual energy level to the

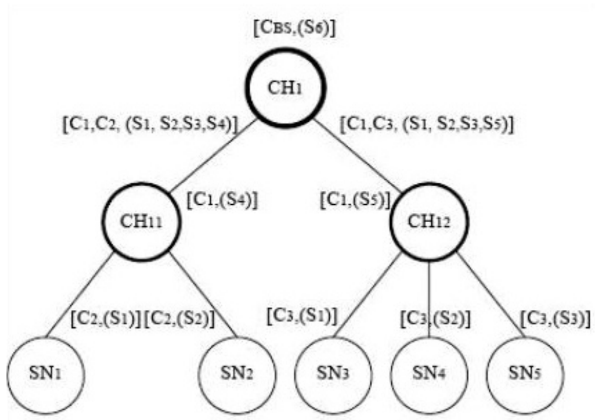


Figure 2.1: TL-LEACH

sink. In addition to determining good clusters, the sink needs to ensure that the energy load is evenly distributed among all the nodes. To do this, sink computes the average node energy, and determines which nodes have energy below this average.

Once the cluster heads and associated clusters are found, the sink broadcasts a message that obtains the cluster head ID for each node. If a cluster head ID matches its own ID, the node is a cluster head; otherwise the node determines its TDMA slot for data transmission and goes sleep until its time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol.

- **M-LEACH:** In LEACH, Each CH directly communicates with BS no matter the distance between CH and BS. It will consume lot of its energy if the distance is far. On the other hand, Multihop-LEACH protocol [2] selects optimal path between the CH and the BS through other CHs and use these CHs as a relay station to transmit data over through them. First, multi-hop communication is adopted among CHs. Then, according to the selected optimal path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS. M-LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between CHs and BS.

- **Distributed Energy-efficient Clustering Hierarchy Protocol (DECHP)**[11], which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings. DECHP uses a geographical and energy aware neighbor cluster heads selection heuristic to transfer fused data to the BS.
The two key elements considered in the design of DECHP are the sensor nodes and BS. The sensor nodes are geographically grouped into clusters and capable of operating in two basic nodes: i) the cluster head nodes ii) the sensing node. In the sensing node, the nodes perform sensing tasks and transmit the sensed data to the cluster head. In cluster head node, a node gathers data from the other nodes within its cluster performs data fusion and routes the data to the BS through other cluster head nodes. The BS in turn supervises the entire network. Initially, the nodes organize themselves into local clusters based on their localization, with one node acting as the cluster head.

The scheme proposed [14] attains a scale-independent emergent clustering algorithm, through which it performs high uniform cluster distribution with less overlap between clusters. In the mean time, PCC requires only a small constant amount of communications overhead, and it achieves clustering despite the overall number of nodes in the network. Furthermore, a virtual migration-based rotation strategy of cluster-head node is introduced into PCC. Once a cluster head detects its inadequate power, the head will indicate unwillingness to return to the scheme. Consequently, PCC can also ensure the reliability of data transmission.

These notations are classified into three types: network layer notations, node layer notations and cluster layer notations. For the network layer notations, all nodes are scattered in a square sensing region, whose area is LL. With limited power capacity, radio ranges of all nodes are predefined as R in PCC.

As for node layer notations, all nodes located within sensing region together form the set of generic nodes P. A node in PCC can have three possible states: it can be non-clustered (not a member node of any cluster), member node or it may be a cluster-head.

Likewise, cluster layer notations reflect the subordinate relationship between cluster-head and member nodes. CH represents a set, which includes all the current cluster heads. To specify a particular cluster-head, element in CH are indexed by its sequence number.

- **Hierarchical Cluster-based Routing** (HCR) Hierarchical cluster-based routing (HCR) technique is an extension of the LEACH protocol. In HCR, each cluster is managed by a set of associates and the energy efficient clusters are retained for a longer period of time. The energy-efficient clusters are identified using heuristics-based approach. Moreover, in a variation of HCR, the base station determines the cluster formation. A Genetic Algorithm (GA) is used to generate energy efficient hierarchical clusters. The base station broadcasts the GA-based clusters configuration, which is received by the sensor nodes and the network is configured accordingly. The main objective of the HCR (Sajid Hussain, Abdul W. Matin, 2006) protocol is to generate energy efficient clusters for randomly deployed sensor nodes, where each cluster is managed by a set of associates called a head-set.

  DECHP uses a class-based addressing of the form $< Location - ID, Node - Type - ID >$. The Location-ID identifies the location of a node that conducts sensing activities in a specified region of the network. It is assumed that each node knows its own location information from GPS or some localization system and remaining energy level. Each node within the cluster is further provided with a Node-Type-ID that describes the functionality of the sensor.

### 2.2.2 LEACH Problems

- It performs single hop routing. Each node transmit information directly to cluster head and also cluster head directly transmit information to base station. Therefore, it is not applicable to networks deployed in large regions.

- It performs dynamic clustering. The idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption.

- LEACH assumes a homogeneous distribution of sensor nodes [4] in the given area. This scenario is not very realistic. Let us consider a scenario in which most of the sensor nodes are grouped together around one or two cluster-heads. As being shown in figure.2.2, cluster-heads A and B have more nodes close to them than the other cluster-heads. LEACHs cluster formation algorithm will end up by assigning more cluster member nodes to both A and B. This could make cluster head nodes A and B quickly running out of energy.

- LEACH [2] 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.

- 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 is going to be uniformly distributed throughout the

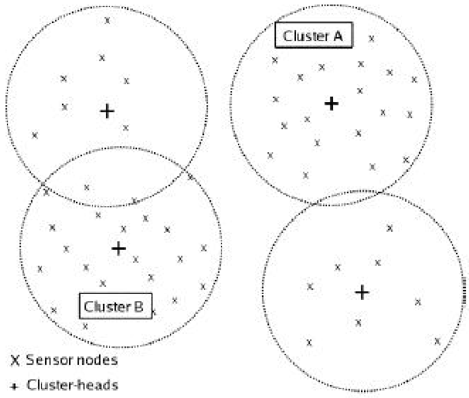


Figure 2.2: Sensor Network

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.

- The protocol assumes that all nodes begin with the same amount of Heads consume approximately same amount of energy in each round.

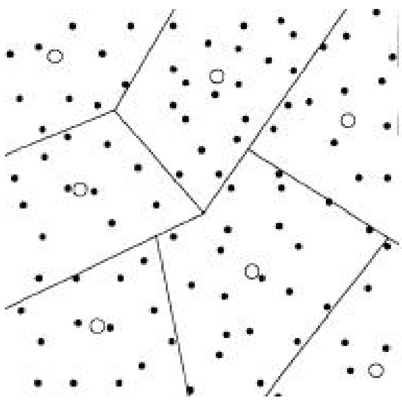

Figure 2.3: Nonuniform clusters in LEACH

- LEACH does not limit the number of cluster and cluster members.

Figure 2.4 shows how nodes with varying distances from the base station died throughout the network. The nodes that are farther away would tend to die earlier because the cluster heads that are farther away have much more work to accomplish than cluster heads that are close to the base.

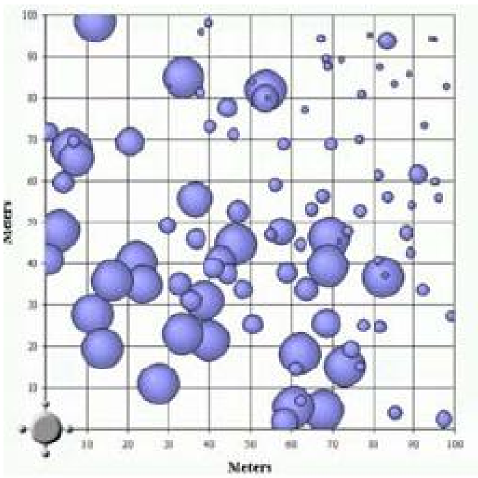


Figure 2.4: Random Distribution

## 2.3 Conclusion

Sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management. There are still chances to improve techniques for the following approaches in the existing hierarchical routing protocols (Ex.LEACH,PEGASIS,V-LEACH) so that energy consumption of node will be reduced and life time of sensor network will be improved.

- Cluster Head Selection.
- Cluster Head Communication.

- Cluster Formation.
- Data Aggregation and fusion among the clusters.
- Distance between Head and base station node consideration.
- Energy level of nodes could be consider during selection of head node.

# Chapter 3

# Problem Definition

## 3.1 Problem Description & Assumption

### Problem

A common and critical operation for wireless sensor networks is data gathering. Sensor nodes are generally battery-powered devices, are constrained in energy supply and bandwidth. So, there is a need of efficient clustering of the sensor network that can save energy and improve coverage efficiency. The critical aspects to face concern how to reduce the energy consumption of nodes, performance of network depends on the routing protocols which are used for the routing. Today there are many routing protocols in sensor network but some of them's clustering is not so good, which take to much time for communication and forming the clusters, also for routing. So, if routing protocol will be optimized, the network lifetime can be extended up to to reasonable times or energy consumption of nodes can be reduced.

### Assumption

For the development of optimized protocol, I make the same assumptions as LEACH about the network model as follows [15]:

- Sensor nodes are dispersed randomly, location unaware, homogeneous.

- The energy of sensor node cannot be recharged.
- The base station is constant and localized far from the sensors.
- All nodes in the sensor network are homogeneous and energy-constrained. No mobility of sensor nodes.
- All nodes can transmit with enough power to reach the BS if needed and the nodes can use power control to vary the amount of transmit power.

## 3.2 Scope of The Project

- Scope of the project is to optimize energy efficient routing protocol for WSN that can be easily implemented using on existing WSN nodes.
- Even though there are numerous WSN routing protocols there is still great need of protocol which can be implemented easily on nodes using current technology and can be used for network of any size also extends the network lifetime.

## 3.3 Objective of The Work

The objective of this dissertation is optimization of cluster-head selection and cluster formation schemes in the existing hierarchical routing protocol so that the energy-consumption of sensor node will be reduced in sensing, processing and communicating activities, also sensor network lifetime will be improved. The optimized protocol must be computationally simple and simple to implement. The main objective was to extend LEACH routing algorithm to improve its energy efficiency.

**Specific Objective**

- To study hierarchical routing protocols, and analyze LEACH in particular.
- To implement LEACH protocol and analyze its characteristics.

- To propose improvements on LEACH protocol.
- To test and validate the efficiency of proposed improvement.

# Chapter 4

# Optimized Protocol Architecture

## 4.1 New Technique/Scheme

- Assign random time interval to the nodes. Nodes which have shortest time interval will win the competition and become the cluster heads.
- Tries to obtain constant no. of cluster heads in given area.
- When the number of the counter has reached specified value, nodes no longer continue competition for cluster heads.
- When the number of cluster members is less than specified threshold, the very small cluster will be merged with the neighboring clusters.
- **Algorithm Objective:**
  - It Selects constant no. of cluster Head (CHs).
  - It focuses on setting up well-distribution of cluster.

## 4.2 Routing Protocol Architecture

In Time Dependant-LEACH, competition for cluster-heads (CHs) no longer depends on a random number as in LEACH, and a random time interval instead. Nodes which have the shortest time interval will win the competition and become cluster heads. In order to obtain a constant number of cluster-heads, set a counter which shows optimum no. of cluster heads($K_{op}$). When the number of the counter has reached specified value, nodes no longer continue competition for cluster-heads.

For example, the nodes need to elect four CHs. Every node in the network produces a random timer at the beginning of a round. When the timer expires, and if the number which node has received of CHs' advertisement messages ($CH\_ADV$) is less than four, the node broadcast a CHs advertisement message to announce its CH status by using a non-persistent carrier-sense multiple access ($CSMA$) MAC protocol. Else, it can't become a Cluster-head.

Once CHs are elected, the following processes are completely similar to LEACH. This algorithm is still a distributed algorithm, that is, nodes make autonomous decisions without any centralized control.

The proposed algorithm also employs cluster member threshold to avoid the very big cluster and the very small cluster existing at the same time. As shown in figure 4.1 [18] there are 6 clusters and marked them A to F and A to D are the very small cluster and E, F are the very big cluster. Very big clusters (E, F) and the very small clusters (A, B, C and D) exist at the same time, the energy of the nodes in the very small cluster will be used up quickly.

The reason that the energy of node in a small cluster declines sharply is explained below: The cluster head must wait until all members of the cluster finished to collect and send data once before starting the data aggregation, and then sent the aggregated data to the BS. The small cluster has fewer members, so the time for completion of data acquisition and delivery is shorter; the result is the small cluster will send data to the base station more frequently than the big cluster(As shown in below Table I). From a simulation result[18], found that in a small cluster the average energy consumption of cluster member node were significantly higher than a big cluster. So there is need to balance the clusters. so, algorithm use cluster member threshold to balance the clusters.

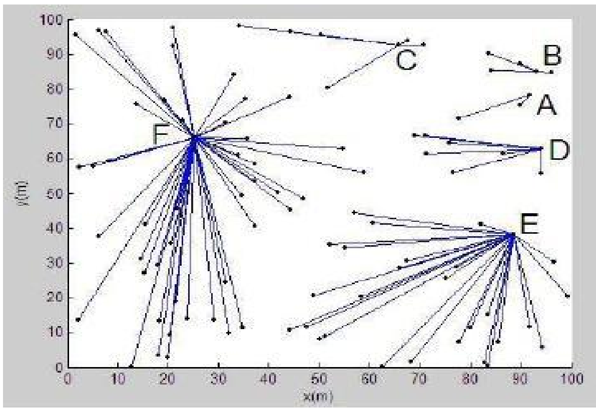


Figure 4.1: The very big cluster and the very small cluster exist at the same time

| **%Cluster** | **No.of members** | **Times of head send data to BS** | **Head's energy consumption** | **Member's energy consumption** |
|---|---|---|---|---|
| A | 2 | 79 | 50.35% | 6.47% |
| B | 4 | 61 | 46.79% | 4.95% |
| C | 6 | 50 | 45.46% | 4.86% |
| D | 7 | 46 | 47.53% | 3.82% |
| E | 27 | 17 | 45.72% | 1.50% |
| F | 48 | 10 | 44.59% | 0.91% |

Table I: Energy Consumption of Clusters

## 4.3 Flowchart

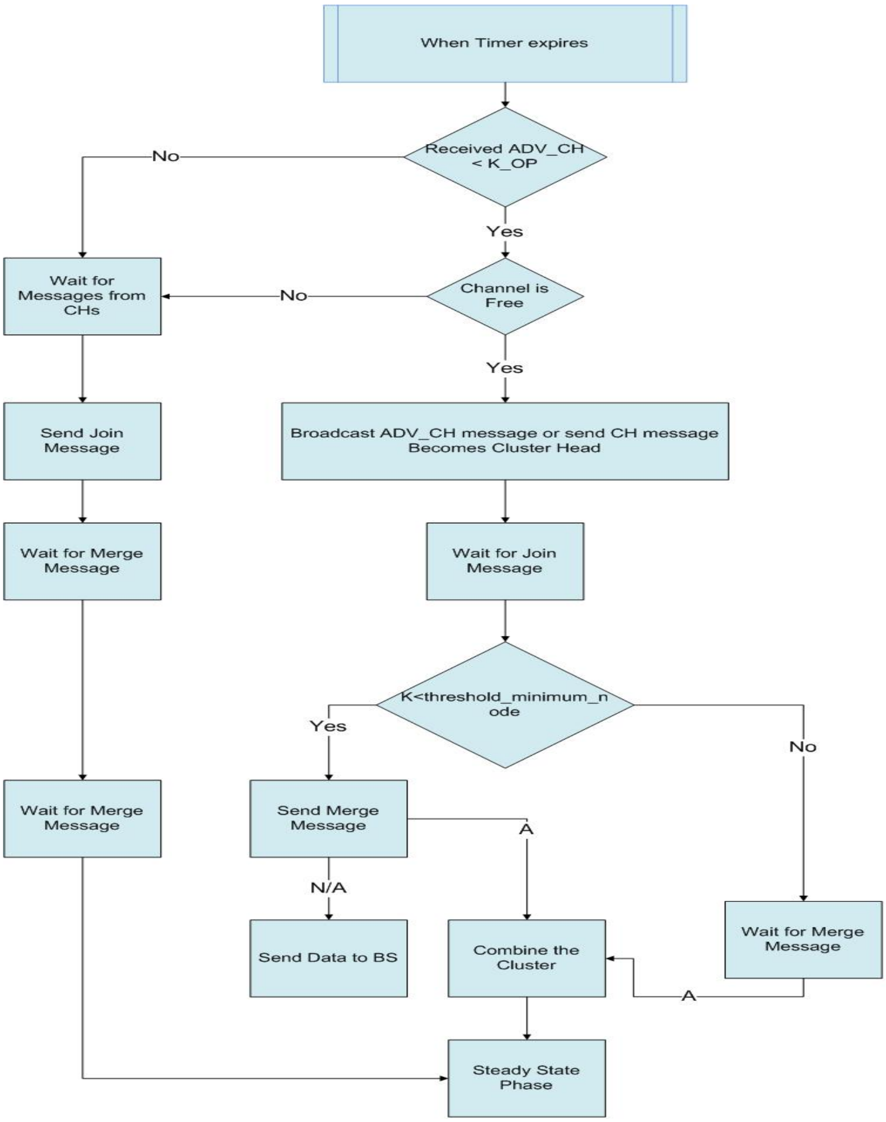


Figure 4.2: Improved flowchart of cluster head selection and formation for distributed algorithm

## 4.4 Proposed Code

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**Procedure** Cluster Head Selection and Formation

**Input** Node i

---

$IfHasbeenCH == Yes$

$then\ Random\_timer = MAX\_timer$

$else$

$Random\_timer = Random\_time\_generator(MAX\_time)$

$if\ Random\_timer\ is\ expire$

$then$

$if\ ReceiveCH\_ADV < K_{op}$

$then\ send(CH\_ADV)$

$HasbeenCH = YES$

$wait\_join()$

$if k < threshold\_minimum\_nodes$

$then$

$send\_Merg()$

$else$

$wait\_Merg()$

$combine\_cluster()$

$else\ HasbeenCH = NO$

$send\_Join()$

---

# Chapter 5

# Simulators and Tools

## 5.1 Sensor Network Simulators

Network simulation is one of the most predominant evaluation methodologies in the area of computer networks. It is widely used for the development of new communication architectures and network protocols. So-called network simulators allow one to model an arbitrary computer network by specifying both the behavior of the network nodes and the communication channels. For example, in order to investigate the characteristics of a new routing protocol, it is usually implemented in a network simulator.

### 5.1.1 Network Simulator 2(NS2)

Network Simulator 2 (NS2) [16] is a most popular discrete event simulator for the Wireless Sensor Networks. It is used it the simulation of TCP, routing and multicast protocol for wired and wireless networks. It supports 802.11 and 802.15.4 type of wireless MAC. NS2 uses two languages, C++ and OTcl. For the protocol implementation it uses C++, OTcl is used for simulation configuration. Simulation can be observed by Trace file or NAM file. NS-2 does not have good scalability for large sensor networks.

### 5.1.2 GloMosim

Global Mobile Information System Simulator (GloMoSim) is a parallel discrete event based simulator for wireless networks. The simulation is performed by Parsec, a parallel programming language. By this one can simulate upto 10000 nodes. GloMoSim uses layered architecture wherein each layer uses different API these layers are integrated by different APIs and may be developed by different people.

### 5.1.3 OMNeT++

OMNeT++ is an extensible, modular, component based C++ simulation library and framework developed in C++. It has simple and powerful GUI library. It is useful for simulation of communication networks, queuing networks and performance evaluation. OMNeT++ is a collection of modules which are written in C++. These modules can be interfaced, nested to form a compound model. The interfacing and nesting is achieved by NED language. The outputs of the simulation are in the scalar and vector form. For the analysis of the result, we can use simulation.

### 5.1.4 TOSSIM

The TinyOS provides a TOSSIM as discrete event simulator/emulator. For wireless sensor networks, programs are written in nesC code. For running nesC code in TOSSIM it requires programming interface i.e. written in Python or C++. Python is a powerful debugger which allows dynamic simulation. Transforming code from one to the other is simple in C++. External programs can connect to TOSSIM by TCP socket for monitoring and actuating.

## 5.2 Simulation Parameter of Energy Efficient Routing Protocol

- No.of nodes N
- No. of cluster K
- Counter which shows how many times node becomes cluster head
- timer assign to each node randomly
- network size
- BS location
- Length of data message
- No of message packet
- Radio electronics energy $E_{elec}$ (nJ/bit)
- Radio amplifier energy $E_{amp}$
- Data aggregation Energy $E_{DA}$
- Initial Energy of node

# Chapter 6

# Implementation and Simulation of LEACH Protocol

## 6.1 LEACH Matlab Code

- LEACH matlab code is available. I have tested the code.
- LEACH matlab code has following important functions.
- (1)Cluster head selection phase.
- (2)Cluster formation phase.
- (3)Cluster head assign the time schedule to cluster members.
- (4)According to the TDMA schedule cluster member node send the data to CH.
- I understood the implementation of LEACH in matlab and after executing, it has generated the graph which is shown in the figure 6.1 of nodes alive over the rounds. Applying this technique it will improve the life time of sensor nodes.

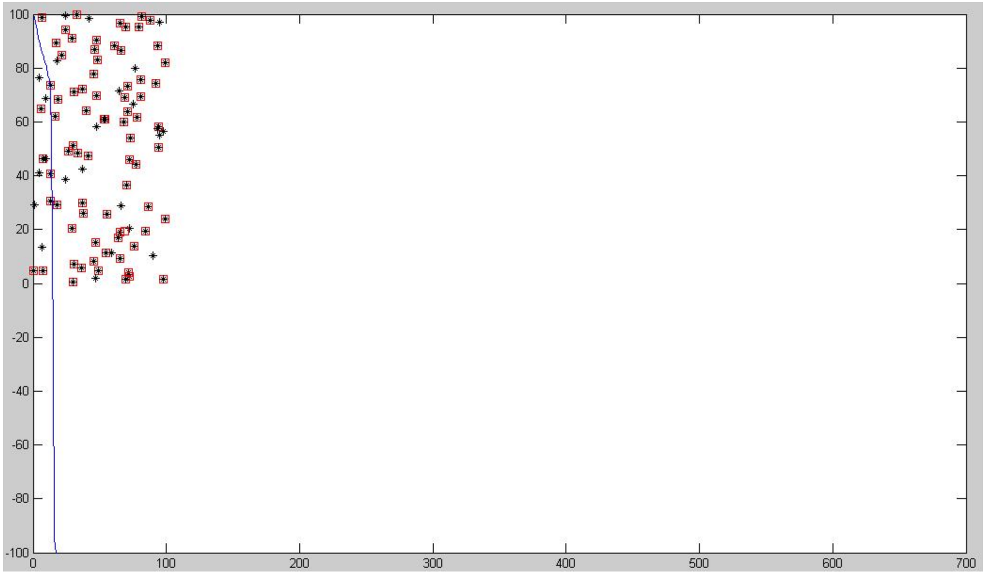


Figure 6.1: No. of nodes alive over the rounds in LEACH

## 6.2 Operating System

- Operating System: Fedora 9.0

## 6.3 NS2 Simulator

- Network Simulator 2 (NS2)[16] is a most popular discrete event simulator for the Wireless Sensor Networks. It is used it the simulation of TCP, routing and multicast protocol for wired and wireless networks. It supports 802.11 and 802.15.4 type of wireless MAC. NS2 uses two languages, C++ and OTcl. For the protocol implementation it uses C++, OTcl is used for simulation configuration. Simulation can be observed by Trace file or NAM file. NS-2 does not have good scalability for large sensor networks

## 6.4 Installation of NS-2.27 and LEACH extension on Fedora Core

One of the challenges faced during the research project is implementation of LEACH in NS-2. WSN is an emerging technology and in spite of being a standard tool, tested and readily available, NS-2(version 2.27) does not adequately support WSN simulations. Most of the tools suited for WSN simulation currently are commercial. NS-2.27 extension with LEACH was used to add WSN functionalities in NS-2. Appendix A outlines the procedure of using MIT guideline to upgrade NS-2. By doing so, the several ns-2.27 files were changed in some way to guarantee that the simulator worked.

**Channel Propagation Model**

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. Both 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 $d_{crossover}$ , two-ray ground propagation model is used. The crossover is defined as follows:

$$d_{crossover} = \frac{4 * \pi * \sqrt{L} * h_r * h_t}{\lambda} \tag{6.1}$$

Where, $L \geq 1$ is system loss factor. $h_r$ is the height of the receiving antenna, $h_t$ is the height of the transmitting antenna and $\lambda$ is the wavelength of the carrier signal. Now transmit power is attenuated based on following formula:

$$P_r(d) = \begin{cases} \frac{P_t * G_t * G_r * \lambda^2}{(4 * \pi * d)^2 * L} & \text{if } d < d_{crossover} \\ \frac{P_t * G_t * G_r * h_t^2 * h_r^2}{d^4} & \text{if } d \geq d_{crossover} \end{cases} \tag{6.2}$$

Where, $P_r$ is the received power at distance d, $P_t$ is transmitted power , $G_t$ is gain of the transmitting antenna and $G_r$ is gain of the receiving antenna.

### Radio Energy Model

The radio energy model described about the radio characteristics, including energy dissipation in the transmit and receive modes. Transmitter will dissipates energy to run the radio electronics and power amplifier and receiver dissipates energy to run the radio electronics [17]. Figure 6.2 shows the energy dissipation model. Using this

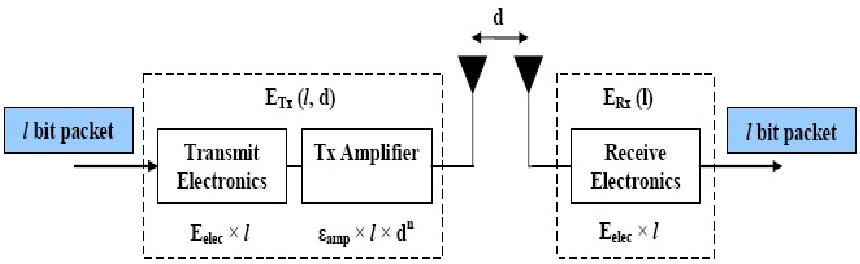


Figure 6.2: Radio energy dissipation model.

radio model, to transmit k-bit message at distance d the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \tag{6.3}$$

$$E_{Tx}(k,d) = \begin{cases} E_{elec} * k + \epsilon_{friss-amp} * k * d^2 : d < d_{crossover} \\ E_{elec} * k + \epsilon_{two-ray-amp} * k * d^4 : d \geq d_{crossover} \end{cases} \tag{6.4}$$

and to receive this message, the radio expends:

$$E_{Rx}(k) = E_{Rx-elec}(k) \tag{6.5}$$

$$E_{Rx}(k) = E_{elec} * k. \tag{6.6}$$

For the simulation experiment, following parameter are used: $G_t = G_r = 1$, $h_t$

= $h_r$ = 1.5m, no system loss (L=1), 914MHz radios and $\lambda = \frac{3*10^8}{914*10^6} = 0.328$m. 100 nodes random test network was used with base station location was (50, 175) as per shown in figure 6.3.

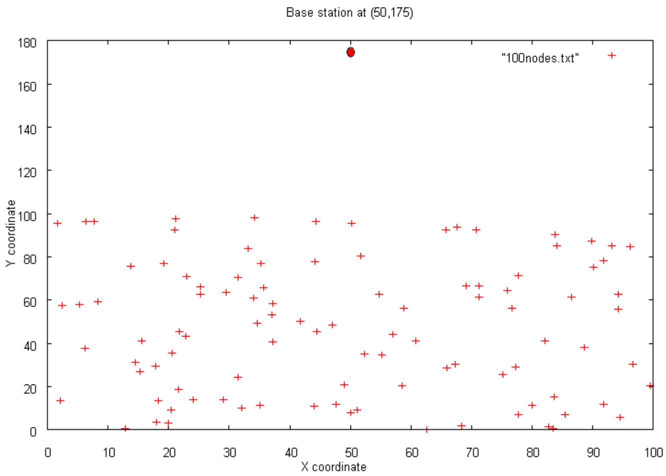


Figure 6.3: Sensor network topology.

## 6.5 Simulation Experiments

For simulation purposes, It is considered a sensor field measuring 1000x1000 and sensor nodes are scattered all over the field.

The parameters as set during simulation are:

- Desired number of clusters = 5
- Changing clusters every 20 seconds

| **No.** | **Parameter** | **Value** |
|---|---|---|
| 1 | Node distribution | (0,0) to (100,100) |
| 2 | BS location | (50,175) |
| 3 | Nodes begin energy | 2J |
| 4 | Data packet length | 500 Byte |
| 5 | Message packet length | 25Byte |
| 6 | Parket header length | 25Byte |
| 7 | $E_{elec}$ | 50nJ/bit |
| 8 | $E_{fs}$ Transmitter amplifier energy dissipation | 10pJ/bit/$m^2$ |
| 9 | $E_{mp}$ | 0.0013pJ/bit/$m^4$ |

Table I: Simulation Parameters of LEACH

The table below indicates the other parameters as set during simulation.

| **No.** | **Item Description** | **Specification** |
|---|---|---|
| 1 | Simulation Area | 1000X1000 |
| 2 | Channel Type | Channel/wireless channel |
| 3 | Radio propagation model | Two ray ground |
| 4 | Maximum Simulation time | 600 s |
| 5 | Antennae model | Antenna/omniantenna |
| 6 | Energy model | Battery |
| 7 | Interface queue type | Queue/Drop tail/ priqueue |
| 8 | Link layer type | LL |
| 9 | Communication model | Bi-direction |
| 10 | Min packet in ifq | 30 |

Table II: Simulation Parameters

- **Simulation area**: Defines the dimensions of the sensor field. It is (1000 by 1000) meters. Number of nodes - The model of sensor network that was considered consisted of 100 nodes randomly deployed into the field.

- **Radio propagation model**: Used to predict the received signal power of each packet. There are three models in NS-2; Free space model, Two ray ground reflection model and the Shadowing model. Two ray ground reflection is used in this simulation. It considers both direct (line of sight) path and ground reflection path between the Transmitter and receiver.

- **Energy model**: The energy model, which is a node attribute, represents the amount of energy in a node. The energy model in a node has an initial value, initial Energy, which is the amount of energy the node has at the beginning of the simulation. It has a given energy usage for each and every packet transmitted (txpower) or received (rxpower).

- **Network interface**: The network interface performs the physical layer functions. When it receives a packet from the Mac layer, it sets the transmit power based on the approximation of distance to the receiver, removes the approximate amount of energy to send the packet and sends the packet to the channel. When receiving data, the packet enters the nodes network interface from the channel.

- **Mac/802 11**: Used as medium access control (MAC) layer protocol. It provides arbitration for access to the wireless channel and also ensures that the sending nodes defer times that they send data hence avoiding collisions.

- **Communication model**: The communication between the nodes is two way. A cluster head advertises itself to the common nodes which in turn join and transmit data to the cluster head.

- **Link Layer (LL) class**: LL object is responsible for simulating the data link protocols.

### 6.5.1 Energy Usage

The following plot in figure 6.4 shows the usage of the energy with time. At every 20 second, the cluster heads are changing. After the 400 seconds the energy consumption will increase sharply.

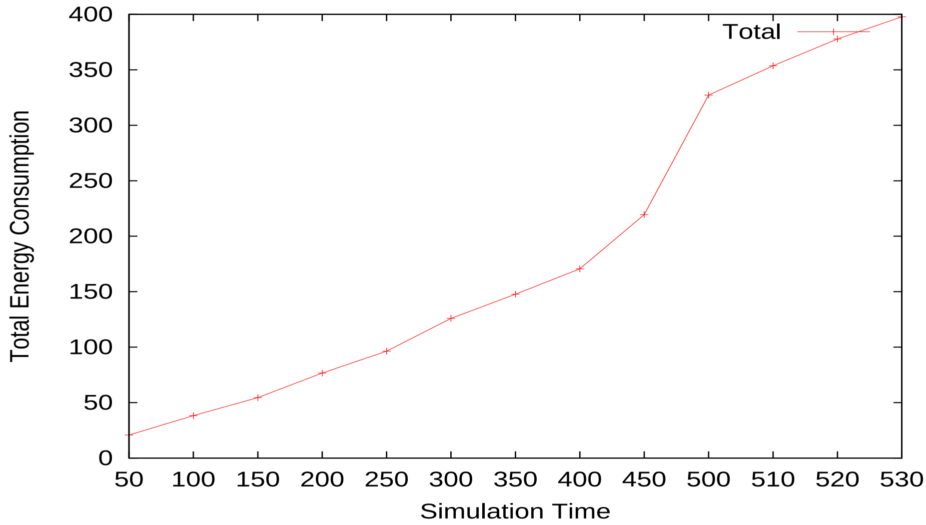


Figure 6.4: Energy consumption V/s Time

### 6.5.2 Network Lifetime

The plot shows in figure 6.5, the no of sensor nodes alive with time. When total no of alive nodes will be less than 4, then simulation will end.

The Results of the simulation are shown in the Table-III , which shows the lifetime, Energy and Throughput of the different no. of clusters or cluster heads in the sensor network, here 5% clusters heads of total network nodes are more energy efficient and also throughput is good as compare to others. Figure 6.6, 6.7 and 6.8 shows the simulation graphs for percentage of cluster heads verses lifetime, throughput and average energy dissipation respectively.

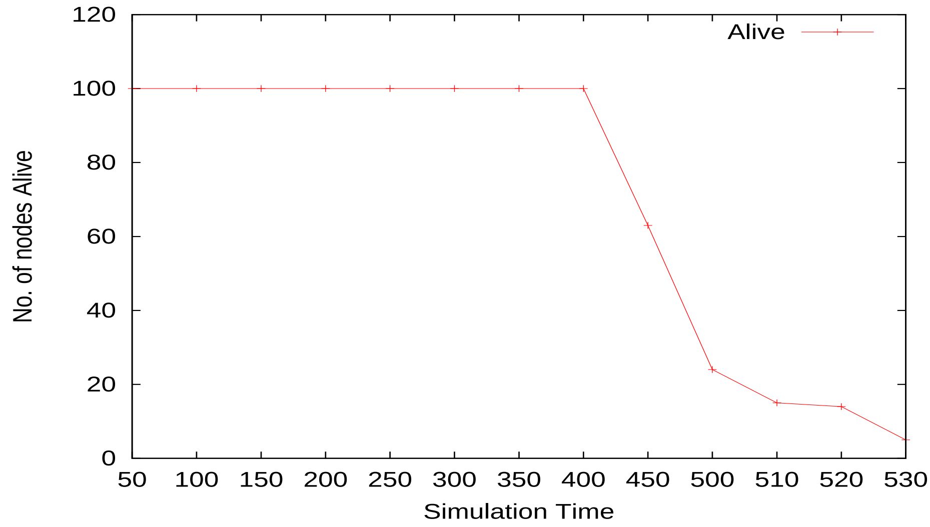


Figure 6.5: Nodes Alive V/s Time

| **%Cluster Head** | **Life Time** | **Throughput** | **Energy(J)** |
|---|---|---|---|
| 2 | 361.00 | 30097 | 84.00 |
| 3 | 285.09 | 32279 | 94.00 |
| 4 | 464.10 | 35897 | 79.50 |
| 5 | 542.30 | 52127 | 76.03 |
| 6 | 464.00 | 42041 | 87.50 |
| 7 | 292.00 | 28709 | 182.00 |
| 8 | 181.39 | 8301 | 192.49 |

Table III: Simulation Results

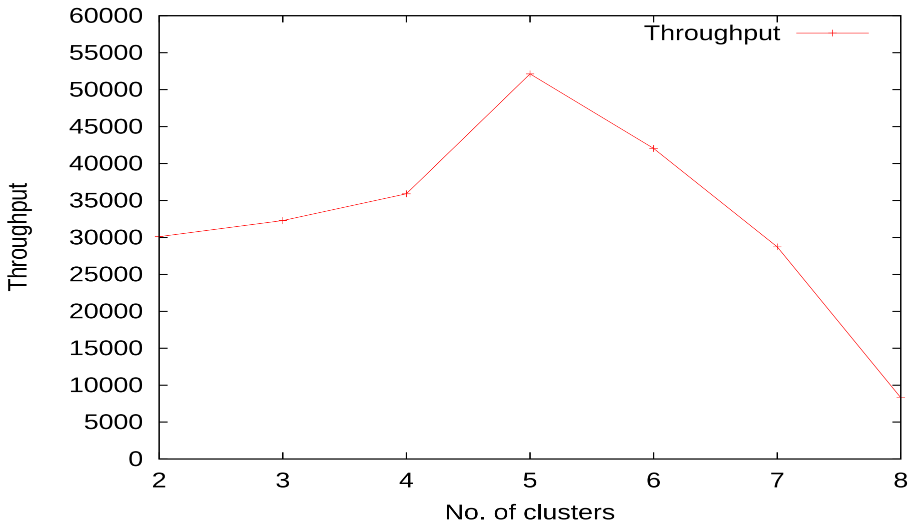


Figure 6.6: %Cluster Head V/s Throughput

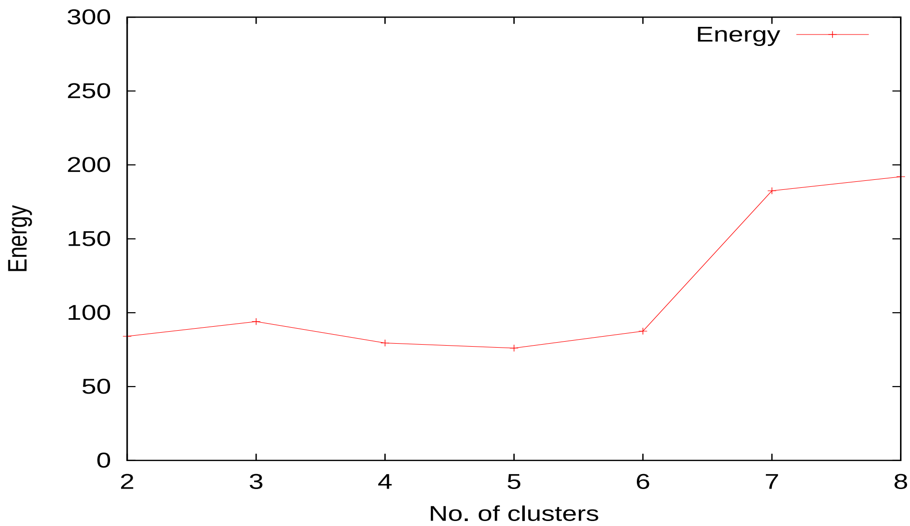


Figure 6.7: %Cluster Head V/s Energy Consumption(J)

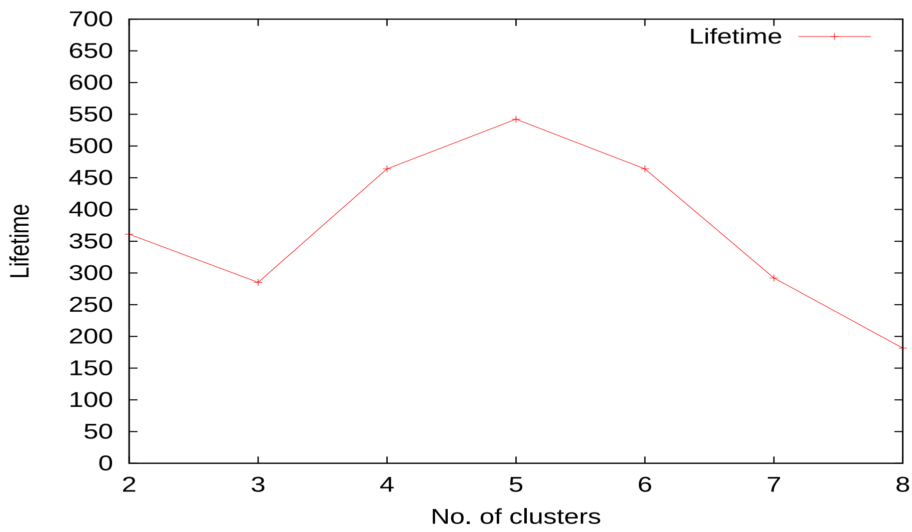


Figure 6.8: %Cluster Head V/s Life Time

### 6.5.3 Result Analysis

- LEACH cluster formation is not uniform and balanced.
- As there are 100 nodes in the simulation, even though the expected number of cluster per rounds is k=5 in LEACH, each round does not always have five clusters.
- LEACH performed better while keeping the 5% of the total sensor nodes as a Cluster Head.

# Chapter 7

# Implementation and Analysis of Algorithm

- Selecting optimal CHs. Forming the optimal clusters the probability of near-optimal cluster distribution in this proposed algorithm is bigger then LEACH.
- For selecting a optimal CHs, algorithm use the following equation 7.1.
- Still it use random time interval, it can't ensure the cluster distribution absolutely balanced.

$$K_{op} = \sqrt{(}N)/\sqrt{(}2 * pi) * \sqrt{(}\epsilon_{fs}/\epsilon_{mp}) * M/d^2_{toCH} \tag{7.1}$$

- $\epsilon_{fs}$, is transmit amplifier energy dissipation=$10pJ/bit/m^2$
- $\epsilon_{mp}$, is amplification factor for transmitter amplifier in multipath=$0.0013pJ/bit/m^4$
- $d^2_{toCH}$, is distance of node to CH
- $M$, is Simulation Area

Here, $K_{op}$ is the value which indicate the optimal no. of cluster in each round, and this value is used to limit the constant no. of clusters in particular round.

For simulation purposes, It is considered a sensor field measuring 1000x1000 and sensor nodes are scattered all over the field. In our experiments, we use the well known tool of network simulator: NS-2 to model our protocol.

The parameters as set during simulation are:

- Changing clusters every 20 seconds

| **No.** | **Parameter** | **Value** |
|---|---|---|
| 1 | Node distribution | (0,0) to (100,100) |
| 2 | BS location | (50,175) |
| 3 | Nodes begin energy | 2J |
| 4 | Data packet length | 500 Byte |
| 5 | Message packet length | 25Byte |
| 6 | Parket header length | 25Byte |
| 7 | $E_{elec}$ | 50nJ/bit |
| 8 | $E_{fs}$ | 10pJ/bit/$m^2$ |
| 9 | $E_{mp}$ | 0.0013pJ/bit/$m^4$ |

Table I: Simulation Parameters of Proposed Optimization

In order to compare with LEACH, algorithm use the same networks and simulation parameters used in experiments (As shown in Table I). The obtained result is shown in figure 7.1. The improved algorithm increases network survival time on average comparing to LEACH, the number of deaths tends to the mean value in every round.

The several times of simulation results about system lifetime is demonstrated in figure 7.2.

The Improved LEACH network has a constant number of clusters and balanced cluster distribution, so its energy dissipation is balanced and near-minimal. Of course, it has longer lifetime than LEACH.

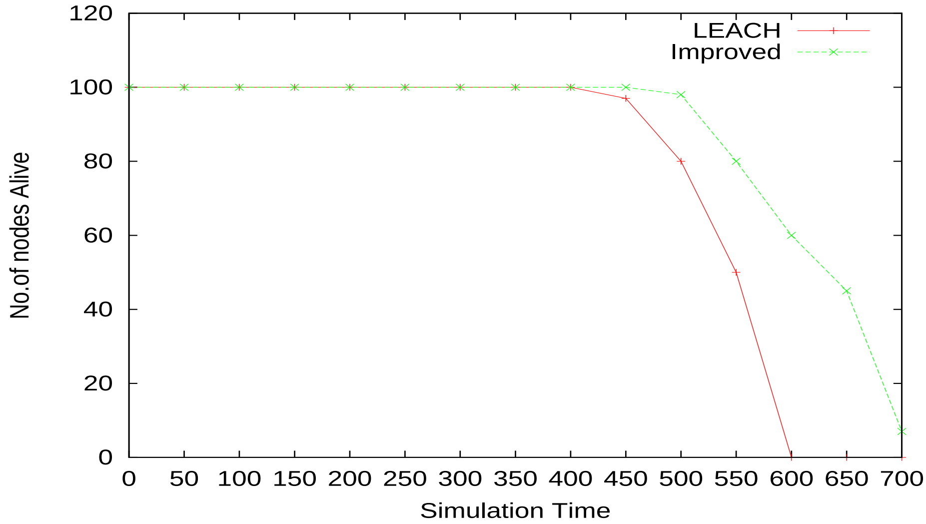


Figure 7.1: Number of nodes alive over time

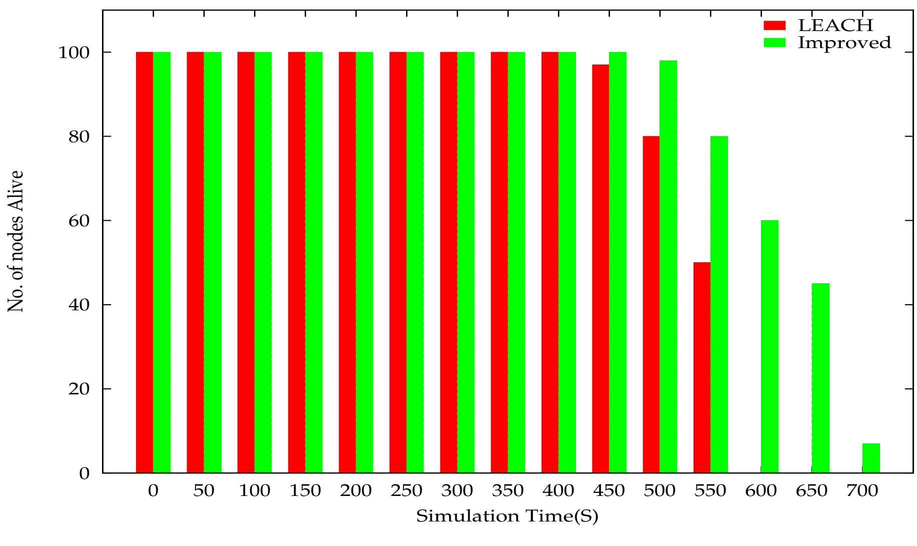


Figure 7.2: Comparison of LEACH and Improved Algorithm

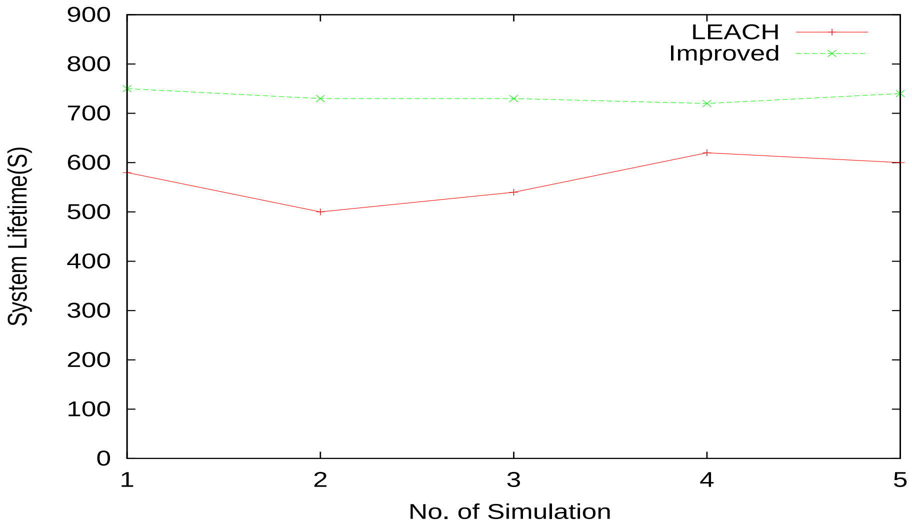


Figure 7.3: System lifetime of every time experiment

# Chapter 8

# Conclusion and Future Scope

## 8.1 Conclusion

This proposed cluster head selection technique put the constraint minimum cluster member nodes, so it tries to balance the clusters in the network. Also it obtains the optimum no. of clusters in each round, which will improve the performance of sensor network as compare to heterogeneous distribution of clusters in LEACH. Simulation results show that the proposed optimized algorithm provides the better energy efficiency and the longer network lifetime than the LEACH.

## 8.2 Future Scope

This proposed implementation performs better compared to the basic LEACH protocol, still there are certain optimizations possible in the protocol like Mobility consideration. In the present implementation the base station is considered to be static but in real deployment of the sensor nodes the base station could be moving also.

The other consideration is the size of the network. As the network grows the location of the base station might be an issue, the cluster head may be out of the coverage of base station. In such scenario the network architecture has to be modified to multilevel clustering so every cluster head comes directly or indirectly under the communication range of base station.

# Appendix A

## Configuration steps of MIT-LEACH in NS-2

- **Step 0: Prepare necessary files for installation**

  a. NS-2.27 package: ns-allinone-2.27.tar.gz

  b. Patch for compiling NS-2.27 with GCC 4.1.x: ns-2.27-gcc410.patch

  c. MIT's LEACH extension: mit.tar.gz

  d. LEACH's Makefile patch: leach_makefile-2.27.patch

- **Step 1: Download NS-2.27, apply ns-2.27-gcc410.patch, and install it**

  a. Get http://www.internetworkflow.com/downloads/ns2leach/ns-allinone-2.27.tar.gz

  b. tar zxvf ns-allinone-2.27.tar.gz

  c. http://www.tekno.chalmers.se/ yusheng/reports/ns-2.27-gcc410.patch

  d. patch -p0 < ns-2.27-gcc410.patch

  e. cd ns-allinone-2.27/

  f. ./install

- **Step 2: Set the environment variables to make NS-2.27 works**

  a. cd

  b. gedit .bashrc

c. $LD\_LIBRARY_PATH$

$OTCL\_LIB = /ns - allinone - 2.27/otcl - 1.8$

$NS2\_LIB = /ns - allinone - 2.27/lib$

$X11\_LIB = /usr/X11R6/lib$ $USR\_LOCAL\_LIB = /usr/local/lib$

$exportLD\_LIBRARY\_PATH$ =LD_LIBRARY _PATH:$OTCL_LIB$ :NS2 $\_LIB$ :X11 _LIB:$USR\_LOCAL\_LIB$

$TCL\_LIBRARY$

$TCL\_LIB = /ns - allinone - 2.27/tcl8.4.5/library$

$USR\_LIB = /usr/lib$

$exportTCL\_LIBRARY$ =TCL _LIB:$USR\_LIB$

$PATH$ $PATH$ =PATH: /ns-allinone-2.27/bin: /ns-allinone-2.27/tcl8.4.5/unix: /ns-allinone-2.27/tk8.4.5/unix

d. source .bashrc

- **Step 3: Download, copy, and extract MIT's LEACH extension**

  a. Get http://www.internetworkflow.com/downloads/ns2leach/mit.tar.gz

  b. cp mit.tar.gz /ns-allinone-2.27/ns-2.27/

  c. cd /ns-allinone-2.27/ns-2.27/

  d. tar xzvf mit.tar.gz

  e. rm mit.tar.gz

- **Step 4: Modify NS-2 source code**

  a. 1 gedit /ns-allinone-2.27/ns-2.27/mac/wireless-phy.cc

  Goto line 59, that is after line 58: define max(a,b) $(((a) < (b))?(b) : (a))$

  Insert: define min(a,b) $(((a) > (b))?(b) : (a))$

- **Step 5: Add environment variables for LEACH extension**

  a. gedit /.bashrc

  Goto line 59, that is after line 58:

export RCA_LIBRARY=*NS/mit/rca*

*exportuAMPS_LIBRARY* =NS/mit/uAMPS

b. source /.bashrc

- **Step 6: Download and apply patch for Makefile.vc, edit Makefile and re-compile NS-2.27 with LEACH extension**

  a. Get http://voyager.ce.fit.ac.jp/wiki/tool/leach _makefile-2.27.patch

  b. patch -p0 < leach _makefile-2.27.patch

  c. gedit Makefile

  (1) Add -DMIT _uAMPS to the DEFINE list

  (2) Add -I./mit/rca -I./mit/uAMPS to the INCLUDE list

  (3) Add the following just prior to the line gaf/gaf.o mit/rca/energy.o mit/rca/rcagent.o mit/rca/rca-ll.o mit/rca/resource.o mac/mac-sensor-timers.o mac/mac-sensor.o mit/uAMPS/bsagent.o

  (4) make clean

  (5) make

- **Step 7: Test and debug**

  a. Modify file test:

  Move line:

  cd ../../

  above line:

  ./leach _test.

# Appendix B

## B.1 List of Websites

1. http://ceng.usc.edu/ anrg/SensorNetBib.html

2. http://www.ece.rochester.edu/ wheinzel/research.html

3. http://www.isi.edu/nsnam/dist/ns-allinone-2.27.tar.gz

4. http://www.internetworkflow.com/downloads/ns2leach/mit.tar.gz

5. http://www.mail-archive.com/ns-users@isi.edu

## B.2 Publication

Paper titled **"Energy and Throughput analysis of Hierarchical Routing Protocol (LEACH) for Wireless Sensor Networks"** published in International Journal of Computer Application(IJCA Journal), April 30, 2011.

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